Thematic Investing

21st Century Cities: Global Smart Cities Primer

Primer

Bank of America Merrill Lynch

Equity | 02 March 2017

A Transforming World: Smart Cities

As part of our work on A Transforming World, we introduce a new Innovation- and People-focused theme – Smart Cities. This Primer sets out the challenges and opportunities posed by cities. We also publish a Primer Picks report.

Urbanisation: 55% of people & $62tn of economic activity

For the first time in history, there are more people living in urban than rural areas. Some 55% of the world's population lives in cities, a number that will grow to 70% by 2050E, including 86% in DMs. Cities have become the engines of global economic growth, with economic activity of about US$62tn pa (c.85% of global GDP), rising to US$115tn by 2030E. Urbanisation has been a major push in development and poverty reduction, and global urban consumption has become a greater driver than population growth, set to grow by US$23tn from 2015-30E.

Tipping points: success or failure will be decided in cities

More than 80% of the world's cities show signs of fragility yet the success or failure in meeting the world's most pressing challenges will be decided in them. Our cities are reaching a tipping point on many issues: poor governance and weak institutions (#1 perceived impediment to prosperity); inadequate infrastructure (US$78tn of investment needed over 10Y); rising inequality (75% of cities are worse off than 20Y ago); housing (1bn new homes needed); crime (a top concern for citizens); environmental challenges (c.75% of natural resource use and emissions); and new and pervasive risks (cybersecurity, terrorism, securitisation, disease and pandemics etc.).

Smart Cities: a 'perfect storm' of disruptive technologies

Smart Cities use 21st century disruptive technologies to meet demographic, economic, environmental, infrastructure and social challenges. These include: ubiquitous broadband coverage (84% globally); nextgen infrastructure (5G up to 100x faster than 4G); the Internet of Things (IoT) (10bn connected devices in cities by 2020E); Big Data (200mn GB of data/day for a city of 1mn by 2020E); the Cloud (secure, open platform); and artificial intelligence (AI) (predictive insights, anticipatory actions). Smart Cities can achieve cuts of 30% in energy use and crime, and 20% in traffic delays and water loss. We see Singapore, London, NYC, Paris and Tokyo as some of today's Smartest Cities.

US$1.3-1.6tn Smart City mkt by 2020E: six entry points

We see the Smart City market growing to US$1.3-1.6tn by 2020E (vs US$1tn today) and highlight six entry points for investors wishing to access the theme: (1) Smart Infrastructure; (2) Smart Buildings; (3) Smart Homes; (4) Smart Safety & Security; (5) Smart Energy; and (6) Smart Mobility. We anticipate fast growth for: 5G, AI, building automation, Big Data, bricks and steel infrastructure, Cloud, cleantech, cybersecurity, electric and autonomous vehicles (AVs and EVs), IoT, sensors, surveillance, telco infrastructure and services, and voice assistants, among other areas.

BofAML Smart City stock exposure and Primer Picks

We present a list of 250+ global stocks covered by BofAML that have exposure to Smart City-related solutions. Our Buy-rated stocks with material exposure to the theme are detailed in an accompanying Primer Picks report, as is our full list of stocks.

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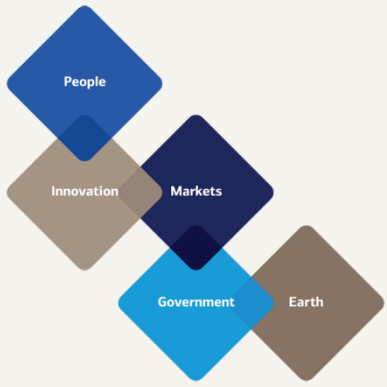
A Transforming World



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Refer to important disclosures on page 269 to 270.

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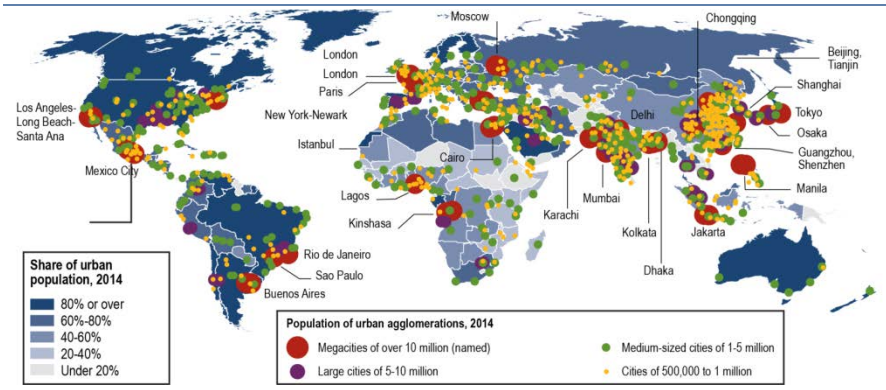
Smart Cities in a nutshell

55% of the world's population lives in cities, a number that will grow to 70% by 2050E, including 86% in DMs. Cities have become the engines of global economic growth, with economic activity of about US$62tn pa (c.85% of global GDP), rising to US$115tn by 2030E.

Exhibit 1: Our urban world in a nutshell

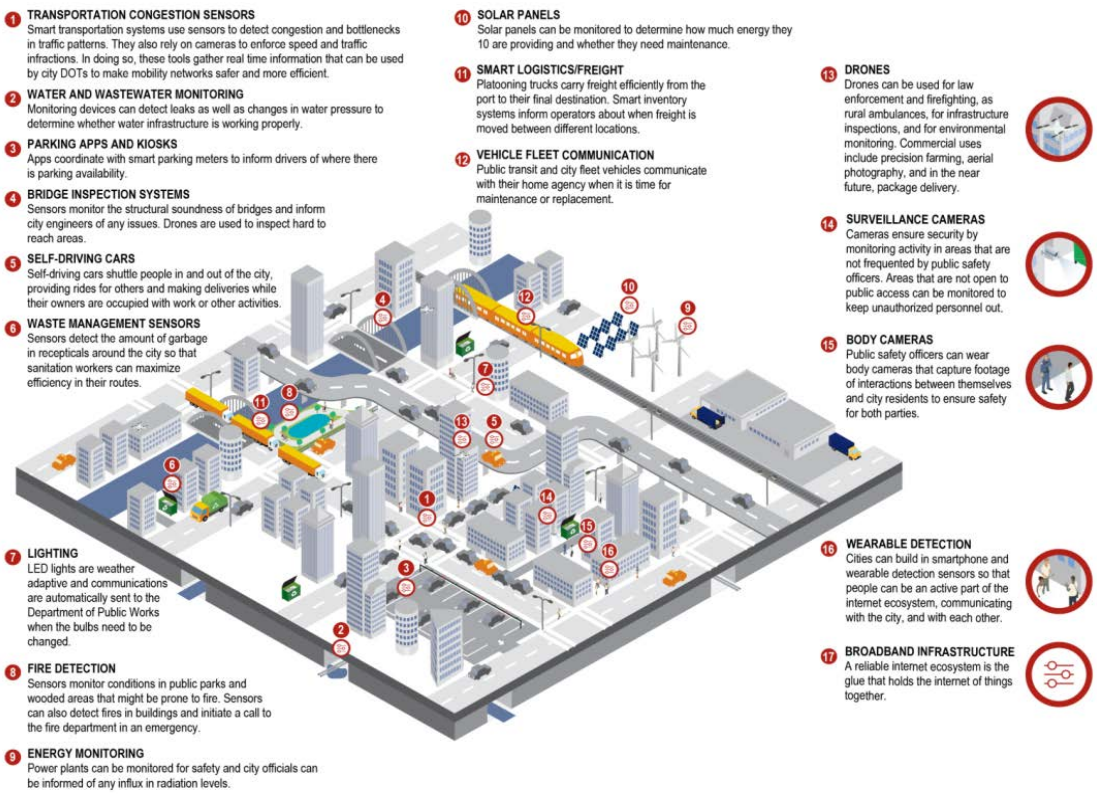


Source: UN

More than 80% of the world's cities show signs of fragility yet the success or failure in meeting the world's most pressing challenges will be decided in them (e.g. poor governance and weak institutions, inadequate infrastructure, rising inequality, housing, environmental challenges et. al.).

Smart Cities use 21st century disruptive technologies to meet demographic, economic, environmental, infrastructure and social challenges (e.g. ubiquitous broadband, the Internet of Things (IoT), Big Data, the Cloud, and AI.

Exhibit 2: Disruptive technology at work in a Smart City



Source: National League of Cities 2016

We have created a BofAML Smart City Indicator of the world's smartest cities and view Singapore, London, New York, Paris, Tokyo, Stockholm, Amsterdam, Seoul and Vienna as some of today's smartest.

Exhibit 3: BofAML's Smart City Indicator of the world's smartest cities

Icon	Map	Rank	BofAML Smart City Index (2017)	Icon	Map	Rank	BofAML Smart City Index (2017)
		1	Singapore			11	Hong Kong
		2	London			12	San Francisco
		3	New York			13	Copenhagen
		4	Paris			14	Boston
		5	Tokyo			15	Berlin
		6	Stockholm			16	Oslo
		7	Amsterdam			17	Osaka
		8	Seoul			18	Auckland
		9	Vienna			19	Dublin
		10	Zurich			20	Sydney

Source: BofAML Global Research based on various sources. Maps reflect greater urban area. Full table indicator in Smart Cities 101 section.

We see the Smart City market growing to US$1.3-1.6tn by 2020E (vs US$1tn today) and highlight six entry points for investors wishing to access the theme.

Exhibit 4: US$1.3-1.6tn global Smart Cities market (2020E)

Source: BofAML Global Research based on various sources

BofAML Global Smart Cities Stock Universe

Please see Global Smart Cities Primer Picks for a list of our Primer Picks and the full list of stocks that have exposure to the BofAML Global Smart Cities theme.

Our list of stocks is with exposure to the BofAML Global Smart Cities theme is not a recommended list either individually or as a group of stocks. Investors should consider the fundamentals of the companies and their own individual circumstances / objectives before making any investment decisions.

We have mapped Smart Cities opportunities across six entry points for investors wishing to access the theme: including: 1) Smart Infrastructure; 2) Smart Buildings; 3) Smart Homes; 4) Smart Safety & Security; 5) Smart Energy; and 6) Smart Mobility.

We outline these areas in much greater detail throughout this report. For each company, we have estimated the level and materiality of companies' exposure to Smart Cities-related themes and have characterised their exposure as follows:

- **Low** – Smart Cities-related products, technologies, services, and solutions are not material to global revenues and/or growth but are one factor, among others, for the business model, strategy & R&D of the company.
- **Medium** – Smart Cities-related products, technologies, services, and solutions are an important factor for the business model, strategy and R&D of the company; material to sales and/or growth.
- **High** – Smart Cities -related products, technologies, services, and solutions are core to the business model, strategy and R&D of the company; material sales and/or growth driver; pure play (i.e. 100% of sales).

Although it is difficult to accurately gauge the link between such exposure and share price performance (as many factors outside the scope of this analysis are likely to play a role in short- and long-term price development), we still consider Smart Cities exposure as an important and positive point to track given that it is a global "Transforming World" theme with a long lifespan.

The aim of our list of stocks that have exposure to our Global Smart Cities theme and its six underlying entry points is to provide investors with information to identify company and sub-sector specific risks and opportunities that are inherent in the theme.

In our Primer Picks report, we present a list of 250+ global stocks covered by BofAML that have exposure to Smart Cities-related solutions. Our Buy-rated stocks with material exposure to the theme are detailed in that report, as is our full list of stocks.

Table 1: BofAML Global Smart Cities Stock Universe

Company	BofAML Ticker	BBG Ticker	Location	Mkt. Cap US$m	Smart Cities Sub-Sector	Smart Cities Exposure
Smart ICT/Infrastructure						
IBM	IBM	IBM US	United States	172,247	Intelligent Cities	High
Alphabet C	GOOG	GOOG US	United States	600,075	Intelligent Cities	Medium
Amazon.com	AMZN	AMZN US	United States	400,656	Intelligent Cities	Medium
Microsoft Corp	MSFT	MSFT US	United States	529,360	Intelligent Cities	Medium
Alibaba	BABA	BABA US	China	251,011	Intelligent Cities	Medium
Baidu.com-ADR	BIDU	BIDU US	China	64,739	Intelligent Cities	Medium
Tencent Holdings	TCTZF	700 HK	China	235,931	Intelligent Cities	Medium
SoftBank Group	SFTBF	9984 JP	Japan	82,109	Intelligent Cities	Medium
Samsung Elec Common	SSNLF	005930 KS	Korea, Republic Of	236,761	Intelligent Cities	Medium
Facebook	FB	FB US	United States	391,430	Intelligent Cities	Low
Twitter	TWTR	TWTR US	United States	11,946	Intelligent Cities	Low
Apple Inc.	AAPL	AAPL US	United States	761,962	Intelligent Cities	Low
Singtel	SNGNF	ST SP	Singapore	43,676	Telecom Providers	Medium
M1	MBOFF	M1 SP	Singapore	1,449	Telecom Providers	Medium
StarHub	SRHBF	STH SP	Singapore	3,701	Telecom Providers	Medium
Verizon Comm	VZ	VZ US	United States	207,346	Telecom Providers	Medium
AT&T	T	T US	United States	242,475	Telecom Providers	Medium
Sprint Corp	S	S US	United States	35,725	Telecom Providers	Medium
T-Mobile US	TMUS	TMUS US	United States	50,250	Telecom Providers	Medium
Deutsche Telekom	DTEGF	DTE GR	Germany	80,524	Telecom Providers	Medium
Orange	FNCTF	ORA FP	France	41,071	Telecom Providers	Medium
BT	BTGOF	BT/A LN	United Kingdom	37,453	Telecom Providers	Medium
Vodafone Group	VOD	VOD US	United Kingdom	63,980	Telecom Providers	Medium
Telecom Italia SPA	TIAOF	TIT IM	Italy	18,205	Telecom Providers	Medium
Telefonica SA	TEFOF	TEF SM	Spain	47,485	Telecom Providers	Medium
Telstra Corp	TTRAF	TLS AU	Australia	45,806	Telecom Providers	Medium
Bharti	BHTIF	BHARTI IN	India	21,929	Telecom Providers	Medium
China Mobile	CHLKF	941 HK	Hong Kong	222,260	Telecom Providers	Medium
China Telecom	CHJHF	728 HK	China	38,269	Telecom Providers	Medium
China Unicom	CHUFF	762 HK	Hong Kong	26,593	Telecom Providers	Medium
LG Uplus	LTCLF	032640 KS	Korea, Republic Of	4,448	Telecom Providers	Medium
KT	KTCNF	030200 KS	Korea, Republic Of	6,783	Telecom Providers	Medium
SK Telecom	SKMTF	017670 KS	Korea, Republic Of	15,633	Telecom Providers	Medium
KDDI	KDDIF	9433 JP	Japan	60,761	Telecom Providers	Medium
NTT DOCOMO	NTDMF	9437 JP	Japan	94,175	Telecom Providers	Medium
Crown Castle	CCI	CCI US	United States	29,146	Telecom Towers	High
SBA Comm. Corp.	SBAC	SBAC US	United States	13,246	Telecom Towers	High
American Tower	AMT	AMT US	United States	44,170	Telecom Towers	High
Inwit	XISWF	INW IM	Italy	2,775	Telecom Towers	High
Cellnex	XWHXF	CLNX SM	Spain	3,339	Telecom Towers	High
Bharti Infratel	XYYAF	BHIN IN	India	9,946	Telecom Towers	High
Telesites	TSSLF	SITESB1 MM	Mexico	2,024	Telecom Towers	High
Ericsson	ERIXF	ERICB SS	Sweden	19,342	Network Connectivity	High
Nokia	NOKBF	NOKIA FH	Finland	27,071	Network Connectivity	High
Intel	INTC	INTC US	United States	178,119	Network Connectivity	High
Skyworks	SWKS	SWKS US	United States	14,872	Network Connectivity	High
QUALCOMM	QCOM	QCOM US	United States	87,100	Network Connectivity	High
Cisco Systems	CSCO	CSCO US	United States	165,413	Network Connectivity	High
CommScope	COMM	COMM US	United States	7,654	Network Connectivity	Medium
CIENA	CIEN	CIEN US	United States	2,559	Network Connectivity	Medium
Corning	GLW	GLW US	United States	23,562	Network Connectivity	Medium
Nvidia	NVDA	NVDA US	United States	63,165	Network Connectivity	Medium
Broadcom	AVGO	AVGO US	Singapore	78,898	Network Connectivity	Medium
Qorvo Inc.	QRVO	QRVO US	United States	9,744	Network Connectivity	Medium
Cypress	CY	CY US	United States	3,824	Network Connectivity	Medium
Cavium	CAVM	CAVM US	United States	4,389	Network Connectivity	Medium
Inphi	IPHI	IPHI US	United States	2,017	Network Connectivity	Medium
IDT	IDTI	IDTI US	United States	3,319	Network Connectivity	Medium
Texas Instr.	TXN	TXN US	United States	79,433	Network Connectivity	Medium
Analog Devices	ADI	ADI US	United States	25,513	Network Connectivity	Medium
Xilinx	XLNX	XLNX US	United States	15,812	Network Connectivity	Medium
Infineon	IFNNF	IFX GR	Germany	21,040	Network Connectivity	Medium
STMicroelectronics	STMEF	STM FP	France	11,654	Network Connectivity	Medium
ASML NA	ASMLF	ASML NA	Netherlands	52,264	Network Connectivity	Medium

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Company	BofAML Ticker	BBG Ticker	Location	Mkt. Cap US$m	Smart Cities Sub-Sector	Smart Cities Exposure
Advantech	ADTEF	2395 TT	Taiwan	5,461	Infrastructure / Design	High
Hexagon AB	HXGBF	HEXAB SS	Sweden	14,278	Infrastructure / Design	High
General Electric	GE	GE US	United States	270,323	Infrastructure / Design	Medium
Siemens	SIEGY	SIEGY US	Germany	107,082	Infrastructure / Design	Medium
ABB Ltd.	ABLZF	ABBN VX	Switzerland	49,962	Infrastructure / Design	Medium
Schneider	SBGSF	SU FP	France	40,076	Infrastructure / Design	Medium
Dassault Systemes	DASTF	DSY FP	France	19,237	Infrastructure / Design	Medium
Autodesk	ADSK	ADSK US	United States	17,248	Infrastructure / Design	Medium
HPE	HPE	HPE US	United States	44,709	Infrastructure / Design	Medium
AECOM	ACM	ACM US	United States	6,138	Engineering / Construction / Other	Low
Fluor Corp	FLR	FLR US	United States	8,095	Engineering / Construction / Other	Low
Jacobs Eng.	JEC	JEC US	United States	6,900	Engineering / Construction / Other	Low
Vinci	VCISF	DG FP	France	42,658	Engineering / Construction / Other	Low
Ferrovial	FRRVF	FER SM	Spain	13,904	Engineering / Construction / Other	Low
ACS	ACSAF	ACS SM	Spain	9,542	Engineering / Construction / Other	Low
Balfour Beatty	BAFBF	BBY LN	United Kingdom	2,356	Engineering / Construction / Other	Low
Eiffage	FGLLF	FGR FP	France	7,131	Engineering / Construction / Other	Low
Abertis	ABFOF	ABE SM	Spain	14,461	Engineering / Construction / Other	Low
Atlantia	ATASF	ATL IM	Italy	19,070	Engineering / Construction / Other	Low
Hochtief	HOCFF	HOT GY	Germany	9,738	Engineering / Construction / Other	Low
OHL	OBSJF	OHL SM	Spain	1,039	Engineering / Construction / Other	Low
Skanska	SKSBF	SKAB SS	Sweden	9,847	Engineering / Construction / Other	Low
Alstom	AOMFF	ALO FP	France	6,079	Engineering / Construction / Other	Low
Hyundai Eng&Con	HYEHF	000720 KS	Korea, Republic Of	3,978	Engineering / Construction / Other	Low
L&T	XYUYF	LT IN	India	20,048	Engineering / Construction / Other	Low
Toshiba	TOSBF	6502 JP	Japan	10,701	Engineering / Construction / Other	Low
Hitachi	HTHIF	6501 JP	Japan	26,124	Engineering / Construction / Other	Low
Mitsubishi Elec	MIELF	6503 JP	Japan	30,981	Engineering / Construction / Other	Low
SPIE SA	XMRJF	SPIE FP	France	3,371	Engineering / Construction / Other	Low
Unibail	UNBLF	UL NA	France	24,485	Engineering / Construction / Other	Low
Workspace	XWRKF	WKP LN	United Kingdom	1,329	Engineering / Construction / Other	Low
JCDecaux	JCDXF	DEC FP	France	6,248	Engineering / Construction / Other	Low
Smart Home						
Alarm.com	ALRM	ALRM US	United States	1,477	Assistant / Hub	High
Alphabet C	GOOG	GOOG US	United States	600,075	Assistant / Hub	Medium
Amazon.com	AMZN	AMZN US	United States	400,656	Assistant / Hub	Medium
Apple Inc.	AAPL	AAPL US	United States	761,962	Assistant / Hub	Medium
IBM	IBM	IBM US	United States	172,247	Assistant / Hub	Medium
Ooma	OOMA	OOMA US	United States	165	Assistant / Hub	Medium
Flex Ltd.	FLEX	FLEX US	Singapore	9,480	Assistant / Hub	Low
Comcast Corp	CMCSA	CMCSA US	United States	188,477	Assistant / Hub	Low
Tesla	TSLA	TSLA US	United States	31,739	Solar Roofing	Medium
SunRun	RUN	RUN US	United States	623	Solar Roofing	Medium
Vivint Solar	VSLR	VSLR US	United States	348	Solar Roofing	Medium
Enphase Energy	ENPH	ENPH US	United States	48	Solar Roofing	Medium
Philips Lighting	XPLVF	LIGHT NA	Netherlands	3,637	Lighting	Medium
CREE	CREE	CREE US	United States	3,430	Lighting	Medium
Osram	OSAGF	OSR GR	Germany	6,144	Lighting	Medium
Whirlpool	WHR	WHR US	United States	15,159	Appliances	Low
Electrolux	ELUXF	ELUXB SS	Sweden	7,217	Appliances	Low
Samsung Elec Common	SSNLF	005930 KS	Korea, Republic Of	236,761	Appliances	Low
LG Electronics	LGEAF	066570 KS	Korea, Republic Of	7,824	Appliances	Low
Panasonic	PCRFF	6752 JP	Japan	26,400	Appliances	Low
Haier	HRELF	1169 HK	Hong Kong	4,390	Appliances	Low
The Home Depot	HD	HD US	United States	186,356	Furnishings	Low
Lowe's	LOW	LOW US	United States	70,749	Furnishings	Low
Bed Bath Beyond	BBBY	BBBY US	United States	6,748	Furnishings	Low
Best Buy	BBY	BBY US	United States	14,186	Furnishings	Low
Select Comfort	SCSS	SCSS US	United States	1,030	Furnishings	Low
Tempur Sealy Interna	TPX	TPX US	United States	2,883	Furnishings	Low
Smart Building						
IBM	IBM	IBM US	United States	172,247	Intelligent Buildings / IoT	High
Cisco Systems	CSCO	CSCO US	United States	165,413	Intelligent Buildings / IoT	High
ABB Ltd.	ABLZF	ABBN VX	Switzerland	49,962	Building Automation Systems	Medium
Legrand	LGRVF	LR FP	France	14,916	Building Automation Systems	Medium

Table 1: BofAML Global Smart Cities Stock Universe

Company	BofAML Ticker	BBG Ticker	Location	Mkt. Cap US$m	Smart Cities Sub-Sector	Smart Cities Exposure
Schneider	SBGSF	SU FP	France	40,076	Building Automation Systems	Medium
Siemens	SMAWF	SIE GR	Germany	107,082	Building Automation Systems	Medium
Melrose plc	XLHVF	MRO LN	United Kingdom	4,664	Building Automation Systems	Medium
Rexel	RXLSF	RXL FP	France	5,229	Building Automation Systems	Medium
General Electric	GE	GE US	United States	270,323	Building Automation Systems	Medium
Honeywell	HON	HON US	United States	91,456	Building Automation Systems	Medium
Emerson	EMR	EMR US	United States	40,526	Building Automation Systems	Medium
HD Supply	HDS	HDS US	United States	8,357	Building Automation Systems	Medium
Delta Elect	DLTEF	2308 TT	Taiwan	12,528	Building Automation Systems	Medium
Ingersoll-Rand	IR	IR US	United States	20,483	HVAC	Medium
Dover Corp	DOV	DOV US	United States	12,536	HVAC	Medium
United Tech	UTX	UTX US	United States	97,978	HVAC	Medium
Alfa Laval	ALFVF	ALFA SS	Sweden	7,582	HVAC	Low
Philips Lighting	XPLVF	LIGHT NA	Netherlands	3,637	Lighting	Medium
Osram	OSAGF	OSR GR	Germany	6,144	Lighting	Medium
CREE	CREE	CREE US	United States	3,430	Lighting	Medium
Epistar	EPIPF	2448 TT	Taiwan	865	Lighting	Medium
Kone OYJ	KNYJF	KNEBV FH	Finland	23,162	Elevators	Medium
United Tech	UTX	UTX US	United States	97,978	Elevators	Medium
Thyssenkrupp	TYEKF	TKA GR	Germany	14,015	Elevators	Medium
Saint-Gobain	CODGF	SGO FP	France	26,587	Windows / Cables	Low
Nexans	NXPRF	NEX FP	France	2,249	Windows / Cables	Low
Prysmian	PRYMF	PRY IM	Italy	5,454	Windows / Cables	Low
Smart Safety & Security						
Assa Abloy	ASAZF	ASSAB SS	Sweden	20,251	Locks	Medium
Allegion	ALLE	ALLE US	Ireland	6,951	Locks	Medium
NEC	NIPNF	6701 JP	Japan	7,551	Surveillance / Biometrics / ID	Medium
Chicony Elect	CCNYF	2385 TT	Taiwan	1,578	Surveillance / Biometrics / ID	Medium
Valid	XNJFF	VLID3 BZ	Brazil	638	Surveillance / Biometrics / ID	Medium
Gemalto N.V.	GTOFF	GTO NA	Netherlands	5,173	Surveillance / Biometrics / ID	Medium
Experian	EXPGF	EXPN LN	United Kingdom	19,085	Surveillance / Biometrics / ID	Medium
Safran SA	SAFRF	SAF FP	France	28,989	Surveillance / Biometrics / ID	Low
Hexagon AB	HXGBF	HEXAB SS	Sweden	14,278	Security Services	Medium
Smiths Group	SMGKF	SMIN LN	United Kingdom	7,343	Security Services	Medium
Everbridge	EVBG	EVBG US	United States	526	Security Services	Medium
Mistras Group	MG	MG US	United States	710	Security Services	Medium
Serco	SECCF	SRP LN	United Kingdom	2,022	Security Services	Low
G4S	GFSZF	GFS LN	United Kingdom	4,645	Security Services	Low
Securitas	SCTBF	SECUB SS	Sweden	5,414	Security Services	Low
Barracuda	CUDA	CUDA US	United States	1,283	Cybersecurity	Medium
Check Point	CHKP	CHKP US	Israel	16,456	Cybersecurity	Medium
CyberArk Software	CYBR	CYBR US	Israel	1,777	Cybersecurity	Medium
FireEye	FEYE	FEYE US	United States	1,997	Cybersecurity	Medium
Fortinet	FTNT	FTNT US	United States	5,873	Cybersecurity	Medium
Palo Alto Networks	PANW	PANW US	United States	13,989	Cybersecurity	Medium
SecureWorks	SCWX	SCWX US	United States	1,004	Cybersecurity	Medium
F5 Networks	FFIV	FFIV US	United States	10,553	Cybersecurity	Medium
Juniper Networks	JNPR	JNPR US	United States	13,195	Cybersecurity	Medium
A10 Networks, Inc.	ATEN	ATEN US	United States	537	Cybersecurity	Medium
Gigamon	GIMO	GIMO US	United States	1,167	Cybersecurity	Medium
Trend Micro	TMICF	4704 JP	Japan	4,097	Cybersecurity	Medium
Symantec	SYMC	SYMC US	United States	17,917	Cybersecurity	Medium
VMware Inc	VMW	VMW US	United States	36,988	Cybersecurity	Medium
Splunk	SPLK	SPLK US	United States	8,551	Cybersecurity	Medium
Booz Allen Hamilton	BAH	BAH US	United States	5,098	Cybersecurity	Medium
Raytheon Co.	RTN	RTN US	United States	43,613	Cybersecurity	Medium
BAE SYSTEMS	BAESF	BA/ LN	United Kingdom	24,057	Cybersecurity	Medium
Ultra Electronics	UEHPF	ULE LN	United Kingdom	1,698	Cybersecurity	Medium
Smart Energy & Grid						
Vestas	VWSYF	VWS DC	Denmark	16,015	Wind	Medium
Gamesa	GCTAF	GAM SM	Spain	6,012	Wind	Medium
EDP Renovaveis	EDRVF	EDPR PL	Spain	6,347	Wind	Medium
DONG Energy	XDJBF	DENERG DC	Denmark	15,575	Wind	Medium
Gamesa	GCTAF	GAM SM	Spain	6,012	Wind	Medium
Nordex	NRDXF	NDX1 GR	Germany	1,691	Wind	Medium

Table 1: BofAML Global Smart Cities Stock Universe

Company	BofAML Ticker	BBG Ticker	Location	Mkt. Cap US$m	Smart Cities Sub-Sector	Smart Cities Exposure
Senvion SA	XSHVF	SEN GR	Germany	814	Wind	Medium
China Longyuan	CLPXF	916 HK	China	6,689	Wind	Medium
Datang Renewable	XGDRF	1798 HK	China	675	Wind	Medium
HuanengRenewable	XNUGF	958 HK	China	3,309	Wind	Medium
Inox Wind	XPJYF	INXW IN	India	706	Wind	Medium
Goldwind	XJNGF	2208 HK	China	4,547	Wind	Medium
Enphase Energy	ENPH	ENPH US	United States	48	Solar	Medium
First Solar	FSLR	FSLR US	United States	3,784	Solar	Medium
SunPower Corp.	SPWR	SPWR US	United States	1,028	Solar	Medium
SunRun	RUN	RUN US	United States	623	Solar	Medium
Vivint Solar	VSLR	VSLR US	United States	348	Solar	Medium
Singyes Solar	CSSXF	750 HK	Hong Kong	385	Solar	Medium
Xinyi Solar	XYPJF	968 HK	China	2,427	Solar	Medium
NEP	NEP	NEP US	United States	1,495	YieldCo	Medium
Saeta Yield	XSTAF	SAY SM	Spain	798	YieldCo	Medium
8Point3 Energy Ptnrs	CAFD	CAFD US	United States	1,166	YieldCo	Medium
NextEra Energy	NEE	NEE US	United States	55,830	Utilities / Renewables	Medium
Edison Int'l	EIX	EIX US	United States	23,606	Utilities / Renewables	Medium
PG&E Corp.	PCG	PCG US	United States	30,864	Utilities / Renewables	Medium
NRG Energy	NRG	NRG US	United States	5,438	Utilities / Renewables	Medium
Advanced Energy	AEIS	AEIS US	United States	2,386	Utilities / Renewables	Medium
Acciona	ACXIF	ANA SM	Spain	4,156	Utilities / Renewables	Medium
Enel	ESOCF	ENEL IM	Italy	37,542	Utilities / Renewables	Medium
EDP	ELCPF	EDP PL	Portugal	11,622	Utilities / Renewables	Medium
Iberdrola	IBDSF	IBE SM	Spain	39,647	Utilities / Renewables	Medium
innogy	XISAF	IGY GR	Germany	18,719	Utilities / Renewables	Medium
Fortum	FOJCF	FORTUM FH	Finland	13,981	Utilities / Renewables	Medium
ABB Ltd.	ABLZF	ABBN VX	Switzerland	49,962	Grid	Medium
Schneider	SBGSF	SU FP	France	40,076	Grid	Medium
Siemens	SMAWF	SIE GR	Germany	107,082	Grid	Medium
Prysmian	PRYMF	PRY IM	Italy	5,454	Grid	Medium
Nexans	NXPRF	NEX FP	France	2,249	Grid	Medium
Advantech	ADTEF	2395 TT	Taiwan	5,461	Grid	Medium
Eaton Corp PLC	ETN	ETN US	United States	32,753	Grid	Medium
Smart Mobility						
Alstom	AOMFF	ALO FP	France	6,079	Automated Trains	High
Siemens	SIEGY	SIEGY US	Germany	107,082	Automated Trains	Medium
Bombardier Inc.	YBBD B	BBD/B CN	Canada	3,974	Automated Trains	Medium
CRRC	CRRRF	1766 HK	China	24,998	Automated Trains	Medium
CRCC	CWYCF	1186 HK	China	17,234	Automated Trains	Medium
Tesla	TSLA	TSLA US	United States	31,739	Automaker	High
BYD	BYDDF	1211 HK	China	13,590	Automaker	Medium
BMW	BAMXF	BMW GR	Germany	60,920	Automaker	Medium
Daimler	XQEJF	DAI GR	Germany	80,149	Automaker	Medium
Ford Motor	F	F US	United States	49,508	Automaker	Medium
General Motors	GM	GM US	United States	55,116	Automaker	Medium
Nissan Motor	NSANF	7201 JP	Japan	41,577	Automaker	Low
Toyota Motor	TOYOF	7203 JP	Japan	182,250	Automaker	Low
Volkswagen AG	VLKAF	VOW GR	Germany	47,848	Automaker	Low
Fiat Chrysler	XFYKF	FCA IM	United States	16,777	Automaker	Low
Hyundai Motor	HYMLF	005380 KS	Korea, Republic Of	27,202	Automaker	Low
Honda Motor	HNDAF	7267 JP	Japan	57,121	Automaker	Low
Volvo	VOLVF	VOLVB SS	Sweden	23,917	Automaker	Low
Renault	RNSDF	RNO FP	France	25,473	Automaker	Low
Peugeot	PEUGF	UG FP	France	17,166	Automaker	Low
Mitsubishi Motors	MMTOF	7211 JP	Japan	6,307	Automaker	Low
Kia Motors	KIMTF	000270 KS	Korea, Republic Of	13,408	Automaker	Low
Suzuki Motor	SZKMF	7269 JP	Japan	17,596	Automaker	Low
Geely	GELYF	175 HK	Hong Kong	12,236	Automaker	Low
BAIC	XMJTF	1958 HK	China	6,831	Automaker	Low
Guangzhou Auto	GNZUF	2238 HK	China	7,777	Automaker	Low
Autoliv	XGHAF	ALIV SS	Sweden	9,452	Autoparts Supplier	Medium
Continental AG	CTTAF	CON GR	Germany	39,249	Autoparts Supplier	Medium
Delphi	DLPH	DLPH US	United Kingdom	20,354	Autoparts Supplier	Medium
Gentex	GNTX	GNTX US	United States	6,365	Autoparts Supplier	Medium

Table 1: BofAML Global Smart Cities Stock Universe

Company	BofAML Ticker	BBG Ticker	Location	Mkt. Cap US$m	Smart Cities Sub-Sector	Smart Cities Exposure
Magna Intl	MGA	MGA US	Canada	18,589	Autoparts Supplier	Medium
Hyundai Mobis	XHMDF	012330 KS	Korea, Republic Of	22,840	Autoparts Supplier	Medium
Mando	XMADF	204320 KS	Korea, Republic Of	2,150	Autoparts Supplier	Medium
Valeo	XVSCF	FR FP	France	14,737	Autoparts Supplier	Medium
TE Connectivity Ltd.	TEL	TEL US	United States	26,986	Autoparts Supplier	Medium
BorgWarner	BWA	BWA US	United States	9,262	Autoparts Supplier	Medium
Sensata	ST	ST US	United States	7,246	Autoparts Supplier	Low
Sunny Optical	SNPTF	2382 HK	China	7,211	Autoparts Supplier	Low
Samsung SDI	SSDIF	006400 KS	Korea, Republic Of	6,829	Batteries	High
LG Chem	LGCLF	051910 KS	Korea, Republic Of	15,783	Batteries	High
Panasonic	PCRFF	6752 JP	Japan	26,400	Batteries	Medium
NGK Insulators	NGKIF	5333 JP	Japan	6,758	Batteries	Medium
Exide Industries	XEDRF	EXID IN	India	2,647	Batteries	Medium
Amara Raja	XAMFF	AMRJ IN	India	2,232	Batteries	Medium
LG Electronics	LGEAF	066570 KS	Korea, Republic Of	7,824	Batteries	Low
Smart Healthcare / Waste / Water						
Philips	PHGFF	PHIA NA	Netherlands	26,609	Healthcare	Medium
Intuitive Surgical	ISRG	ISRG US	United States	28,286	Healthcare	Medium
Siemens	SIEGY	SIEGY US	Germany	107,082	Healthcare	Medium
IBM	IBM	IBM US	United States	172,247	Healthcare	Medium
Apple Inc.	AAPL	AAPL US	United States	761,962	Healthcare	Low
Brookdale	BKD	BKD US	United States	2,722	Healthcare	Low
Capital Senior Livin	CSU	CSU US	United States	405	Healthcare	Low
Almost Family	AFAM	AFAM US	United States	614	Healthcare	Low
Estia Health Limited	XZZBF	EHE AU	Australia	651	Healthcare	Low
Japara Healthcare	XZZQF	JHC AU	Australia	387	Healthcare	Low
Regis Healthcare	XZZRF	REG AU	Australia	1,072	Healthcare	Low
Ecolab Inc	ECL	ECL US	United States	37,616	Water & Waste	Medium
American Water Works	AWK	AWK US	United States	13,171	Water & Waste	Medium
Veolia	VEOEF	VIE FP	France	8,883	Water & Waste	Medium
Suez	SZEVF	SEV FP	France	7,729	Water & Waste	Medium
SIIC Environment	AWAEF	SIIC SP	Singapore	841	Water & Waste	Medium
China Everbright	CHFFF	257 HK	Hong Kong	5,390	Water & Waste	Medium
BJ Water	BJWTF	371 HK	Hong Kong	5,966	Water & Waste	Medium
Guangdong Invest	GGDVF	270 HK	Hong Kong	8,031	Water & Waste	Medium
Conch Venture	XIUSF	586 HK	China	3,232	Water & Waste	Medium

Source: BofAML Global Research

The century of cities: urbanisation as a transformative and disruptive force

For the first time in history, there are more people living in urban than rural areas with 54.5% of the world's population inhabiting cities in 2016 (vs 50% in 2000, 29% in 1950, 13% in 1900 and 2% in 1800). There are 65mn new city residents every year (178k every day), and there could be up to 380mn more in the next five years and 2bn in the next 15 years. The world will have 41 "megacities" of 10mn+ people by 2030E with Delhi, Shanghai, São Paulo, Mumbai and Mexico City being the largest. EMs will account for 90% of urban growth to 2050E with the fastest pace in Africa followed by Asia. By 2050E, 70% of the world's population – including 86% in DMs – will live in urban areas (source: UN).

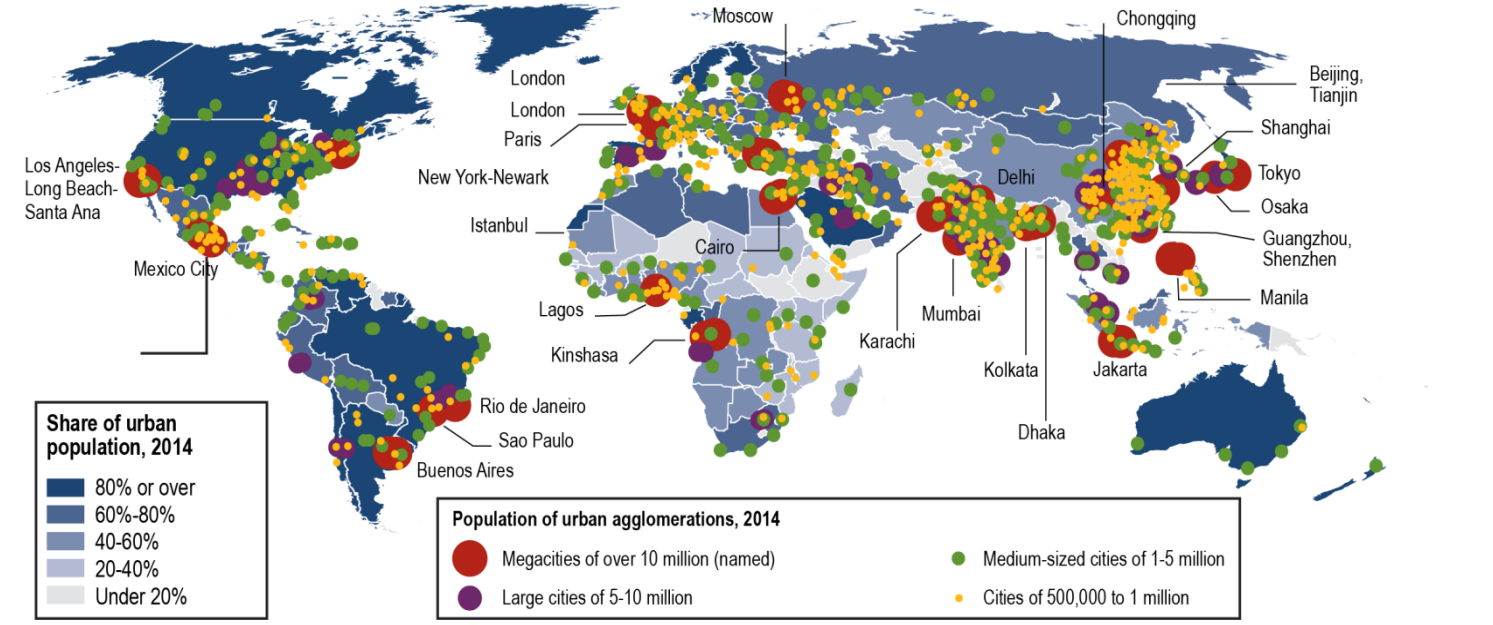
Cities are engines of economic growth, with annual economic activity of about US$62tn, or c.85% of global GDP in 2015. By 2030E, this is expected to rise to US$115tn, or 87% (source: The Global Commission on the Economy and Climate). In the modern era, no country has achieved middle-income status without urbanising and in virtually all cases worldwide, the contribution of urban areas to national income is greater than their share of the national population (source: UN-Habitat 2016). As a rule of thumb, a 230% increase in a country's urbanisation rate will double the income per person (source: World Bank).

Global urban consumption is expected to grow by US$23tn between 2015 and 2030E, a 3.6% CAGR. US$17tn of the estimated US$23tn increase (74%) is forecast to come from rising per capita consumption (vs population growth, the historical driver). By 2030E, consumers in large cities will account for 81% of global consumption and generate 91% of global consumption growth from 2015 to 2030E. Three groups of urban consumers will account for 50% of this growth: DM citizens of 60+ years; working-age consumers aged 15-59 years in China; and working-age consumers aged 15-59 years in NAm. Services will command an ever-larger share of urban consumption as per capita GDP rises (source: McKinsey 2016).

The success or failure in meeting the world's most pressing challenges will be decided in cities, which are reaching a tipping point on many issues: poor governance and weak institutions (#1 perceived impediment to prosperity); inadequate infrastructure (US$78tn of investments needed over the next 10 years); rising inequality (1bn living in poverty in cities, 75% of cities worse off than 20 years ago; housing (881mn living in slums, 1bn new homes needed in cities); crime (top concern for citizens); environmental challenges (cities occupy 2-3% of land mass but account for 75% of natural resource use and emissions, 70% are already dealing with the effects of climate change); and new and pervasive risks (terrorism, higher securitisation, disease and pandemics) (source: UN-Habitat, UN, World Bank).

We believe there that needs to be a fundamental rethink of the urban agenda based on a new vision of sustainable cities. The United Nations' Sustainable Development Goals (SDGs) and the New Urban Agenda from UN Habitat III set global standards of achievement in sustainable urban development. Many cities score well on the prosperity path including Oslo, Copenhagen, Stockholm, Helsinki and Paris, but only 36% have a solid prosperity index (source: UN-Habitat City Prosperity Index). Cities with high levels of prosperity and upward mobility tend to share five characteristics: lower levels of residential segregation, a larger middle class, stronger families, greater social capital, and higher quality public schools than average (source: The Equality of Opportunity Project).

Exhibit 5: Our urban world in a nutshell



Source: UN

Cities in quotes through the centuries:

"This City is what it is because our citizens are what they are." – Plato (428-348 BC)

"I found Rome a city of bricks and left it a city of marble." – Augustus (63BC-14 AD)

"Cities are the abyss of the human species." – Jean Jacques Rousseau in Émile (1762)

"Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody." – Jane Jacobs in in Death and Life of Great American Cities (1961)

"We will neglect our cities to our peril, for in neglecting them we neglect the nation." - John F. Kennedy's Special Message to the Congress Transmitting Reorganization Plan 1 (1962)

"Our struggle for global sustainability will be won or lost in cities." - Ban Ki Moon, ex-UN Secretary General (2012)

"...the well-connected open city is a powerful paradigm and an engine for integration and inclusivity." – Richard Rogers (2013)

"The city has always been a canvas for our dreams. But today it's not just a physical canvas, it's a digital one too." – Carlo Ratti (2016)

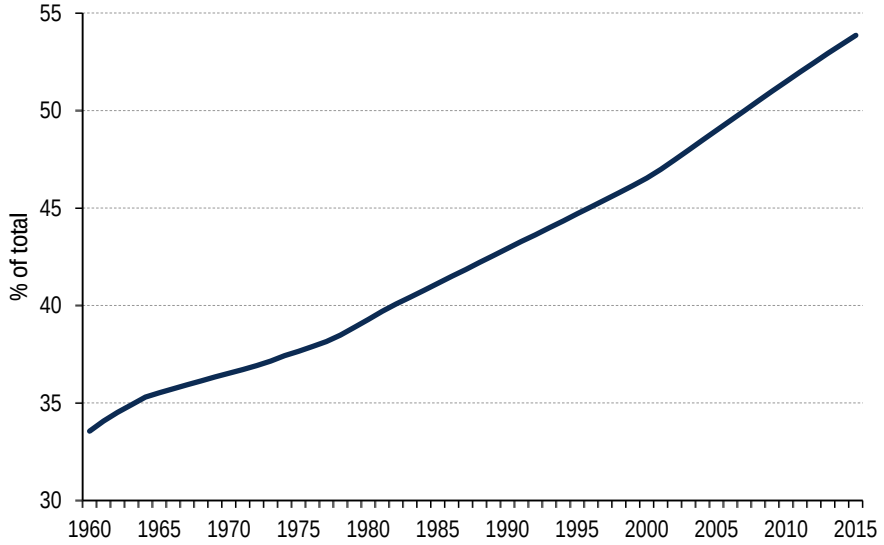
"We are going to fix our inner cities and rebuild our highways, bridges, tunnels, airports, schools, hospitals… We're going to rebuild our infrastructure, which will become, by the way, second to none. And we will put millions of our people to work as we rebuild it." – Donald Trump (2016)

Urban population: 55% today rising to 70% by 2050E

For the first time in history, there are more people living in urban than rural areas with 54.5% of the world's population city habitants in 2016 (vs 50% in 2000, 29% in 1950, 13% in 1900 and 2% in 1800).

Chart 1: 54.5% of the world's population lived in cities in 2016

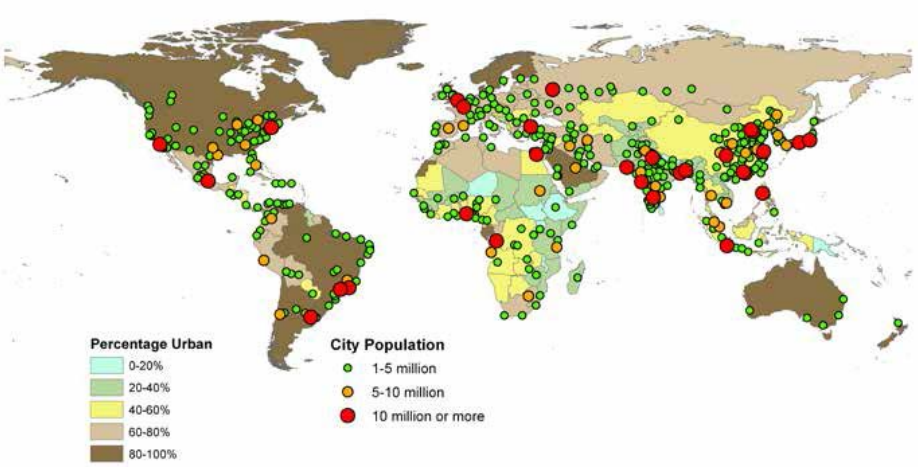
Global urban population (% of total)



Source: UN DESA 2015

82% of North Americans live in cities followed by South America (79%), Europe (74%), Asia-Pacific (48%), and Africa (40%) (source: UN).

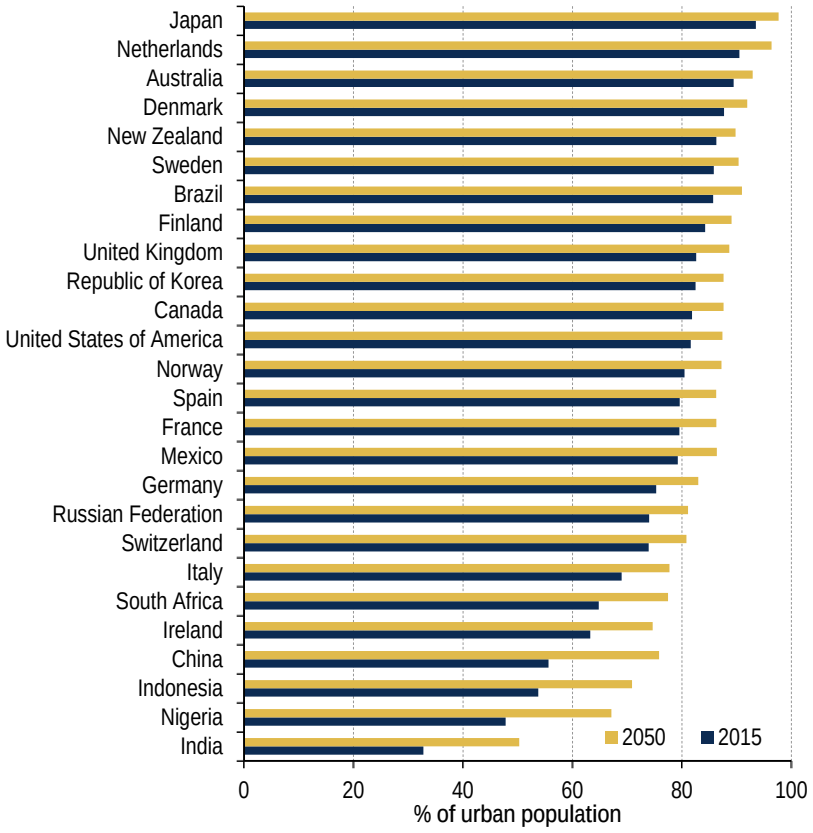
Exhibit 6: Global patterns of urbanization (2015)



Source: UN-Habitat World Cities Report 2016

- **A handful of countries account for over half of the world's urban population today**. China has the largest urban population (758mn, 20% of the global total), followed by India with 410mn and the US at 263mn. Together with Brazil, Indonesia, Japan, and Russia, these countries account for just over half of the world's urban population (source: UN 2014, UN 2016).

Chart 2: Share of population living in urban areas



Source: UN

- **The US is among the world's most urbanised nations**. 86% of the population is urban and there are 758 US cities with populations of over 50,000 people (collectively accounting for 124mn people) (source: C40 Cities-Arup 2016).

- **Cities are becoming denser with the worldwide human population density at 47 km² (120/mile²) but up to 24-44k per km² (65-114k/mile²) in some of the world's densest cities** (source: UN, Demographia).

Table 2: Top 10 built-up urban areas

Ranked by population per square mile/km

				Land Area		Population Density	
Rank	Geography	Urban Area	Population Estimate	Square Miles	Square Kilometers	Per Square Mile	Per Square Kilometer
1	Bangladesh	Dhaka	16,235,000	142	368	114,300	44,100
2	Pakistan	Hyderabad	2,900,000	28	73	106,800	41,200
3	India	Vijayawada	1,775,000	22	57	80,700	31,200
4	Bangladesh	Chittagong	3,250,000	43	111	75,600	29,200
5	India	Mumbai, MH	22,885,000	340	881	67,300	26,000
6	China: Hong Kong SAR	Hong Kong	7,280,000	110	285	66,200	25,600
7	India	Aligarh, UP	1,050,000	16	41	65,600	25,300
8	China: Macau SAR	Macau	655,000	10	26	65,500	25,100
9	Syria	Hamah	1,300,000	20	52	65,000	25,000
10	Somalia	Mogadishu	2,265,000	35	91	64,700	24,400

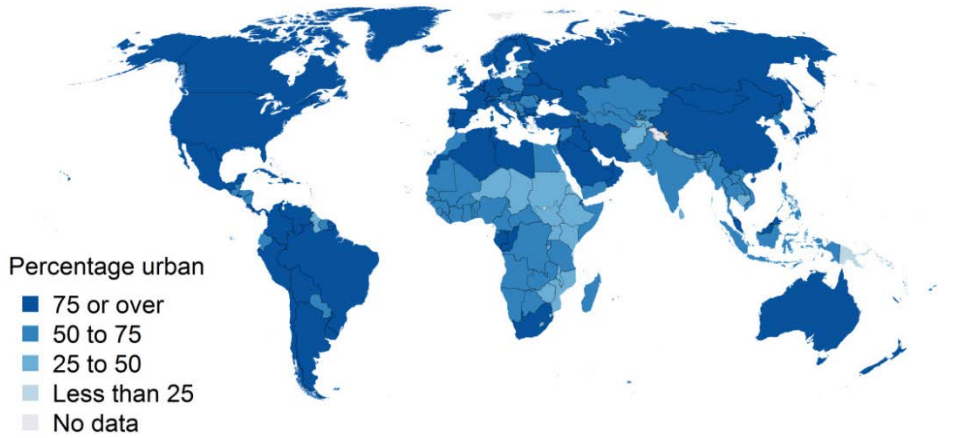
Source: Demographia 2016

- **There are 65mn new city residents every year (178k every day), and there could be up to 380mn more in the next five years and 2bn in the next 15 years** (source: UN).

1.4mn people are added to the urban population every week, an area the size of Manhattan is added every day and by 2050E, two-thirds of the world's population will be urban (source: UN 2014).

- **By 2050E, 70% of the world's population – including 86% in DMs – will live in urban areas** (source: UN).

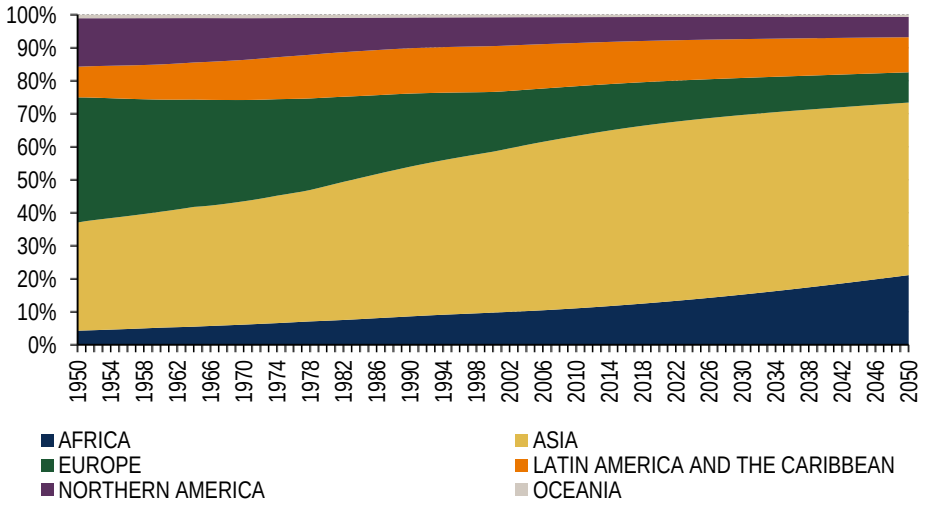
Exhibit 7: Percentage of the population expected to live in urban areas 2050E



Source: UN World Urbanization Prospects, The 2014 Revision

- **China, India and Nigeria are expected to account for 37% of the increase of nearly 2.5bn urban residents by 2050E**. India will be the #1 contributor (+404mn). The countries with the greatest urban populations in 2050E will be China (1bn), India (875mn), the US (365mn) and Nigeria (218mn). By region, the fastest pace of growth will occur in Africa, from just <5% in 1950 to c.20% by 2050E – increasing its share by 15ppt in a century (source: UN).

Chart 3: Percentage share of global urban population

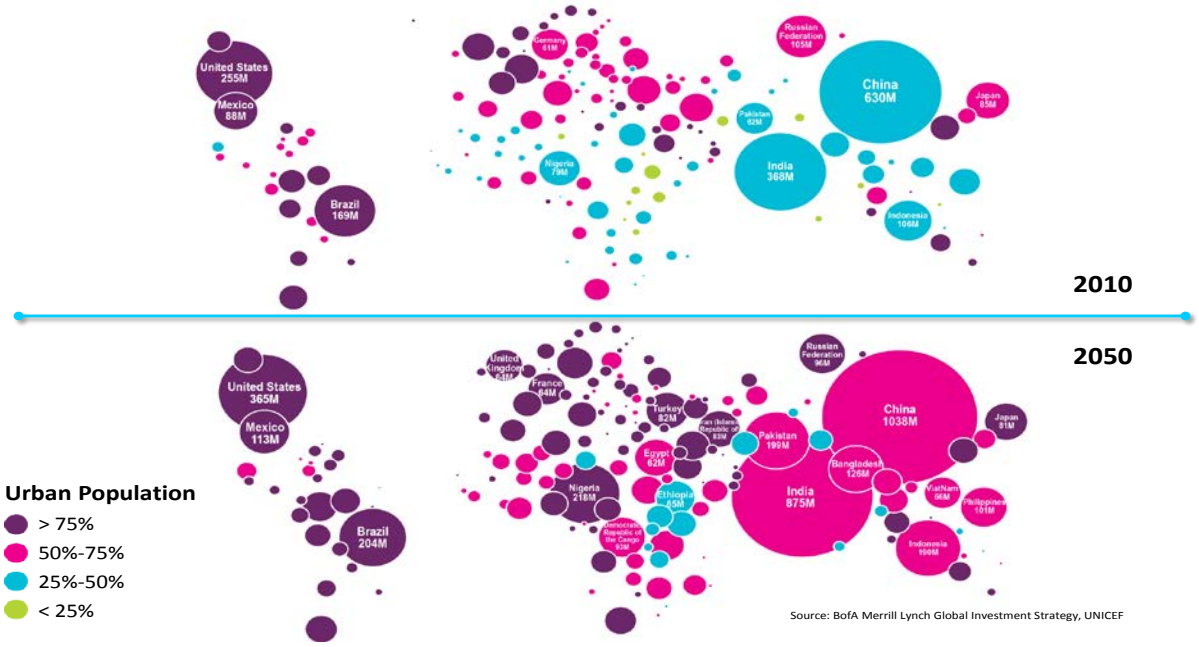


Source: UN

- **EMs to account for 90% of urban growth to 2050E**. The bulk of the 2016-50E urbanisation of 2.5bn people globally will take place in EMs, with 90% expected in Africa and Asia. From 2015-45, the urban population will increase by 1.1bn in Asia and 706mn in Africa (source: UN).

Exhibit 8: Worldwide growth in urban populations

Urban population by country in 2010 vs 2050



Source: UN, BofA Merrill Lynch Global Investment Strategy

The end of urbanisation after 8,000Y: urbanisation rates to slow to 2050E

Eight thousand years after the emergence of the first cities, the process of urbanisation will more or less come to an end. Based on current projections, by the end of the 21st century, 85% of the world's population is expected to live in cities. At that point, there will be little scope for further increases in urban population, because cities will still rely on rural areas and their residents for the provision of food and other essential resources as well as services such as recreation and tourism (source: OECD 2015).

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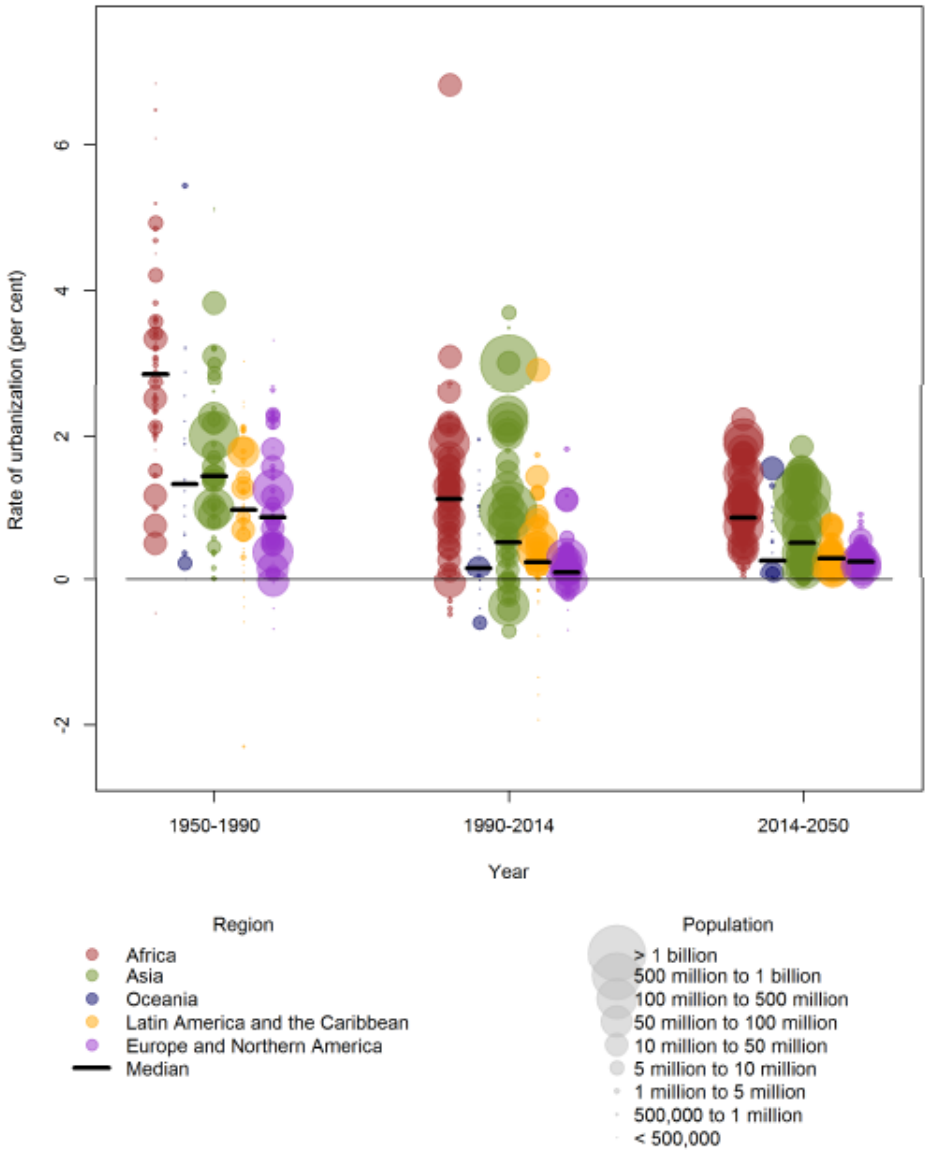
The median pace of urbanization had slowed in all regions by 1990-2014, when the median rate of change in the proportion urban was 1.1% on the high end in Africa and 0.1% on the low end in Europe and Northern America (source: UN 2014).

Exhibit 9: Rate of urbanisation by region (1950-1990, 1990-2014, 2014-2050E)



Source: UN World Urbanization Prospects: The 2014 Revision

Between 2000 and 2010, only four OECD countries (Australia, Canada, Mexico and the United States) had cities of 500 000+ inhabitants that reached growth rates over 2% p.a. (source: OECD 2015)

Changing global demographics: urban declines, rural declines, age wave

Any understanding of the growth of cities also needs to be balanced by an understanding of other demographic megatrends.

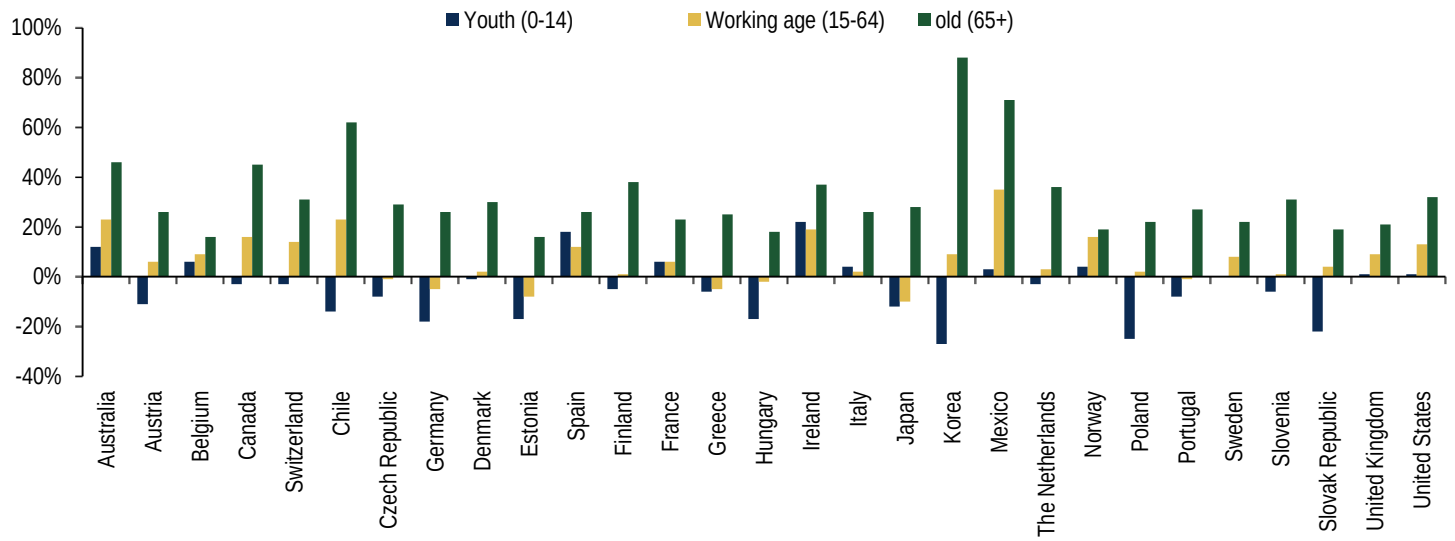
The double hit of slowing population growth and plateauing urbanisation caused population to decline in 6% of the world's largest cities from 2000-2015.

From 2015 to 2025E, the population is expected to decline in 17% of large cities in DMs and in 8% of all large cities (source: McKinsey 2016).

28 of the world's 600 largest cities are expected to shrink between 1990-2025E including: Dnipropetrovsk (-16.8%), Budapest (-14.7%), Donestsk (-14.2%), Zaporizhzhya (-13.2%), Nizhniy Novgorod (-11.8%), Saratov (-11.5%), Monrovia (-10.6%), Busan (-9.8%), Perm (-9.7%) (source: UN-Habitat).

- **12 countries have experienced declines in both their urban and rural populations since 1990**. Most are in North or Eastern Europe (Bosnia and Herzegovina, Bulgaria, Croatia, Estonia, Latvia, Lithuania, Moldova, Romania, Russia, Ukraine), as well as Armenia and Georgia (source: UN 2014).
- **19 countries will see the size of their urban population decrease to 2050E including Japan (-12mn or 10%), (-7mn or -7%)**. A number of European countries will see declines (Belarus, Bulgaria, Estonia, Germany, Gibraltar, Latvia, Lithuania, Malta, Moldova, Serbia and Ukraine) – as well as Bermuda, Cuba, Greenland, Puerto Rico, the Northern Mariana Islands and the US Virgin Islands (source: UN 2014).
- **The global rural population is projected to decline from its current level of 3.4bn to 3.2bn by 2050E**, reflecting reductions in the rural populations in around two thirds countries. India is currently home to the largest rural population (857mn) followed by China (635mn). The largest declines to 2050E are expected in China (-300mn rural dwellers by 2050E) and India (-52mn) (source: UN 2014).
- **Coming age wave**: Urbanisation trends closely mirror the global demographic megatrend of Ageing, and a shrinking of many global economies. The global 60+ years population is growing by 3.26% per year and is expected to reach 2.1bn by 2050E (vs 901mn today) (source: UN).

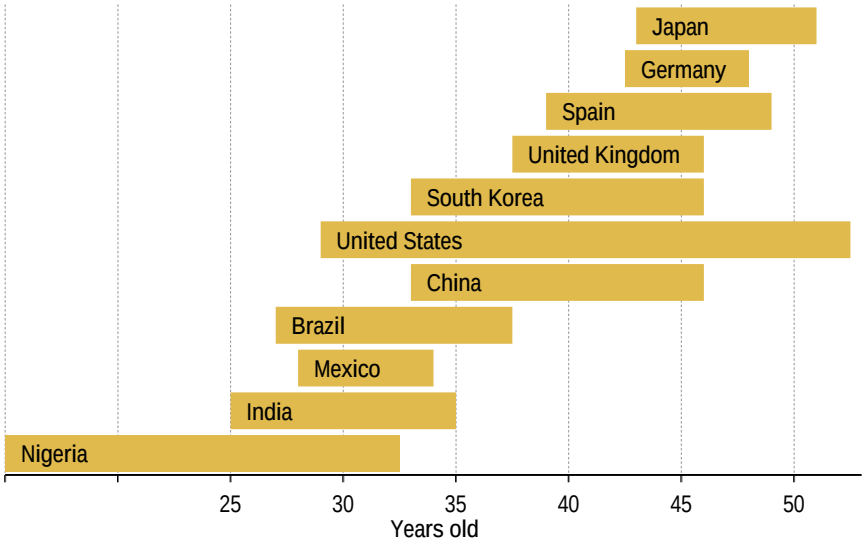
Chart 4: Population growth in OECD metropolitan areas by age group (2000-2014)



Source: OECD 2016

Populations in metropolitan areas are aging. Metro areas in 25 out of 29 OECD countries have increased the older population (65+). Metro areas in 12 countries have seen their younger (0-14) population decrease, indicating that they may face a declining active labour force in the future (source: OECD 2016).

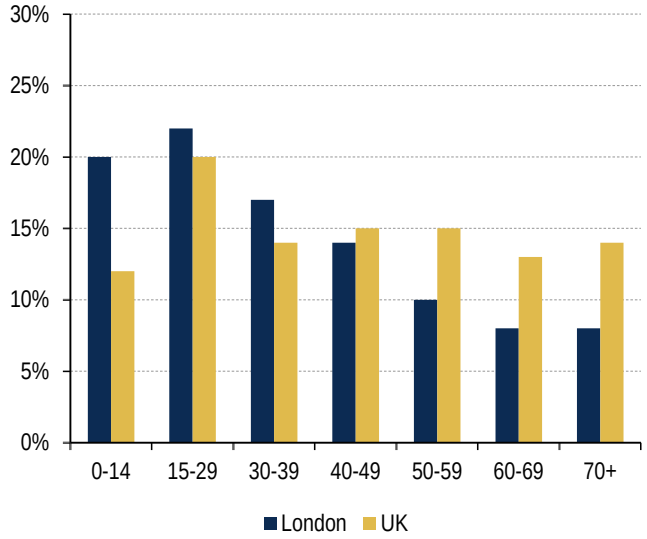
Chart 5: Range of cities' average age by country (2015)



Source: McKinsey

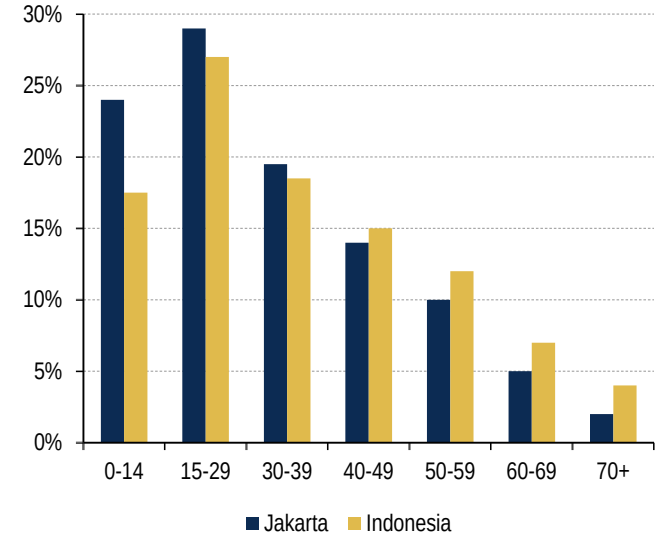
- **Cities tend to attract younger populations than the rest of their nation – which means a prominent role for Millennials (Gen Y) and Centennials (Gen Z) over the next generation**. Those under 24 years account for 40% of the global population, while Gen Y and Gen Z collectively account for 59% (4.4bn), with close to 90% living in EMs (source: UN).

Chart 6: London: youth think they will served by the good life in town
Population distribution in London and the UK (2015)



Source: PwC Cities of Opportunity 7 2016

Chart 7: Jakarta youth thinks exactly the same thing
Population distribution in Jakarta and Indonesia (2015)



Source: PwC Cities of Opportunity 7 2016

The rise of megacities & metacities: 10-37mn+

In 2014, 18 countries accommodated 28 so-called megacities (i.e. urban agglomerations with 10mn+ inhabitants), ranging from 10.2-37.8mn inhabitants and together being home to 453mn people (source: UN 2014).

World's 10 fastest growing megacities (2010-15) are all in EMs: Guangzhou (+5.2%), Beijing (+4.6%), Kinshasa (+4.2%), Lagos (+3.9%), Dhaka (+3.6%), Shanghai (+3.4%), Chongqing (+3.4%), Tianjin (3.4%), Karachi (+3.3%), Delhi (+3.2%) (source: UN).

China's Pearl River Delta is becoming a megalopolis: It has overtaken Tokyo as the world's largest urban area in both size and population – and at 42mn+ is already greater than either Canada, Australia or Argentina (source: World Bank, UN).

The rise of megacities poses and exacerbates multiple challenges: air pollution, crime, energy use, gentrification, homelessness, resource consumption, slums, traffic congestion, urban sprawl, waste et. al.

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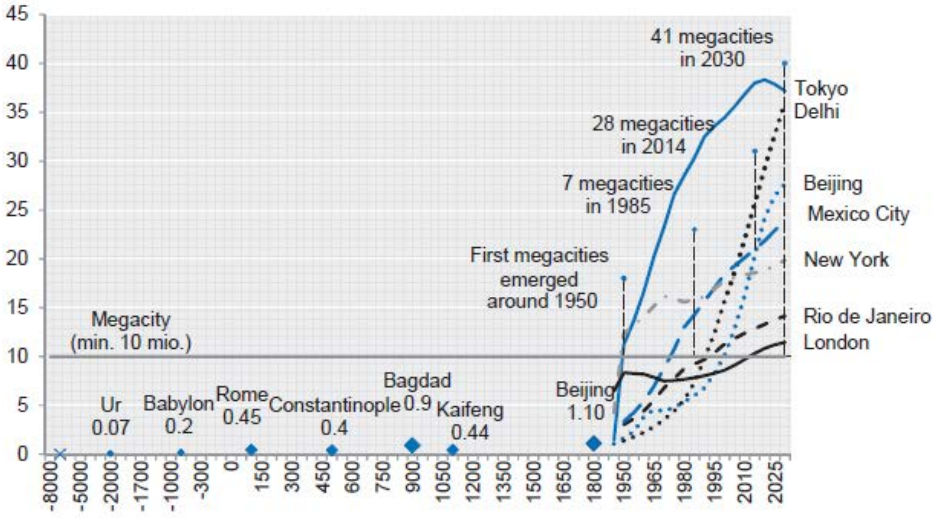
Exhibit 10: The rise of the megacities (8000 BCE to 2030E)

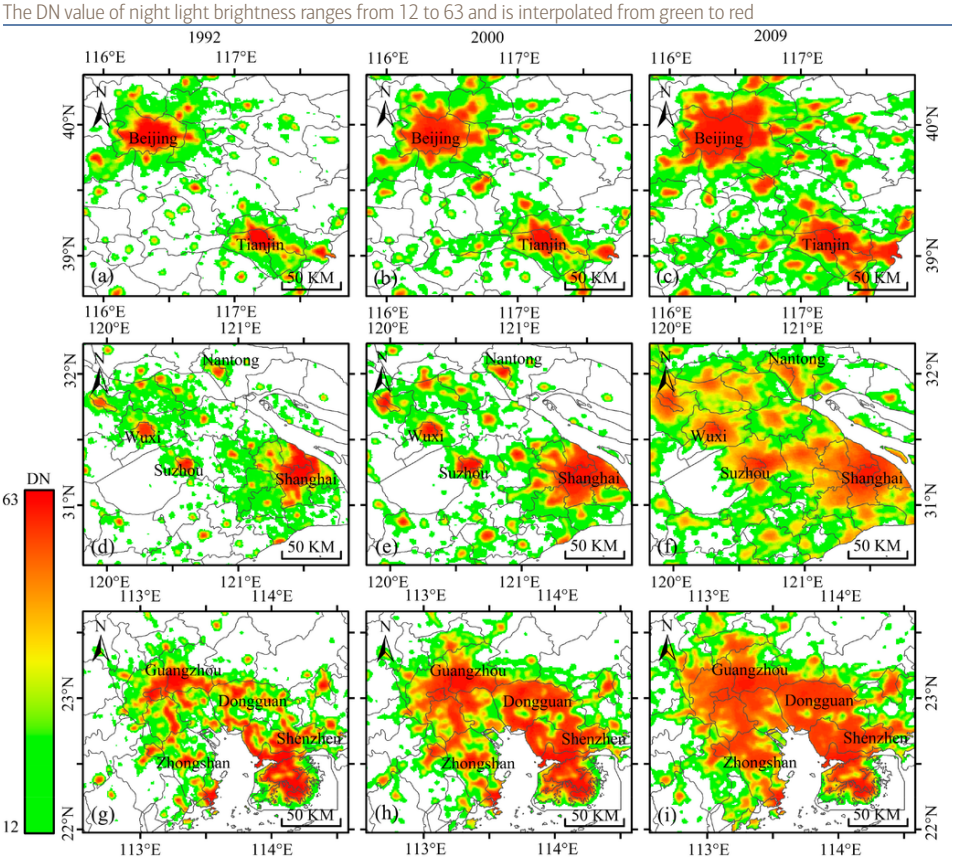


Source: OECD 2015

- **China and India host six and three of the largest megacities respectively**. Brazil, Japan and the US have two megacities each, and the remaining 13 countries have one megacity each (source: UN 2014).

Exhibit 11: Urbanisation of Chinese megacities located in Beijing-Tianjin region (top row), Yangtze River Delta (second row) and Pearl River Delta (third row) as measured by night light brightness (1992-2009)

The DN value of night light brightness ranges from 12 to 63 and is interpolated from green to red



Source: Xu et. al. Remote Sensing 2014

- **There are seven meta- or hyper-cities worldwide with 20mn+ inhabitants**. Tokyo is the world's largest city with an agglomeration of 38mn inhabitants, followed by

Delhi with 25mn, Shanghai with 23mn, Mexico City, Bombay and São Paulo, each of around 21mn, and Kinki M.M.A. (Osaka) with 20mn (source: UN 2014).

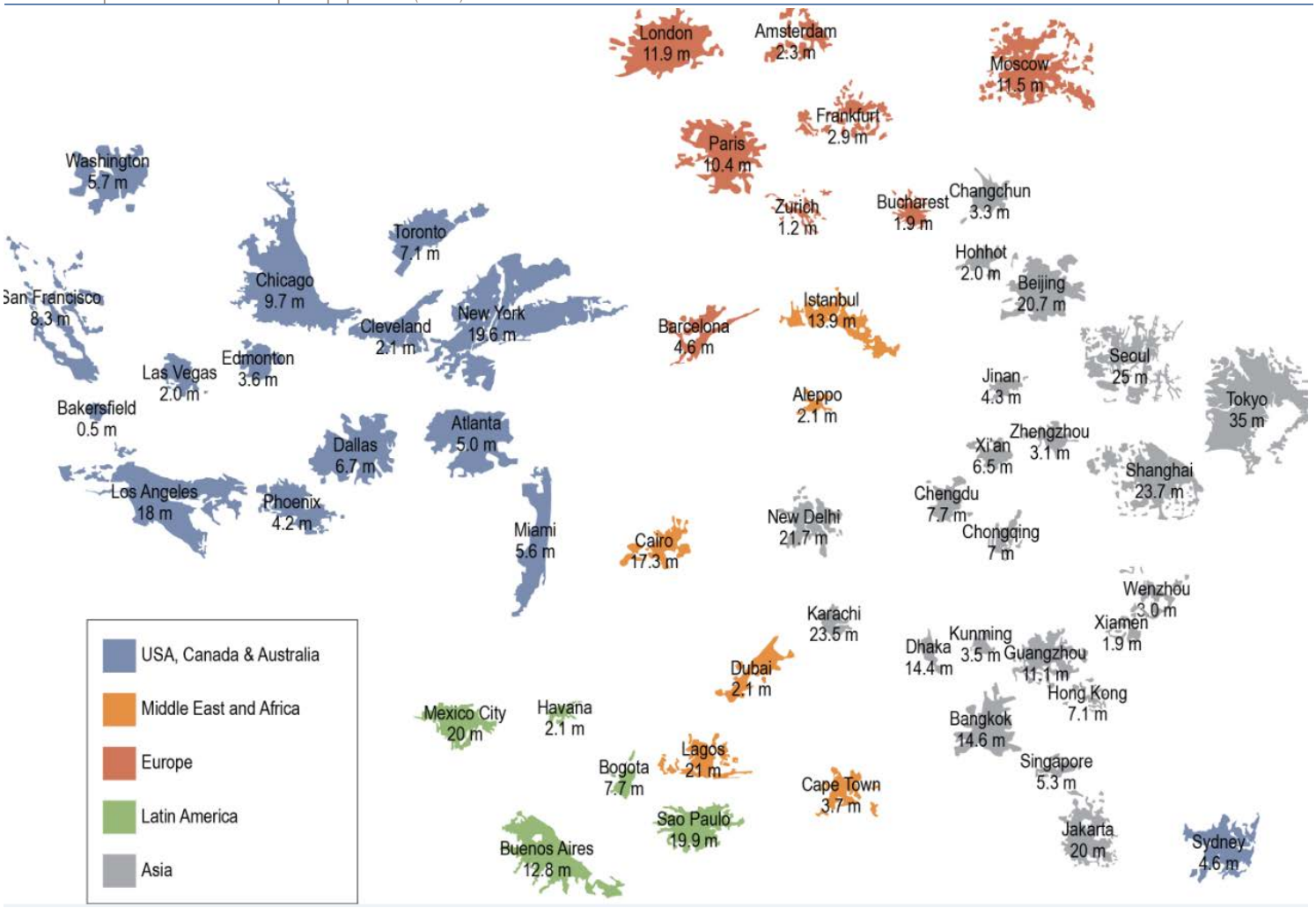
Table 3: Projected increases in city sizes (2000-30E)

	Number of Cities		Increase	
City Population	2000	2030	Absolute	%
300,000 to 500,000	501	832	331	66%
500000 to 1 million	385	731	364	90%
1 to 5 million	314	558	244	78%
5 to 10 million	30	63	33	110%
10 million or more	17	41	24	141%
Grand Total	1247	2225	978	78%

Source: UN

Exhibit 12: The global footprint of cities

Global metropolitan urban area footprints population (2014)



Source: Matthew Hartzell (2014). Areas reflect total urban built up area, including suburbs, and do not reflect municipal boundaries

- **The world will have 41 megacities and 11 metacities by 2030E**. Tokyo is expected to remain the world's largest urban agglomeration in 2030E, with Delhi and Shanghai maintaining their second and third positions respectively (source: UN 2014).

- **EMs are expected to dominate the list of the world's megacities and metacities by 2030E**. In addition to Delhi and Shanghai - Bombay, Beijing, Cairo, Dhaka, Karachi, and Lagos are expected to reach 24mn+ inhabitants. In contrast

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both LatAm metacities of today (Mexico City and São Paulo) as well as cities such as New York-Newark and Osaka will move down the global list (source: UN 2014).

Table 4: Top 20 global megacities (2030E)

Rank in 2030	Country	Urban agglomeration	Population (thousands)				Average annual rate of change (%)			
			1970	1990	2014	2030	1970-1990	1990-2014	2014-2030	Rank in 2014
1	Japan	Tokyo	23298	32530	37833	37190	1.67	0.63	-0.11	1
2	India	Delhi	3531	9726	24953	36060	5.07	3.93	2.3	2
3	China	Shanghai	6036	7823	22991	30751	1.3	4.49	1.82	3
4	India	Mumbai (Bombay)	5811	12436	20741	27797	3.8	2.13	1.83	6
5	China	Beijing	4426	6788	19520	27706	2.14	4.4	2.19	8
6	Bangladesh	Dhaka	1374	6621	16982	27374	7.86	3.92	2.98	11
7	Pakistan	Karachi	3119	7147	16126	24838	4.15	3.39	2.7	12
8	Egypt	Al-Qahirah	5585	9892	18419	24502	2.86	2.59	1.78	10
9	Nigeria	Lagos	1414	4764	12614	24239	6.08	4.06	4.08	19
10	Mexico	Ciudad de Mexico (Mexico City)	8831	15642	20843	23865	2.86	1.2	0.85	4
11	Brazil	Sao Paulo	7620	14776	20831	23444	3.31	1.43	0.74	5
12	DR of the Congo	Kinshasa	1070	3683	11116	19996	6.18	4.6	3.67	23
13	Japan	Kinki M.M.A. (Osaka)	15272	18389	20123	19976	0.93	0.38	-0.05	7
14	United States of America	New York- Newark	16191	16086	18591	19885	-0.03	0.6	0.42	9
15	India	Kolkata (Calcutta)	6926	10890	14766	19092	2.26	1.27	1.61	14
16	China	Guangzhou, Guangdong	1542	3072	11843	17574	3.45	5.62	2.47	22
17	China	Chongqing	2237	4011	12916	17380	2.92	4.87	1.86	16
18	Argentina	Buenos Aires	8105	10513	15024	16956	1.3	1.49	0.76	13
19	Philippines	Manila	3534	7973	12764	16756	4.07	1.96	1.70	18
20	Turkey	Istanbul	2772	6552	13954	16694	4.3	3.15	1.12	15

Source: UN World Urbanization Prospects: The 2014 Revision

USA: no megacities, but 19 out of the 20 largest US cities grew in 2015

19 out of the 20 largest cities in the US experienced population growth in 2015 of 1.03%, nearly double the rate from 2000-2010. With the exception of NYC, each of the top 15 cities that gained the greatest number of people between 2004-2015 were in the South or West (US Census Bureau 2016). By 2050E, it is expected that the city population in the U.S. will grow by 20%, from 124mn today to 149mn (source: C-40 Cities-Arup 2016)

Fastest growing US cities with 50k+ populations (2014-2015): Georgetown (TX), New Braunfels (TX), Ankeny (IO), Frisco (TX), South Jordan (UT), Dublin (CA), Pearland (TX), Milpitas (CA), Broomfield (CO), Mount Pleasant (SC)

Top large US cities with population increases (2014-2015): NYC, Houston, LA, San Antonio, Phoenix, Fort Worth, Dallas, Austin, Denver, Charlotte

Top large US cities with population decreases (2014-2015): Detroit, Chicago, Baltimore, Cleveland, Anchorage, St. Louis, Pittsburgh, Buffalo, Toledo, Memphis (source: US Census Bureau 2016)

Table 5: The 10 most populous US cities on July 1, 2015

Rank	Area Name	State Name	2015 Total Population
1	New York	New York	8,550,405
2	Los Angeles	California	3,971,883
3	Chicago	Illinois	2,720,546
4	Houston	Texas	2,296,224
5	Philadelphia	Pennsylvania	1,567,442

Table 5: The 10 most populous US cities on July 1, 2015

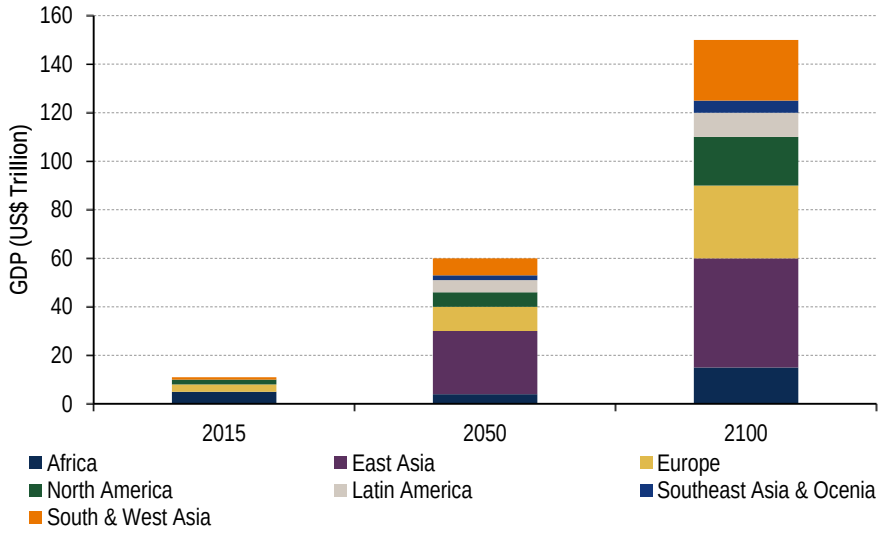
Rank	Area Name	State Name	2015 Total Population
6	Phoenix	Arizona	1,563,025
7	San Antonio	Texas	1,469,845
8	San Diego	California	1,394,928
9	Dallas	Texas	1,300,092
10	San Jose	California	1,026,908

Source: US Census Bureau 2016

Economic development: 85% of GDP generated in cities

Cities are engines of economic growth, with annual economic activity of about US$62tn, or about 85% of global GDP in 2015. By 2030E, this is expected to rise to US$115tn, or 87% (source: The Global Commission on the Economy and Climate).

Chart 8: Projected economic growth in current C40 cities*



Source: C40 Cities-Arup 2016, Arup analysis of Economist Intelligence Data

Cities are the #1 contributor to GDP, the world's 600 largest cities will comprise nearly 65% of global GDP growth in the next 10 years (source: McKinsey).

In 2015, 90.8% of US GDP was generated in metro areas and the 10 highest-producing metropolitan economies generated US6.2tn in economic value, more than the total value output of 37 US states (source: C-40 Cities-Arup 2016)

Paris is 16% of the population of France but accounts for 27% of GDP, Manila 12% and 47%, and Kinshasa 13% and 85%, respectively (source: UN-Habitat).

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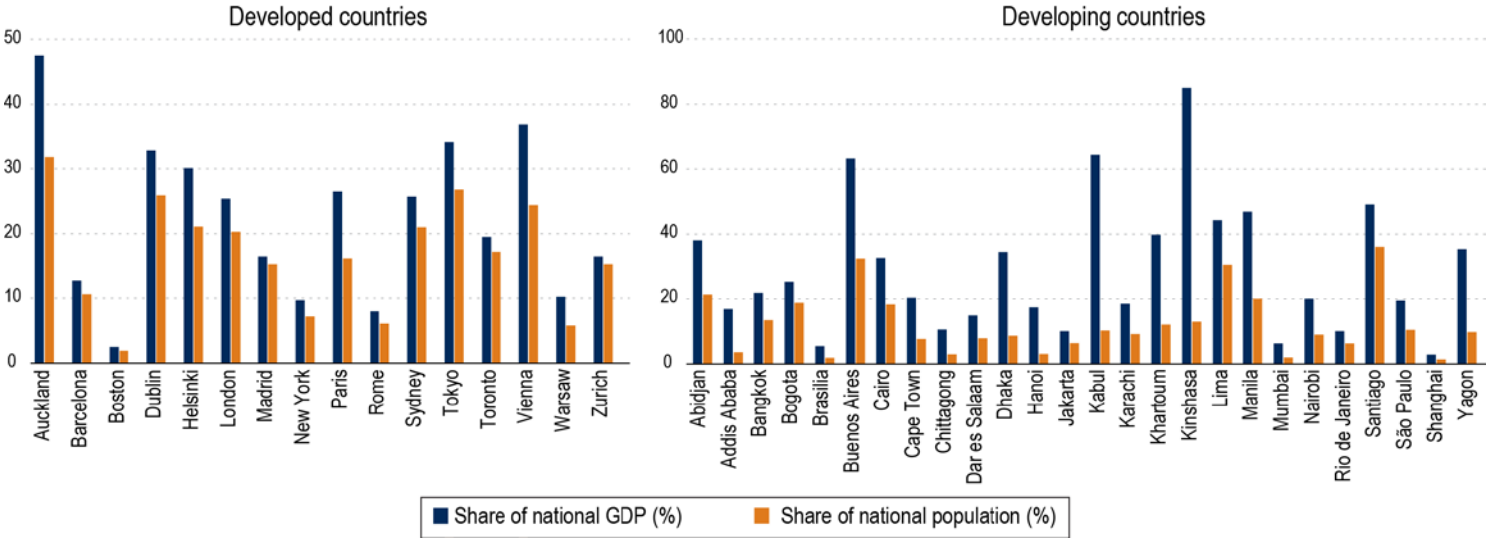
Exhibit 13: Share of GDP and national population of selected cities



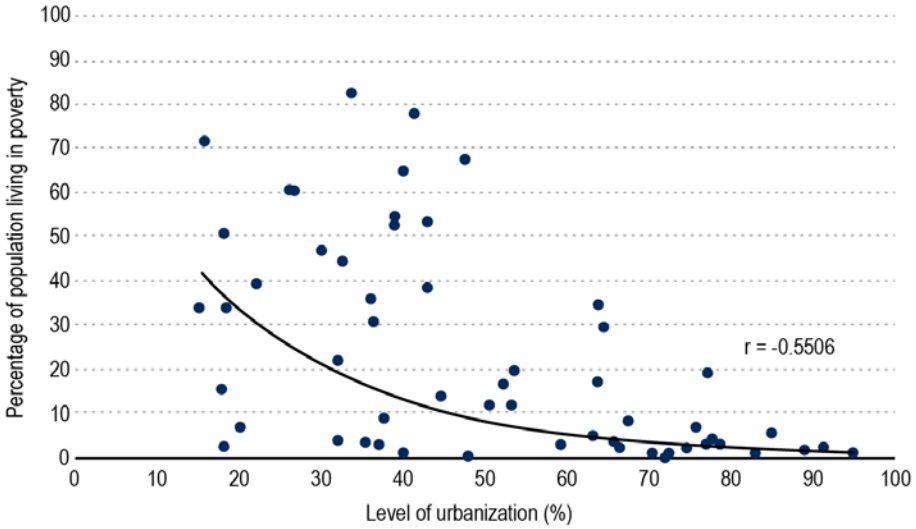
Source: UN Habitat World Cities Report 2016

No country has achieved development without urbanisation

In the modern era, no country has achieved its level of development without urbanising – and in virtually all cases worldwide, the contribution of urban areas to national income is greater than their share of the national population (source: UN-Habitat 2016).

Exhibit 14: Cities and inclusive prosperity

Urbanisation and poverty



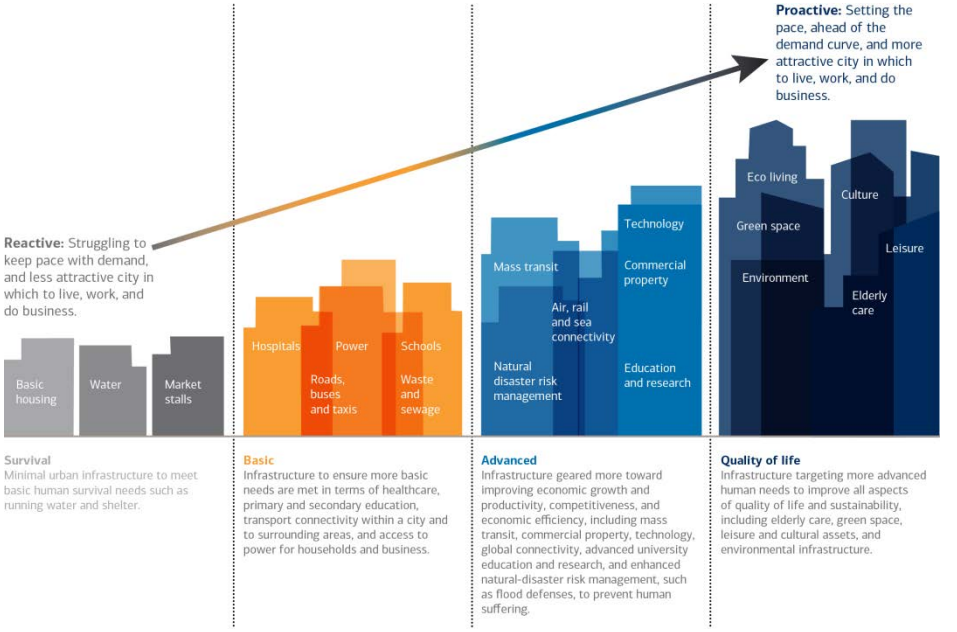
Source: UN-Habitat 2016 based on UN 2014 and World Bank 2016

Economic growth and urbanisation are directly correlated

No country has achieved middle-income status without a significant population shift to cities. Urbanisation is a major investment opportunity driving higher productivity and innovation by facilitating economies of scale, and combining production, low(er) transaction costs, and skilled workers (source: Brookings Institute). Further, cities and their newfound consumers with rising purchasing power need infrastructure in the broad sense of the term – energy, housing, transportation, education and healthcare (source: Abraaj). The rise of China's middle class – and the lifting of 500mn people out of poverty – is one of many examples of the power of urbanisation.

EMs can capture an "urbanisation dividend" that creates jobs, raises productivity, reduces infrastructure costs and environmental impact, supports new enterprise and shares this prosperity widely (source: PWC).

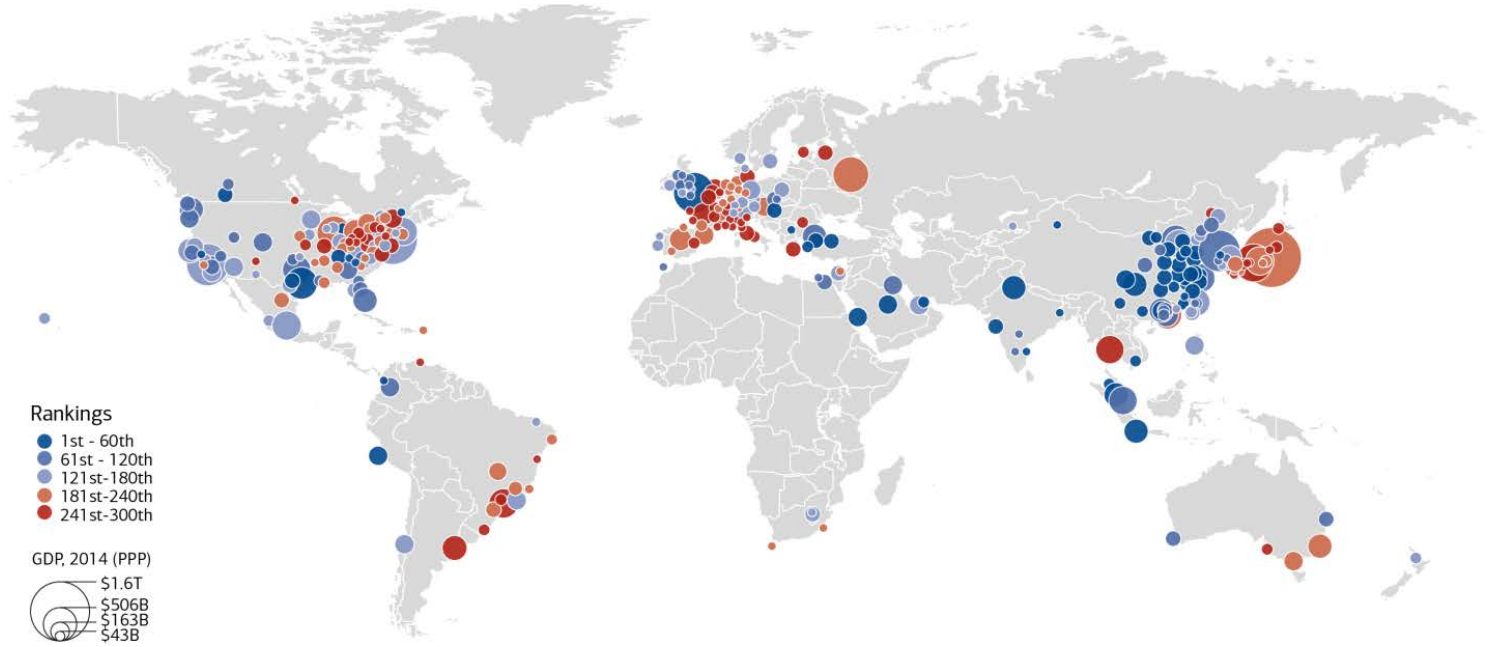
Exhibit 15: Urbanisation brings infrastructure improvements and better quality of life



Source: PwC

As a rule of thumb, a 230% increase in a country's urbanisation rate will double the income per person (source: World Bank).

Exhibit 16: Combined change in employment and GDP per capita (2014)



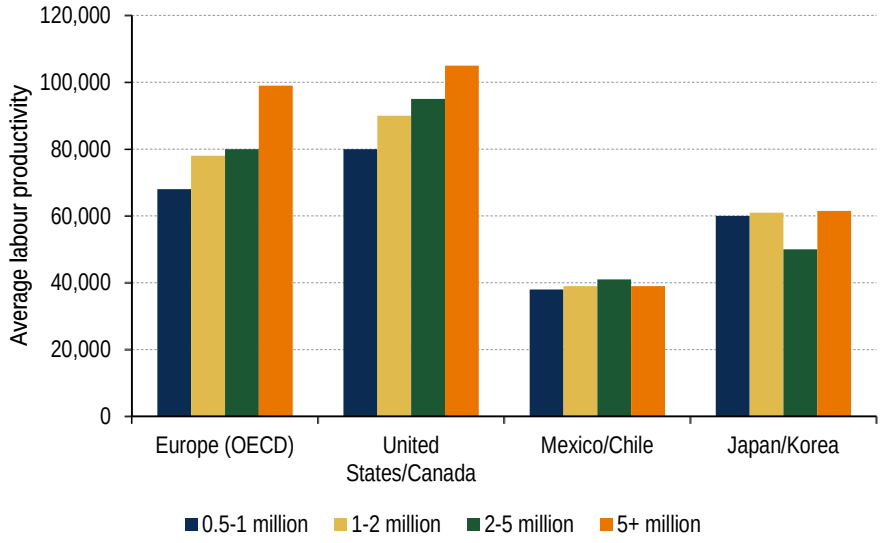
Source: Brookings Institute

Economically successful cities: size matters

The productivity levels of cities (and thus their GDP) is correlated to their population size, and larger cities are generally more productive than smaller ones. Recent OECD studies suggest that for each doubling in population size, the productivity level of a city increases by 2-5%. This is due to several factors, such as greater competition or deeper labour markets (and thus a better matching between workers and jobs) in larger cities, but also due to a faster spread of ideas and a more diverse human capital, intellectual and entrepreneurial environment (source: OECD 2015).

Chart 9: Larger metropolitan areas are more productive

Average labour productivity in US$ 1'000

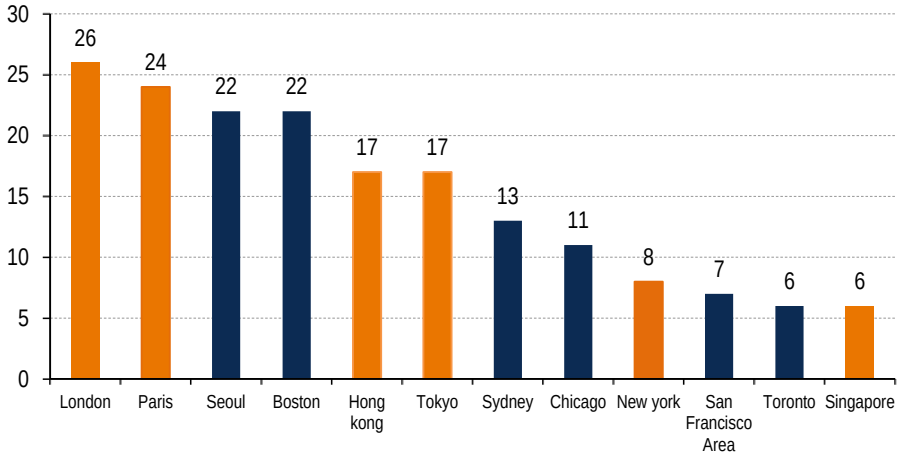


Source: OECD 2015

- **Larger cities tend to have a higher share of highly educated people** which has important implications for productivity levels. This is partly due to more educated people being more productive themselves. But in addition there are important spillover effects: the productivity of less educated people increases with the share of university graduates. And the benefits of size partly reflect that individuals with high human capital are themselves even more productive in the presence of other highly skilled residents (source: OECD 2015).

Chart 10: London, Paris, Seoul and Boston are world leading education centres

Number of leading universities in three higher education rankings

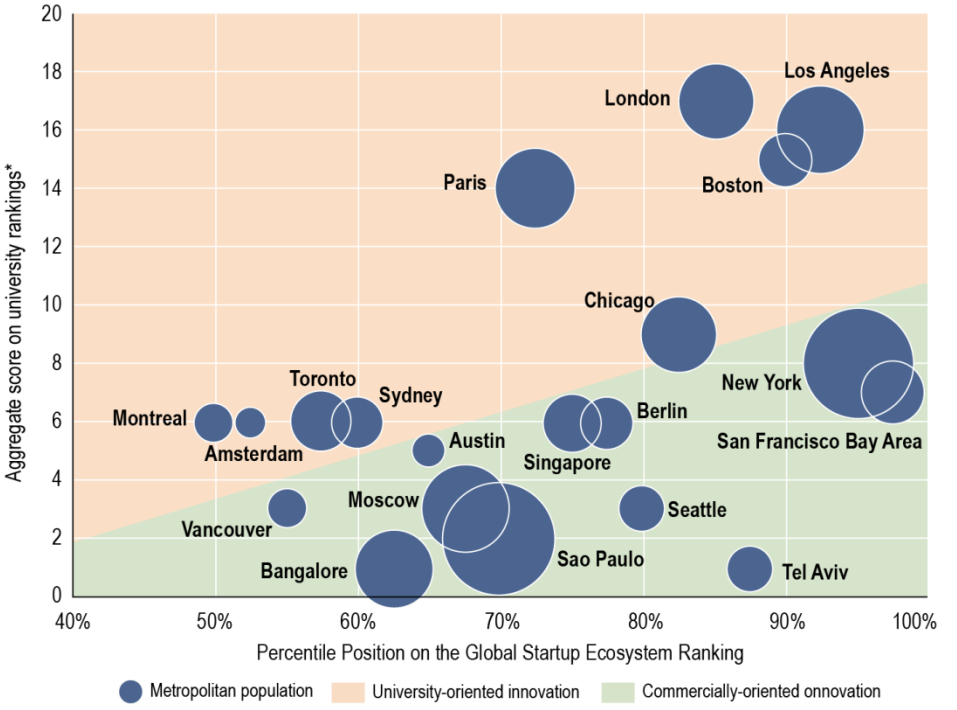


Source: JLL The Business of Cities 2015 based on the number of higher education establishments in each city featured in the top 500 entries of The Times, QS and Shanghai Higher Education rankings

- **Cities economic success is increasingly linked to their capacity to leverage their knowledge assets and foster innovation)**. Disruptors such as Big Data, Robots & AI, VR, and the sharing economy are transforming business models and workplace needs, and lowering barriers for more cities to foster entrepreneurship (source: JLL 2016).

Exhibit 17: There is growing interest in how capable cities are at supporting digital and technology clusters, given the impact these sectors have in shaping demand

Global top 20 start-up ecosystems and university performance



Source: JLL 2016

Cities economic clout is reconfiguring global politics & economics

As cities expand in size and influence – and realise that they often have more in common with one another than their own nation - they are playing an increasingly influential role in reconfiguring global politics and economics.

If mayors ruled the world – a miracle of civic "glocality": "Because they are inclined naturally to collaboration and interdependence, cities harbor hope. If mayors ruled the world.... urban dwellers... could participate locally and cooperate globally at the same time — a miracle of civic 'glocality' promising pragmatism instead of politics, innovation rather than ideology and solutions in place of sovereignty." – Benjamin Barber, author of If Mayors Ruled the World

- **Cities are raising their profiles on issues ranging including climate change, disease, inequality, refugees and safety**.
- **Cities are also forging innovative new forms of international cooperation, with c 200 inter-city networks**, more than the number of inter-state associations. A new Global Parliament of Mayors was launched in 2016 to tackle major challenges facing the world's cities.

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- **Cities are forming their own "diplomatic corps"** with mayors, urban planners, city entrepreneurs, local cultural leaders, academics and municipal services leaders serving as emissaries (source: Citiscope).

Companies need to better understand cities

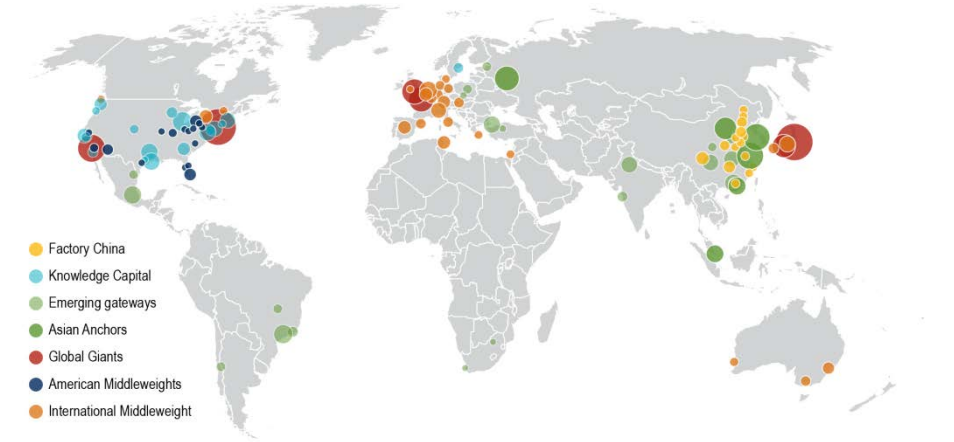
Companies need to understand how shifting demographics around global cities impact their organisation's footprint. That is, knowing which cities will be home to key future consumers, matching footprints with promising urban markets, managing parallel products and channels for increasingly disparate consumer groups, and focusing on the growing importance of services for urban consumers (source: McKinsey).

Three in five companies perceive cities as an "irrelevant unit of strategic planning" – despite the fact that there are often fewer risks and greater opportunities at the city level (source: McKinsey).

Not all cities are created equal: seven types of global cities

Beyond economic clout, however, there is significant variation in which competiveness factors play out across the world's largest cities. Brookings Institution has clustered 123 metro economies based on their size, industrial structure, and competitiveness factors. In some cases, these groupings align to specific regions, like in China or the US. But, just as often, the groupings unite metros from different parts of the world, showcasing that they share more in common with far-flung counterparts than with their regional neighbours (source: Brookings Institute 2016).

Exhibit 18: Seven types of cities among the world's largest metro areas (metro area dots are sized according to 2015 GDP)



Source: Brookings Institution 2016

- **Global Giants**: six large, wealthy hubs with concentrations of corporate headquarters; they serve as the command and control centers for the world's largest advanced economies
- **Asian Anchors**: five large, business and financial nodes anchoring inward investment into the Asia-Pacific and Russia.
- **Emerging Gateways**: 28 large business and transportation entry points for major national and regional emerging markets in Africa, Asia, Eastern Europe, and Latin America.
- **Factory China**: 22 second- and third-tier Chinese cities distinctly reliant on export-intensive manufacturing to power economic growth and global engagement.

- **Knowledge Capitals**: 19 mid-sized, highly productive knowledge creation centers in the United States and Europe with talented workforces and elite research universities.

- **American Middleweights**: 16 mid-sized U.S. metro areas striving for a post-recession niche in the global economy.

- **International Middleweights**: 26 mid-sized cities in Australia, Canada, and Europe globally connected by people and investment flows, but where growth has lagged after the financial crisis (source: Brookings Institute 2016).

Table 6: Seven types of global cities based on their size, industrial structure, and competitiveness

Group name	Metro areas
Global Giants	London, Los Angeles, New York, Osaka-Kobe, Paris, and Tokyo
Asian Anchors	Beijing, Hong Kong, Moscow, Seoul-Incheon, Shanghai, and Singapore
Emerging Gateways	Ankara, Brasilia, Busan-Ulsan, Cape Town, Chongqing, Delhi, East Rand, Guangzhou, Hangzhou, Istanbul, Jinan, Johannesburg, Katowice-Ostrava, Mexico City, Monterrey, Mumbai, Nanjing, Ningbo, Pretoria, Rio de Janeiro, Saint Petersburg, Santiago, Sao Paulo, Shenzhen, Tianjin, Warsaw, Wuhan, and Xi'an.
Factory China	Changchun, Changsha, Changzhou, Chengdu, Dalian, Dongguan, Foshan, Fuzhou, Harbin, Hefei, Nantong, Qingdao, Shenyang, Shijiazhuang, Suzhou, Tangshan, Wenzhou, Wuxi, Xuzhou, Yantai, Zhengzhou, and Zibo
Knowledge Capitals	Atlanta, Austin, Baltimore, Boston, Chicago, Dallas, Denver, Hartford, Houston, Minneapolis, Philadelphia, Portland, San Diego, San Francisco, San Jose, Seattle, Stockholm, Washington DC, and Zurich
American Middleweights	Charlotte, Cincinnati, Cleveland, Columbus, Detroit, Indianapolis, Kansas City, Miami, Orlando, Phoenix, Pittsburgh, Riverside, Sacramento, San Antonio, St. Louis, and Tampa
International Middleweights	Brussels, Copenhagen-Malmö, Frankfurt, Hamburg, Karlsruhe, Köln-Düsseldorf, Milan, Munich, Nagoya, Rome, Rotterdam-Amsterdam, Stuttgart, Vienna-Bratislava, Athens, Barcelona, Berlin, Birmingham, (UK), Kitakyushu-Fukuoka, Madrid, Melbourne, Montreal, Perth, Sydney, Tel Aviv, Toronto, and Vancouver

Source: Brookings Institute 2016

The 5 kinds of cities we will see in the "populist era":

- **Besieged City**: budget cuts and regulatory rollbacks
- **Opposition city**: opposing anti-trade and anti-immigrant efforts
- **Progressive city**: actively pursuing their own progressive agendas
- **Prosperous city**: economic power and market relevance
- **Networked city**: public, private, civic, university, and community institutions (source: CityLab 2017)

US metros exposed to a potential Trump "trade shock" (by exports as a share of GDP):

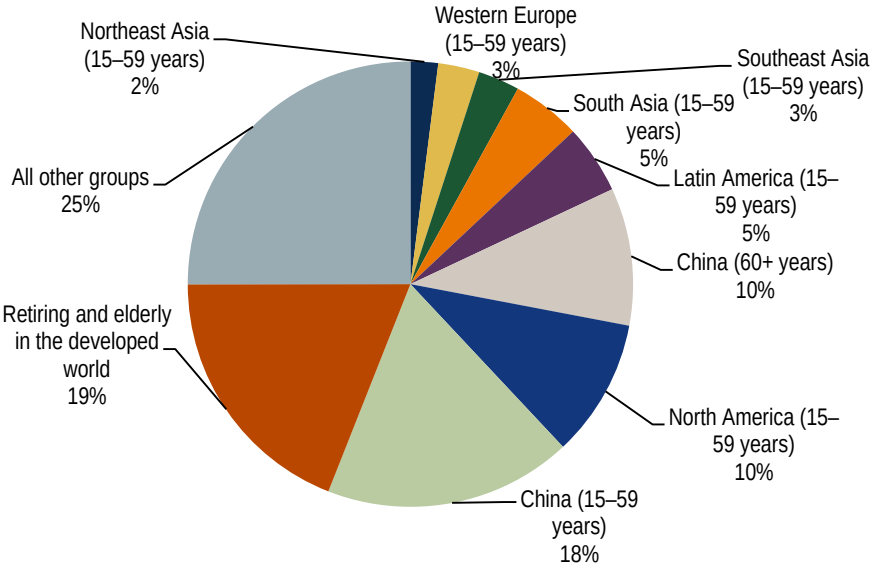
- Baton Rouge (24.3%), Wichita (19.9%), New Orleans-Metairie (18.7%), Seattle-Tacoma-Bellevue (17.9%), Detroit-Warren-Dearborn (17.4%), Greensboro-High Point (16.9%), Portland-Vancouver-Hillsboro (16.0%), Ogden-Clearfield (15.9%), Houston-The Woodlands-Sugar Land (15.9%); Youngstown-Warren-Boardman (15.4%) (source: Brookings 2017)

Power of urban consumers: +US$23tn from 2015-30E

Global urban consumption is expected to grow by US$23tn between 2015 and 2030E, a 3.6% CAGR, with nine consumer groups expected to account for 75% of this growth (source: McKinsey 2016).

Chart 11: Nine consumer demographics will generate 75% of global urban consumption growth from 2015-30E

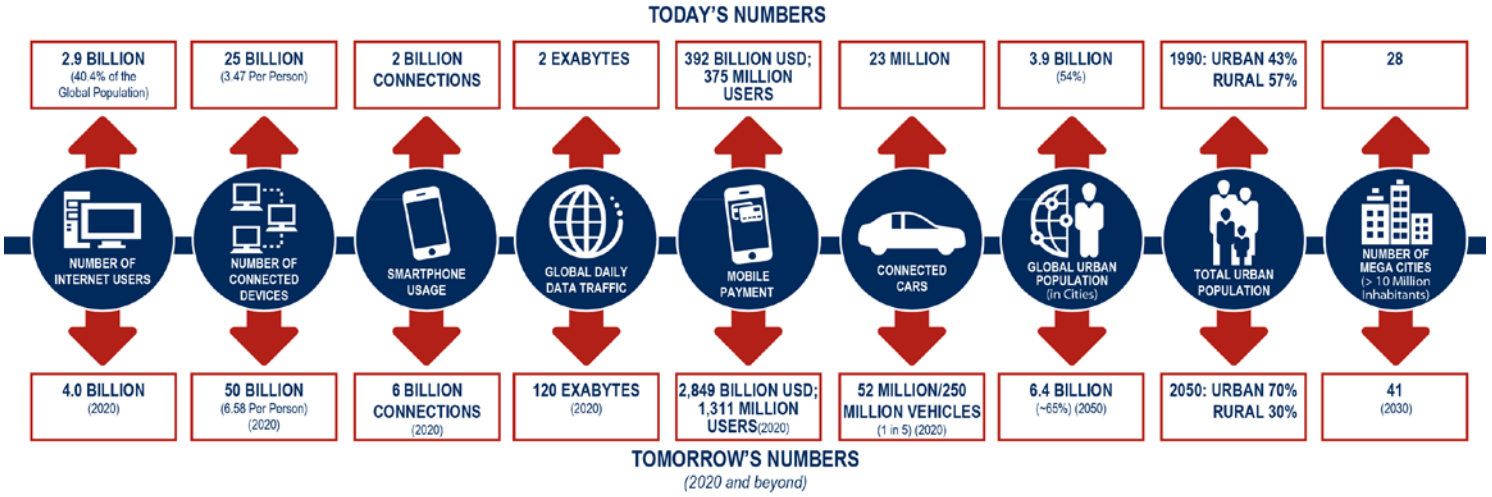
Share of global urban consumption growth 2015-30



Source: McKinsey 2016

Urban consumers are driving a variety of thematic megatrends in our view – from the rise of smartphones to connected devices to Big Data to demographic changes.

Exhibit 19: Digitisation: Today Versus Tomorrow

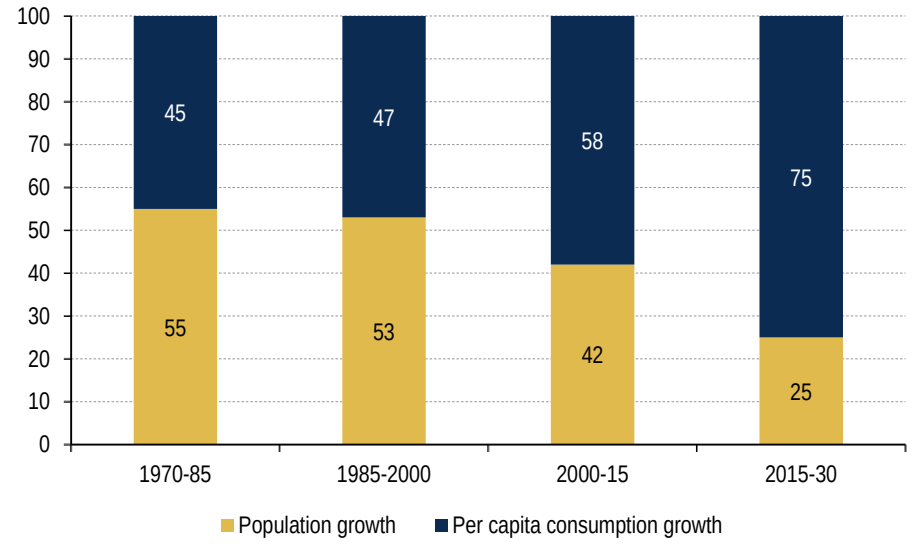


Source: Booz Allen Hamilton based on ITU & UNESCO, Microsoft, Cisco, GSMA, EMC, BusinessWire (FMI), Forbes, Gartner, UN – 1 of the 2 people in the world today lives in urban areas, UN.

- **Per capita consumption to fuel 75% of global consumption growth**: US$17tn of the estimated US$23tn increase in consumption to 2030E is expected to come from rising per capita consumption. This is a significant shift from the 20th century – when more than 50% of consumption growth was driven by an expanding population – and is driven by waning population growth, declining fertility, ageing and an easing in the pace of rural-to-urban migration in certain countries (source: McKinsey 2016).

Chart 12: 75% of global consumption growth to 2030E will come from increases in per capita spending

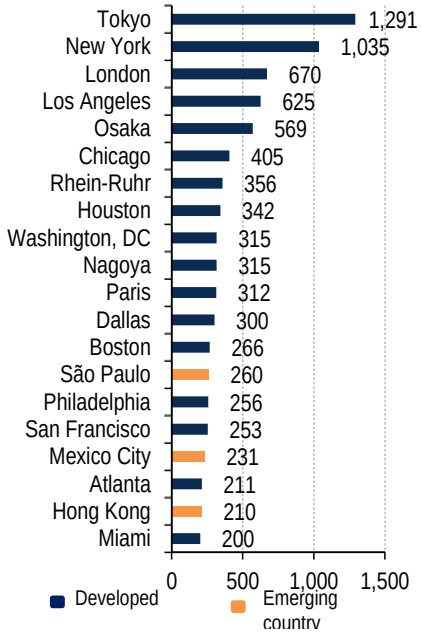
Source of consumption growth (% of growth)



Source: McKinsey 2016

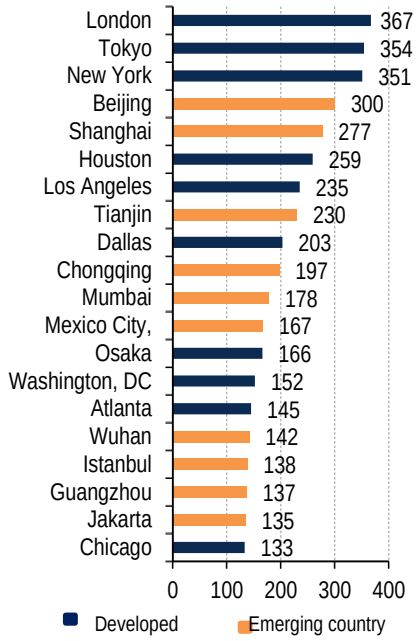
- **Global urban consumption is extraordinarily concentrated with 100 cities expected to generate 45% of the US$23tn growth**. By 2030E, consumers in large cities will account for 81% of global consumption and generate 91% of global consumption growth from 2015 to 2030E (source: McKinsey 2016).

Chart 13: Top 20 global cities by absolute 2015 consumption (US$bn)



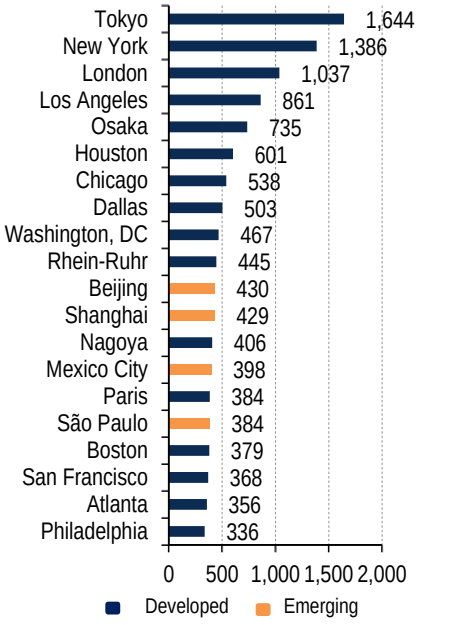
Source: McKinsey 2016

Chart 14: Top 20 global cities by 2015-30E consumption growth (US$bn)



Source: McKinsey 2016

Chart 15: Top 20 global cities by absolute 2030E consumption



Source: McKinsey 2016

- **Nine groups of consumers are projected to generate c.75% of global urban consumption growth from 2015 to 2030E with three groups accounting for c.50%**: (1) DM consumers of 60 years+ (164mn in 2015 to 222mn in 2030E, 51% of urban consumption growth in DMs); (2) China's working-age consumers aged 15-59 years (+100mn by 2030E, per capita consumption is expected to more than

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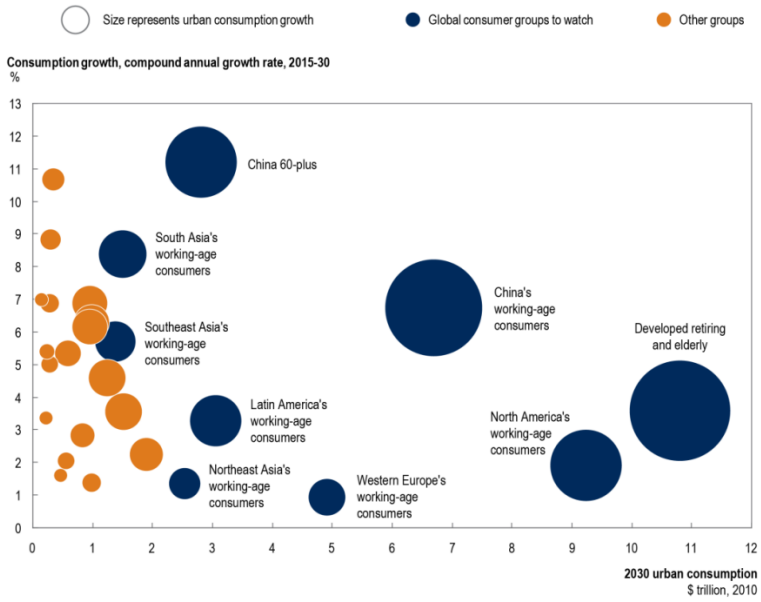
double and they will account for 12% of worldwide urban consumption by 2030E); and (3) North American working-age consumers aged 15-59 years (+7% in numbers and +24% in per capita consumption by 2030E) (source: McKinsey 2016).

Exhibit 20: Nine consumer groups to generate c.75% of global consumption growth (2015-30E)



Source: McKinsey 2016

Highest urban consumption growth (2015-2030E): China 60-74Y (6.74%), China 30-44Y (6.71%), China 45-59Y (5.96%), NAm 60-74Y (5.76%), China 15-29Y (5.57%)

Lowest urban consumption growth (2015-2030E): SSA 75Y+ (0.06%), MENA 75Y+ (0.14%), Australia 0-14Y (0.16%), Australia 15-29Y (0.20%), Australia 75Y+ (0.20%) (source: McKinsey 2016)

Exhibit 21: Global consumers to watch

Share of urban consumption growth, 2015–30
%

Low — High

Age group Years	Developed regions: United States and Canada	Western Europe	North-east Asia	Austral-asia	Emerging regions: China	Latin America	South Asia	South-east Asia	Eastern Europe and Central Asia	Sub-Saharan Africa	Middle East and North Africa	Total
0–14	2.35	0.79	0.43	0.16	2.62	0.64	0.81	0.64	0.40	0.58	0.33	9.73
15–29	2.82	1.00	0.38	0.20	5.57	1.28	1.56	1.10	0.67	0.99	0.55	16.12
30–44	4.44	1.05	0.23	0.24	6.71	1.79	1.69	1.20	0.83	0.95	0.56	19.68
45–59	2.67	0.68	1.39	0.21	5.96	2.03	1.37	1.10	1.19	0.64	0.70	17.96
60–74	5.76	3.00	1.08	0.24	6.74	1.69	0.91	0.72	0.93	0.34	0.41	21.81
75-plus	4.99	2.14	2.33	0.20	3.07	0.79	0.26	0.21	0.48	0.06	0.14	14.70
Total	23.02	8.67	5.84	1.24	30.68	8.22	6.60	4.98	4.50	3.56	2.68	

Global consumers to watch
1. Developed retiring and elderly
2. North America's working age
3. China's working age
4. China's 60-plus
5. Southeast Asia's working age
6. South Asia's working age
7. Western Europe's working age
8. Northeast Asia's working age
9. Latin America's working age

Source: McKinsey 2016

- **Middleweight EM cities may offer the best growth opportunities**: It is not the megacities, but emerging mid-sized EM cities such as Ahmedabad, Cali, Kochi, Huambo, Medan, Pune, and Viña del Mar, that may offer the best growth opportunities.

c.700 large cities in China alone will account for US$7tn, or 30%, of global urban consumption growth to 2030E (source: McKinsey).

Table 7: Incomes vary significantly across the world's 300 largest metropolitan economies

Highest & lowest GDP per capita, 300 largest metropolitan economies (2013, US$)

Highest				Lowest			
Rank	Metro	Region	GDP p.c.	Rank	Metro	Region	GDP p.c.
1	Zurich	Western Europe	$82,410	281	Kunming	Developing Asia-Pacific	$6,680
2	Oslo	Western Europe	$82,040	282	Xuzhou	Developing Asia-Pacific	$6,550
3	San Jose	North America	$77,440	283	Shijiazhuang	Developing Asia-Pacific	$6,540
4	Hartford	North America	$76,510	284	Manila	Developing Asia-Pacific	$6,160
5	Geneva	Western Europe	$74,580	285	Medellin	Latin America	$5,940
6	Paris	Western Europe	$70,760	286	Wenzhou	Developing Asia-Pacific	$5,630
7	Boston	North America	$70,390	287	Chongqing	Developing Asia-Pacific	$5,590
8	Bridgeport	North America	$68,570	288	Casablanca	Middle East and Africa	$5,400
9	Washington DC	North America	$68,530	289	Jakarta	Developing Asia-Pacific	$5,020
10	Seattle	North America	$67,830	290	Nanning	Developing Asia-Pacific	$4,860
11	Macau	Developing Asia-Pacific	$67,780	291	Shantou	Developing Asia-Pacific	$4,150
12	San Francisco	North America	$66,790	292	Delhi	Developing Asia-Pacific	$3,580
13	Perth	Developing Asia-Pacific	$65,500	293	Ho Chi Minh City	Developing Asia-Pacific	$3,300
14	Calgary	North America	$64,540	294	Cairo	Middle East and Africa	$2,980
15	New York	North America	$64,460	295	Alexandria	Middle East and Africa	$2,680
16	Portland	North America	$64,370	296	Mumbai	Developing Asia-Pacific	$1,990
17	Munich	Western Europe	$64,180	297	Chennai	Developing Asia-Pacific	$1,870
18	Houston	North America	$63,730	298	Hyderabad	Developing Asia-Pacific	$1,430
19	Dublin	Western Europe	$63,600	299	Bangalore	Developing Asia-Pacific	$1,420
20	Luxembourg-Trier	Western Europe	$63,350	300	Kolkata	Developing Asia-Pacific	$1,110

Source: Brookings Institution 2015

- **Services are commanding an ever-larger share of urban consumption as per capita GDP rises**: With rising urban incomes, a smaller share of spending goes

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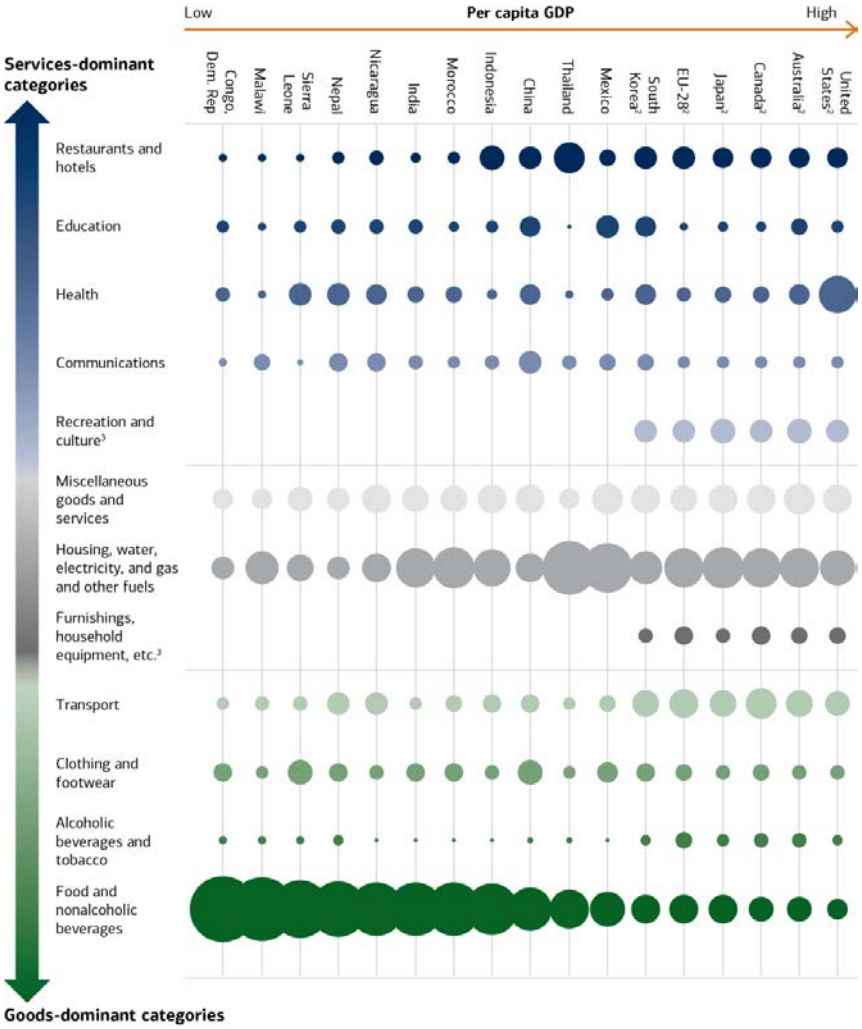
toward necessities, while the proportion on services rises. The underlying for this reasons vary with DMs seeing growth in healthcare spending by the ageing 60+ years cohort while in EMs, an expanding consuming class is fuelling demand for cinemas, restaurants and banking services (source: McKinsey 2016).

Exhibit 22: Services share of household consumption increases with per capita income

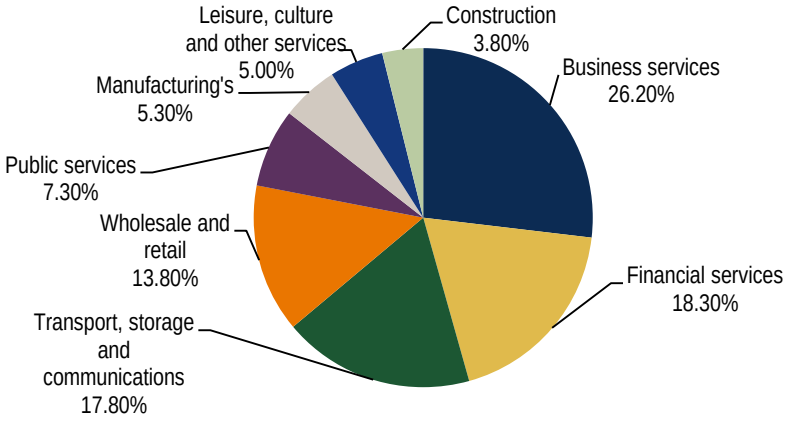
Proportion of total household expenditure by sample countries (Low to High)



Source: McKinsey 2016 based on World Bank Global Consumption Database; Eurostat; McKinsey Global Institute analysis
1 Figures do not include public spending on health care and education.
2 Household consumption figures from Eurostat; all other figures from the World Bank Global Consumption Database.
3 Category data only available for select countries

- **Finance and business services drive almost half of all GDP growth in cities (45%) from 2010-2015**. Other intellectually based jobs are increasingly important in areas like communications and healthcare. If current trends continue, digital and technology needs will increase. Human capital will continue to be in demand with good education. And requirements to navigate risk and regulatory complexity will increase along with the dominance of business and finance (source: PwC).

Chart 16: Contribution of sectors to overall GDP growth (2010-2015)

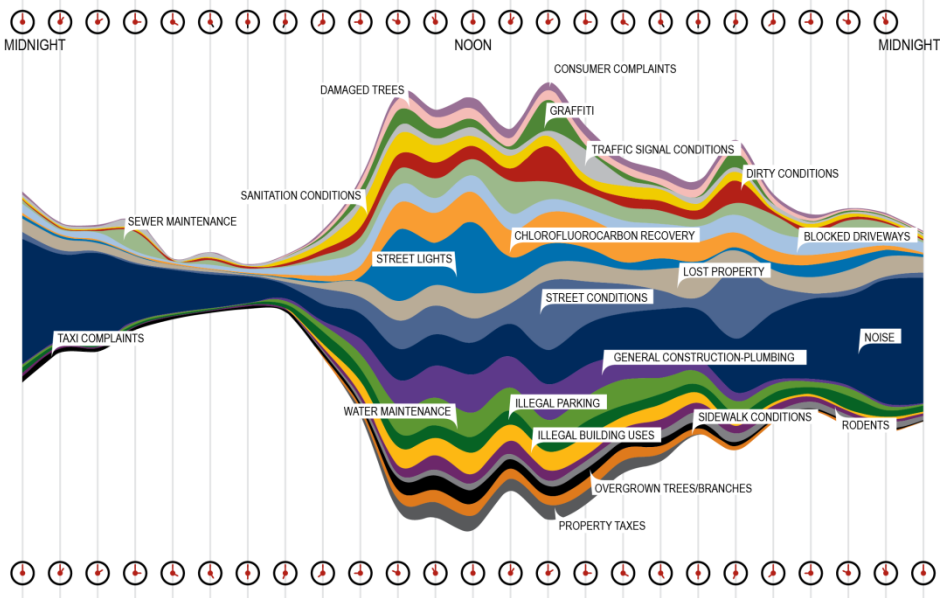


Source: PwC Cities of Opportunity 7 2016

Challenges to urban prosperity: cities reaching a tipping point

Drastic global changes to ideas and practices, modes of production and consumption, demographic structures, as well as education and health conditions over the past two decades are changing the way cities are shaped and functionality. Many of these changes have been for the better, but others for the worse (source: UN-Habitat 2016). Governments are facing increasing challenges as urbanisation needs to adapt to salient realities such as changing demographics, inequality, climate change, insecurity, migration, corruption, and poor governance and a broad range of issues around unsustainable urban expansion. These challenges have implications for local economies, quality of life, and socioeconomic advancement and are pushing many cities towards a tipping point, in our view.

Exhibit 23: What 100mn calls to 311 in 24 hours reveal about New York City residents*



Source: Wired

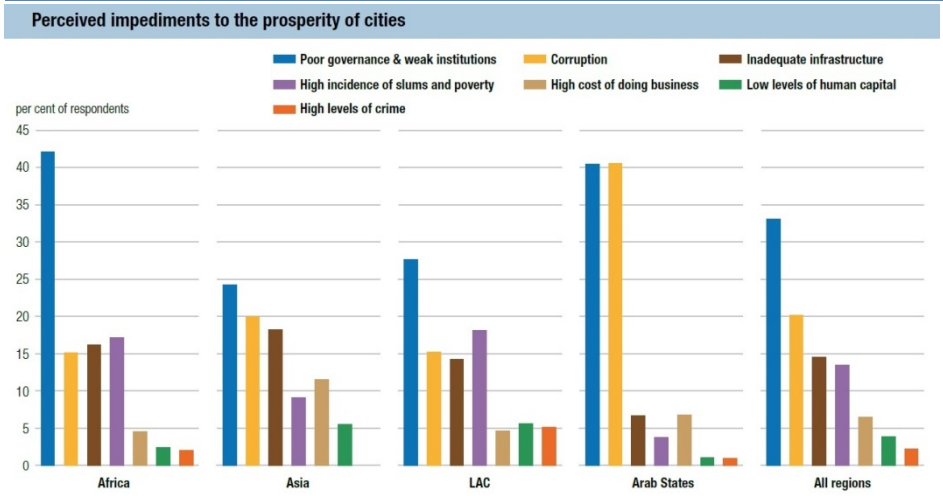
* There were 34,522 complaints called in to 311 (which provides access to non-emergency municipal services) between September 8 and September 15, 2010

Cities are facing the '3S menace'. The scale and speed of this global urbanisation, and the scarcity of means with which we must respond to it, has no precedents in human history." (source: Alejandro Aravena).

Poor governance and weak institutions: #1 perceived impediment to prosperity

Poor governance and weak institutions were recognised by UN-Habitat as the #1 perceived impediment to the prosperity of cities. More than 40% of experts cite this factor as the single biggest impediment to prosperity in EMs in Africa and Arab States. Indeed, in these cities, as in many others in EMs, the institutions required for urban prosperity, if they exist, are weak. Institutional inadequacies take the form of weak (if not altogether lacking) legal and institutional frameworks, disregard for the rule of law, poor enforcement of property rights, excessive bureaucracy, and proliferation of corrupt practices, among others. All these are incompatible with urban prosperity (source: UN-Habitat).

Exhibit 24: Poor governance & weak institutions: #1 perceived impediment to the prosperity of cities



Source: UN-Habitat State of the World's Cities 2012/2013

- **Corruption, the #2 global impediment, has a drastic impact in urban areas**. A high-density and expanding population puts pressure on space, water and public services like health and education. This causes shortages and whenever there are shortages, there are big corruption risks (source: Transparency International). Corruption in cities acts as a deterrent to FDI, undermines the ability of authorities to provide fair municipal services, distorts infrastructure spending for the poor, and causes poor delivery of urban services (source: UN-Habitat, Transparency International).

The Chicago-based Federal Judicial District for Northern Illinois continues to report more public corruption convictions than any of the US's 92 other judicial districts. Numbers two to five comprise: the Central District of California (Los Angeles), the Southern District of New York (Manhattan), District of Columbia (DC) and Florida Southern (Miami) (source: University of Illinois at Chicago 2015 analysis of US DoJ's public corruption conviction statistics).

Inadequate infrastructure: US$78tn needed over next 10 years

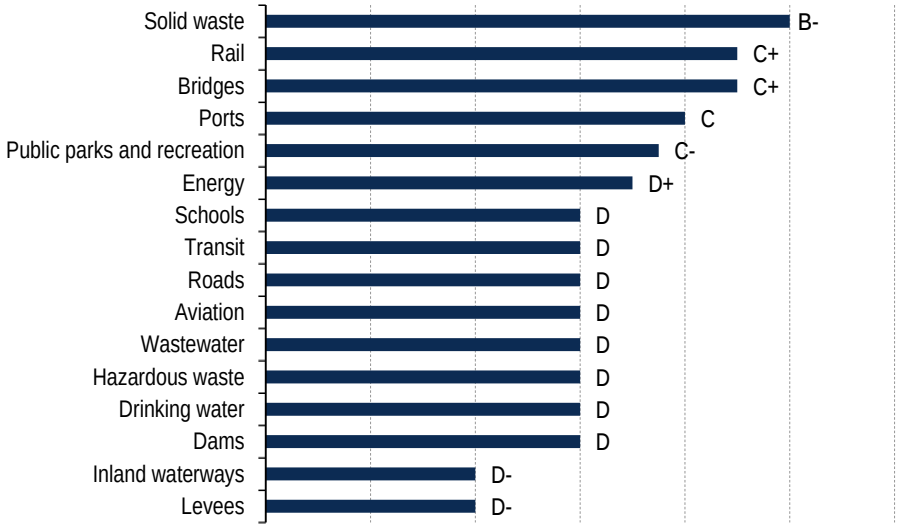
The rise of megacities is creating an urgent need for infrastructure investments, including the revamping of antiquated infrastructure in DMs and build-out of infrastructure in EMs. Inadequate infrastructure is a major impediment to urban prosperity and is most pronounced in Asian and African cities. Deficient infrastructure can adversely affect cities on many fronts: it can raise the costs of doing business and reduce firm productivity by as much as 40% (source: UN-Habitat).

US$78tn in global infrastructure investments are needed over the next 10 years to accommodate the growth of cities – and New York, Beijing, Shanghai and London alone will need US$8tn (source: PwC 2013, UN-Habitat 2013).

The investment needed in cities into low carbon transport, energy, water, waste and telecommunications infrastructure is estimated at US$57tn between now and 2030E (source: WWF and Z/Yen Group 2015).

Chart 17: US infrastructure report card (A = exceptional, F = failing)

Each category was evaluated on the basis of capacity, condition, funding, future need, operation & maintenance, public safety & resilience



Source: American Society of Civil Engineers 2013

Rising inequality: 1bn living in poverty in cities, 75% of cities worse off vs 20 years ago

Inequality is one of the defining issues of our age with the world more unequal than it was 20 years ago. Of the c.3bn urban dwellers today, 1bn live below the poverty line (source: UN). Seventy-five percent of the world's cities have higher levels of income inequality than two decades ago and by the early 2030s, 2bn people will be living below the poverty line in cities (source: UN-Habitat). The redistribution of wealth and opportunities across diverse backgrounds that has historically characterised urban dynamics seems to have stalled in many regions of the world and many cities are becoming sites of deprivation and exclusion (source: UN-Habitat). This has profoundly negative consequences including narrowing the tax base, diminishing the abilities of schools, and raising the price of private-sector goods and services (source Brookings Institute).

51% of countries have seen their levels of inclusive development decline over the past five years reiterating public concern regarding translating economic growth into broad social progress (source: WEF 2017).

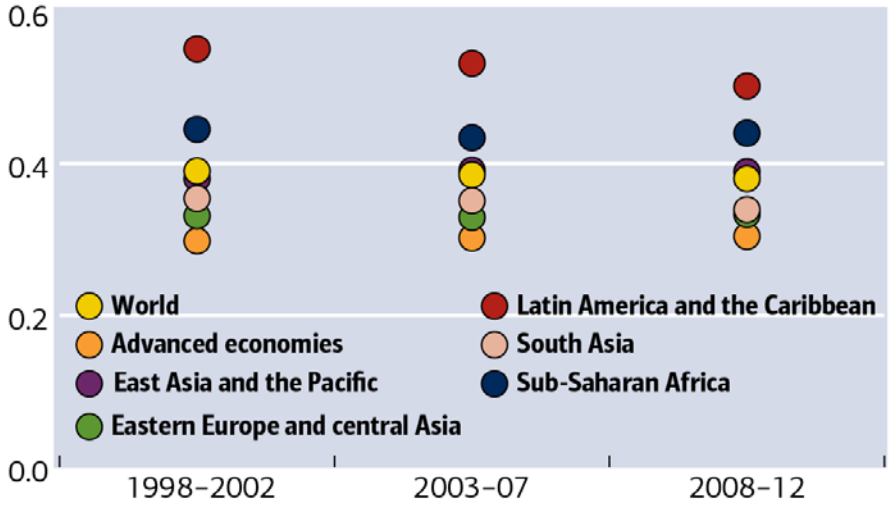
More than two-thirds of the world's population lives in cities that are more unequal today than 20 years ago (source: UN-Habitat World Cities Report 2016).

- **The gap between rich and poor is widening in DMs and EMs, including in countries that were considered the most egalitarian**. While global poverty is on the decline and the middle class is on the rise, income inequalities continue to grow. According to the World Bank, the world's Gini ratio increased from 0.65 points in 1980 to 0.70 in 2010, pointing to higher inequality even as wealth accumulated like never before.

A majority of US mayors across 102 cities now say poverty is their most pressing economic concern (44%) followed by shrinking middle class (28%), and income inequality (23%) (source: 2016 Menino Survey of Mayors).

Exhibit 26: Only LatAm and South Asia are seeing a fall in inequality

Average Gini coefficient by region and income level, five-year averages (0 = perfect equality, 1 = maximal inequality)



Source: IMF

Table 8: World Economic Forum's Inclusive Development Index 2017 – top performers

Advanced Economies		Developing Economies	
Top Ranked	Most Improved 5-Year Trend	Top Ranked	Most Improved 5-Year Trend
Norway	Iceland	Lithuania	Lesotho
Luxembourg	New Zealand	Azerbaijan	Nepal
Switzerland	Israel	Hungary	Georgia
Iceland	Iceland	Poland	Mongolia
Denmark	Germany	Romania	South Africa
Sweden	Norway	Uruguay	Romania

Table 8: World Economic Forum's Inclusive Development Index 2017 – top performers

Advanced Economies		Developing Economies	
Top Ranked	Most Improved 5-Year Trend	Top Ranked	Most Improved 5-Year Trend
Netherlands	Switzerland	Latvia	Kazakhstan
Australia	Korea Rep.	Panama	Uruguay
New Zealand	Denmark	Costa Rica	Sierra Leone
Austria	Czech Republic	Chile	Paraguay

Source: WEF 2017

- **Inequality in US cities has worsened over the past 10 years and is largely attributable to incomes declining at the bottom** vs stable or rising at the top. Moreover, both large metro areas and their big cities tend to be more unequal places than the nation as a whole (source: Brookings Institute 2016). Urban inequalities are often reflected in brutal ways – from the distance people must travel to work every day, to the lack of quality public spaces, urban amenities and civic services. (source: Alejandro Aravena).

Of the 100 largest US metro areas, 57 had a significantly higher level of inequality in 2014 than in 2007; the same was true for 36 of 97 central cities. Metros seeing the largest increase included Bridgeport, New Orleans, San Francisco, Boston, and New Haven (source: Brookings Institute 2016).

Table 9: US metro areas and cities with the highest income inequality overlap

Rank	Metro Area	Household Income, 2014		95/20 Ratio, 2014
		20th percentile	*95th percentile*	
1	Bridgeport-Stamford-Norwalk, CT	$31,333	$558,970	17.8
2	New York-Newark-Jersey City, NY-NJ-PA	$23,853	$282,359	11.8
3	San Francisco-Oakland-Hayward, CA	$31,761	$353,483	11.1
4	New Orleans-Metairie, LA	$18,173	$196,658	10.8
5	McAllen-Edinburg-Mission, TX	$12,760	$136,570	10.7
6	Boston-Cambridge-Newton, MA-NH	$27,883	$293,653	10.5
7	Los Angeles-Long Beach-Anaheim, CA	$23,743	$243,771	10.3
8	Miami-Fort Lauderdale-West Palm Beach, FL	$19,775	$202,461	10.2
9	New Haven-Milford, CT	$22,652	$221,661	9.8
10	Houston-The Woodlands-Sugar Land, TX	$24,758	$240,711	9.7
	City			
1	Boston, Mass.	$14,942	$266,224	17.8
2	New Orleans, La.	$11,466	$203,383	17.7
3	Atlanta, Ga.	$16,057	$281,653	17.5
4	Cincinnati, Ohio	$10,454	$164,410	15.7
5	Providence, R.I.	$12,795	$196,691	15.4
6	New Haven, Conn.	$12,293	$187,984	15.3
7	Washington, D.C.	$21,230	$320,679	15.1
8	Miami, Fla.	$12,262	$184,242	15.0
9	San Francisco, Calif.	$26,366	$383,202	14.5
10	New York, N.Y.	$17,691	$249,609	14.1

Source: Brookings Institute 2016

- **Growing urban/rural divide**: The flipside of global urbanisation trends is that a growing number of rural residents in both DMs and EMs feel left behind by the urban political elites. For instance, support for Britain leaving the EU was highest in rural areas in the June 2016 referendum (source: UK Electoral Commission, Office for National Statistics). Rural voters also played a big part in helping Trump defeat Clinton in the 2016 US election.

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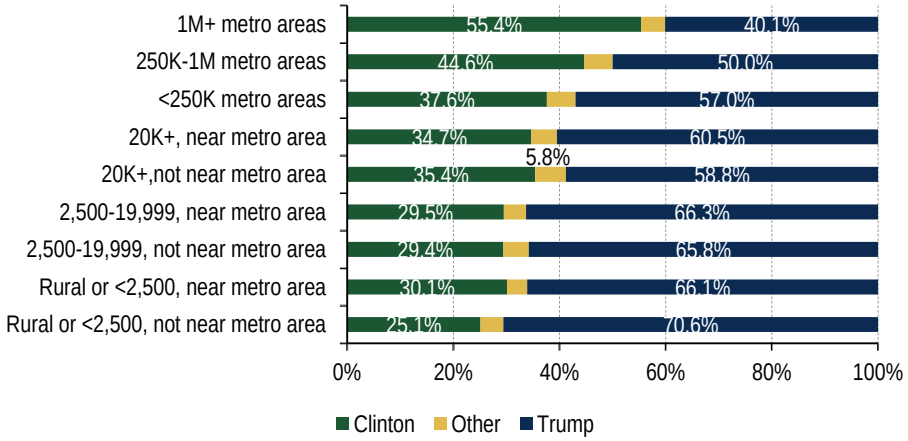
Chart 18: "Rural resentment" strongly influenced the 2016 US election vote

The USDA breaks down counties into "rural-urban continuum codes"



Source: Rural-Urban Continuum Codes from the U.S. Department of Agriculture

- **Poor job quality remains a pressing issue worldwide**. The incidence of vulnerable employment – the share of own-account work and contributing family employment, categories of work typically subject to high levels of precariousness – is declining more slowly than before the start of the global crisis (source: UN-Habitat 2016).

Over 46% of workers are in vulnerable employment accounting for 1.5bn people globally. In both Southern Asia and Sub-Saharan Africa, more than 70% of workers are in vulnerable employment.

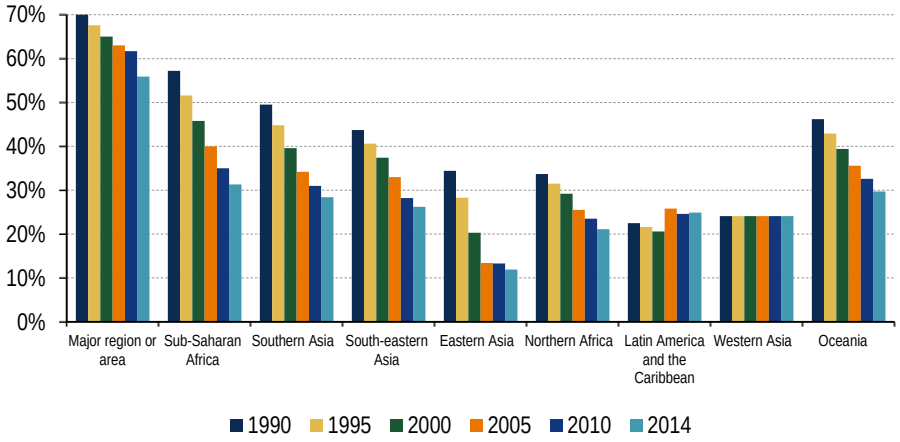
Informal, undocumented and migrant labour are major issues worldwide. For example, 47% of Tunisia's labour force is informal, 54% of Los Angeles' labour force is informal and 61% is undocumented, and 95% of the UAE's labour force is made up of migrants (source: ILO 2016).

Housing shortfall: 1bn new homes needed at a cost of US$9-11tn

Housing accounts for more than 70% of land use in most cities and determines urban form and densities, as well as providing employment and contributing to growth. But in 2010, as many as 980mn urban households lacked decent housing, as will another 600mn between 2010 and 2030E. One billion new homes will be needed worldwide by 2025E, costing an estimated US$650bn per year, or US$9-11tn overall. In addition, the most urgent housing problem relates to quality rather than quantity (source: UN-Habitat 2016).

- **The number of urban residents living in slums increased by 28% from 1990 to 2014 from 689mn to 881mn**. However, there has been improvement with thirty percent of the urban population in EMs lived in slums in 2014 vs 39% in 2000 (source: UN-Habitat 2016).

Chart 19: Percentage of urban population living in slums (1990-2014)



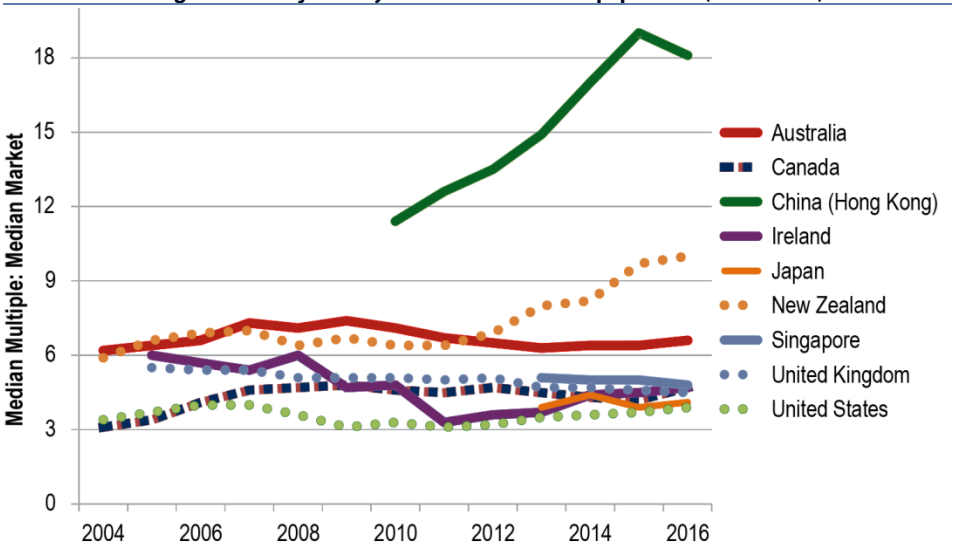
Source: UN-Habitat 2016 based on Global Urban Observatory Urban Indicators Database 2015

- **Housing affordability is the largest element in household budgets and is a major concern worldwide** as house prices have skyrocketed relative to incomes in many urban areas. Ireland has the most affordable housing with a national Median Multiple of 3.4 (moderately unaffordable). The US is second (3.5), followed by Canada (3.9). Japan (4.1), the UK (4.6) and Singapore (4.8) are all rated seriously unaffordable. The least affordable markets are China (Hong Kong), at 18.1, Australia (5.5) and New Zealand (5.7), both severely unaffordable (source: Demographia 2017). Lack of affordable housing could hold back cities on talent attraction, retention, and ultimately hands-on-skills (source: PwC 2016).

Least affordable housing in major cities (relative to income): Hong Kong, Sydney, Vancouver, Melbourne, LA, San Francisco, San Diego, London, Toronto, Brisbane (source: Demographia 2017).

In the most unequal US cities, low-cost rental units represent on average 52% of low-income households' income (vs 40% in the most equal cities) (source: Brookings Institute 2016).

Exhibit 27: Housing affordability for major markets with 1mn+ population (2004-2016)*



Source: Demographia International Housing Affordability Survey: 2017
* Benchmark for housing affordability that links median house prices to median household incomes.

High crime rates and violence: top concern for citizens

Crime and violence continue to be pervasive in cities and among the top concerns for citizens. One study showed that 60-70% of urban residents have been victims of crime in those developing or transitional countries where rapid urban population growth is at its highest (source: UN-Habitat 2016).

437,000 homicides take place every year, which is more than 13 times the number of deaths from terrorism (source: IEP 2015) .

Table 10: Safety Index top 10 vs bottom 10 cities (100 = safest, 0 = least safe)

Top 10		Bottom 10	
City	Safety index	City	Safety index
Abu Dhabi, United Arab Emirates	84.95	Caracas, Venezuela	13.67
Basel, Switzerland	84.59	San Pedro Sula, Honduras	14.20
Munich, Germany	84.48	Fortaleza, Brazil	17.21
Doha, Qatar	83.48	Pietermaritzburg, South Africa	18.48
Singapore, Singapore	83.42	Johannesburg, South Africa	20.39
Taipei, Taiwan	83.34	Salvador, Brazil	21.13
Boise, ID, United States	82.83	Rio De Janeiro, Brazil	21.91
Mangalore, India	82.44	Pretoria, South Africa	22.01
Quebec City, Canada	81.35	Durban, South Africa	22.05
Zurich, Switzerland	81.19	Recife, Brazil	22.68

Source: Numbeo

New and pervasive risks: terrorism, higher securitisation, disease & pandemics

Cities are becoming targets for a growing number of new and pervasive risks as they provide high levels of visibility and impact as a result of their social, political and economic centrality:

- **There has been a more than five-fold increase in terrorism-related deaths in the past 15 years.** High concentrations of people and complex infrastructure leave cities vulnerable to potentially devastating attacks and disruptions to vital services.

64 cities including 12 of the world's capitals are considered at "extreme risk" of a terrorist attack – Abuja, Baghdad, Cairo, Islamabad and Nairobi (source: Verisk Maplecroft).

- **War is being urbanised, with cities targeted as sites for the confrontation of opposing powers, regimes and ideologies**. States are now responding to these security breaches with urban militarisation – the extension of military ideas of tracking, identification and targeting into city space and everyday life.
- **A parallel trend has been the intensification and privatisation of security and the unprecedented growth of mass urban surveillance** to tackle emerging threats – which also pose significant cyber insecurity challenges.
- **There are higher levels of urban health risks with the spread of disease in cities often occurring as a result of inadequate infrastructure and services**. Examples in recent years include respiratory infections and premature deaths, communicable, vector and waterborne diseases, SARS, and Ebola (source: UN-Habitat World Cities Report 2016).

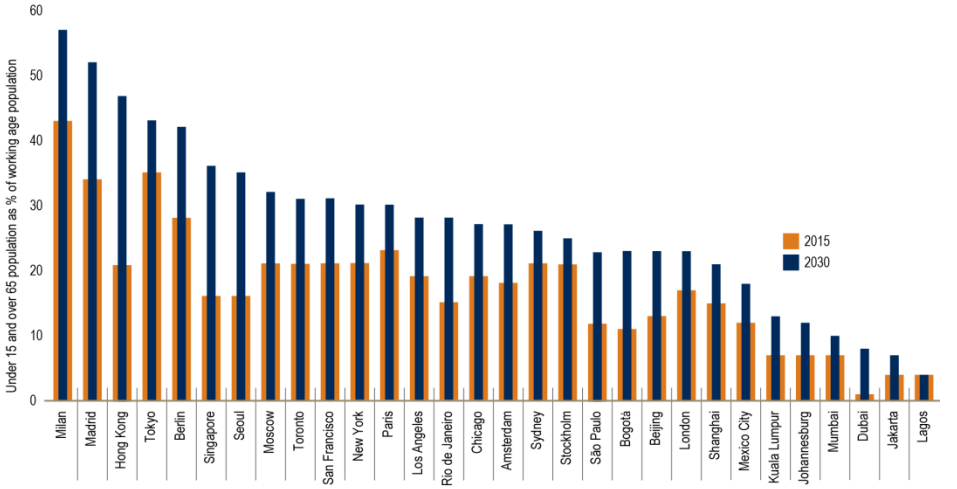
Ageing & slowing birth rates: challenges to cities' growth & finances

Demographics will challenge the growth and the finances of many cities - i.e. increasing pension, healthcare, and service costs, and a shrinking workforce and tax base.

- **Total dependency ratio in cities on the rise to 2030E:** Many major cities are expected to have higher dependency ratios of working age population (15-64Y) to children and seniors by 2030E, with DM cities the oldest collectively. By 2030E, Madrid and Milan will have a population of elderly aged 65Y+ and children under 15Y that is over half the size of the working age population (based on the dependency ratio of the over 65 and under 15 population to the population of 15–64). Berlin is only slightly more balanced (source: PwC 2017).

Exhibit 28: Many major cities are expected to have higher dependency ratios of working age population (15-64Y) to children and seniors by 2030E

Total dependency ratios in major cities on the rise to 2030E



Source: PwC 2016 based on Oxford Economic, UUEPC

- **The working age population (15-64Y) is projected to grow just 9% from 2015–2030E vs. 62% among over 65s** based on an analysis of 30 major global cities (source: PwC 2016).

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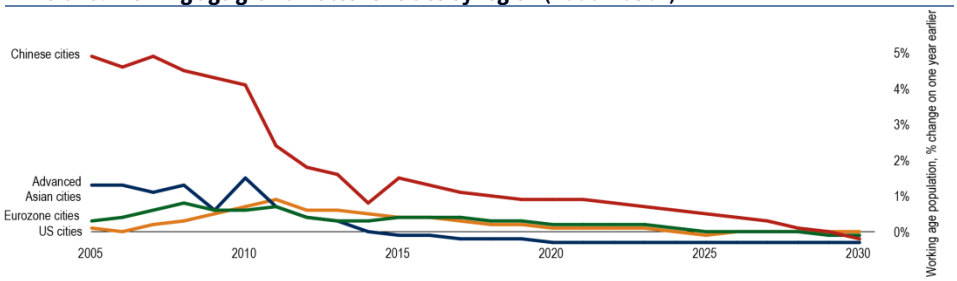
Exhibit 29: Working age growth rates for cities by region (2006-2030E)

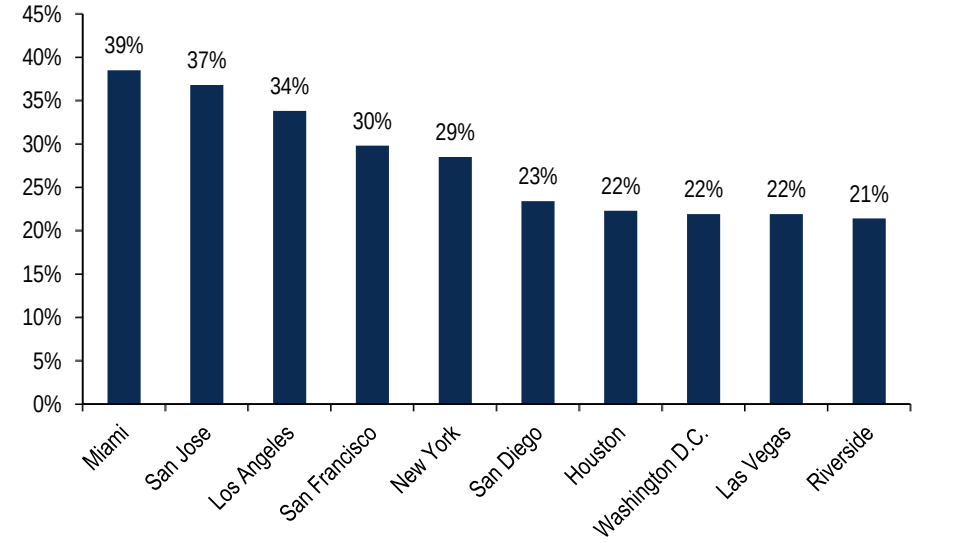


Source: PwC 2016 based on Oxford Economic, UUEPC

- **Cities will need to attract more prime age workers with immigration being part of the solution**. Effective domestic and international migration policies must be developed. Businesses will also need to develop new services, products, and policies to respond to the changing pattern (source: PwC 2016). Currently in the US the cities with the highest % of immigrants are Miami, San Jose, Los Angeles, San Francisco and New York (source: CityLab, American Community Survey).

Chart 20: Top 10 US Metro Areas with the Largest % of Immigrant Population

% of Foreign-Born vs. Total Population



Source: CityLab, American Community Survey

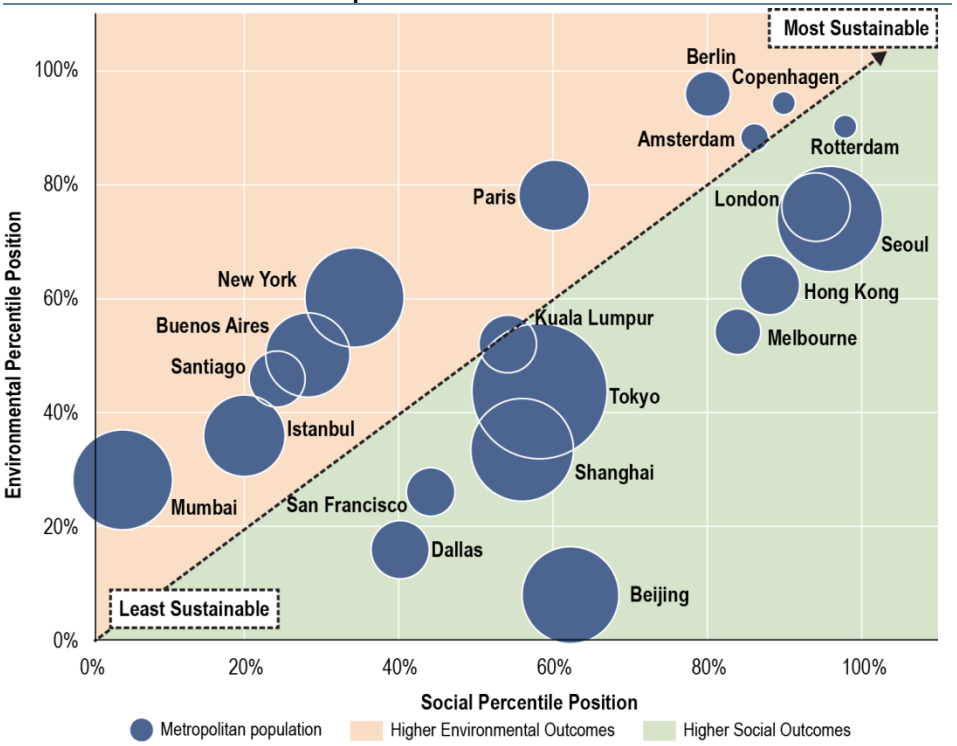
Environmental challenges: pressure on basic services to climate change impact

While urbanisation acts as a major factor in socioeconomic development, it also has all-too visible negative effects on ecosystems, biodiversity, resource use and public health. By 2030E, global demand for energy, food and water is expected to grow by 40-50%. According to UN-Habitat, cities are facing a growing array of environmental challenges: (1) providing public services in an equitable manner: water, sanitation, waste management, energy, food and mobility; (2) addressing environmental risks from pollution to climate change impacts; (3) minimising the negative effect of land transformations; and (4) responding to the global call for decarbonisation. We outline a few of these challenges below and throughout the report.

Cities occupy 2-3% of the earth's land mass but consume 75%+ of natural resources and account for 50% of global waste, 67-76% of energy use and 71-76% of GHG emissions.

China's poor urban air quality and water pollution cost the economy 6% of GDP each year while the cost of US urban sprawl is estimated to be US$1tn per year (source: The Global Commission on the Economy and Climate 2015).

Exhibit 30: Social and environmental performance of a selection of the world's cities



Source: Arcadis Sustainable Cities Index 2015, JLL 2016

- **Cities account for 2-3% of land mass vs c.75% of resources and emissions**: While cities occupy only 2-3% the world's land mass, they consume more than 75% of its natural resources and account for 50% of global waste, 67-76% of energy use and 71-76% of energy-related GHG emissions (source: World Bank 2011, UN 2015, The Global Commission on the Economy and Climate 2015).
- **Ninety-two percent of the world's population lives in places where air pollution levels exceed WHO limits** of an annual mean of 10 micrograms m3 of particles less than 2.5 micrometres in diameter. Major sources of air pollution include inefficient modes of transport, household fuel and waste burning, coal-fired power plants and industrial activities, as well as natural phenomenon such as dust storms. Air pollution has risen by 8% globally in the past five years, with the WHO estimating that it causes 3mn premature deaths a year, making it one of the greatest environmental risks to human health (source: WHO 2016).

The Nigerian city of Onitsha has recorded the world's worst levels of PM10 air pollution at 594 µg/m3 (vs. the WHO's annual guideline limit of 20). Up to 712,000 deaths in Africa every year are associated with air pollution (source: WHO, UNEP, OECD).

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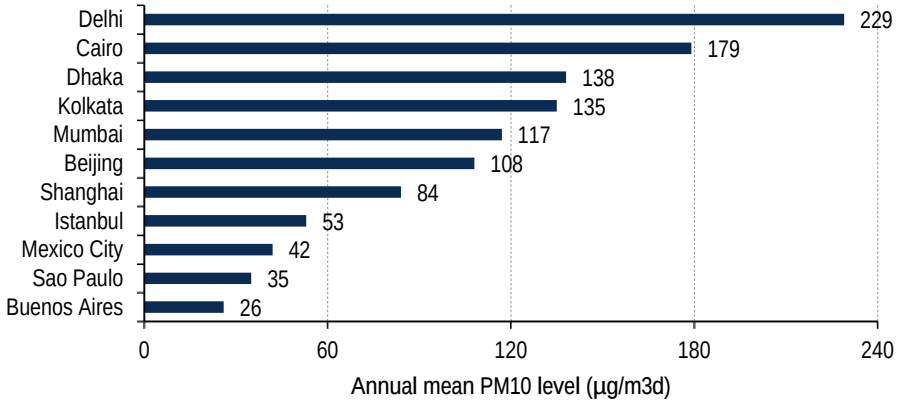
Chart 21: Among megacities, Delhi and Cairo have the highest levels of air pollution

Annual mean PM10 level µg/m3 (2011-2015)



Source: WHO 2016

- **Solid waste management dominates municipal annual budgets in low- and middle-income EMs, with shares of 30-50%** (source: UN-Habitat). This is set to become more pressing as the higher the income level and rate of urbanisation, the greater the amount of solid waste produced (eg waste generation per capita per day is 2.2kg across the highly urbanised OECD vs 0.65kg across largely rural Africa (source: World Bank).

Exhibit 31: Waste management per capita and urbanisation rates in the main regions of the world

AFR: Sub-Saharan Africa
EAP: East Asia and Pacific
ECA: Eastern and Central Europe
LAC: Latin America and the Caribbean
MENA: Middle East and North Africa
OECD: member countries of the Organisation for Economic Cooperation and Development
SAR: South Asia Region

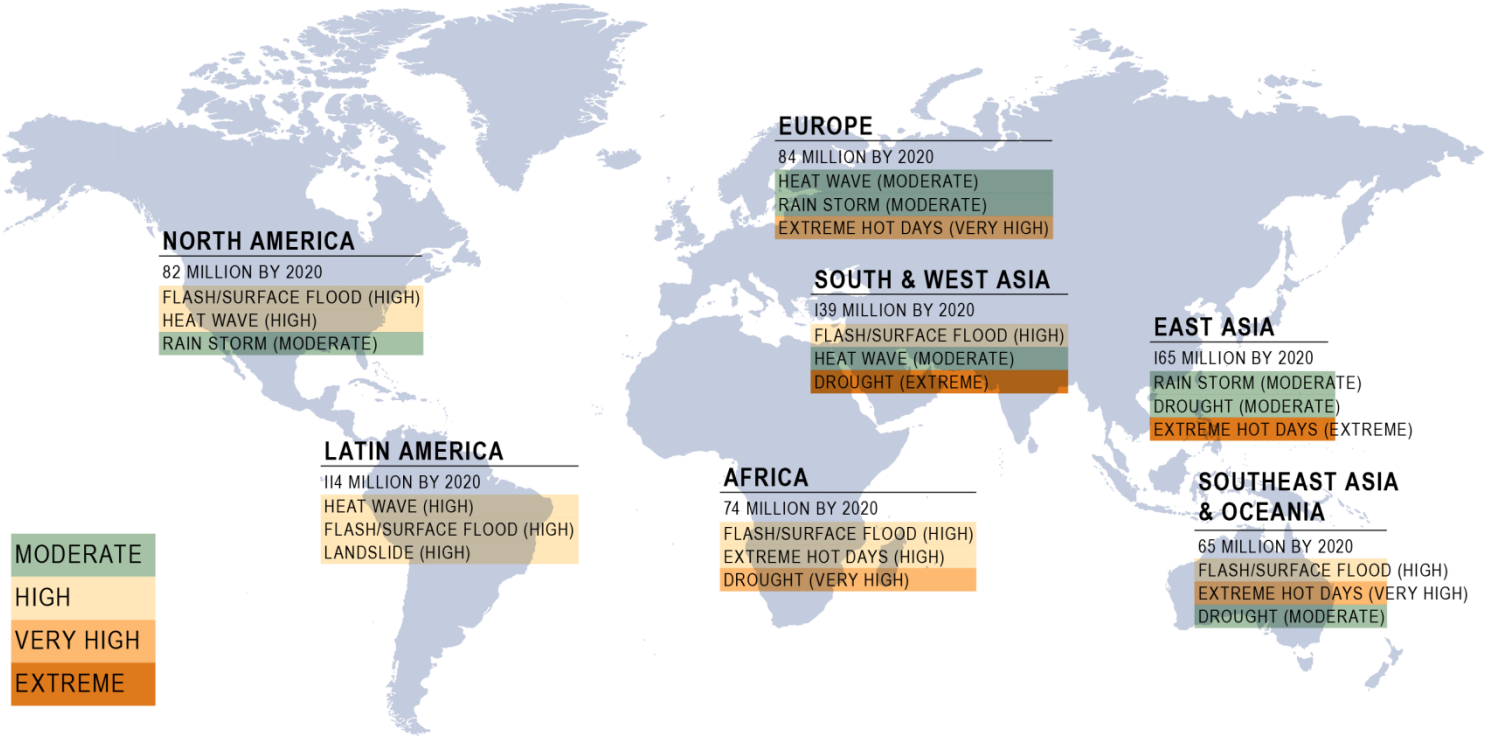
Source: UN-Habitat World Cities Report 2016 based on Vergara and Tchobanoglous, 2012.

- **Water availability in cities could decline by as much as two-thirds by 2050E**, as a result of the combined effects of growing populations, rising incomes and expanding cities – as well as climate change and competition from energy generation and agriculture (source: World Bank).

- **Seventy percent of cities are already dealing with the effects of climate change, and nearly all are at risk.** More than 90% of all urban areas are coastal,

putting most cities at risk of flooding from rising sea levels and powerful storms. Larger cities have a ravenous appetite for energy, consuming two-thirds of the world's energy and creating more than 70% of global CO2 emissions. Unexpected expenditures related to storms, flooding, snow removal and drought can lead to major disruptions in business operations and deplete city budgets (source: C40Cities).

Exhibit 32: C40 cities and climate risk by region



Source: C40 Cities-Arup 2016

Tipping points for climate extremes are 2047E worldwide and 2038E for the tropics (mean): Lagos 2029E, Mexico City 2031E, Mumbai 2034E, Tokyo 2041E, Beijing 2046E, New York 2047E, London 2056E (source: Camilo Mora et al./Nature 2013).

The top 10 US cities that face the greatest challenges from climate change are: New Orleans, Minneapolis, Las Vegas, NYC, Kansas City, Boston, Denver, St Paul, Washington, Philadelphia (source: weather.com Climate Disruption Index 2016).

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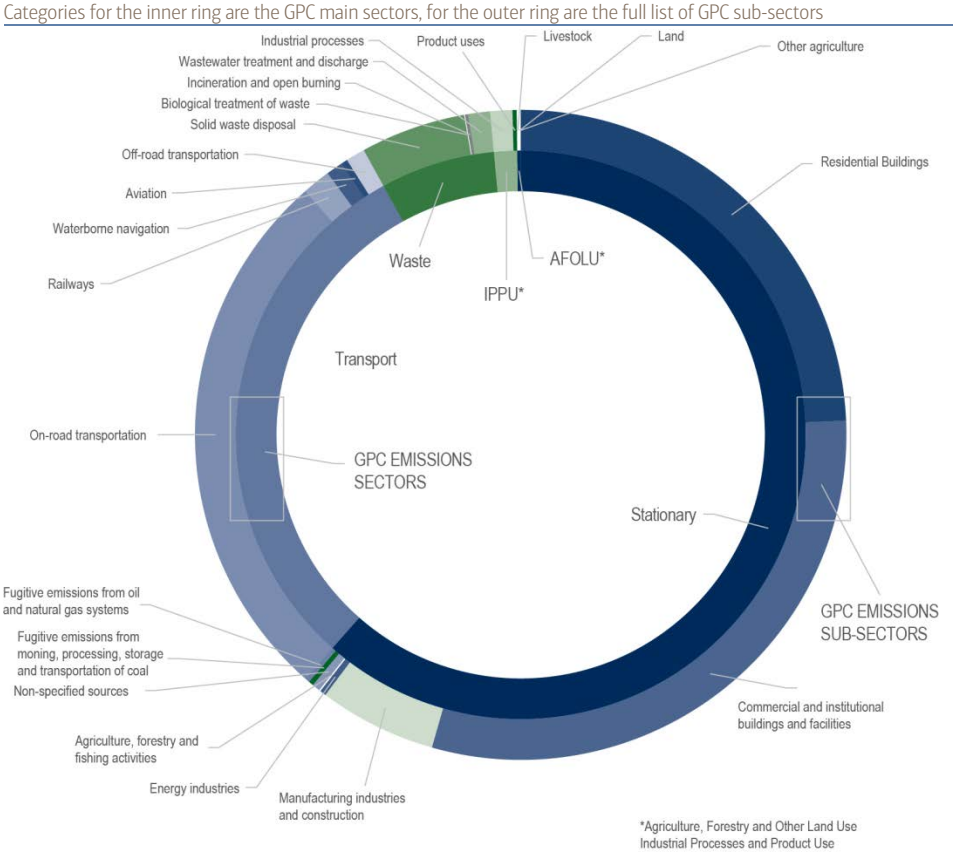
Exhibit 33: C40 cities GHG emissions are dominated by buildings and transport

Categories for the inner ring are the GPC main sectors, for the outer ring are the full list of GPC sub-sectors



Source: C40 Cities-Arup 2016

- **Food security: the world is set to lose 30mn km² (11.6mn miles²) to urbanisation**. In most parts of the world, urban land is expanding faster than urban populations, and from 2000-30E, the world will lose up to 2.4% of arable land to urbanisation. Worryingly, urban expansion is expected to take place on cropland that is 1.77x more productive than the global average (source: d'Amour et. al., Proceedings of the National Academy of Sciences of the USA 2016).

Forecast cropland loss, 2000-30 and impact as % of total crop output: China: 7.6m ha (8.7%), India: 3.4m ha (3.9%), Nigeria: 2.1m ha (11.7%), Pakistan: 1.8m ha, (8.8%), US: 1.5m ha (0.7%), Brazil: 1.0m ha (2.4%) (source: d'Amour et. al. 2016).

Urban butterflies have declined by 69% from 1995-2015 (vs. -45% in rural areas) (source: Dennis et. al., Ecological Indicators 2017).

Towards a new urban agenda: sustainable cities

With success or failure in meeting the world's most pressing challenges to be decided in cities, we believe there that needs to a fundamental rethink of the urban agenda based on a vision of sustainable cities.

Exhibit 34: An urbanisation action blueprint for sustainable cities

UN-Habitat and the New Urban Agenda (NUA)

Source: UN-Habitat 2016

UN SSDGs: template for making cities inclusive, safe, resilient and sustainable

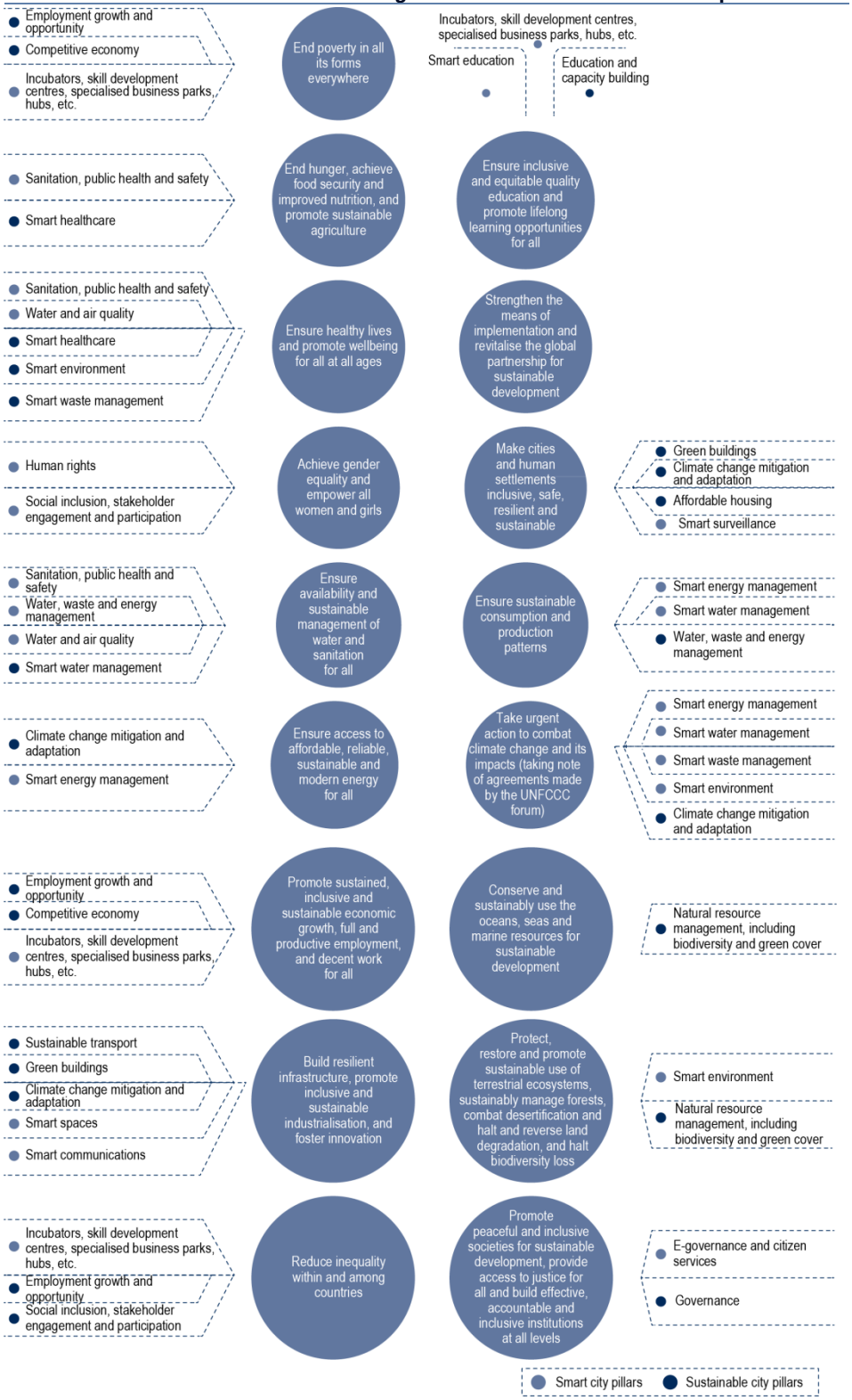
The United Nations' Sustainable Development Goals (SDGs) – officially known as Transforming Our World: the 2030 Agenda for Sustainable Development – are a universal set of 17 goals, 169 targets and 304. The SDGs were adopted in September 2015 and became applicable in January 2016. The 193 UN member states will be expected to use these SDGs to frame their agendas and political policies over the next 15 years (source: UN).

Exhibit 35: United Nations' Sustainable Development Goals (SDGs)

Source: UN

The SDG's include a dedicated goal on "Sustainable Cities and Communities", and Smart Cities both align with and enable the realisation of the SDGs.

Exhibit 36: How smart sustainable cities are aligned with the UN's Sustainable Development Goals



Source: PwC 2015

UN Habitat III: towards a new urban agenda

The New Urban Agenda (NUA) was adopted at the United Nations Conference on Housing and Sustainable Urban Development, known as Habitat III, in Quito, Ecuador in 2016. The NUA is an action-oriented document setting global standards of achievement in sustainable urban development, rethinking the way we build, manage, and live in cities

through cooperation with committed partners, relevant stakeholders, and urban actors at all levels of government as well as in the private sector.

- **Shared vision, principles and commitments**: Cities and human settlements must be for everyone, ensuring cities for all, sometimes referred as the "right to the city". This entails equal rights, the right to adequate housing and fundamental freedoms, along with functional social and civic systems, with participatory access. Gender equality, accessible urban mobility for all, disaster management and resilience, and sustainable consumption are envisaged. The commitment to an urban paradigm shift in the long term includes integrated urban planning and design, and sustainable financing frameworks and the cooperation of all levels of government, with the participation of civil society and stakeholders.

- **Call for action:** A seven-point call for action includes the acknowledgement that the NUA is universal in scope. The collective vision and political commitment to sustainable urban development take into account different national realities, capacities and levels of development, and respects unique and emerging challenges specific to each context. Special attention is merited in many instances, including, but not limited to: developing and least developed countries, slum and informal settlement dwellers, migrants and refugees. The New Urban Agenda is a historic opportunity to leverage the key role of cities and human settlements – and their inhabitants – as drivers of sustainable development in an increasingly urbanised world.

Who's getting it right: Oslo, Copenhagen, Stockholm, Helsinki and Paris

UN-Habitat's City Prosperity Index is a useful tool to compare cities on the prosperity path, including gaining critical insights into which programmes and policies work, and the impacts these actions may have. It uses six dimensions: productivity, infrastructure, quality of life, equity and social inclusion, environmental sustainability, and governance and legislation – as well as a battery of sub-dimensions and indicators. The cities that score highly include Oslo, Copenhagen, Stockholm, Helsinki and Paris.

Only 36% of cities have a solid prosperity index and present an overall balanced development of the prosperity dimension. Eight-five percent of cities with a very solid prosperity index are in Europe (source: UN-Habitat 2015 Global City Report).

Table 11: A tool to measure human development in cities

UN Habitat's 2015 Global City Report: City Prosperity Initiative

Rank	City	CPI	Rank	City	CPI	Rank	City	CPI
1	Oslo	86.76	21	Lisbon	76.10	41	Bangkok	56.71
2	Copenhagen	84.79	22	Madrid	74.78	42	Ulaanbaatar	56.58
3	Stockholm	83.47	23	New York	74.43	43	Guatemala City	56.19
4	Helsinki	81.41	24	Hong Kong	73.35	44	Manila	55.81
5	Paris	80.67	25	Dublin	73.23	45	Quito	55.50
6	Vienna	80.53	26	Budapest	73.22	46	Abha	54.25
7	Melbourne	80.30	27	Barcelona	72.88	47	Yerevan	53.23
8	Montreal	79.88	28	Athens	70.79	48	Fortaleza	50.96
9	Toronto	79.80	29	Warsaw	70.57	49	Nairobi	47.77
10	Sydney	79.77	30	Buenos Aires	68.56	50	Cape Town	47.32
11	Berlin	79.27	31	Mexico City	68.07	51	Kathmandu	46.98
12	Milan	79.20	32	Lima	67.82	52	Accra	44.28
13	Amsterdam-Utrecht	78.93	33	Almaty	67.44	53	Mekelle	44.16
14	Brussel	78.32	34	Ciudad Obregon	64.35	54	Kampala	43.27
15	Tokyo	77.82	35	Guadalajara	64.21	55	Dar es Salaam	40.75
16	Manchester	77.50	36	Medellin	62.49	56	Lagos	37.45

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Table 11: A tool to measure human development in cities

UN Habitat's 2015 Global City Report: City Prosperity Initiative

Rank	City	CPI	Rank	City	CPI	Rank	City	CPI
17	Prague	77.39	37	Panama City	61.17	57	Karachi	37.00
18	London	77.06	38	Guayaquil	61.17	58	Addis Ababa	36.72
19	Osaka	76.99	39	Sao Paulo	59.35	59	Lusaka	35.99
20	Zurich	76.50	40	Jakarta	57.23	60	Harare	35.68

Source: UN-Habitat 2015 Global City Report

- **Africa – urbanisation and positive change**: Economies of agglomeration, location advantages, and diversification of the economic base are typical drivers of prosperity in Africa. The data shows that most African cities are still lacking in basic infrastructure and communication networks and face serious public transport deficiencies, which inevitably also affect the productivity dimension. African cities must connect to regional and global business networks to enhance quality of life and respond to inequality and poverty issues, if they are to turn into real engines of national growth and prosperity.

- **The Americas – one region, different challenges**: NAm cities must develop strategies to help them to understand and anticipate trends and harness the growth in some areas while offsetting the decline in others. LatAm cities must become more productive and generate local jobs, while improving transport infrastructure and living conditions. In both sub-regions, the dimension of governance and legislation has still to be improved to better exploit their strategic advantages with national economic policies and creative capital used to increase the prosperity index.

- **Asia – new economic geographies for cities**: Half of the world's urban population now lives in Asia. Large population concentrations in megacities are to remain a prominent feature in urban Asia and the newly industrialised agglomerations tend to be more dispersed and less well planned than other regions. In Arab States, there are very few large urban configurations. In the Near East, the evolution is from mono- to polycentric or diffuse urban corridor formats, especially in Iraq, Iran, Saudi Arabia and Turkey. Trans-border cities are expanding along highways and modern transportation networks, and tend to be linear along urban corridors.

- **Europe – demographic ageing and prosperity**: There is no clear association between the demographic growth or decline of cities and their prosperity. Although population numbers have fallen in a number of cities in Western Europe, this did not affect living standards. The prosperity of entire regions is largely dependent on the largest cities and the concentration of services and manufacturing that comes with it. On the other hand, and as might be expected, population declines in a number of cities in Eastern Europe are strongly associated with economic decay (source: UN-Habitat 2015 Global City Report).

Smart Cities 101: US$1.3-1.6tn market by 2020E

A Smart City is an "innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects" (source: ITU 2015). At its most basic level, a Smart City can be seen as the manifestation of a broader technological trend: the Internet entering the spaces we live in (source: Carlo Ratti, Director of the MIT Senseable City Lab).

Smart Cities will enable everyday objects to become smarter and facilitate real-time connectivity, heralding in the autonomous era. Everyday objects like meters, street lights, park benches, trash cans and cars will be connected via the Internet of Things (IoT), with capabilities well beyond the uses they were created for. New services will emerge that require constant connectivity and the intelligence to facilitate real-time adaptability based on data from the mesh of connected devices (source: Intel). The increasingly popularity of the theme was on view in terms of the launch of multiple products, services, and partnership at two of the tech/telco industry's biggest events, the 2017 CES (Consumer Electronics Show) and MWC (Mobile World Congress).

There is a growing business case for Smart Cities based on demographic, economic, environmental and financial pressures. These encompass: rapid urban population growth and changing age structures; increased competition for capital, citizens, business, and technology; urban strains on resource use; budgetary pressures and the desire to do more with less; and the inability of many cities' fragile infrastructures to cope with rapid socioeconomic change.

We believe that cities will be positively transformed by technologies such as ubiquitous broadband coverage (84% globally); nextgen infrastructure (5G up to 100x faster than 4G); IoT (10bn connected devices in cities by 2020E); Big Data (insights from billions of sensors, 200mn GB of data/day for a city of 1mn by 2020E); the Cloud (secure, open platform); and cognitive computing and artificial intelligence (AI) (predictive insights and anticipatory action). Over 90% of government respondents globally view Smart City initiatives as transformational with the potential for long-term positive impacts (source: Black & Veatch 2016).

Smart Cities generally abide by the principle of "Collect, Communicate, Crunch": (1) Collect means devices out on the edges collecting information about a city's conditions; (2) Communicate means a citywide network that carries that data to where it is needed; and (3) Crunch means computers in the centre that are analysing this information, doing the analytics, and sending out operational signals to improve city conditions (source: Smart Cities Council).

Essential elements of a Smart City include nextgen infrastructure, smart services, an enabling environment, and empowered citizens: (1) nextgen infrastructure (sophisticated ICT infrastructure, connected by the central convergent layer of a service delivery platform); (2) smart services (apps and programs that improve the daily lives of citizens and visitors, and help businesses and government work more efficiently, are the visible ROI and core of a Smart City's offerings); (3) a cohesive enabling environment (a robust governance structure, Big Data openness, innovation and entrepreneurship, mass human capital literacy, resilient security controls, policies and standards, and private sector participation); and (4) empowered citizens (two-way engagement through multiple channels) (source: Booz Allen Hamilton).

Degrees of smartness – from connected to integrated to personalised to predictive: (1) connected (city agencies make services and information accessible online); (2) integrated (formerly siloed operations are connected to a centralised command and control centre); (3) personalised (eg, customised alert services, specific

locations and delivery methods, etc); and (4) predictive (most advanced degree of "smartness" where sophisticated data collection and analytics enable city agencies to turn hard field intelligence into predictive insights and anticipatory action) (source: Booz Allen Hamilton).

Cities of all sizes and in all parts of the world are developing and implementing Smart City projects. Major initiatives include China (US$73bn in the 13th 5Y Plan), India (109 cities, US$15bn in investments), UAE (Dubai, US$8bn+), Singapore (Smart Nation, S$2bn+), the US (US$165mn on Smart Mobility), Spain (Barcelona, US$90mn+), and Australia (US$50mn) (source: various governments). In the US, mobility and transport, governance, and physical infrastructure dominate the list of current and planned projects – with the top priorities of increasing citizen satisfaction and improving government responsiveness (source: US Conference of Mayors 2017).

Smart Cities can capitalise on the deployment of available technologies to achieve cuts of 30% in energy use and crime, and 20% in traffic delays and water loss, in our view. Surveys of Smart City stakeholders show that they are trying to become smarter to improve the efficiency of urban operations and reduce costs, become more environmentally sensitive and resource-sustainable, better manage community systems, and adopt a long-term vision and pro-active governance (source: Black & Veatch 2016).

We view Singapore, London, New York, Paris, Tokyo, Stockholm, Amsterdam, Seoul and Vienna as some of today's Smartest Cities. Our analysis is based on a wide range of global rankings, indices and awards, encompassing multiple Smart City factors including connectivity, ease of doing business, education, environmental footprint, governance, human capital, innovation, infrastructure, and liveability, among others.

The pure-play Smart City market is set to grow from US$1tn today to up to US$1.6tn by 2020E, while the broader market for Smart City-related technologies could be worth US$3.5tn+, in our view. The Smart Cities Council – a network of leading companies in the space – estimates that US$1tn is being spent annually on Smart City initiatives. The market is set for strong growth and will reach US$1.3-1.6tn by 2020E (source: Frost & Sullivan, Grand View Research, Mordor Intelligence, Technavio, Transparency Market Research). Some view it as growing to as much as US$3.5tn by the mid-2020Es (source: Persistence Market Research). North America is the largest Smart Cities market, while APAC will grow the fastest to 2020E.

The roll-out of Smart Cities is in its infancy partly because most cities are not homogenous entities, but rather a collection of multiple ecosystems with their own challenges and stakeholders (eg, airports, businesses, homes, factories, government, etc). Many, if not most, cities operate services in silos and investments are made independently, resulting in poorly informed decision-making for cities as a whole. Smart City platforms help to eliminate vertical silos through interdepartmental data-sharing. New technologies foster horizontal collaborations between unexpected city actors and the elimination of duplicated services. City residents will emerge as the ultimate winners, in our view, via improved quality of life, efficiency of urban operation and services, and two-way dialogue and engagement.

Multiple industry sectors stand to benefit from Smart Cities with participants taking a number of different roles: pure-play product vendors (Capital Goods), enablers (Semiconductors and Semi Equipment, Technology Hardware and Equipment), integrators (Software and Services), network service providers (Technology Hardware and Equipment, Telecommunication Services), and managed service providers (Commercial & Professional Services, Software and Services) (source: Frost & Sullivan). Additional beneficiaries will be created across the Smart City entry points (Smart Infrastructure, Smart Buildings, Smart Homes, Smart Grid, Smart Safety & Security, Smart Mobility), which we have detailed throughout this Primer as well as in the accompanying Primer Picks report.

Smart Cities also pose risks with technology failures, digital divide, privacy, and security/cybersecurity ranking highest, in our view. Other challenges include job displacement, cost of living increases/gentrification, negative socio-cultural impacts of a top-down approach, negative environmental impacts, greater income and social inequality, and opportunity costs (source: Black & Veatch 2016).

Exhibit 37: A Smart City in action

Source: National League of Cities 2016

Smart Cities in a nutshell: ICT to improve lives, efficiency & competitiveness

There is a lack of consensus on what the term 'Smart City' means – with up to 200 commonly used definitions that we came across in our work. Being 'Smart' means different things to different audiences. What most definitions have in common, however, is that they consider the use of new technologies (usually ICT) and data as the means to solve a city's economic, social and environmental challenges.

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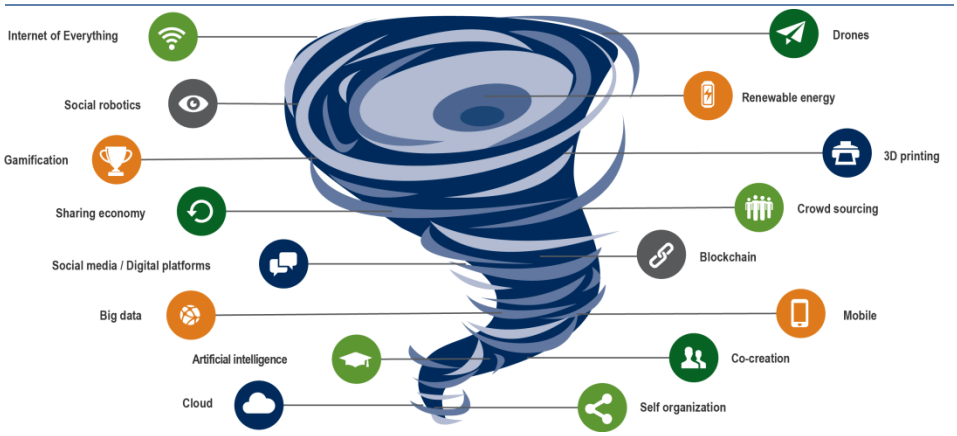
Exhibit 38: Smart Cities are fuelled by a 'perfect storm' of disruptive technologies and social innovations



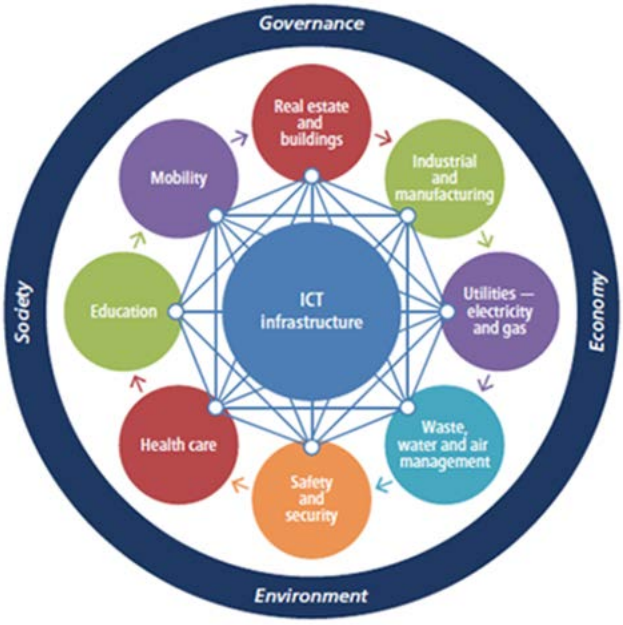
Source: Deloitte 2015

We've gone with the ITU definition of Smart Cities

We have chosen to use the International Telecommunications Union's (ITU) definition which came out after analysing over 100 different definitions:

- "***A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness****, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects*" (source: ITU 2015).

Exhibit 39: ICT infrastructure is the nervous system of the smart sustainable city



Source: ITU

Case study of the Smart City of Barcelona (Spain):

- **A 500km (311-mile) fibre-optic network**, which acts as a backbone for a host of connected services as well as providing citizens with city-wide Wi-Fi.

- **1,100 lamp-posts have been converted to smart LED**, offering cost savings of 30%. Sensors in the lights can determine when people are passing and light up or dim according to footfall. They form part of the Wi-Fi network and are equipped with air-quality sensors.
- **19,500 smart meters** in targeted areas of the city monitor and optimise energy consumption.
- **Electric cars, bike-sharing schemes and digital bus-stops** which give waiting passengers updates on when buses will arrive and provide charging stations, free Wi-Fi and information about the best apps to download to learn more about the city.
- **ApparkB App for drivers** that can identify empty parking spaces and allow users to pay for the spot online.
- **Smart garbage bins** monitor waste levels and optimise collection routes.
- **Irrigation system uses sensors to monitor rain and humidity**, allowing park workers to decide how much water is needed in each area.
- **Smart City data is also shared with citizens**.
- **Barcelona has made its city operating system available to other cities**: 'Sentilo' controls all the sensors open-source and (source: Barcelona, press sources).

Essential elements: empowered citizens, smart services, nextgen infrastructure

Successful Smart Cities require a number of essential elements including nextgen infrastructure, empowered citizens, smart services, and a cohesive enabling framework (source: Booz Allen Hamilton).

Table 12: Key parameters that will define a Smart City

Parameter	Definition
Smart energy	Smart energy uses digital technology through advanced meter infrastructure (AMI), distribution grid management, and high-voltage transmission systems, as well as for demand response for the intelligent and integrated transmission and distribution of power.
Smart building	Smart buildings are green, energy efficient, and intelligent, with advanced automated infrastructure that controls and manages aspects such as lighting and temperature, security and energy consumption independently or with minimal human intervention.
Smart mobility	Smart mobility enables intelligent mobility through the use of innovative and integrated technologies and solutions, such as low emission car and multimodal transport systems.
Smart technology	Smart technology will connect the home, office, mobile phone, and car on a single wireless IT platform. Smart technology includes adoption of smart grid system, smart home solutions, a high-speed broadband connection, and roll-out of 4G and 5G technology.
Smart healthcare	Smart healthcare is the use of eHealth and health systems and intelligent and connected medical devices. It also involves the implementation of policies that encourage health, wellness, and well-being for its citizens, in addition to health monitoring and diagnostics as opposed to treatment.
Smart infrastructure	Smart infrastructure includes intelligent and automated systems that manage, communicate with, and integrate into different types of intelligent infrastructure, such as energy grids, transportation networks, water and waste management systems, and telecommunications.
Smart governance and smart education	Smart governance and smart education policies and digital services from the government that help and support the adoption of green and intelligent solutions through incentives, subsidies, or other promotions.
Smart security	Smart security includes technology and solutions such as video, surveillance, public safety LTE, and managed security services that are designed to protect people, property, and information.
Smart citizens	Smart citizens possess interest in embracing smart and green solutions in daily activities. More citizen proactivity is expected in adopting smart concepts and smart products, including lifestyle choices

Source: Frost & Sullivan

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- **Next-generation infrastructure**: Sophisticated ICT infrastructure, connected by the central convergent layer of the service delivery platform is at the heart of enabling Smart Cities. This includes broadband, 5G, IoT, Big Data, the Cloud, and AI.
- **Empowered citizens**: Smart Cities can engage residents through multiple channels (e.g., TVs, smartphones, tablets, wearable devices, VR/AR/MR et. al) – but need to make citizens aware of such services and make them comfortable including via education to use the technologies.

City residents should be the biggest winners of Smart Cities via better engagement between citizens, businesses, and government:

- Intelligent operating systems with citizen-facing interfaces take direct feedback from people via connected devices and mobile-ready applications.
- Citizens can report city service issues via any internet-connected device, while the operating system analyses social media and the internet for references to city problems or needs.
- Government can directly communicate with citizens via push-to-call functions, social media and messaging to gather service feedback, report actions or promote community participation.
- Citizens can report issues from broken street lights to crime to potholes using two-way feedback mechanisms (source: Vodafone 2016).

- **Smart services**: Apps and programs that improve the daily life of citizens and visitors, and help businesses and government work more efficiently are the visible ROI and core of a Smart City's offerings. These services include: smart education, smart entertainment and retail, smart government services, smart health, smart safety and security, smart transport, and smart utilities, among other areas. Transforming city services into smart services requires a number of imperatives including smart interfaces, smart applications, smart analytics, smart infrastructure, and smart security (source: Booz Allen Hamilton).
- **Human resources skills to ensure that all the different facets of the city are adequately and efficiently addressed**. Relevant HR skills include planning and design, digital citizenship, data literacy, implementation and management. Investing in smart people, not only smart technology is essential. As discussed in our Education report, this will require accelerating education programmes in science, technology, engineering and mathematics (STEM), reforming curriculums and promoting multidisciplinary learning, and partnering with technology firms to train smart city workforces (source: UNCTAD).
- **A cohesive enabling environment**: A robust governance structure (including stakeholder engagement and new leadership positions such as Chief Data/Digital Officers), Big Data openness, innovation and entrepreneurship ecosystem and culture, mass human capital literacy, resilient security controls, policies and standards, savvy strategic communications, and private sector participation (source: Booz Allen Hamilton).

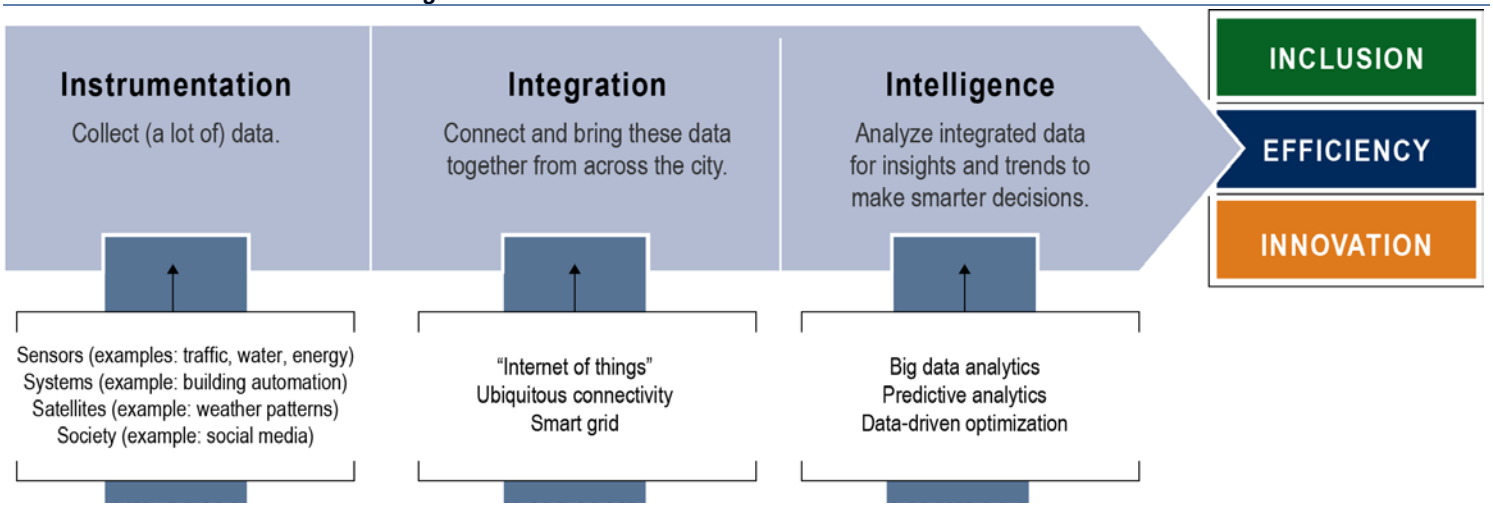
Exhibit 40: Smart Cities encompass a full potential range of city services

Source: GSMA

From data to intelligence: efficiency, innovation, inclusion

A Smart City leverages the latest in ICT to make better decisions and achieve the urban aspirations of its citizens. Specifically, Smart Cities collect lots of data through instrumentation, bring these data together through integration, and then analyse the integrated data for intelligence on how to improve the city's services and quality of life (source: World Bank).

Exhibit 41: Smart Cities – from data to intelligence



Source: World Bank WDR 2016 adapted from Palmisano 2008

- **Efficiency, doing more with less**: By collecting large amounts of data in real-time from cameras and sensors, and then translating these data into insights, cities are able to boost the efficiency and responsiveness of their operations. Data helps cities better match the supply of public services with real-time needs, engage in evidence-based decision-making and planning, undertake predictive analysis, and uncover emerging problems before they turn into crises.

- **Innovation, through collaboration at city scale**: For individual 'smart systems' to add up to a Smart City, innovations must be city-wide. That requires contributions and ideas from commercial firms, governments, citizens and stakeholders through public-private-people partnerships. Open data, social media, and smartphones are all cost-efficient or no-cost enablers of real-time collaboration – with open data promoting transparency, accountability, and collaborative problem solving. Initiatives such as 'living labs', where governments designate parts of the city as test beds allow for collaborative piloting of new ideas, as do partnerships with academia and business.

- **Inclusion, to ensure everyone benefits**: City leaders need to focus efforts on the needs of all residents. EMs are leading the way in this space: using data to target the most vulnerable (e.g., São Paulo's comprehensive geographic database of socioeconomic and physical indicators to prioritise housing and slum upgrading investments; opening up data to promote accountability (e.g., Kibera Nairobi's mapping of facilities, pollution, and community needs); and tapping mobile connectivity to expand civic participation (e.g., Philippines cities participatory budgeting and crowdsourcing of the identification of polluting vehicles) (source: World Bank).

Table 13: 10 steps for cities to make a Smart City happen

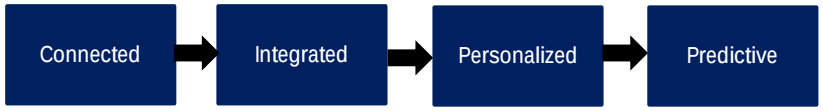
	Step	Overview
1	Identify the city's needs	Defining a city's needs will require engagement with citizens, businesses and local community representatives. Listening to these and crafting them into a long term plan requires strong leadership and a clarity of vision that goes beyond the needs of today and into the long term future of the city's inhabitants.
2	Devise a strategy	Utilise 'bottom up' thinking and innovation from citizens, communities and businesses to refine a strategy and develop a clear set of objectives to meet a city's strategic needs. With this clearly defined, use top down leadership to identify how a city will achieve it and create change on an urban scale via policy, regulation, enterprise partnerships and investment.
3	Use smart finance and efficiency	Identify which actions have a business case and how a city will financially deliver the strategy so it is self-supporting. Does the project initially need governmental funding, special purpose vehicles, finance or delivery as part of an LEP? Can enterprise help you with the modelling and finance? Can it run with an OPEX model? Do the efficiencies gained from connecting a product drive efficiencies elsewhere?
4	Use smart policies, procurement and long term partnerships	Private sector investment will not deliver social, economic or environmental outcomes unless it is incentivised to do so. Establish smart policy tools into everything a city does – smart procurement, smart data collection, smart operations, smart outsourcing and contracting. Smart Policy tools: • Incentivising entrepreneurial businesses and investors • Scaling up social enterprise • Harnessing education and innovation • Regulated industries – use their regulation to deliver results • Outcome-based public procurement • Harness smart building planning and control
5	Take security seriously	How will you manage security? What services need it and what level of security is required? Identify who should hold governance and security responsibility. Take this security into every project.
6	Phased Development	Start small, move in phases, test and learn, use simple successes to get enterprise and citizen buy in. Identify developments that can be your test bed and initial deployment. As part of a city's phasing, deliver succinct applications with clear business cases to drive further investment e.g. smart parking, smart payment, smart lighting and waste management.
7	Form Partnerships and Ecosystems	Delivering smart cities requires capabilities that no single company holds as a core competency. Form a consortium and make long term ecosystem partnerships part of the smart procurement policy.
8	Drive citizen awareness	Citizens need to know they are involved and that they play a part. Utilise the data they can generate and make it easier for citizens, employees and contracted services to access and use a city's services with modern consumer technology.
9	Consolidate & Connect	Use an expert in IoT and Communications infrastructure to deliver a consolidated view of the city and connect as many devices as possible via an established, secure and managed telecommunications network.
10	Get Innovative	Commercialise the data collated by opening it up to the local enterprise through innovation hubs and developer hackathons. Test a city's local entrepreneurs to solve real city problems and create localised services.

Source: Vodafone

Degrees of smartness: connected, integrated, personalised, predictive

There are different degrees of "smartness" in terms of where cities are positioned on the Smart City theme.

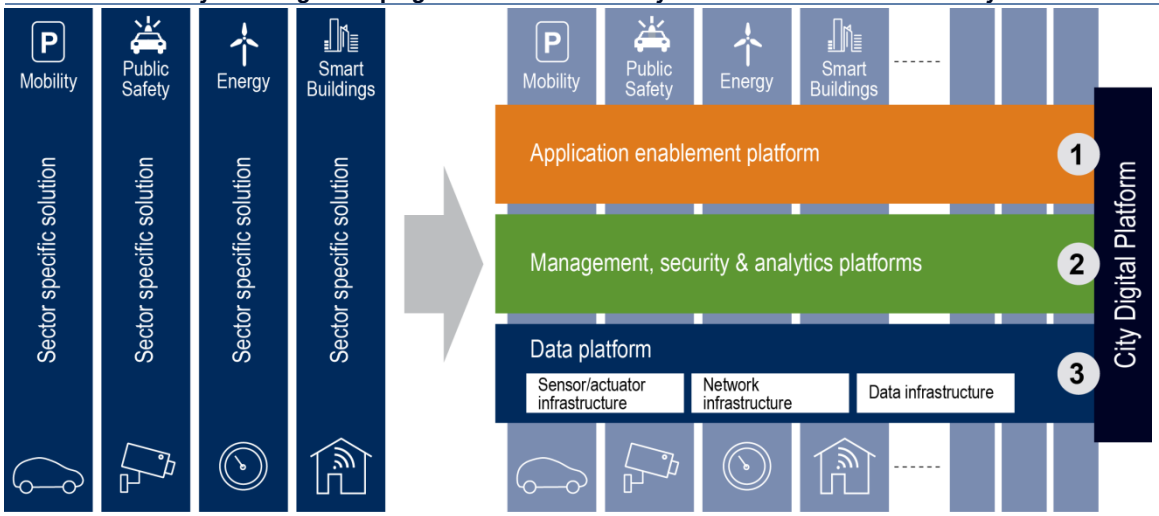
Exhibit 42: Four degrees of "smartness"



Source: Booz Allen Hamilton 2015

- **1st degree, Connected**: City agencies make services and information accessible online at any time, from anywhere, e.g., a website or App for a city's transportation system with real-time updates).
- **2nd degree, Integrated**: Operations that were in silos are now connected to a centralised command and control centre, with communications and information flowing seamlessly across the system. This facilitates multi-city-agency efforts (e.g., emergency notification and dispatch services via departments of health, transportation and safety).
- **3rd degree, Personalised**: Here is where the Smart City gets personal (e.g., a customised traffic-congestion alert service, citizens can choose specific locations and delivery methods, city agencies can prioritise users such as emergency vehicles).
- **4th degree, Predictive**: In this most advanced degree of 'smartness', sophisticated data collection and analytics enables city agencies to turn hard field intelligence into predictive insights and anticipatory action (e.g., an analytics program that evaluates current road and transit patterns to predict future usage, guiding informed decisions for maintenance and expansion projects to city officials (source: Booz Allen Hamilton).

Exhibit 43: Smart City technologies and programmes links horizontally across vertical sector silos of a city



Source: Nokia 2017

A holistic concept: goes beyond technology

A Smart City optimises the quality of life of its citizens and drives sustainability and economic growth by integrating and actively managing its infrastructure subsystems and engaging its citizens. The Smart City development approach can be top-down or bottom-up.

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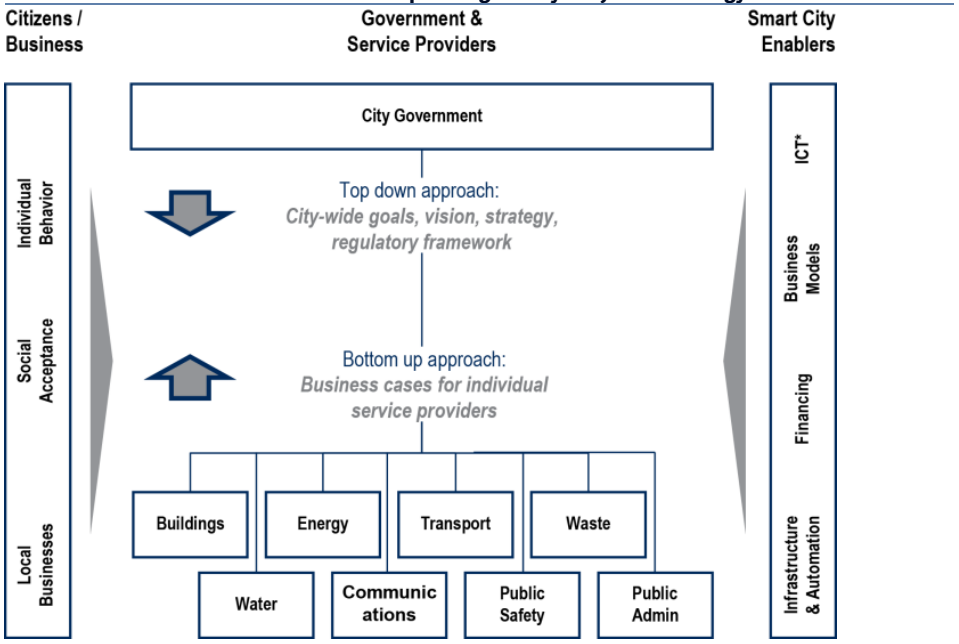
US National League of Cities' recommendations for Smart City development (2017):

- Cities should consider the outcomes they want to achieve.
- Cities should partner with universities, non-profits, and the private sector.
- Cities should look for best practices and frameworks for smart city development.

Exhibit 44: Smart Cities are a holistic concept that goes beyond just technology



Source: ABB 2016

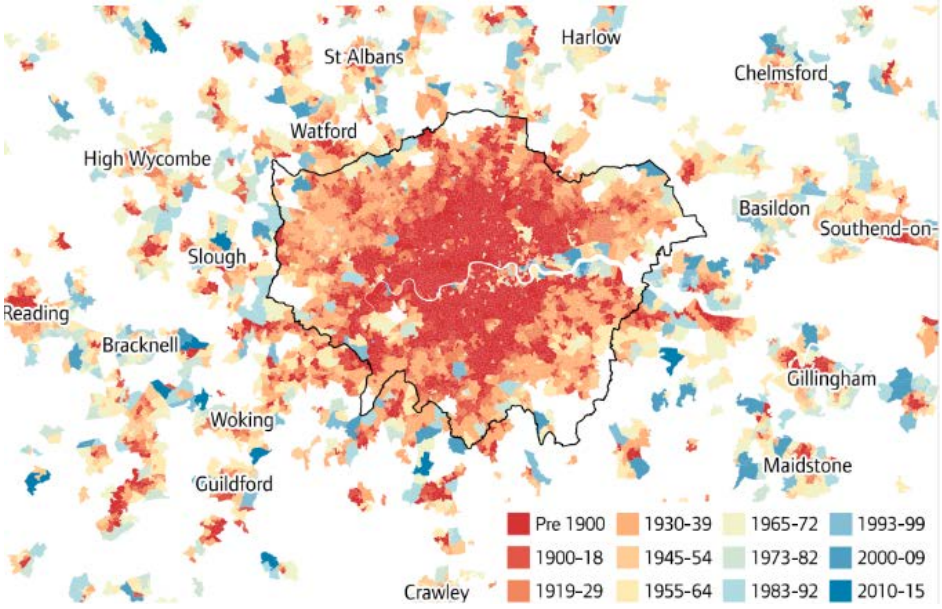
Case study of the Smart City of London (UK):

- **London is one of the top tech hubs in the world** (e.g., home to 20% of UK tech firms, 'Silicon Roundabout' by Old Street – the EC1V postcode hosts over 3,200 companies, European Digital City Index 2015).
- **'Smart London Board' advises the Mayor which includes experts from many leading companies**: Siemens, BT, Arup, Intel, Huawei, McKinsey, Telefonica and IBM.
- **Forward-thinking approach in using technology to address traffic**. In addition to a congestion charge and planned pollution charge, the city has made big investments in smart traffic technology, e.g., traffic lights respond in favour of buses).
- **Philips Lighting's connected lighting "CityTouch" system currently powers 42,000 lights** in London.

- **City Airport is the first in the world to test how IoT can transform the operation** of air hubs.
- **'SmartEye', individual parking space sensors** that gather and transmit information for management, payment and compliance monitoring.
- **A plan for 12 'Cycle Superhighways'**, of which are seven in operation.
- **It has committed to making available data from its Smart City initiative public via its London Datastore** (e.g., an App built on open data will take your location, and you can say where you want to go, and it will give you the best route) (source: City of London, TfL, Nominet, Juniper, Nesta, press sources).

Exhibit 45: Illustration of London's urbanisation over the past 100Y

Estimated period when each Lower Layer Super Output Area (LSOA) reached at least 400 dwellings per square mile



Source: Mayor of London

Economic model and drivers: cost/ROI, efficiency, vision

There is a strong and growing business case for Smarter Cities:

- **Demographic pressures**, including the rapid growth of many cities and changing age structures (ageing, the rise of the Millennials (Gen Y) and Centennials (Gen Z)).
- **Economic pressures**, as a result of increased competition between cities to attract globalised capital, affluent citizens, human capital and businesses/technology.
- **Environmental pressures**, caused to some degree by urbanisation and urban strains on resource use – as well as high(er) levels of concern from urban citizens on environmental issues, and are thus becoming a political issue.

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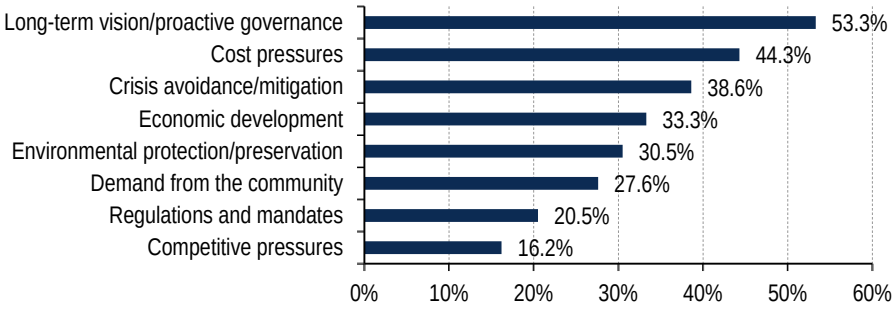
- **Financial pressures**, exacerbated by the financial crisis, has meant that many cities continue to face budgetary pressures and are both looking to do more with less, as well as being open to new business models and public-private partnerships.

- **Fragility**, in terms of vulnerability to natural disasters but also the inability of a city infrastructure's to cope with rapid social and economic change.

#1 global driver for Smart Cities: long-term vision & pro-active governance

The #1 driver for Smart Cities according to a 2016 survey of Smart City stakeholders worldwide by Black & Veatch is long-term vision and proactive governance – underscoring the salient reality that it takes vision to prioritise foundational tools that provide across-the-board yet difficult-to-quantify benefits. Vision was followed by cost pressures and crisis avoidance and mitigation.

Chart 22: What are the three major forces driving your community to adopt smarter communication technologies and data analytics



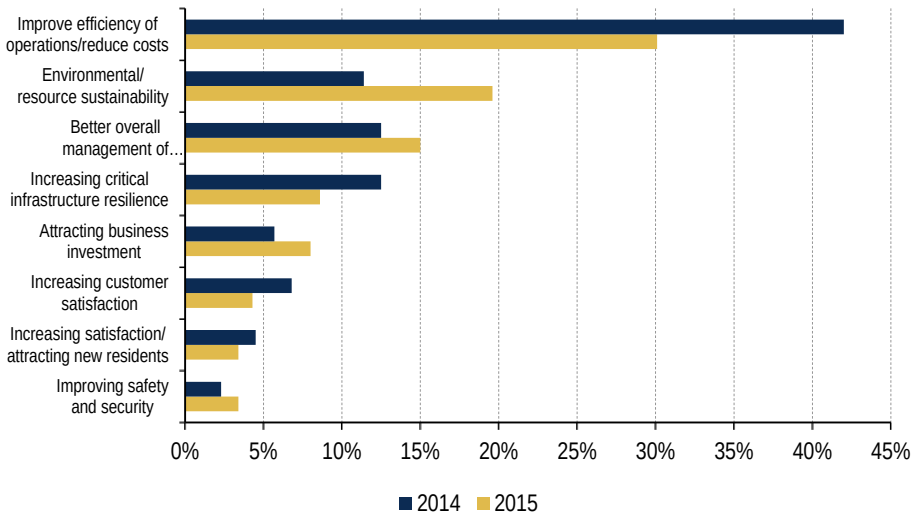
Source: Black & Veatch 2016

91% of government respondents view Smart City initiatives as transformational with the potential for long-term positive impacts on cities worldwide (source: Black & Veatch 2016)

Drivers for US city govts: efficiency, sustainability & better management

According to US government respondents to the Black & Veatch survey, the #1 driver for cities and communities to implement Smart City initiatives was to improve the efficiency of operations and reduce costs. This was followed by environmental/resource sustainability and better overall management of community systems (source: Black & Veatch 2016).

Chart 23: Q to government respondents: what do you see as the primary driver for cities to implement Smart City initiatives?



Source: Black & Veatch 2016

Case study of the Smart City of NYC (USA):

- **'LinkNYC', a communication network** of up to 10k structures that bring GB-speed, free, public Wi-Fi to residents and visitors.
- **'Marketplace NYC', a digital discovery tool to help government agencies** discover smart city solutions.
- **'Urban Tech NYC', an accelerator programme providing 9,300 square metres of affordable space** and prototyping equipment to help entrepreneurs build smart and sustainable solutions.
- **'City24/7' –- SmartScreens incorporate touch, voice, and audio technology** to deliver a wide array of hyper-local (about two square city blocks) information, services, and offerings in real time.
- **'Midtown in Motion' – nearly 300 sensors, cameras, and EZ-Pass Readers enable the Traffic Management Centre** to modify traffic light patterns in a 270-block region, which has resulted in over 10% improvement in travel times since the program was implemented in 2010.
- **A set of comprehensive guidelines for ensuring the equitable deployment of Smart City** technologies (source: NYC.gov, Nominet, Juniper, press sources)

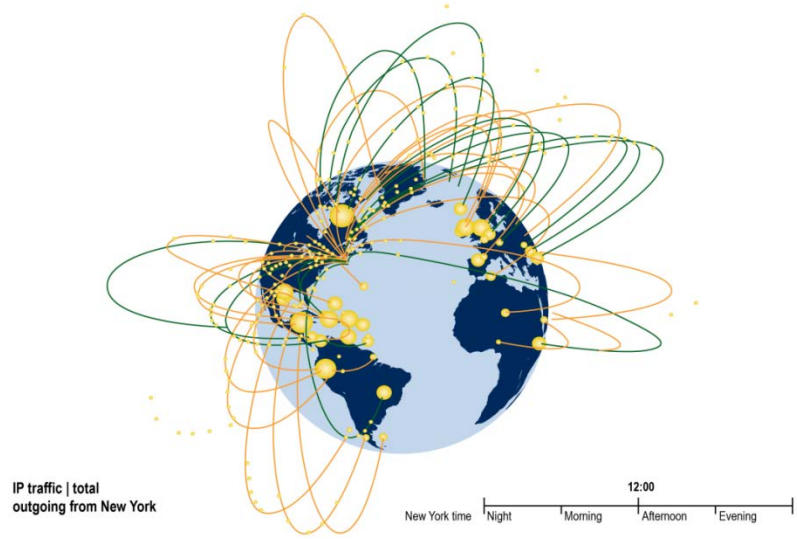
Tech is the key enabler: IoT, connected devices, smart sensors, Big Data, 5G, AI et. al

Developments in disruptive technologies and new business models have helped to enable cities to become smarter. These include ubiquitous broadband coverage (84% globally); nextgen infrastructure (5G up to 100x faster than 4G); the Internet of Things (IoT) (10bn connected devices in cities by 2020E); Big Data (insights from billions of sensors, 200mn GB of data/day for a city of 1mn by 2020E); the Cloud (secure, open platform); and cognitive computing and artificial intelligence (AI) (predictive insights and

anticipatory action). We outline some of these issues below and discuss them in greater detail in the Smart Infrastructure section.

A hallmark of smart systems is the union of data and action. Information gathered by sensors and smart devices is sped across high-speed networks and crunched by sophisticated software (source: Black & Veatch 2016).

Exhibit 46: A visualization of volumes of Internet data flowing between New York and cities around the world over a 24 hour period

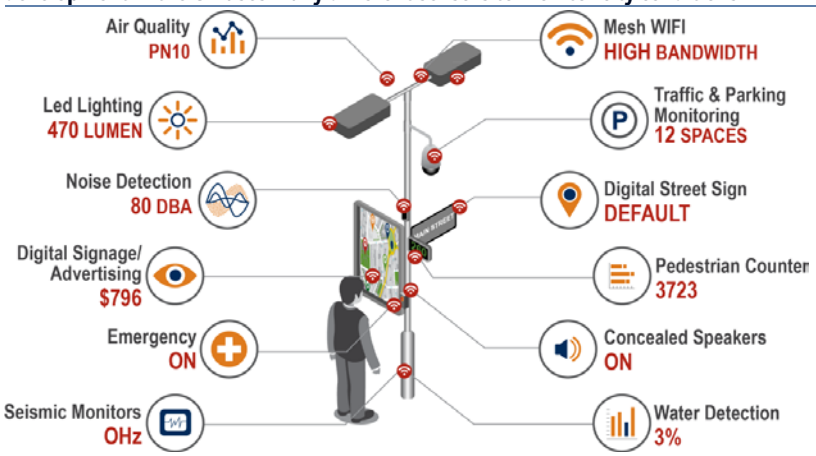


Source: New York Talk Exchange

Underlying tech model: connect, communicate, crunch

There are many technical models that Smart Cities are following, but according to Jesse Berst, founder and chairman of the Smart Cities Council, they generally abide by a mnemonic device he likes to use: "Collect, Communicate, Crunch." Collect means devices out on the edges collecting information about a city's conditions; Communicate means a citywide network that carries that data to where it is needed; and Crunch means computers in the centre that are analysing all this information, doing the analytics, and sending out operational signals to improve city conditions.

Exhibit 47: Smart city in action – a smart light pole envisaged for Old Oaks & Royal Park City development in the UK uses many different sensors to monitor city conditions



Source: Nokia 2017

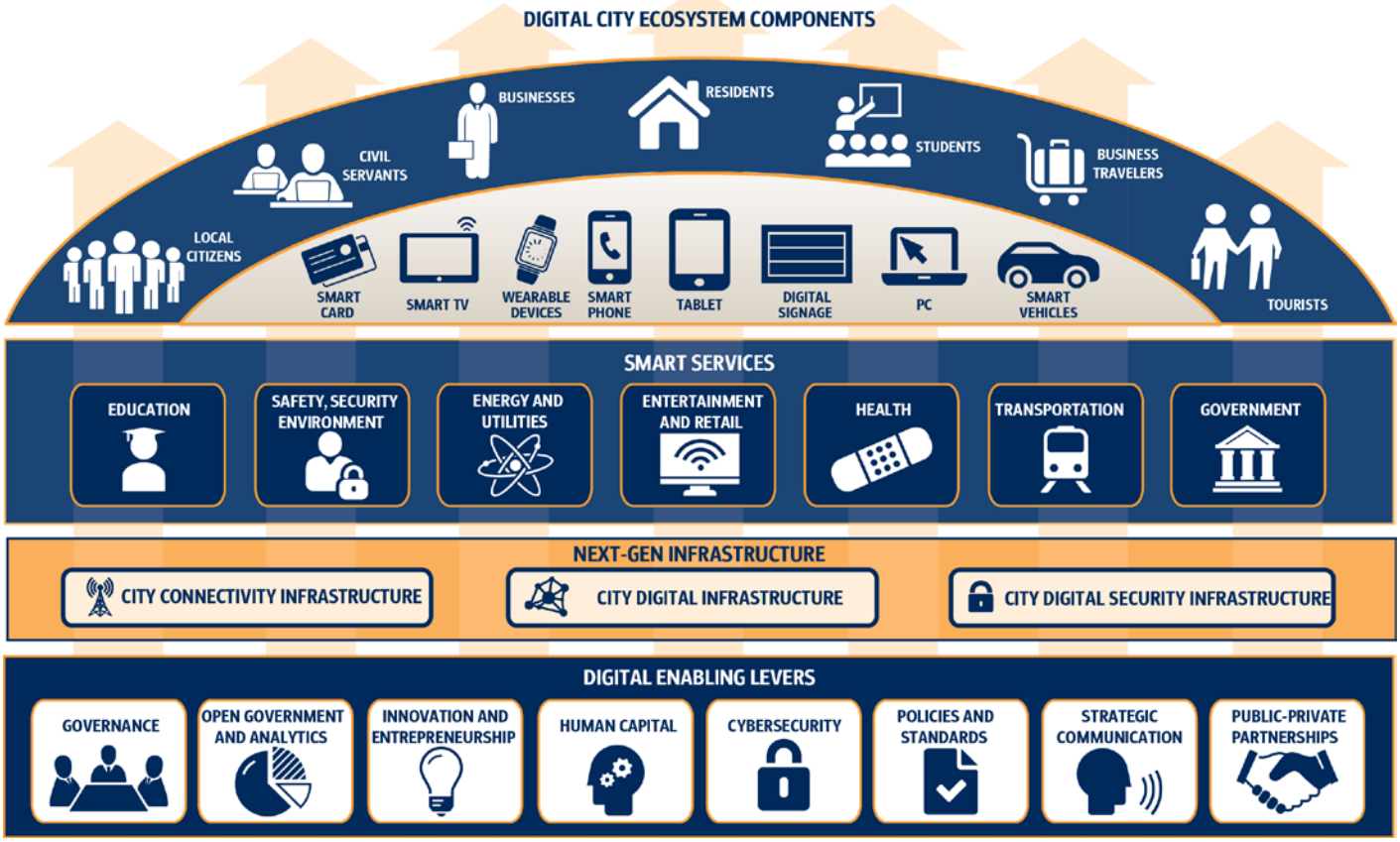
More and better connectivity options: smartphone to 5G

More and better connectivity options, including new network technologies such as high-speed fixed and mobile broadband, public access Wi-Fi, and low power wide area (LPWA) technologies offer low-touch, cheaper devices and better link margins for connecting objects. The advent of variants of 4G LTE more suited to IoT implementations in terms of cost and performance characteristics is important (source: Machina-Nokia). 5G will also be an important long-term driver and game changer, in our view.

6bn+ smartphones by 2020E: Smart City interface in everybody's hands

The 4bn installed smartphone base in use today is set to grow to 6bn+ by 2020E and become a near-ubiquitous sensing and user interface device in the hands of citizens (source: IHS Markit 2017, Machina-Nokia). Smartphones together with tablets now account for 60% of all smart connected consumer devices (vs. 18% in 2008). Nearly 50% of citizens in large cities globally will benefit from smart city programmes by sharing personal data by 2019E (source: Gartner 2016). As smartphones see ever larger uptake worldwide, they will smart services and smart cities (source: IHS Markit 2017).

Exhibit 48: Smart city digital ecosystem components



Source: Booz Allen Hamilton 2015

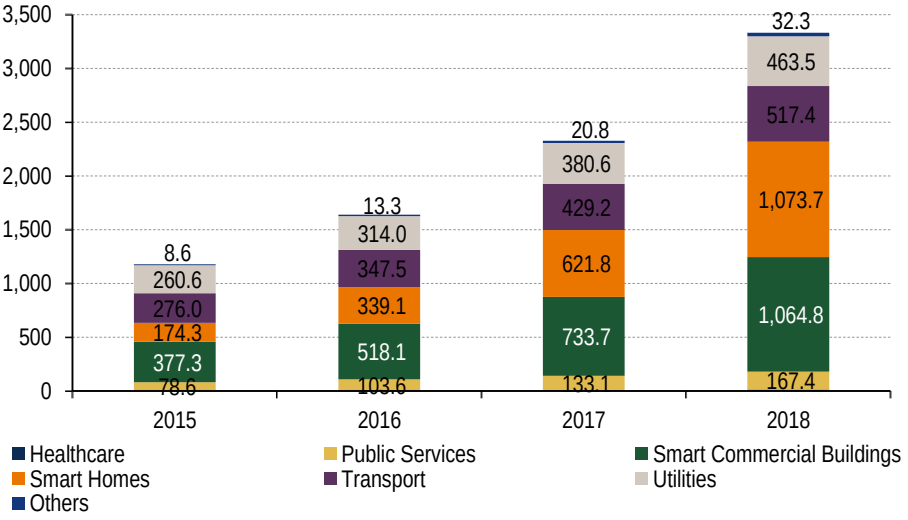
IoT of cities: 10bn connected devices by 2020E

Making cities smarter will require developing, managing and monitoring a complex system of connected and intelligent sensors, networks, devices, cameras, traffic lights, smart meters, power grids, and utility frameworks. This means that an IoT structure ultimately carrying billions of connections will form the backbone of the Smart City. Citizens and businesses will benefit from improvements in air quality, convenience, cost, energy provision, healthcare, safety, traffic, waste management etc. Meanwhile, data collected and analysed from intelligent sensors will allow Smart Cities to better engage with them, and improve infrastructure, services, and utilities.

Smart Cities IoT network connections grew 43% yoy from 2014 to 2015, while other Smart City-related areas saw significant growth: energy/utilities (+58%), home monitoring (+50%), and transportation (+49%) (source: Verizon 2016).

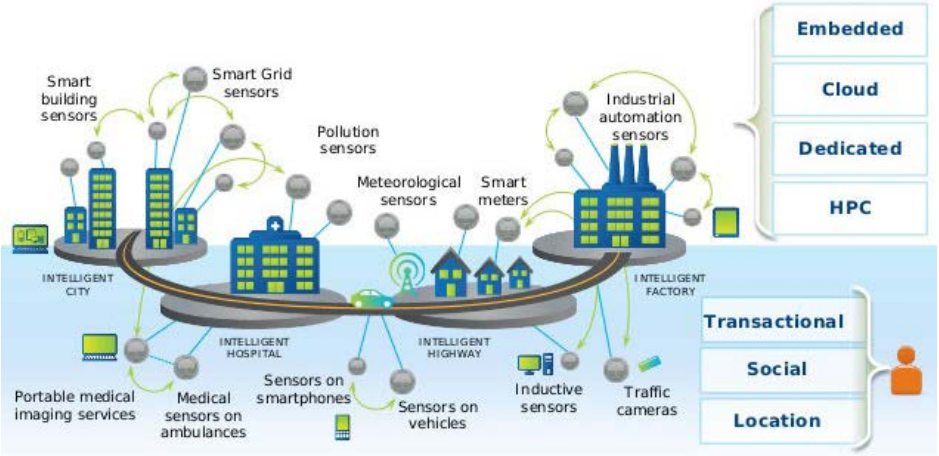
The IoT can help reduce the cost of energy, spatial management and building maintenance by up to 30% especially in large sites, such as industrial zones, office parks, shopping malls, airports or seaports (source: Gartner)

Chart 24: Connected Things: installed base within smart cities (mn)



Source: Gartner December 2015

Exhibit 49: Smart Cities = Sensor-based Cities



Source: IDF 2013

- **An estimated 1.6bn connected things are being used by Smart Cities in 2016, +39% on 2015**. Smart commercial buildings are expected to be the biggest user until 2017E, after which smart homes will take the lead with just over 1bn connected things in 2018E (source: Garner).

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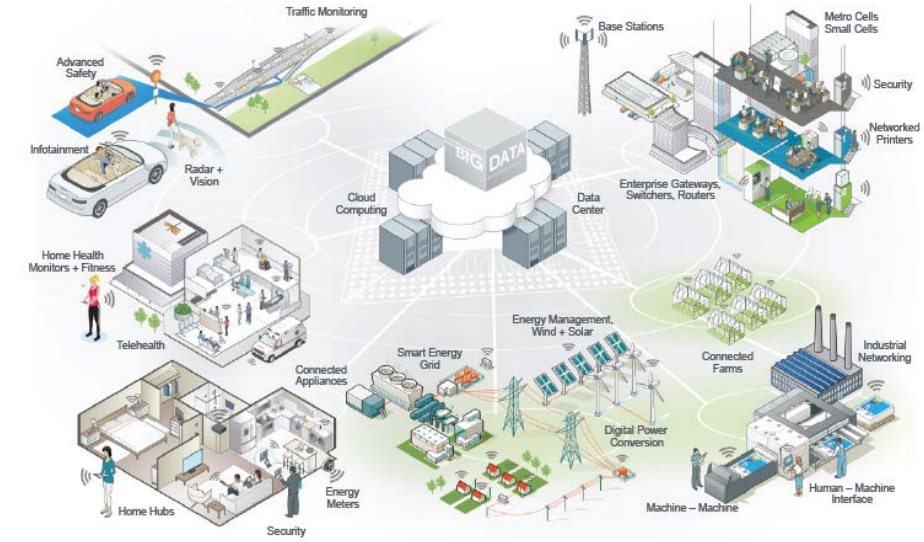
Exhibit 50: Enabling smart connected solutions



Source: NXP

- **Together smart commercial buildings and homes are expected to account for 64% of the installed base by 2018E**. Also contributing to take-up and growth are connected things used in transport, utilities, public services, and healthcare (source: Gartner).

Table 14: Connected Things: installed base within smart cities (mn)

Smart City Subcategory	mn	As % of total	mn	As % of total	mn	As % of total	mn	As % of total
Healthcare	3.4	0.3%	5.3	0.3%	8.4	0.4%	13.4	0.4%
Public Services	78.6	6.7%	103.6	6.3%	133.1	5.7%	167.4	5.0%
Smart Commercial Buildings	377.3	32.0%	518.1	31.6%	733.7	31.5%	1,064.8	32.0%
Smart Homes	174.3	14.8%	339.1	20.7%	621.8	26.7%	1,073.7	32.2%
Transport	276.0	23.4%	347.5	21.2%	429.2	18.4%	517.4	15.5%
Utilities	260.6	22.1%	314.0	19.1%	380.6	16.4%	463.5	13.9%
Others	8.6	0.7%	13.3	0.8%	20.8	0.9%	32.3	1.0%
Total	1,179.7	100%	1,641.0	100%	2,327.7	100%	3,332.5	100%

Source: Gartner December 2015

- **The growing maturity of smart home platforms through an ecosystem of home appliances, infotainment and home sensors will mean that smart home investments overtake those of commercial buildings in 2018E**, and see the fastest 5Y IoT-smart city growth according to Gartner. In smart homes, the consumer IoT applications that are fuelling growth are smart TVs, smart set-top boxes, smart light bulbs and various home automation tools such as smart thermostats, home security systems and kitchen appliances (source: Gartner).

- **Services and analytics will become increasingly important for technology and service providers (TSPs)** and by 2020, many IoT TSPs will have grown their hardware revenues through services and software by more than 50% (source: Gartner).

- **Chipmakers will be the biggest beneficiary in our view** – and will work with smart-city solution providers, system integrators, software designers, and chip designers to develop more secure sensors that are power-efficient and easy to control and monitor.

PYMNT's "The Intelligence of Things Tracker" February 2017 ranks IoT actors according to four categories (devices, software, services, infrastructure):

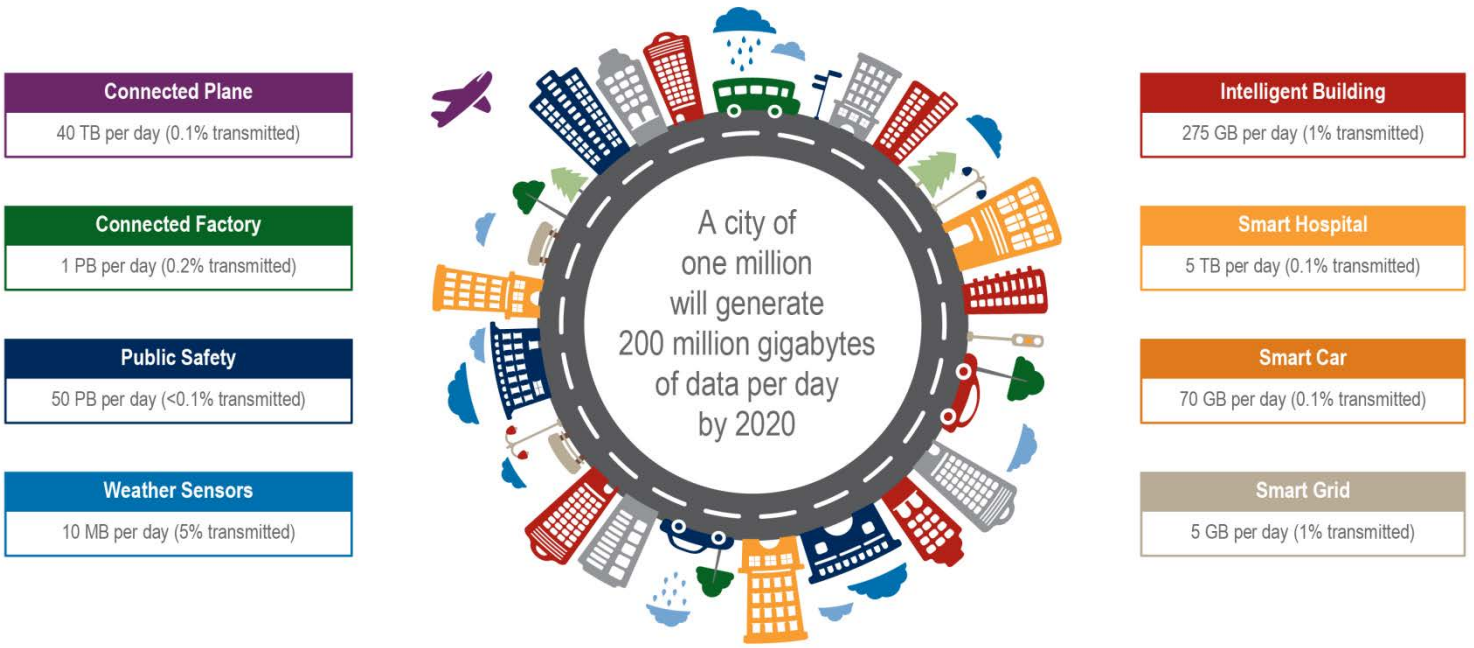
- **IoT Implementers Top 10:** Dell, Huawei, Samsung, LG, HP Enterprise, Fujitsu, Marvell, Arrow, Enlightened, Apple, Microsoft.

- **IoT Enablers Top 10:** Intel, Amazon, Cisco, Google, Verizon, ARM (Softbank), Vodafone, Comcast, Silicon Labs, Telit.

Big Data: a city of 1mn to produce 200mn GB of data a day!

Big Data is everywhere, largely generated by connected devices and automated systems operating in real time that can tell us how cities are performing and changing (source: Batty et al. Built Environment 2016). This data will come from many sources, including: the IoT, crowdsourced data, city agencies, and open sources. New tools and paradigms for ingesting, managing, storing and analysing data, including cloud architectures and machine learning can put this data into use vis-à-vis smart cities (source: Machina-Nokia). By 2020E, a city of 1mn people will produce an estimated 200mn GB of data/day (source: Cisco 2016).

Exhibit 51: Enormous amounts of Big Data will be created by buildings, cars, and planes in Smart Cities



Source: Cisco 2016

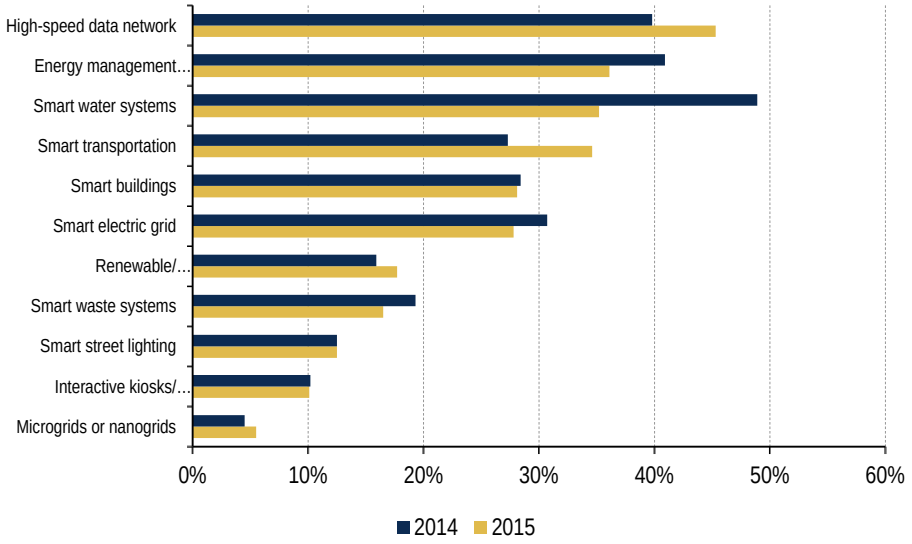
- **Nearly 50% of citizens in large cities globally will benefit from Smart City programmes by sharing personal data by 2019E** (source: Gartner 2016). This data will come from many sources, including: the IoT (connected devices, buildings, infrastructure etc.), crowdsourced data (actively contributed by citizens via smartphone applications, web pages and messages, or passively by automated smartphone apps), and operational procedures of city agencies (e.g. demographic and household data, school rolls or highway repairs) (source: Machina-Nokia 2016). The adoption of open data policies in major cities like Atlanta, Chicago and LA – is another driver (source: IDC).

- **Organisations that effectively use the data to drive decisions in their organisations out-perform their competitors by a margin of 5-6%** (source: Provost er al, Big Data 2013).

- **The increasing influence of open data models in the public sector** (i.e., that some data should be freely available, in standardised formats, to everyone to use and republish, without constraint from copyright, patents or other mechanisms of control).

- **#1 government spending priority is high-speed data networks** according to government respondents to the Black & Veatch's 2016 Smart City survey. These are crucial to moving data collected from system sensors that can be analysed in the cloud and used to adjust consumption patterns and behaviours.

Chart 25: What do you see as the top three most important systems in a smart city program to invest in first?



Source: Black & Veatch 2016

- **A key issue is shared digital infrastructure which standardises data collection, storage and analysis for automated monitoring and control of the city**. Data collected from across a city is the basis for a 360 degree operational view. Types of data might include continuous and very high bit rate video data from surveillance cameras and otherwise infrequent low bit rate telemetry data used to alert on filled waste bins, for example. The value of data multiplies significantly if it is processed in real-time and the total store of data is readily accessible by software developers. A high value example is combining video surveillance with intelligent analytics to automatically detect security events and then link this information to map navigation applications to keep people safe (source: Nokia).

Exhibit 52: San Francisco plans to collect data from as many sources as possible leading to greater accuracy, prediction of problems & optimizing outcomes

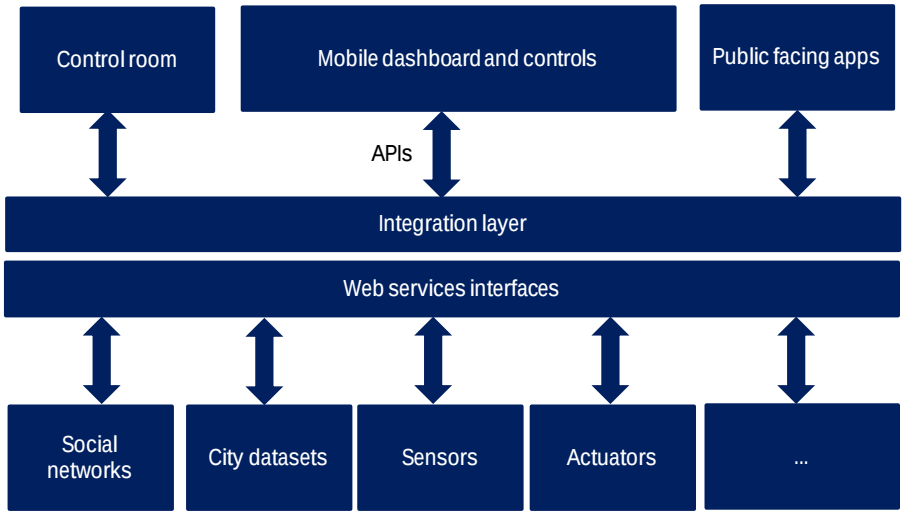
Technology Elements	Innovative Approaches to Urban Transportation Element		Smart City Element
Intelligent, Sensor-Based Infrastructure • Roadway Sensor • In-vehicle Sensor • Application Specific Sensor	User-Focused Mobility Services & Choices • Transport as a Service Platform • Convenient Accessible Transit	Strategic Business Models and Partnering Opportunities	Architecture & Standards • Automation Standards • CV Standards • Open Data Standards
Connected Vehicles • CV Safety Zones • MMITSS Corridors • Connected Highways and Bridges • Low Emission Eco-Zones	Smart Grid & Roadway Electrification • E-charge Garage Pilots • Electric Transit • Smarter Street Lights • Inductive Charging Pilot	Urban Delivery & Logistics • Smart Delivery Systems • Curb Space Management • Loading/Unloading Access Points	Low-Cost, Efficient, Resilient & Secure ICT • Critical Infrastructure • Access and Transparency • Secure Cloud Analytics
Urban Automation • Shared, Electric, Connected, and Automated Vehicles • Automated Transit • Dedicated	Urban Analytics • Performance Measurement • Real-time Analytics Dashboards • Proactive/Predictive Management	Connected, Involved Citizens • Crowd-sourcing city inputs • Citizen Engagement Platform • Developer Engagement	Smart Land Use • Mixed Use Smart Developments • Shared Transit Hubs • Smart ROW Management • Accessibility Improvement

Source: Nokia 2017

Cloud: flexible, cost effective and secure solution and US$296bn mkt by 2021E

Smart Cities are increasingly taking advantage of cloud-based solutions in infrastructure, platforms and application (IaaS (infrastructure as a service), PaaS (platform as a service), SaaS (software as a service)) vis-à-vis the deployment of Smart City applications and services. The cloud offers cities flexible, scalable, cost-effective and secure infrastructure to implement Smart City applications connecting thousands of endpoints and manage the large amount of heterogeneous data produced by the functioning of cities (source: Kakderi et al URENIO; Machina).

Exhibit 53: Leveraging the Cloud for Smart City services delivery



Source: Machina 2016

- **With cities accounting for 85% of global GDP, they will dominate the roll-out of the overall Cloud TAM** (IaaS, PaaS, SaaS) per our BofAML Server and Enterprise

Software team's estimate would be ~US$296bn in five years while third-party forecasts points to cloud revenues growing at 18-20% to ~US$205-220bn by 2020 from ~US$100-110bn now. This compares with enterprise IT spend growth of just 3% CAGR. See our team's Software: Battle in Seattle 23 February 2017.

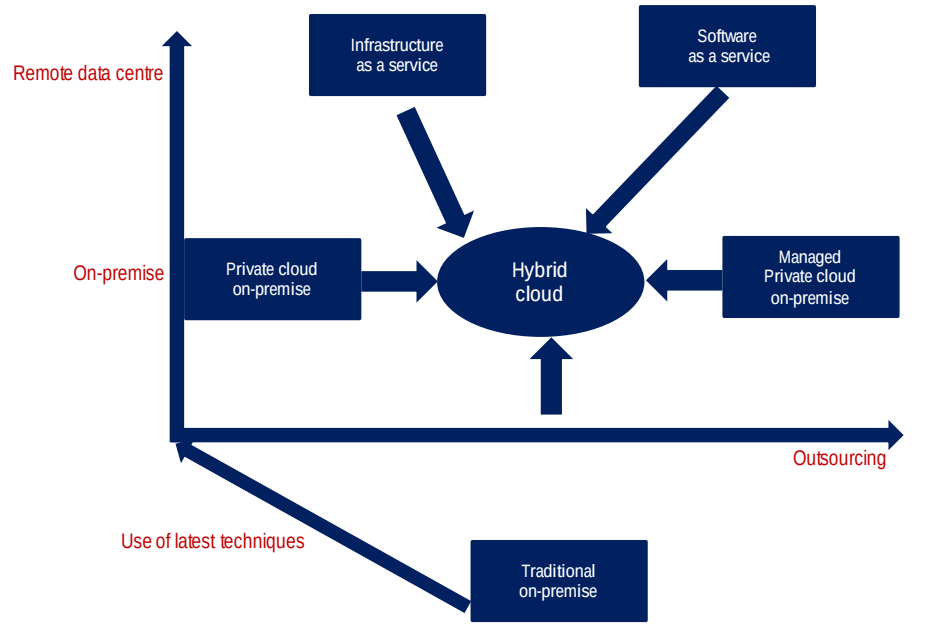
Exhibit 54: Public cloud revenue to grow at 18-20% CAGR till 2020 to reach around $205-220bn, still only 70-75% of BofAML's $296bn TAM estimate

	2013	2014	2015	2016	2017	2018	2019	2020	2014-16	2016-20
Enterprise IT spend (Gartner forecast)		$2,770.5	$2,657.5	$2,691.0	$2,772.9	$2,863.2	$2,956.2	$3,054.3	-1%	3%
BAML TAM estimate (IaaS, PaaS, SaaS) (5 year target)	$220			$296.0						
IaaS				$50.0						
PaaS				$35.0						
SaaS				$211.0						
Gartner estimate (IaaS, PaaS, SaaS)	$66	$80.9	$93.4	$111.8	$133.6	$158.9	$187.0	$218.3	18%	18%
IaaS		$12.1	$17.7	$25.3	$34.6	$45.6	$57.9	$71.6	45%	30%
PaaS		$4.5	$5.7	$7.2	$8.9	$10.6	$12.6	$14.8	26%	20%
SaaS		$64.3	$70.0	$79.4	$90.1	$102.7	$116.5	$131.9	11%	14%
IDC estimate (IaaS, PaaS, SaaS)	$46	$59.4	$77.3	$98.7	$123.2	$147.6	$174.6	$204.5	29%	20%
IaaS		$8.1	$12.4	$18.6	$26.1	$32.1	$38.8	$46.3	52%	26%
PaaS		$5.7	$8.8	$12.4	$17.0	$22.3	$28.4	$35.6	47%	30%
SaaS		$45.6	$56.1	$67.7	$80.1	$93.2	$107.5	$122.6	22%	16%

Source: BofA Merrill Lynch Global Research, Gartner, IDC

- **Hybrid Cloud offers the most cost-effective infrastructure**: As cities implement their Smart City applications, they will find that making use of cloud infrastructure for new applications, while maintaining existing in-house infrastructure, at least in the short term, is the only practical solution. Expanding an on-premise infrastructure to support the requirements of these new applications would be a lengthy and expensive project carrying a significant risk of failure. Nevertheless new Smart City services will need to work with legacy on-premise systems and across multiple verticals if they are to deliver the full benefits that a Smart City implementation can bring. Robust APIs are the key to ensuring that services implemented in the cloud can work together in the future.

Exhibit 55: Dimensions of Smart City Cloud strategy



- **Cloud solutions are likely to be the most secure**: Physical location is no longer a major factor in ensuring the security of today's networked IT systems. The most secure infrastructure is one for which all the latest security techniques are applied as soon as they become available. This is best achieved by professional data centre managers for whom security is a full-time job. And it can be most effectively realised in the cloud where there is the capacity to test backup routines rigorously and to apply big data analytics to filter out the false alarms which often overwhelm in-house IT teams (source: Machina 2016).

Case study of the Smart City of Paris (France):

- **'Grand Paris Express', a US$25bn expansion of the Paris Métro.** By 2030, the system will have gained four lines, 68 stations, and more than 120 miles of track. Planners estimate that the build-out will boost the entire network's ridership by almost 40%.
- **Renovation of Paris's street lighting: the city's largest public contract (€800mn over 10Y).**
- **Plans to ban diesel vehicles by 2025E** in order to improve air quality.
- **'Velib', a large public bicycle sharing system encompassing c14,500 bicycles and 1,230 bicycle** stations.
- '**Autolib', an electric car sharing service operated by Bolloré which maintains a fleet of c4,000 all-EV Bluecars and c6,000 charging stations for public use** on a paid subscription basis.
- '**ClimEspace' operates the world's leading district cooling system.**
- **'Halle Pajol' – France's largest city-centre solar power station.**
- **'IssyGrid' – France's first operational district smart grid.**
- '**Smart/Wind Trees' piloted** at Place de la Nation in a bid to curb the city's pollution crisis with sensors. 'Wind Trees' are being piloted at Place de la Concorde where 'aeroleaves' operate as mini wind turbines generating renewable energy (source: Mairie de Paris, Paris Green, Juniper, press sources).

Cities of all sizes and types are moving on smart cities

There is no precise or definitive numbers on how many Smart Cities exist worldwide, but the numbers are on an upward trend – in terms of the quantity, level, and variety of cities – as well as the move from small-scale pilot projects to large-scale integrated programmes. We believe the number of cities that are making a comprehensive effort to become Smart is in the hundreds, while the number of cities adopting Smarter technologies on a more ad hoc basis is in the thousands. We outline some of the largest and most ambitious projects to date below (although the list is far from exhaustive):

- **China (RMB500bn/US$73bn in the 13th FY Plan 2016-20)**: As part of the its urbanisation strategy, China is looking to develop 'new cities' which encompasses Smart Cities, Green Cities, and 'Sponge Cities' (with a stronger ecological footprint). The National development and Reform Commission (NDRC) has stressed the importance of private capital to build its Smart Cities.

- **India (109 cities, INR98,000 crore/US$15bn in investment):** Under its Smart Cities Awas Yojna Mission, India aims to make 109 cities smart and rejuvenate 500 others by the end of this decade. Cities will see general connectivity boosted, as well as e-government and citizen participation enhanced though IT systems, and an improvement of the overall urban mobility strategy and smarter public transports.

- **UAE (Dubai, US$8bn+):** Under the Dubai Plan 2021, the Smart City strategy includes 100+ initiatives and a plan to transform 1,000 government services into smart services, mostly based on data. The plan covers healthcare, industrial, education, safety, telecoms, tourism and utilities. Dubai along with neighbouring Abu Dhabi is also deploying over 5,000 Wi-Fi hotspots to offer free internet. It is also investing heavily on smart mobility systems (i.e. traffic sensors, mobile traffic apps, driverless vehicles).

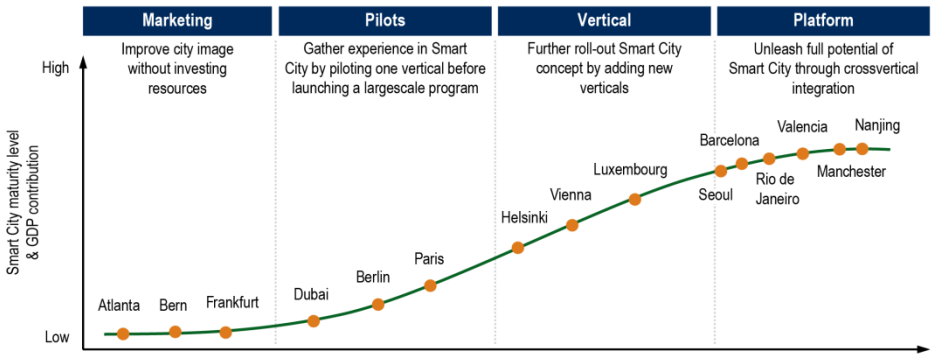
- **Singapore (S$2bn):** The Singaporean government launched one of the largest Smart Cities roll outs in the world in 2014 with Smart Nation, and has plans to cover the entire city-state with sensors and smart cameras to collect data across all verticals, including healthcare, water, and waste. The government plans to the data onto an online platform (Virtual Singapore).

- **USA (US$165mn):** In 2016, as part of the Obama White House's Smart Cities Initiative, the US Department of Transportation announced a US$165mn investment in Smart-City solutions. This includes US$65mn in funding and US$100mn in matching funds geared to smart mobility technologies, easing congestion, and improving safety.

- **Barcelona (US$90m+):** It is deploying sensors to measure noise control, air quality, waste management, and for street parking (ApparkB gives motorists real-time information on street parking). Street lights are a focus with LEDs and 3,000+ lights with the intelligence to activate when motion is detected, and gather environmental data. It has installed close to 1,000 Wi-Fi spots and is looking to bring free internet access across the whole city. It is also rolling out more e-government services, contactless services, more city apps, smart bus stops etc.

- **Australia (US$50mn):** Under the 'Commonwealth's Smart Cities Plan', the Australian government will invite state and territory governments to partner in City Deals which provide common objectives across levels of government, support for key industry and employment centres, infrastructure investment linked to broader reform and changes to planning and governance arrangements.

Exhibit 56: Smart City maturity level



Source: Arthur D. Little

US: all cities, all sizes moving to become Smarter

The US Conference of Mayors (USCM) released a survey in January 2017, jointly developed and conducted with IHS Markit, which shows that cities of all sizes are

developing and implementing Smart City projects. Within the 54 cities responding to the survey, 335 smart city projects are being implemented and 459 are being planned through 2017. Of the 335 implemented projects, 69 are taking place in large cities, 168 in mid-sized cities and 98 in small cities; of the 459 planned projects, 103 are in large cities, 225 in mid-sized cities and 131 in small cities.

- **The top three functional areas by number of implemented projects are: governance (86), mobility and transport (74), and physical infrastructure (59)**. The top three functional areas by number of planned projects are: mobility and transport (104), governance (90), and physical infrastructure (90).

- **The top two priorities for US smart city projects are increasing citizen satisfaction (9.0) and improving government responsiveness (8.3)**.

GE Current – a start-up within GE blending advanced energy technologies – announced the first large-scale use of Smart City tools for the city of San Diego in February 2017

- GE Current is working with AT&T, Intel, ShotSpotter, CivicSmart and Proximetry to deploy the intelligent network across the city.

- 3,200 intelligent sensor nodes will help optimise traffic and parking, plus enhance public safety (e.g. locate gunshots, vehicle speeds), environmental awareness and overall liveability for San Diego residents.

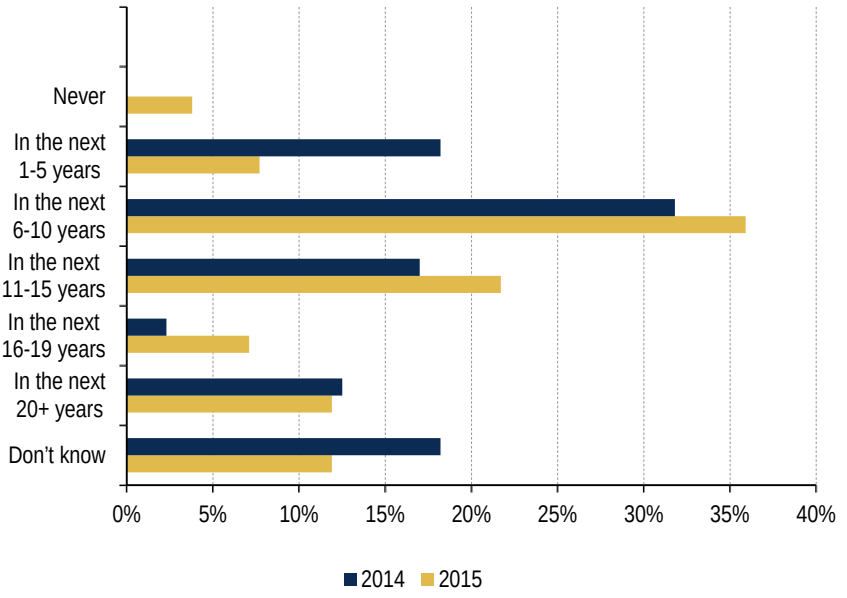
- The system is included in a US$30mn GE LED lighting upgrade to 14,000 of San Diego's 60,100 street lights, which is expected to save the city US$2.4mn pa (source: company, press sources).

Time horizon for Smart City implementation: 1-20+ years

According to a 2016 Black & Veatch Smart City stakeholder survey, 44% of respondents believe that there will be widespread adoption and implementation of the Smart City model across the US in the next 1-10Y. But that said, 41% of respondents believe that the timeframe will be 11-20Y+ (source: Black & Veatch).

As more municipalities move beyond the hype to build master plans and consult with stakeholders, they realize the need for more infrastructure, resources and funding than they originally contemplated (source: Black & Veatch 2016)

Chart 26: When, if ever, do you believe there will be widespread adoption and implementation of the Smart City model across the US?

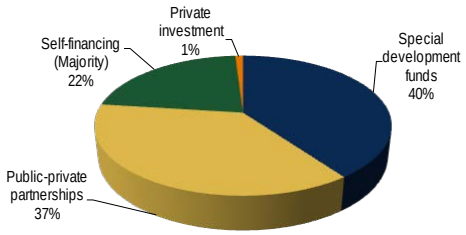


Source: Black & Veatch 2016

Cost & budgetary constraints: who pays for Smart Cities

Smart City projects require pooling public and private resources through creative financing and public-private partnership models. Policies, taxation and regulatory certainty also play an important role in this process. Governments need to address such issues to encourage the private sector to grow and innovate in new, thoughtful and increasingly strategic ways to invest in smart city projects. Strategically funding Smart City infrastructure and technology investments is critical to the realization of smarter cities. Smart City projects are often complex undertakings, involving long time horizons, multiple stakeholders and risks. Citizens must be made aware of the costs involved, the associated benefits and the prices they will be charged before the commencement of projects (source: UNCTAD 2016).

Exhibit 57: Smart Cities: most adopted funding mechanisms for projects



	Funding Mechanism
Special Development Funds	Specific funds set up for implementing and scaling up urban development or smart city initiatives (e.g., European Commission 'JESSICA')
Public-private Partnerships	Funded and operated through a partnership of government and one or more private sector companies (e.g., Cisco-Songdo Partnership)
Self-financing (majority)	Self-financing of smart city projects from public budgets in collaboration with central governments or state governments (e.g., Seoul Smart City)
Private Investment	Financed through commercial stakeholders, service providers, private investors, and venture capitalists (e.g., Amsterdam Smart City Platform)

Source: Frost & Sullivan 2012

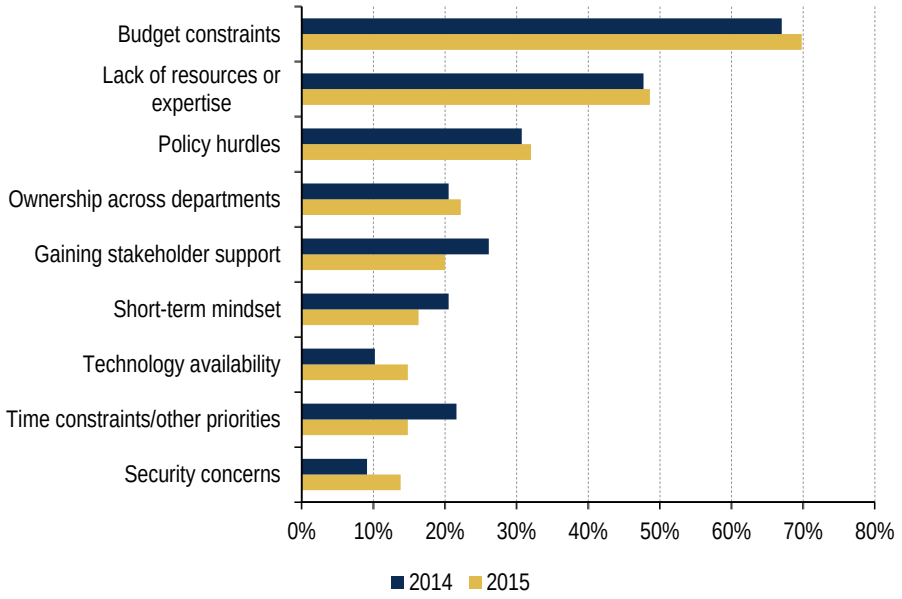
Strained budgets: a major obstacle to participation & planning

Strained city budgets are a major obstacles to Smart City participation and planning. Nearly 70% of government respondents, and 44% of smart service providers in Black & Veatch's 2016 Smart City stakeholder survey, labelled budget constraints as an acute inhibitor of smart city initiatives. 50-60% of the respondents replied "don't know" to questions regarding the ability of municipalities to fund Smart City initiatives, the rate

of return needed to justify investment and the opportunities to create revenue or savings from the data generated through the initiatives.

The fundamental question is, "Who pays for this?" Compounding this, the overall cost and ROIs are not broadly understood. These are technology investments that often require pilot projects and testing while competing for funds against more mundane capital and operating projects. Siloed organisations often cannot look beyond their own department budgets (source: Black & Veatch).

Chart 27: What are the top three hurdles that must be overcome to enable city/community systems to be managed in a smarter, more integrated way?



Source: Black & Veatch 2016

- **Given the fiscal constraints in many cities, it can be difficult to trade near-term pain for long-term gain**, especially when Smart City investments entail a high degree of inter-department coordination and a certain level of politics as to which departments win or lose (e.g., being able to trade a slice of the ongoing operational cost of energy in the form of payments to the utility for a one-time capital cost of purchasing new highly efficient light fixtures may seem simple but can actually be pretty challenging).

- **Another often overlooked aspect to funding new smart city technology is the long-term strain on capital and operations and maintenance budgets, and the long-term cost trends in every area of essential municipal services**. Proponents of new technology investment see reasonable ROI associated with new technologies while decision-makers see the full front of emerging budget strains associated with the need to address aging infrastructure, cybersecurity, resilience and population growth (source: Black & Veatch).

Two camps of Smart City thinking: ad hoc add-ons vs. master plans

Adoption of Smart City initiatives have sometimes been kept at bay by cash-strapped cities whose leaders believe smart integrated infrastructure changes are up to a decade

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away – and questions of cost appear to be dividing most Smart City Initiatives into two major camps:

- **Cities with lean(er) budgets but deep interest in Smart City efficiencies are opting for incremental system add-ons** (e.g., street lights, digital kiosks, EV charging stations – that produce quicker results.

- **Other cities are pursuing some form of root-level master planning, which puts cities on a broad, years-long smart city path** and envisions a thorough rethinking of how a city uses its energy, water, communication and transportation systems (source: Black & Veatch).

BofAML's ranking of the world's Smartest Cities: Singapore, London, NYC Paris, Tokyo, Stockholm et al.

Just as there is no definitive definition of Smart Cities, there is no definite list of the world's Smartest Cities. As a result, we have created a BofAML list of the world's Smartest Cities based on a wide range of global rankings, indices and awards, encompassing multiple Smart City factors including connectivity, ease of doing business, education, environmental footprint, governance, human capital, innovation, infrastructure, and liveability, among others. We view Singapore, London, New York, Paris, Tokyo, Stockholm, Amsterdam, Seoul and Vienna as some of today's Smartest Cities.

Exhibit 58: BofAML's Smart City Indicator of the world's smartest cities

Icon	Map	Rank	BofAML Smart City Index (2017)	AT Kearney Global Cities Index (2016)	PwC Cities of Opportunity (2016)	Ericsson Smart City Index (2016)	The Economist Safe Cities Index (2015)	Mercer Quality of Living Survey (2016)	fDi's Global Cities of the Future (2016)	Innovation Cities Global Index (2015)	IESE Cities in Motion Index (2016)	Mori Global Power City Index (2016)	Arcadis Sustainable Cities Index (2016)	Global Green Economy Index (2016)
		1	**Singapore**	London	London	Stockholm	Tokyo	Vienna	Singapore	London	New York	London	Zurich	Copenhagen
		2	**London**	New York	Singapore	London	Singapore	Zurich	London	San Francisco	London	New York	Singapore	Stockholm
		3	**New York**	Paris	Toronto	Singapore	Osaka	Auckland	Dublin	Vienna	Paris	Tokyo	Stockholm	Vancouver
		4	**Paris**	Tokyo	Paris	Paris	Stockholm	Munich	Shanghai	Boston	San Francisco	Paris	Vienna	Oslo
		5	**Tokyo**	Hong Kong	Amsterdam	Copenhagen	Amsterdam	Vancouver	New York	Seoul	Boston	Singapore	London	Singapore
		6	**Stockholm**	Los Angeles	New York	Helsinki	Sydney	Dusseldorf	Hong Kong	New York	Amsterdam	Seoul	Frankfurt	New York
		7	**Amsterdam**	Chicago	Stockholm	New York	Zurich	Frankfurt	Amsterdam	Amsterdam	Chicago	Hong Kong	Seoul	Berlin
		8	**Seoul**	Singapore	San Francisco	Oslo	Toronto	Geneva	Dubai	Singapore	Seoul	Amsterdam	Hamburg	Helsinki
		9	**Vienna**	Beijing	Hong Kong	Tokyo	Melbourne	Copenhagen	Paris	Paris	Geneva	Berlin	Prague	Paris
		10	**Zurich**	Washington DC	Sydney	Seoul	New York	Sydney	San Francisco	Tokyo	Sydney	Vienna	Munich	Tokyo
		11	**Hong Kong**	Seoul	Seoul	Taipei	Hong Kong	Amsterdam	Tokyo	Toronto	Copenhagen	Frankfurt	Amsterdam	London
		12	**San Francisco**	Brussels	Berlin	Los Angeles	San Francisco	Wellington	Beijing	Munich	Tokyo	Shanghai	Geneva	San Francisco
		13	**Copenhagen**	Madrid	Chicago	Barcelona	Taipei	Berlin	Zurich	Seattle	Washington DC	Los Angeles	Edinburgh	Melbourne
		14	**Boston**	Sydney	Los Angeles	Hong Kong	Montreal	Bern	Houston	Berlin	Zurich	Sydney	Copenhagen	Reykjavik
		15	**Berlin**	Melbourne	Tokyo	Berlin	Barcelona	Toronto	Atlanta	Copenhagen	Los Angeles	Stockholm	Paris	Washington DC
		16	**Oslo**	Berlin	Madrid	Munich	Chicago	Melbourne	Bucharest	Chicago	Berlin	Zurich	Hong Kong	Portland
		17	**Osaka**	Toronto	Dubai	Miami	Los Angeles	Ottawa	Seoul	Stockholm	Melbourne	Beijing	Berlin	Los Angeles
		18	**Auckland**	Moscow	Milan	Warsaw	London	Hamburg	Stockholm	Sydney	Baltimore	Toronto	Canberra	Abu Dhabi
		19	**Dublin**	Vienna	Beijing	Rome	Washington DC	Luxembourg	Sydney	Tel Aviv	Dallas	Copenhagen	Rotterdam	Seoul
		20	**Sydney**	Shanghai	Kuala Lumpur	Sydney	Frankfurt	Stockholm	Miami	Shanghai	Vancouver	Barcelona	Madrid	Bogota

Source: BofAML Global Research based on cited sources above and methodology as outlined below:
1 Firstly we aggregated 11 leading Smart City indices that covered a broad range of Smart City-related issues and themes.
2 Secondly, we took the average score for each city across these surveys/indices, as well as their appearance frequency and we ranked each of the two with respect to the universe of global cities
3 Finally we took a weighted average of these two rankings to reach our BofAML Smart City Indicator ranking score.

The Mori City Perception Index 2016 analyses the public image of major cities (by ranking):

- **London**: expensive, history, Big Ben, culture, rain, tradition, beautiful
- **NYC**: busy, skyscraper, Statue of Liberty, metropolis, diverse, big apple
- **Paris**: Eiffel Tower, romantic, beautiful, fashion, love, culture, art
- **Tokyo**: crowded, technology, modern, Japan, busy, expensive, culture

Sizing the market: up to US$1tn today growing up to US$1.6tn by 2020E

Defining the exact size of the Smart City market is challenging given its lack of clearly delineated parameters with everything from infrastructure (traditional to ICT) to self-driving vehicles to free Wi-Fi to bike sharing and cycling lanes potentially fall within its remit:

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- **Conservative estimates put the current size of the market at US$312-622bn** (source: Grand View Research, Marketsandmarkets, Mordor Intelligence, Scalar Market Research, Technavio, Transparency Market Research)

- **The Smart Cities Council – a network of leading companies in the space - estimates that US$1tn is currently being spent annually** on Smart City initiatives.

US$1.3-1.6tn market by the 2020E: up to US$3.5tn by the mid-2020Es

From its current size, the Smart City market is set for strong growth and will reach US$1.3-1.6tn by 2020E (source: Frost & Sullivan, Grand View Research, Mordor Intelligence, Technavio, Transparency Market Research). Some view it as growing to as much as US$3.5tn by the mid-2020Es (source: Persistence Market Research). North America is currently the largest market, while APAC is expected to see the fastest growth to 2020E.

Exhibit 59: Smart Cities market in a nutshell

Source: BofAML Global Research based on various sources

Near term market growth: top 10 predictions for 2017E

The IDC FutureScape Worldwide Smart Cities 2017 Predictions provides a top 10 predictions for the 2017 Smart City agenda including a timeframe for roll-out of some of the key areas driving the growth of the market.

Table 15: IDC FutureScape Worldwide Smart Cities 2017 Predictions

Impact area	Year (est.)	Prediction
Digitisation	2017	Countries with 50% of Their Midsize to Large Cities in the Repeatable Stage or Higher of Smart City Maturity Will Be More Successful in Country Digitization Efforts
Data	2017	75% of Cities Worldwide Will Fail to Take Full Advantage of Smart City Data and Digital Assets Due to a Lack of Process, Project Management, and Change Management Skills
Partnerships	2018	Cities Will Spend 2x More with Partners That Are Committed to Open APIs, Sharing Data, and Long-Term Relationships as Demonstrated via a Sales Force That Can Talk Business Outcomes
Open data	2019	50% of Open Data Initiatives Will Evolve to Provide Both Free and Monetized Data Services as Cities Test Data Revenue Models and Seek to Justify Open Data Investments
Cybersecurity	2017	at Least One Midsize to Large City Will Suffer a Cyberattack That Will Impact Its Ability to Effectively Function for One Day
Healthcare	2018	20% of Public Safety Agencies Will Test Cognitive Computing to Predict and Prevent Domestic, Mental Health, and Addiction Incidents, Drastically Reducing Service Requests
Mobility	2017	By 2019, 30% of Urban Consumers Will Use Bots or Intelligent Assistants for Multimodal Route Planning to Manage Cost, Carbon Impact, and Other Travel Preferences
Mobility	2017	20% of Cities Will Nudge Transit Behaviour by Limiting Parking, Promoting EV and Car

Table 15: IDC FutureScape Worldwide Smart Cities 2017 Predictions

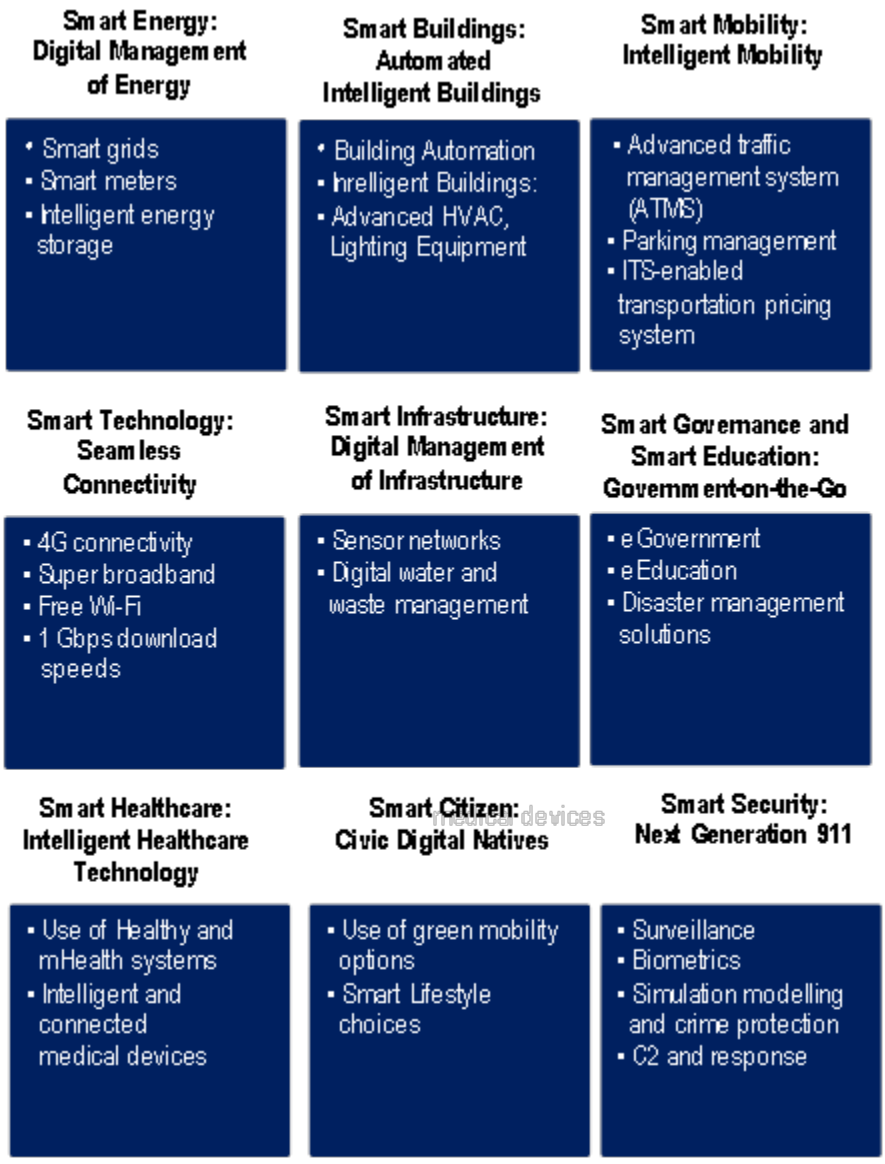
Impact area	Year (est.)	Prediction
		Sharing, and Investing in Mobile Payments, Navigation, and Violations Tracking Apps
Buildings	2019	With 180 Million Global LED Street Light Conversions and Spending of $80 Billion, Light Infrastructure Will Become the Key Smart City Platform for Connected IoT Devices
M&A	2019	To Scale and Survive, One-Third of Civic Engagement App Companies Will Merge with or Be Acquired by Larger Companies as Part of a Smart City Platform Offering

Source: The IDC FutureScape Worldwide Smart Cities 2017

Smart City participants: multiple sectors to benefit

As we explore throughout the report and in our Primer Picks, multiple industry sectors stand to benefit from Smart Cities with participants taking a number of different roles.

Exhibit 60: Key parameters that will define a smart city in 2020



Source: Frost & Sullivan

- **Pure-play product vendors**: provide "hard assets" such as traditional infrastructure, smart meters and distribution systems that operate as the main modes of connectivity. Sector participants include Capital Goods.

- **Enablers**: are the underlying hardware and sensor technologies that bring 'smartness' to connected devices, wireless transmission of data between devices,

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and the backend intelligence that acts on the data. Sector participants include Semiconductors and Semi Equipment, Technology Hardware and Equipment.

- **Integrators**: bring together various sectors of the Smart city through pre-packaged platforms, thereby providing a unified, holistic, and end-to-end integration of multiple sectors. Sector participants include Software and Services.
- **Network service providers**; offer collaborative networks, data analytics, and enterprise working solutions that connect people, assets, systems and products by leveraging on their networking M2M capabilities. Sector participants include Technology Hardware and Equipment and Telecommunication Services.
- **Managed service providers**: offer round-the-clock monitoring, complete management, compliance monitoring, and on-site consulting either via in-house, co-managed or completely outsourced services. Sector participants include Commercial & Professional Services and Software and Services (source: Frost & Sullivan).

Table 16: Smart City risks: technology failures, digital divide, privacy and security rank highest
What (if any) smart city initiative unintended consequences or risks should city/government leaders be most concerned about and/or focused on avoiding?

	By Organization Type	
Smart City Consequences or Risks	Government/ Municipality	Smart Services Providers
Disruptions due to technology failure or glitches	56.8%	52.7%
Job displacement	12.3%	10.9%
Digital divide	34.2%	43.6%
Privacy and security concerns	49.3%	29.1%
Vulnerability to terrorist or hacker threats	31.5%	38.2%
Cost of living increases/gentrification	18.5%	25.5%
Negative community social/cultural impacts of top-down design	13.7%	16.4%
Negative environmental sustainability impacts	11.0%	10.9%
Greater income and social inequality	10.3%	9.1%
Opportunity cost	26.7%	25.5%

Source: Black & Veatch 2016

Humans do dumb things with Smart Cities: New York City's LinkNYC kiosks allow people to get online for free as part of a project spearheaded by Alphabet's urban innovation division, Sidewalk Labs. However, they have been used to blast out music and watch pornography in the middle of Times Square, as well as attracting the homeless (source: Bloomberg, New York Times).

> *"We didn't know what to expect with free Internet access on the street. We built this to change over time, and that's how we handled anticipating these issues. If it wasn't this it would have been something else."* (source: LinkNYC's general manager, Jen Hensley via Bloomberg).

Smart Infrastructure: greater resilience & connected cities

Infrastructure is the foundation that connects the nation's businesses, communities and people, driving our economies and improving our quality of life – but it only garners headlines when a bridge collapses or a dam bursts (source: ASCE, Brookings Institution).

The need to deal with the triple challenges of infrastructure in Smart Cities is pressing: i) revamping traditional bricks and steel infrastructure, ii) making infrastructure more resilient to new and emerging stresses and shocks, and iii) putting in place and enabling nextgen infrastructure for Smart Cities. Building urban resilience will be vital to maintaining systems that provide critical services, protect, and connect urban assets enabling the flow of goods, services, and knowledge – and to surviving growing stresses and shocks (source: 100 Resilient Cities). Cities must also adapt to new demographic realities including ageing populations, and the changing behaviour of Gen Y and Gen Z (e.g. no longer hearing the call of the open road).

Inadequate infrastructure is a major impediment to urban prosperity in both EMs and many DMs. Eleven percent of the world's cities are considered highly fragile, with 71% registering medium levels of fragility (source: The Igarapé Institute). It is not just about EM cities with the American Society of Civil Engineers rating US infrastructure as D+, with US$3.6tn in investment needed by 2020E. Many city roads, bridges, subways, water mains, sewer systems, school buildings and other public buildings are over 50Y old, and many critical components are past their useful life and highly susceptible to breaks and malfunctions (source: Centre for an Urban Future 2014).

Increased urbanisation is leading to denser cities and heavier infrastructure use, with disasters and slow-burning stresses affecting a larger population and putting a strain on already taxed city resources (source: Brookings Institution). There are also more frequent and intense natural disasters with US$92bn of worldwide economic losses in 2015 alone, according to Swiss RE (including US$37bn of insured losses). Total economic losses in H1 2016 hit US$71bn, due primarily to natural catastrophe (source: Swiss RE).

A "fix it first" approach to repairing and preserving existing infrastructure is an economic "no-brainer." Deficient infrastructure can adversely affect cities on many fronts: it can raise the costs of doing business and reduce firm productivity by as much as 40% (source: UN-Habitat). Closing the urban infrastructure investment gap should have at least four beneficial consequences: i) boosting the creation of jobs; ii) enhancing economic growth; iii) better connecting households; and iv) reducing greenhouse gas emissions (source: Brookings Institution).

The fragile state of the world's cities is evidenced by the estimated US$71-78tn in global infrastructure investments that are needed over the next 10 years to accommodate their growth – and New York, Beijing, Shanghai and London alone will need US$8tn (source: OECD 2006, PwC 2013, UN-Habitat 2013). Another estimate is that investment needed in low-carbon transport, energy, water, waste and telecommunications infrastructure alone is estimated at US$57tn between now and 2030E (source: WWF and Z/Yen Group 2015).

Globally, capital investment has accounted for a steadily declining proportion of total government expenditure over the past 50Y. Gross fixed capital formation is 23.75% of world GDP, below modern-era highs (source: World Bank). The trend in OECD infrastructure investment as a share of GDP is slightly positive, with the US and continental Europe moving up from 4-5% in the early 1980s to 5-6% in 2010 (source: OECD 2015). US President Trump's 'America's Infrastructure First' policy could boost stagnant investments in transportation, clean water, the grid, telecoms and security infrastructure.

Positively, private investment in infrastructure assets hit a record US$413bn in 2016 (+14% on the US$362bn in 2015) (source: Preqin 2017). Demand for infrastructure investment has increased over the past 10Y off the back of growing competition for low(er) risk assets, low interest rates, renewed political interest in infrastructure, and government support for private investment. Macquarie and Brookfield are the leading capital raisers, while c75 institutional investors currently have more than US$1bn allocated to infrastructure (source: PEI Alternative Insight 2016, Preqin 2016).

Globally, the smart city ICT infrastructure market is projected to reach US$712bn by 2020E and the most attractive country markets for investment include London, Singapore, Shanghai, Dubai et. al. The most attractive markets for investors are countries and cities with the strongest growth potential, most secure business environments, well-established legislative and regulatory systems and stable political environments (source: Technavio, Arcadis GIII 2016).

21st century infrastructure or Infrastructure 3.0 involves moving from bricks and steel to fully integrated intelligent infrastructure. We need to move towards a new vison of infrastructure which brings all parts of the infrastructure puzzle together and incorporates them into a single interdependent and reliable whole. Siemens refers to this as "Infrastructure 3.0", which provides real-time optimisation and incident handling across all domains – and allows us to adapt to the pressures of rapid urbanisation, climate change, demographics and other trends by utilising advances in sensors, controls, and software to predict outcomes, take actions and manage systems more effectively.

Telcos are the Smart City-era equivalent of the bricks and steel companies that built the infrastructure of previous generations. They have a unique positioning and significant opportunity in Smart Cities: connectivity (the bedrock foundation of both the IoT and Smart Cities); Big Data; and unique touch points with consumers at the levels of devices, services, data, and billing. They also have multiple revenue opportunities including monetising Big data, selling Apps, and providing a Unified Control Centre Service to cities (source: Arthur D. Little). Our BofAML ASEAN Telcos team has explored the impact of Smart Cities for telcos in their "Smart nation" report: Telecommunications - ASEAN: The Future is Smart 18 January 2017.

5G will be a key Smart City enabler and could spur infrastructure investments of up to US$700bn, create up to 3mn jobs, and boost GDP by US$500bn (source: Accenture Strategy 2017, BofAMLe). 5G will be a massive IoT enabler offering higher speeds (up to 100x faster than 4G), more connections and quicker, more adaptive response times, lower latency, lower energy requirements, greatly increased security, and network slicing and cellular. It will likely mean opportunities for fibre companies, tower companies and installers, while posing potential threats to cable and wireless companies. Other nextgen wireless enablers of Smart Cities include small cell technology. 5G is already being piloted in the US and China, and our BofAML Telco and Semis teams believes that 5G standardisation is expected in 2019 globally, followed by commercial network deployments from 2020 onwards.

Smart City technologies are transforming traditional infrastructure and the Smart Water market could grow to US$20.1bn, Smart Waste to US$2.4bn by 2021E, and Smart Agriculture to US$18.45bn by 2022E (vs. US$8.5bn, US$1.1bn respectively in 2016 (source: MarketsandMarkets 2016). Globally, utility companies which apply smart water solutions could save between US$7.1- 12.5bn p.a. from using Smart Water solutions (source: SENUS 2012). Smart Waste technologies can reduce costs and improve recycling performance for cities (source: UK DBIS). Meanwhile, Smart Agriculture via urban and vertical farms has the potential to produce 15% of our food (source: University of Florida).

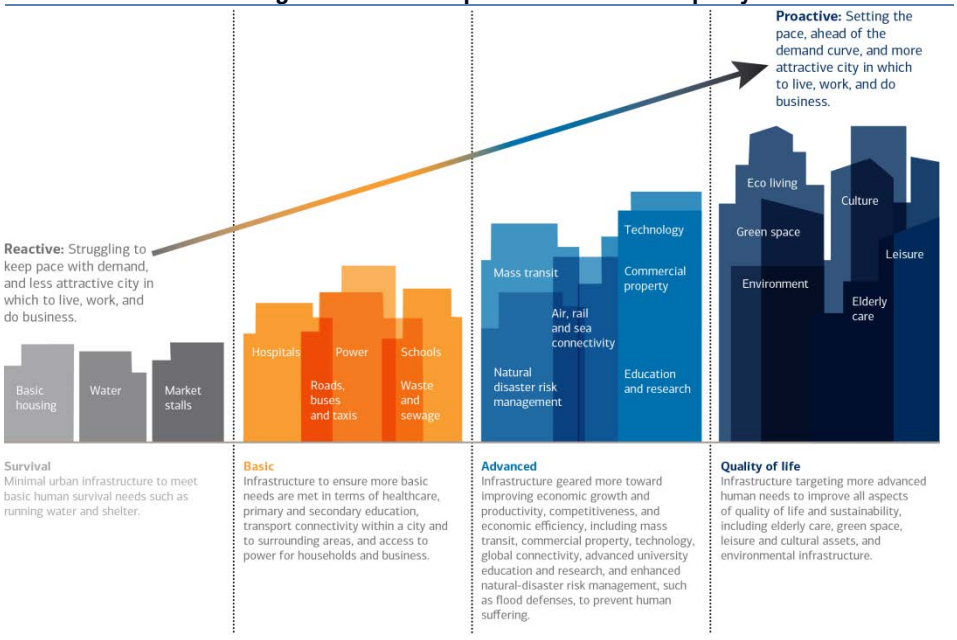
Climate-resilient infrastructure is key for Smart Cities with 1.3bn people and US$158tn in assets at risk by 2050E (source: World Bank 2016 GFDRR). Eighty-five percent of cities are dealing with temperature increases/heatwaves and 53% report these risks as serious and near term (source: C40 Cities). The world's top 10 most vulnerable cities from flooding are: Guangzhou, Mumbai, Kolkata, Guayaquil, Shenzhen, Miami, Tianjin, New York-Newark, Ho Chi Minh City and New Orleans (source: Nature Climate Change 2013). This reiterates the need for cities to invest in climate-resilient infrastructure with US$375bn needed to 2020E and US$1tn to 2050E for the C40 Cities alone (source: C40 Cities-Arup 2016). Positively, close to 11,000 climate actions were carried out by C40 cities in 2016 (source: C40 Cities).

Infrastructure 3.0: moving from bricks & steel to fully integrated, intelligent infrastructure

There is widespread agreement that: i) cities and their newfound consumers with rising purchasing power need infrastructure in the broad sense of the term – energy, housing, transportation, education and healthcare; and ii) DMs and EMs can capture an 'urbanisation dividend' that creates jobs, raises productivity, reduces infrastructure costs and environmental impact, supports new enterprise and shares this prosperity widely (source: Abraaj, PWC).

There is a pressing need to deal with the triple challenges of revamping traditional bricks and steel infrastructure, making infrastructure more resilient to new and emerging stresses and shocks, and putting in place an enabling nextgen infrastructure for Smart Cities.

Exhibit 61: Urbanisation brings infrastructure improvements and better quality of life



Source: PwC

Nextgen infrastructure: efficient, reliable, flexible, resilient, and adjustable

We need to move towards a new vison of infrastructure, which brings all parts of the infrastructure puzzle together and incorporates them into a single interdependent and reliable whole. Siemens refers to this as 'Infrastructure 3.0', which provides real-time optimisation and incident handling across all domains – and allows us to adapt to the pressures of rapid urbanisation, climate change, and other trends by utilising advances in sensors, controls, and software to predict outcomes, take actions, and manage

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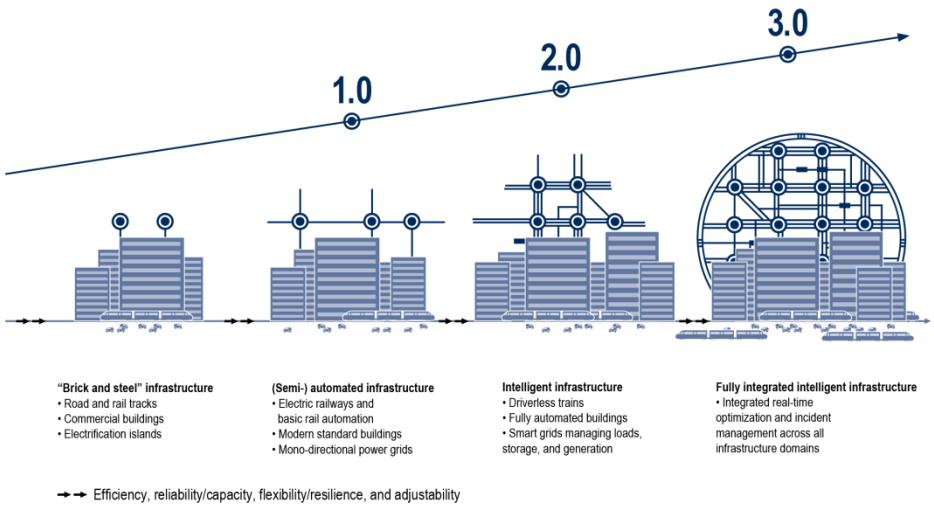
systems more effectively. It contrasts with Infrastructure 2.0 ('Intelligent Infrastructure'), 1.0 (Semi-Automated infrastructure), and traditional 'bricks and steel' infrastructure.

Exhibit 62: Stages of Smart City infrastructure development



Source: Siemens

State of urban infrastructure: the world's fragile cities

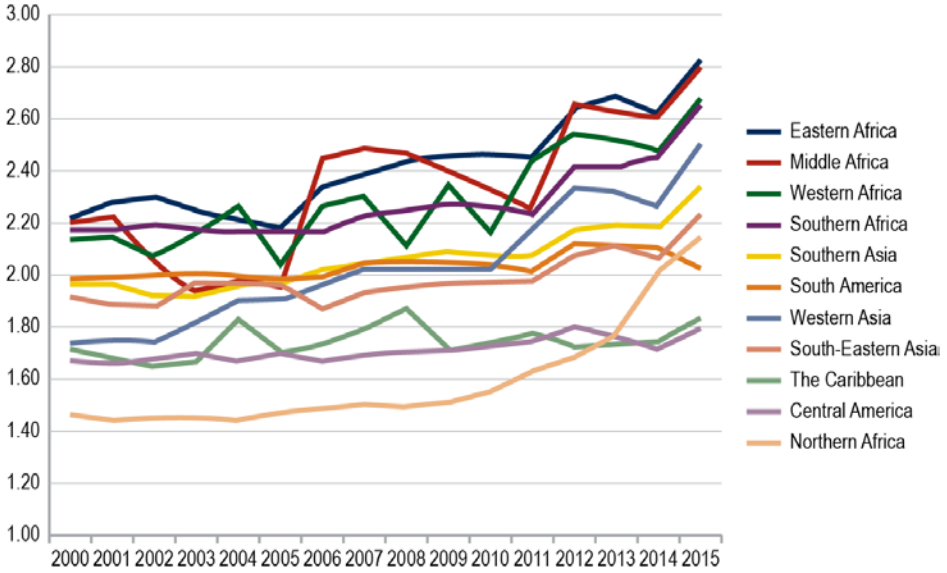
One of the key challenges in moving to Smart City-friendly Infrastructure 3.0 is addressing the massive legacy issues around traditional bricks and steel and semi-automated infrastructure. Increased urbanisation has been leading to denser cities and heavier infrastructure use and is creating an urgent need for infrastructure investments, including the revamping of antiquated infrastructure in DMs and build-out of infrastructure, often from scratch, in EMs. Inadequate infrastructure is a major impediment to urban prosperity and while most pronounced in Asian and African cities, is an increasing impediment in many DMs.

Tracking fragility: 11% of world's cities are highly fragile, 71% medium fragile

The Igarapé Institute, United Nations University, World Economic Forum and 100 Resilient Cities initiative has developed a new platform to track fragility in 2,100 cities with populations of >250,000 worldwide. Eleven metrics of urban fragility are mapped out at the urban scale including population growth, inequality, unemployment, access to electricity, pollution, exposure to terrorism, homicide rates, and reported conflict events. The data shows that while the most fragile cities are concentrated in Asia and Africa – with a high correlation between low income and high fragility – city fragility is much more widely distributed than assumed.

Exhibit 63: Where the world's fragile cities are (1 = least fragile, 4= most fragile)

Sub-regional distribution of fragile cities (fragility score, 2000-2015)

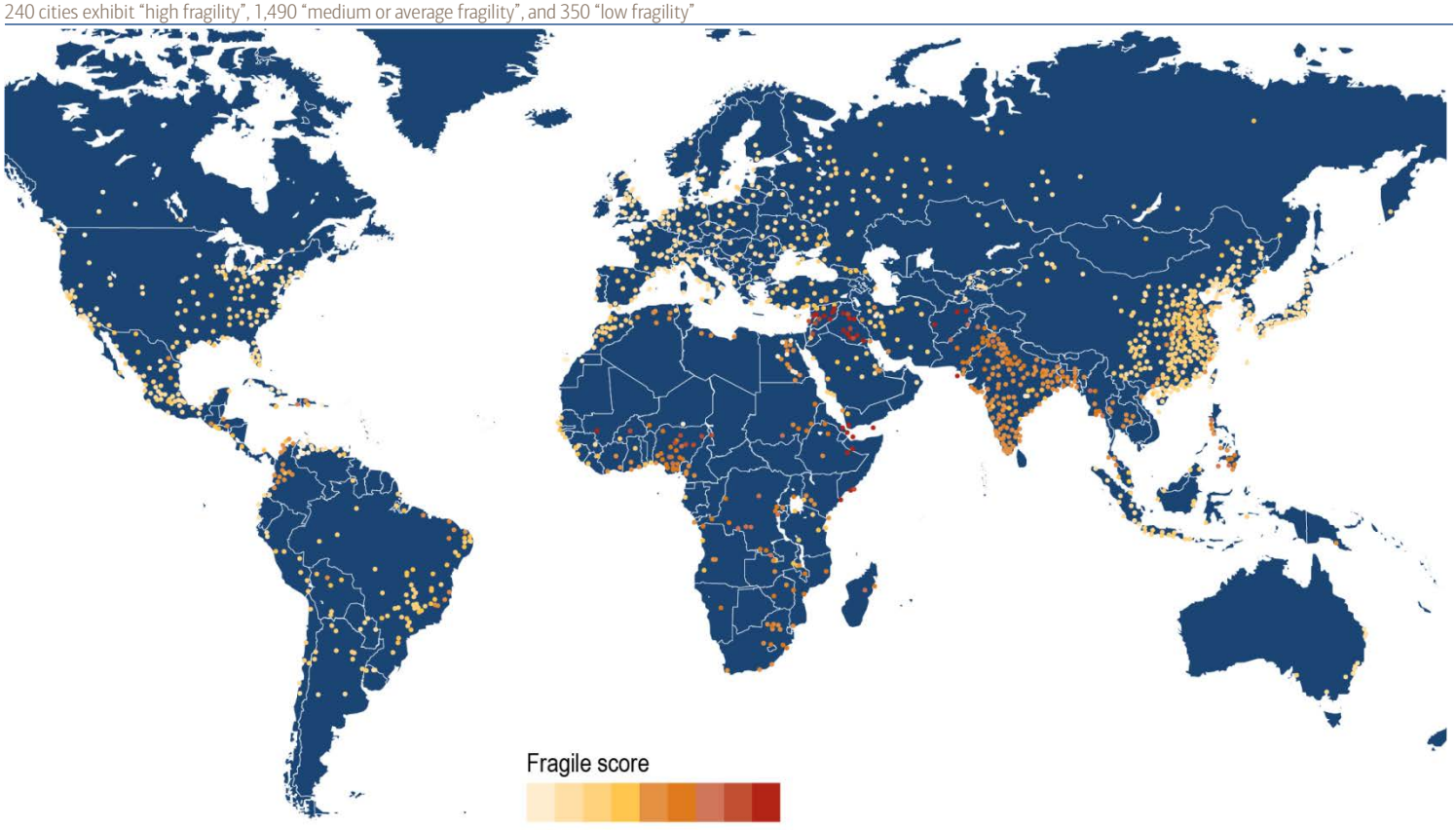


Source: Igarapé Institute 2016

- **The data shows that all cities are fragile but some cities are more fragile than others** with approximately 240 cities (11%) exhibiting 'high' fragility, 1,490 (71%) registering 'medium' or 'average' fragility, and 350 (13%) reporting 'low' fragility.

Exhibit 64: Level of urban fragility for 2,100 cities worldwide

240 cities exhibit "high fragility", 1,490 "medium or average fragility", and 350 "low fragility"



Source: Igarapé Institute 2016

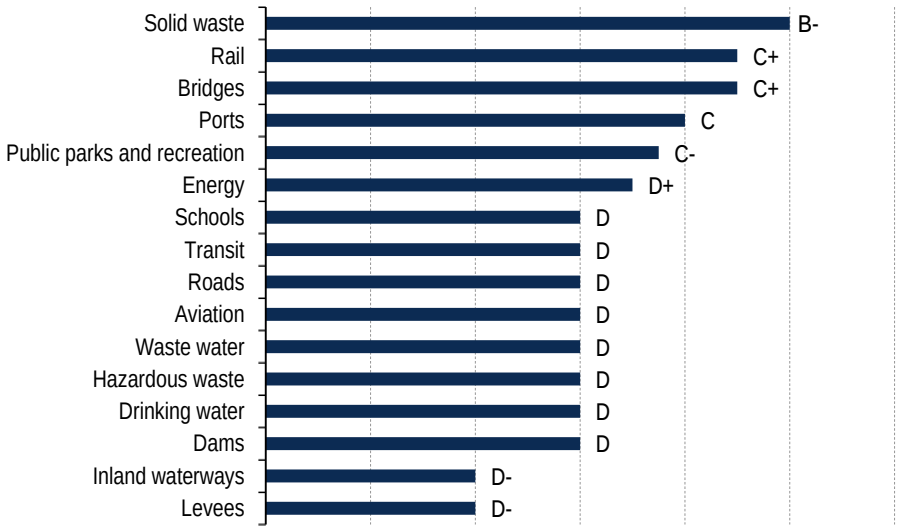
It's not just about EMs: US infrastructure rated D+

Every four years, the American Society of Civil Engineers' Report Card for America's Infrastructure depicts the condition and performance of American infrastructure in the familiar form of a school report card assigning letter grades based on the physical condition and needed investments for improvement. According to the 2013 report card, the US got mainly Cs (mediocre) and Ds (poor) for an overall average which would disappoint most parents (D+) – with US$3.6tn in investment needed by 2020E.

A bridge too far? There are 185mn daily crossings on nearly 56,000 structurally deficient US bridges. About 1,900 of those bridges are on the Interstate Highway System. 15 of the most travelled structurally deficient bridges are in California including Interstate 110 over Dominguez Channel which sees 273,760 daily crossings (source: ARTBA 2017 Bridge Report).

Chart 28: US infrastructure report card (A = exceptional, F = failing)

Each category was evaluated on the basis of capacity, condition, funding, future need, operation & maintenance, public safety & resilience



Source: American Society of Civil Engineers 2013

NYC case study: roads, bridges, subways, water mains, sewers aged 50Y+

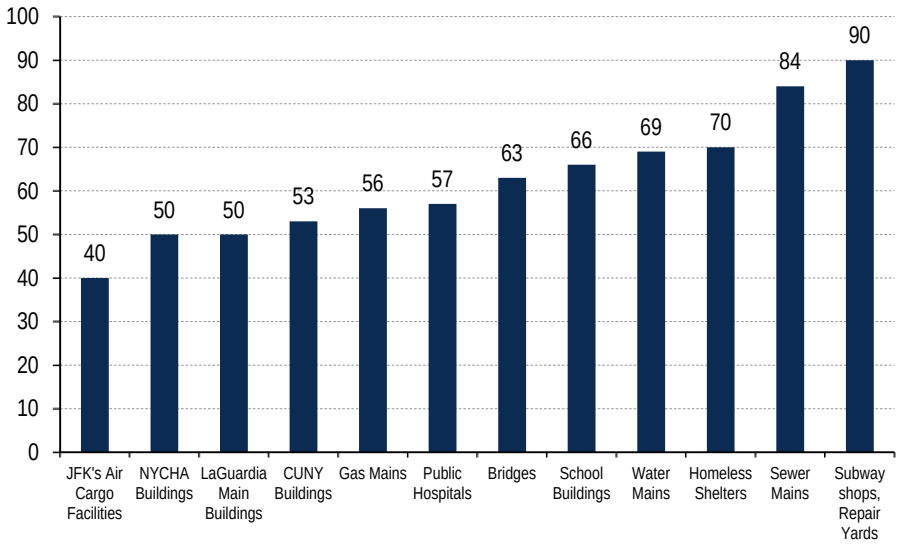
New York City's core infrastructure is in much better shape than it was in the 1980s, when the city closed the Williamsburg Bridge for fear of collapse, track fires were a regular occurrence in the subway system – and the Brooklyn Bridge, FDR Drive and West Side Highway all experienced structural failures. However, much of the city's roads, bridges, subways, water mains, sewer systems, school buildings and other public buildings are more than 50Y old, and many critical components are past their useful life and susceptible to breaks and malfunctions (source: Centre for an Urban Future 2014).

The state of New York City's infrastructure:

- Over 1,000 miles (1,600km) of water mains are more than 100Y old
- Over 160 bridges across the five boroughs are over 1100Y old
- 269 miles of mainline subway signals exceed their 50Y useful life
- Over 200 of the city's public school buildings were built before 1920
- US$47.3bn: the minimum cost to repair/replace existing infrastructure (source: Centre for an Urban Future 2014)

Mayor Fiorello La Guardia to President Roosevelt on La Guardia airport in 1939: "the greatest, the best, the most up-to-date, and the most perfect airport in the United States ... 'the' airport of the New World."

Chart 29: Average age of New York City infrastructure (in years)



Source: Centre for an Urban Future 2014

Growing business case for building resilient cities

There is a growing business case for stepping up infrastructure investment with the goal of building more resilient cities:

- **Natural disasters are becoming more frequent and intense with US$92bn of worldwide economic losses in 2015,** according to Swiss RE (including US$37bn of insured losses). Total economic losses in H1 2016 hit US$71bn, primarily due to natural catastrophes (source: Swiss RE).

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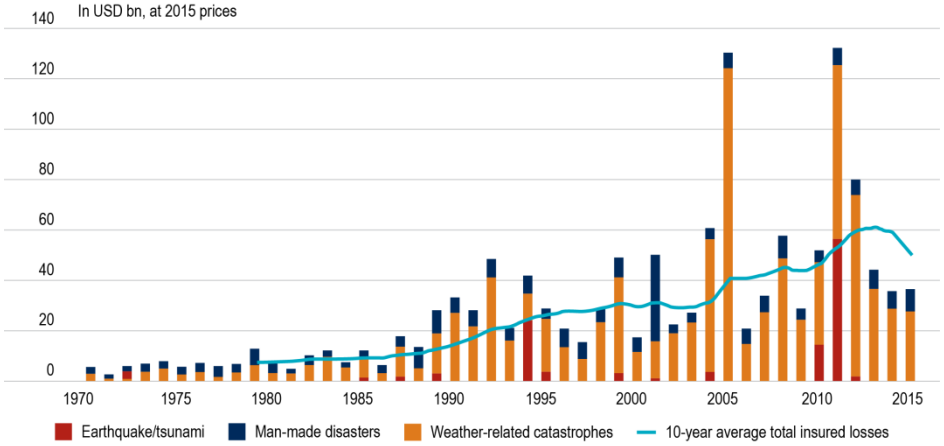
Exhibit 65: Economic losses from natural disasters are skyrocketing



Source: Swiss Re Economic Research & Consulting 2016

In 2016, there were 15 weather and climate disaster events with losses exceeding US$1bn each across the US. These events included a drought, four floods, eight severe storms, a tropical cyclone, and a wildfire – and killed 138 people (source: NOAA NCEI 2017)

Exhibit 66: Billion-dollar weather and climate disasters to affect the US from 1980-2016 (CPI-adjusted)

DISASTER TYPE	NUMBER OF EVENTS	PERCENT FREQUENCY	CPI-ADJUSTED LOSSES *(BILLIONS OF DOLLARS)*	PERCENT OF TOTAL LOSSES	AVERAGE EVENT COST *(BILLIONS OF DOLLARS)*	DEATHS
Drought	24	11.8%	$223.8	19.1%	$9.3	2,993†
Flooding	26	12.8%	$110.7	9.4%	$4.3	515
Freeze	7	3.4%	$25.3	2.2%	$3.6	162
Severe Storm	83	40.9%	$180.1	15.3%	$2.2	1,546
Tropical Cyclone	35	17.2%	$560.1	47.7%	$16.0	3,210
Wildfire	14	6.9%	$33.0	2.8%	$2.4	184
Winter Storm	14	6.9%	$41.3	3.5%	$3.0	1,013
All Disasters	**203**	**100.0%**	**$1,174.3**	**100.0%**	**$5.8**	**9,623**

Source: NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2017).
†Deaths associated with drought are the result of heat waves

- **Increased urbanisation leads to denser cities and heavier infrastructure use with disasters and slow-burning stresses affect a larger percentage of the global population** – putting a strain on already taxed city resources.
- **Globalisation – our global interconnectedness – enhances every city's and city resident's exposure to the effects of disruptive events**, regardless of geographic distance (source: Brookings Institution).

Case study of AT&T-IBM-Mueller Water Products development of a solution that makes it possible to detect leaks in water mains:

- **The three companies came together after the US federal government issued an invitation for companies** to showcase their smart city solutions.
- **Acoustic sensors placed along the pipes trigger alarms when they sense sound changes that may indicate leaks**.
- **AT&T's LTE network carries the sensor information to computing resources running a water management application from IBM**.
- **The proof of concept is now a commercialised smart water solution** for large companies, municipalities, or even water parks (source: AT&T).

Investment: falling short on the US$71tn+ needed on bricks and steel infrastructure by 2030E

Public investment in DM cities has been largely on the decline since the 1960s with many finding it difficult to maintain existing infrastructure, never mind launch and build new projects. We believe that traditional infrastructure investment in bricks and steel in cities needs to be increased substantially in most DMs and EMs in order to meet social needs, and support more rapid economic growth.

Fragile cities: US$70tn+ needed over 10Y for cities

The fragile state of the world's cities is evidenced by the estimated US$71-78tn in global infrastructure investments that are needed over the next 10 years to accommodate the growth of cities – and New York, Beijing, Shanghai and London alone will need US$8tn (source: OECD 2006, PwC 2013, UN-Habitat 2013). Another estimate is that investment needed in cities into low-carbon transport, energy, water, waste and telecommunications infrastructure alone is estimated at US$57tn between now and 2030E (source: WWF and Z/Yen Group 2015).

Table 17: Estimated average annual world infrastructure expenditure for selected sectors (2000-30E) (US$bn, % of world GDP)

Type of Infrastructure	2000-10	Approximate % of world GDP	2010-20	Approximate % of world GDP	2020-30	Approximate % of world GDP
Road	220	0.38	245	0.32	292	0.29
Rail	49	0.09	54	0.07	58	0.06
Telecoms[1]	654	1.14	646	0.85	171	0.17
Electricity[2]	127	0.22	180	0.24	241	0.24
Water[1, 3]	576	1.01	772	1.01	1037	1.03

Source: OECD Infrastructure to 2030
1 Estimates only apply to the years 2005, 2015 and 2025
2 Transmission & distribution only
3 Only OECD countries and BRICs are included

Long-term infrastructure investment: a mixed picture

Globally, capital investment has accounted for a steadily declining proportion of total government expenditure over the past 50Y. Gross fixed capital formation is 23.75% of world GDP, below modern historical highs (2007: 25.49%, 1989: 26.15%, 1979: 27.11%, 1974: 25.02%). GFCF includes land improvements; plant, machinery and equipment purchases; and the construction of roads, railways, and the like, including schools,

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offices, hospitals, private residential dwellings, and commercial and industrial buildings (source: World Bank).

Exhibit 67: Gross fixed capital formation (% of GDP, 2015)

Source: World Bank 2015

OECD trends are slightly positive: 5-6% of GDP

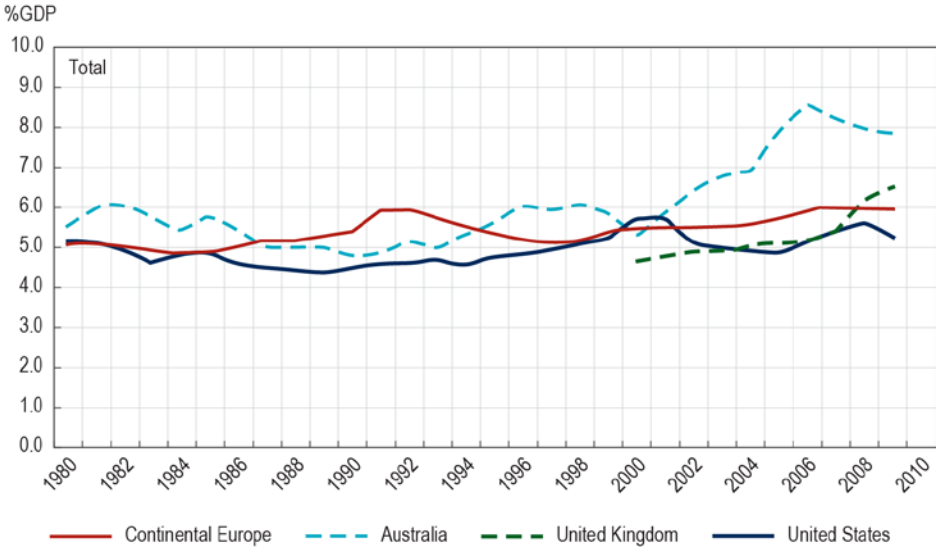
The trend in OECD infrastructure investment as a share of GDP is slightly positive, though with a significant interruption after the tech bust in the early 2000s. Overall, total infrastructure spending in the US and continental Europe has moved up from 4-5% in the early 1980s to 5-6% in 2010 (source: OECD 2015).

- **The US invests less in economic infrastructure than other countries**: around 1.5% of GDP prior to the mid-1990s vs. >2% in continental Europe and 2.5-3% in Australia. From the mid-1990s, the communications component rose quickly and unsustainably during the tech boom in the US and the UK. The decline in the early 2000s in both countries was pronounced. Since the financial crisis, the share of economic infrastructure investment has risen quickly in the US, driven by the electricity and gas supply component (e.g., fracking). The UK recovery has once more been driven by transport, storage and communications.

- **In continental Europe economic infrastructure investment began to rise from the late 1990s**, from around 2% to 2.6% of GDP by 2010. This was driven by the transport and communication component.

- **Australia invests much more in economic infrastructure than other regions** due to the capital intensity of requirements for the mining sector. This has accelerated to even higher levels during the more recent mining boom (source: OECD 2015).

Exhibit 68: Infrastructure investment in OECD countries



Source: OECD 2015

Trump boost for infrastructure spend: putting America's cities first

Public investment in US cities has largely been on the decline since the 1960s, a pattern that President Trump is on record as wanting to reverse. His pre-election 'vision' included commitments to transform America's crumbling infrastructure and pursuing an 'America's Infrastructure First' policy that supports investments in transportation, clean water, a modern and reliable electricity grid, telecommunications, security infrastructure, and other pressing domestic infrastructure needs.

> **Donald Trump's presidential acceptance speech [on infrastructure]**: "We are going to fix our inner cities and rebuild our highways, bridges, tunnels, airports, schools, hospitals. We're going to rebuild our infrastructure, which will become, by the way, second to none. And we will put millions of our people to work as we rebuild it."

Filling the trillion-dollar infrastructure gap

Trump has called for US$1tn in infrastructure spending over 10Y. His pre-election website referenced the National Association of Manufacturers (NAM), which found that US$8bn in infrastructure tax credits would support US$226bn in infrastructure investment over 10Y. Innovative financing programs also provide a 10-to-1 return on investment. Assuming an incremental US$50bn to US$100bn pa on US public construction spending, that would represent an 18-37% increase on public spending from current levels (based on SAAR of c.US$270bn) and a 4-8% increase in total construction spending (based on SAAR of c.US$1.15bn).

Cities moving on infrastructure: 2016 ballot measure wins in US elections

Infrastructure stood out as a major priority during the US presidential election in 2016, and many cities and states got a head start on election day by passing a variety of infrastructure ballot measures. This continues a trend whereby billions of dollars in additional infrastructure investment are coming in the form of newly approved bonds, taxes, and other sources of revenue. Such measures overemphasise areas such as transportation at the expense of other infrastructure gaps such as trade and logistics, water and telcos (source: Brookings Institution).

Greater role for private sector needed: finance, skills, investment opportunity
According to the OECD there is a widespread recognition that governments cannot afford to bridge these growing infrastructure gaps through tax revenues and aid alone, and that greater private investment in infrastructure is needed. Private sector participation in infrastructure can help in a number of ways:

- **Reduce pressure on public finances** and increase the portfolio of projects in the public sector investment programme.
- **Governments can also benefit from private sector skills and reap cost and efficiency gains** by delegating the construction and oftentimes the management of infrastructure projects to private investors.
- **infrastructure is an enabling factor for development and for facilitating private investments and competitiveness across all sectors, and can also be an attractive investment opportunity in itself** (source: OECD 2015).

Closing urban infrastructure gap: multiple benefits
Closing the urban infrastructure investment gap would have at least four beneficial consequences.

Deficient infrastructure can adversely affect cities on many fronts: it can raise the costs of doing business and reduce firm productivity by as much as 40% (source: UN-Habitat).

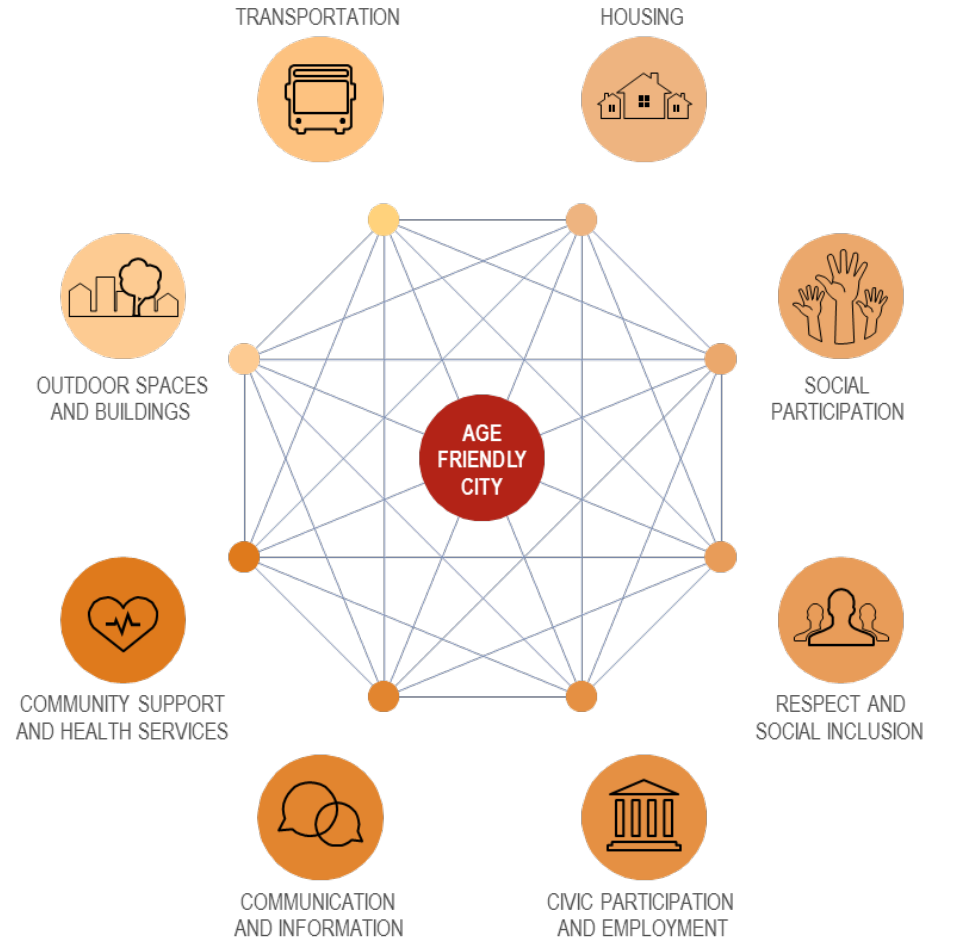
- **Boosting the creation of jobs that often provide middle-class wages and opportunities** to workers with modest levels of formal education.
- **Enhancing economic growth by decreasing overhead cost to business while efficiently moving people, goods and ideas**.
- **Better connecting households across metropolitan areas to higher-quality opportunities** for employment, healthcare, and education.
- **Reducing greenhouse gas emissions while helping to protect nations from an increasingly unpredictable natural environment** (source: Brookings Institution).

Case study on shaping ageing cities - Age-friendly infrastructure is becoming a necessity in Smart Cities with average life expectancy expected to reach 77.1 by 2050E (vs. 48 in 1950), and the 60Y+ population to grow to 2.1bn by 2050E (vs. 901mn today) (source: UN):

- **Outdoor spaces:** pleasant and clean environment, green spaces, somewhere to rest, age-friendly pavements, safe pedestrian crossings, accessibility, a secure environment, walkways and cycle paths, adequate public toilets.
- **Age-friendly buildings:** elevators, escalators, ramps, wide doorways and passages, suitable stairs, non-slip flooring, rest areas with comfortable seating, adequate signage, public toilets with handicapped access.

- **Transportation:** availability, affordability, reliable and frequent, coverage, age-friendly vehicles, specialised services for older people, priority seating and passenger courtesy, trained drivers, safety and comfort, adapted stations, taxis, community transport, information, adapted parking.
- **Housing:** affordability, essential services, design, modifications, maintenance services, ageing in place, community integration, housing options, living environment.
- **Age-friendly communication:** information on offer, oral communication, printed and digital, plain language, automated communication and equipment, computers and ICT (source: WHO's Global Age Friendly Cities Guide)

Exhibit 69: A Smart City needs to be an age-friendly city



Source: Arup based on WHO's Global Age Friendly Cities Guide

Reason to believe: record US$413bn of private investment in infrastructure assets in 2016

Positively, private investment in infrastructure assets hit a record US413bn in 2016 (+14% on the US$362bn in 2015) (source: Preqin 2017).

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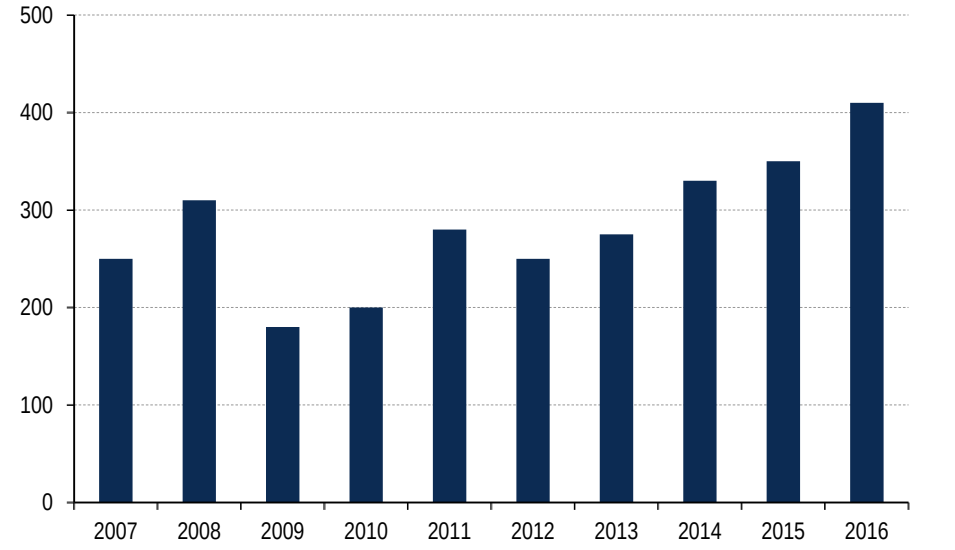
Demand for infrastructure investment has increased over the past 10Y off the back of growing competition for low(er) risk assets (e.g., SWFs, pension funds, insurance companies, asset managers), low interest rates, renewed political interest in infrastructure, and government support for private investment.

- **While the deal value increased significantly, the number of deals has stayed steady at 1,700-1,800 since 2013**, meaning that there is a surplus of money chasing relatively rare infrastructure deals.
- **Infrastructure managers raised a record amount of capital in 2016, with 51 funds closing on US$58bn** (vs. 70 funds that raised US$40bn in 2015). Infrastructure funds last year closed after an average of 18 months of fundraising (vs. 27 months in 2015).
- **Green energy projects represented 42% of all deals last year**, up from 39% in 2015 and 37% in 2013 (source: Preqin 2017).

Chart 30: Record US$413bn in global infrastructure deals in 2016 (US$bn)



Source: Preqin 2017

World's biggest infrastructure investors: top 5 account for 41% of capital raised

Macquarie Infrastructure and Real Assets (MIRA) has been the world's largest infrastructure investor for the past seven years according to the Infrastructure Investor 50. It is followed closely by Brookfield Asset Management – with the top five actors ranked actors accounting for 41% of capital raised (source: PEI Alternative Insight 2016).

Table 18: The world's 20 largest infrastructure investors (2016)

2016 Rank	2015 Rank	Position	Company	Fundraising ($m)	Country	Region
1	1	Unchanged	Macquarie Infrastructure and Real Assets	32,830	Australia	Asia-Pacific
2	2	Unchanged	Brookfield Asset Management	31,985	Canada	North America
3	6	Up	Global Infrastructure Partners	20,780	USA	North America
4	7	Up	Borealis Infrastructure	19,246	Canada	North America
5	5	Unchanged	IFM Investors	12,519	Australia	Asia-Pacific
6	10	Up	Colonial First State Global AM	12,452	Australia	Asia-Pacific
7	4	Down	ArcLight Capital Partners	10,675	USA	North America
8	43	Up	AMP Capital	7,745	Australia	Asia-Pacific
9	14	Up	KDB Infrastructure Investments AM Co.	7,167	S. Korea	Asia-Pacific

Table 18: The world's 20 largest infrastructure investors (2016)

2016 Rank	2015 Rank	Position	Company	Fundraising ($m)	Country	Region
10	11	Up	Ardian	6,116	France	West. Europe
11	9	Down	Kohlberg Kravis Roberts (KKR)	5,913	USA	North America
12	3	Down	Energy Capital Partners	5,882	USA	North America
13	40	Up	Stonepeak Infrastructure Partners	5,275	USA	North America
14	15	Up	J.P. Morgan Investment Management	5,171	USA	North America
15	21	Up	Hastings	4,769	Australia	Asia-Pacific
16	13	Down	InfraRed Capital Partners	4,704	UK	West. Europe
17	18	Up	EnerVest	4,400	USA	North America
18	26	Up	Partners Group	4,070	Switzerland	West. Europe
19	24	Up	Copenhagen Infrastructure Partners	3,904	Denmark	West. Europe
20	19	Down	First Reserve	3,769	USA	North America

Source: PEI Alternative Insight The Infrastructure Investor 50 2016

Institutional investors in the US$1bn club: 75 actors with US$8.1tn in AUM

There are 75 institutional investors that currently have more than US$1bn allocated to infrastructure with a combined US$8.1tn in assets under management (AUM). Public pension funds are the largest investor (23%) followed by asset managers (21%) and insurance companies (15%). Japan Bank for International Cooperation has the largest allocation to infrastructure – while six out of the top 10 are Canada-based (source: Prqin 2016).

Table 19: Top 10 institutional investors by allocation to infrastructure (at August 2016)

Rank	Investor	Location	Current Allocation to Infrastructure ($bn)	Current Allocation to Infrastructure
1	Japan Bank for International Cooperation	Japan	41.6	24.0%
2	CPP Investment Board	Canada	15.3	5.5%
3	OMERS	Canada	12.5	22.0%
4	CDPQ	Canada	9.9	5.2%
5	Ontario Teachers' Pension Plan	Canada	9.6	8.2%
6	APG - All Pensions Group	Netherlands	9.1	2.0%
7	AustralianSuper	Australia	6.9	10.0%
8	Alberta Investment Management Corporation (AIMCo)	Canada	6.1	8.9%
9	British Columbia Investment Management Corporation	Canada	6.0	6.0%
10	PGGM	Netherlands	6.0	3.0%

Source: Preqin 2016

Most attractive markets for investment: London, Shanghai Singapore and Dubai

The most attractive markets for investors remain those countries and cities with the strongest growth potential, most secure business environments, well established legislative and regulatory systems and stable political environments (source: Arcadis GIII 2016).

- **Singapore, Canada, Qatar, the UAE, Norway, Sweden, Malaysia, the UK, the US and the Netherlands remain the top 10 locations in the world in which to invest in infrastructure** according to Arcadis' Global Infrastructure Investment Index 2016, which ranks 41 countries by their attractiveness to investors based on issues such as the ease of doing business in each market, tax rates, GDP per capita, government policy, the quality of the existing infrastructure and the availability of debt finance.

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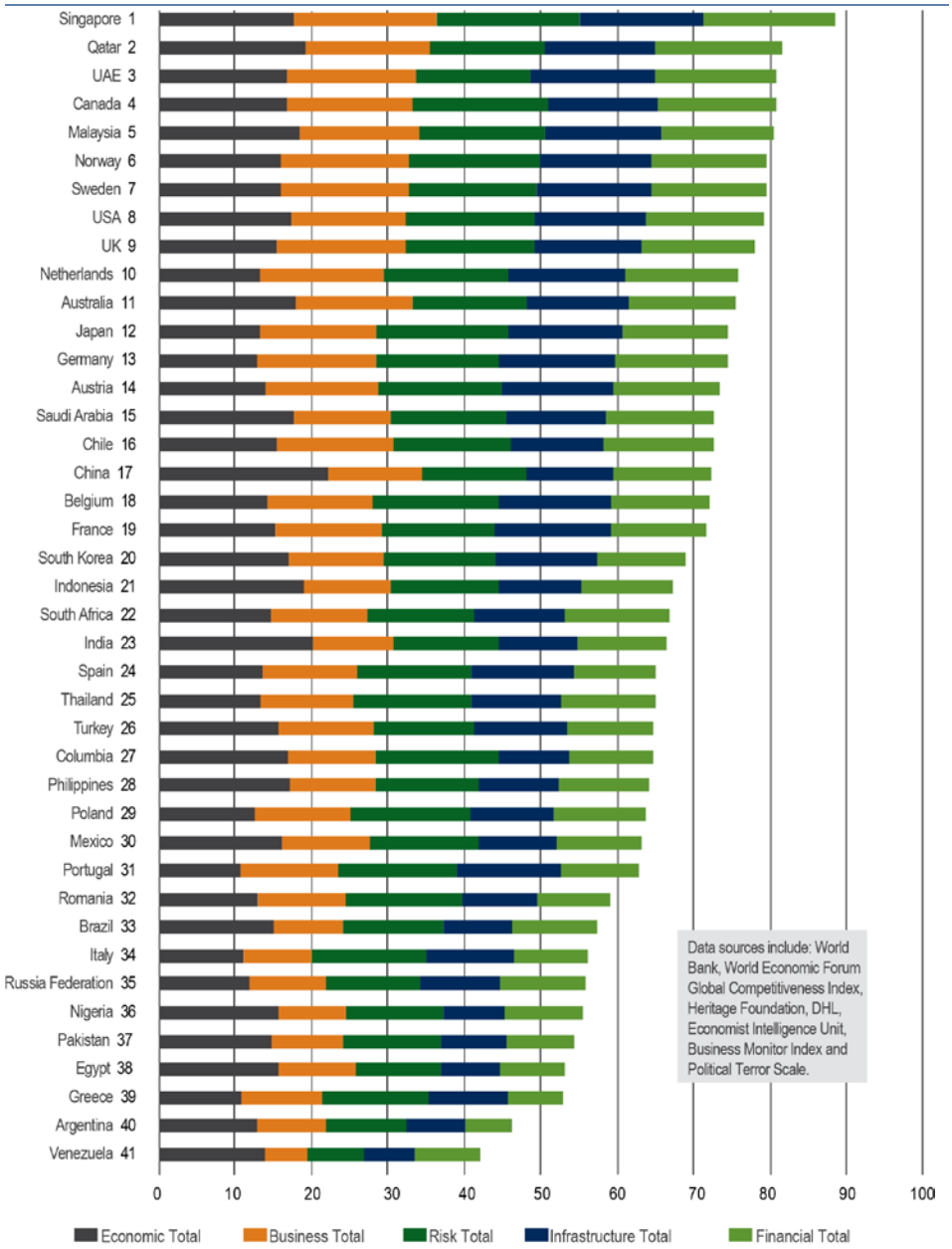
Exhibit 70: Global Infrastructure Investment Index 2016



Source: Arcadis 2016 based on various sources

- **Top cities for FDI strategy 2016/17: Edinburgh, Hong Kong, Chicago, Brisbane, Barcelona**, Manchester, Glasgow, Austin, Copenhagen and Perth (source: fDi 2017).

- **Most attractive cities for FDI 2016: London, Singapore, Shanghai, Dubai and Hong Kong**. London, Singapore, Shanghai, Dubai and Hong Kong have set atop the list of top global cities in terms of attracting inward investment (source: fDI 2016).

Table 20: Number of announced greenfield FDI projects for top 10 destination cities

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015*
London	228	267	271	337	302	333	393	386	407	414	439
Singapore	161	210	268	327	328	363	391	403	430	441	387
Shanghai	344	365	306	318	263	307	305	265	289	271	193
Dubai	185	240	234	370	286	217	265	249	258	240	261
Hong Kong	132	179	167	256	281	231	258	251	235	199	199
Paris	129	168	161	213	134	156	143	139	215	203	165

Table 20: Number of announced greenfield FDI projects for top 10 destination cities

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015*
Beijing	169	200	181	236	158	166	153	152	127	116	88
NYC	44	71	70	96	109	151	150	161	204	202	217
Bangalore	125	142	81	108	84	97	114	88	79	100	119
Sydney	39	48	72	70	86	113	124	147	133	136	138

Source: fDI 2016
* Estimated

Case study on Edinburgh which ranked first in the 2016/17 FDI Strategy category for Global Cities of the Future

- The investment department in the city council is responsible for the promotion of the city as an investment destination, and focuses on working with, and sharing knowledge with, other agencies and cities.
- It has entered an agreement with Shenzhen to encourage investment and broaden links between the cities.
- Free soft landing services are offered to all new investors coming into the city (i.e., property, relocating staff, access to meeting/work space)
- The Invest Edinburgh website is published in English, French, German, Spanish, Mandarin and Arabic (source: FDI Strategy 2016)

Telco infrastructure: connectivity backbone is the modern day equivalent of bricks and steel

As cities around the world use technology to become smarter, the role of telcos will become increasingly critical to connectivity, which is the bedrock of Smart City devices and services from smart lightbulbs to thermostats to biometric surveillance to robo-taxis to the smart grid. Hundreds of billions of dollars are already being invested in telco infrastructure and technologies required for Smart Cities and this could be a significant source of job creation and economic growth.

Unique positioning: connectivity, Big Data and customers

We see telcos as the Smart City-era equivalent of the bricks and steel companies that built the infrastructure of previous generations. Telcos have a unique positioning and significant opportunity to enable and deliver a wide variety of new IoT-enabled infrastructure, services and conveniences. We are already seeing instances of telco engagement in cities such as Valencia (Telefonica) and Nanjing (China Comservice), where operators are playing a significant role, including as "project leader" for managed services in enabling the Smart City platforms (source: Arthur D. Little).

- **Connectivity:** Telco networks are providers of connectivity via the network for IoT-based Smart City connected devices and deployments, but they will need to take on improved network features (nextgen LTE, LPWAN, 5G, robustness, low latency, scale, battery life, satellites, purpose-built networks etc.).

- **Big Data:** Telco networks enable the IoT, connect key devices and allow the resulting volumes of Big Data to flow and be processed and analysed. Telcos are critical actors in terms of efficient data centre infrastructure, managing data from disparate systems, and addressing the emerging challenges around control, resilience, and security.

- **Unique touch points with consumers:** Telcos connect with consumers at the levels of devices, services, data and billing.

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Case study of "Vodafone Connected Cities Spain", a pilot seeking to boost the efficiency of Andalucían Cities in a number of different areas (energy and water management, transport and mobility, infrastructure and building design and management, security and emergency response, health care, education & tourism):

- **City assets were fitted with smart sensors**, capable of transmitting data via M2M SIMs and utilising the existing cellular network.
- **Using smart asset management software to track and manage a wide variety of public assets** like smart bins, lights, electrical boards, environmental stations.
- **Data generated by assets is analysed for optimal adjustments and to provide insight for future decisions**. Data from 3rd parties and open sources are integrated into the platform to provide citizens and administration further insights.
- **Accessible through the cloud, so data can be shared** with end customers if wanted or run independently from the cloud to protect vital and sensitive information.
- **The creation of a citizen focused mobile app created a feedback mechanism** between the end recipient of city wide services, aiding data collection and the further refining of services
- **IBM provided the technical infrastructure, hardware, software and software** developments needed to implement the initiative.
- **Managed by a dedicated team enabling a single and centralised view of what is going, in real time**, across the cities via its connected assets.
- **Developed projects to help educate local business and the civilian population of the value of smart cities initiatives**, and show how they can deliver value and enable growth (source: Vodafone 2016).

Three main revenue models: data, apps and "unified control centre"

There are three main revenue generation models for a telco Smart City platform targeting consumers, enterprises or public entities, as well as end users: i) monetising and extracting value from the data aggregated through the Smart City platform; ii) selling smart applications or dashboards built on the Smart City services or use cases deployed; and iii) providing an integrated "unified control centre" service – that can coordinate multiple departments and functions - to municipalities or public entities (source: Arthur D. Little)

- **Vertical and horizontal service offerings:** While selective vertical activities offer quick, easy opportunities, horizontal service allows telcos to use their capabilities

across verticals (e.g., enabling an energy/utility-driven Smart Metering solution will allow a direct transfer of capabilities for Smart Building services).

- **Multiple business models:** Beyond restricting themselves to a limited role as connectivity providers, telcos can pursue models such as sensor networks management (e.g., network operations, managed and security services, sensor data aggregation, and analytics). There is also scope to move up the value chain towards more "solution-oriented" services – offering their own (horizontal) services to various vertical segments – with clear differentiation and up to three times higher revenue potential (source: Arthur D Little).

- **Need for partnering approaches:** While telcos have strong capabilities in connectivity and service provisioning, most lack capabilities within the platform, application and system integration space. There will be a growing need for them to partner to gain capabilities outside their core competency areas and offer vertical end-to-end solutions, especially as third-party enablement often underlies the Smart City concept (e.g. 'open innovation platforms', 'developer gardens') (source: Arthur D Little).

Exhibit 71: Rio de Janeiro's 24-7 control centre incorporates 50 agencies covering traffic management, public safety and public services

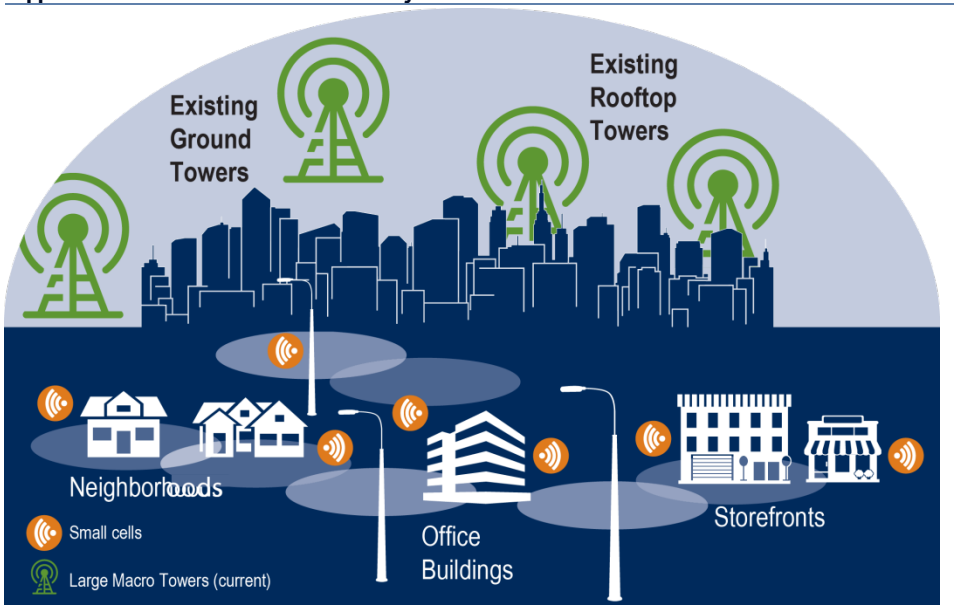
Source: Nokia 2017

Nextgen wireless infrastructure: small cells to deal with growth in demand

Nextgen wireless connectivity for Smart Cities will require a wireless infrastructure that is significantly denser than what is required by the current 4G to deal with the growth in demand for capacity and coverage. One of the potential keys is small cell technology – hundreds or thousands of units which can be as small as shoeboxes, discretely deployed almost anywhere in cities, and which supplement traditional macro cell towers. Analogous to the supply operations concept of distributing dispatch centres across a geographic area, small cells offer greater speed to deliver, capacity to serve, and specialisation and diversification. The challenges in this area include local permitting and regulations, access to public rights of way and fee structures (source: Accenture Strategy).

- **Looking to the US as a case study, Crown Castle are already building small cells, mainly on behalf of Verizon** whose aspirations for network quality lead the market; the business relies on colocation economics to be NPV positive (c.2x tenants for double digit IRR returns) according to our BofAML Telecoms team.

Exhibit 72: Existing towers will provide coverage for kilometres (miles), while small cells with support the increased needs of a Smart City



Source: Accenture Strategy

Sigfox case study - is a first-mover and leading global provider of Internet of Things (IoT) connectivity, combining low energy consumption and ultra-low cost enabling connected devices to work seamlessly over decades. Today, the network is present in 31 countries and on track to cover 60 by 2018E – covering a population of 486 million people.

5G will be a key Smart City enabler: massive infrastructure opportunity

Fifth generation (5G) mobile networks – the proposed nextgen telcos standards beyond the current 4G/IMT-Advanced standards – will be a key enabler of IoT and Smart Cities. Its key elements (beam forming, massive MIMO, fibre, spectrum) will enable higher speeds, more connections, and quicker, more adaptive response times – and will make a range of services available that we cannot even imagine today. To put the importance of 5G into perspective, a 4G/LTE connected-driverless car could take as long as 4.6 feet to apply its brakes because of poor latency. 5G is being piloted in markets like the US and China in 2017, and our BofAML Telecom Equipment team believes that 5G standardisation is expected in 2019 globally, followed by commercial network deployments from 2020 onwards.

Key 5G takeaways by our US Semis team from the February 2017 Mobile World Congress in Barcelona (Life in the fast lane with 5G mobile, 28 February 2017:

- **The mobile industry is preparing to upgrade to advanced (gigabit speeds) 4G and eventually 5G networks**, driven by consumer demand for unlimited mobile video, massive IoT, virtual/augmented reality and connected cars.

- **While 5G inflexion is ~3 years away, the industry is gearing up with multiple evolutionary (from 4G) paths**.

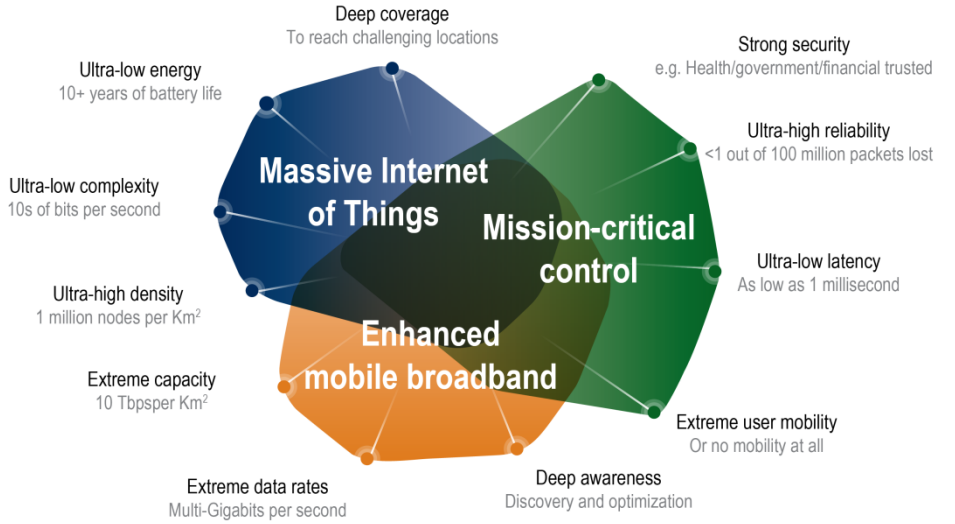
- **5G and other millimeter wave technologies could also be attractive alternative** for wireless backhaul, and cost effective residential internet service, as alternative to expensive "last-mile" cable, DSL and all-fiber solutions.

- **Chipmakers will be key beneficiaries of the ~$700bn telcos could spend** over next few years transforming their networks to support explosive man and machine traffic.

"The implications [of 5G] are tremendous. It means people will be able to remotely operate machinery — computers, mechanical equipment, surgical robots — in what is essentially real time. It means cities can be programmed to respond to us. In a Smart City on a 5G network, data transfer speeds will be so fast that we will wonder how we ever lived for so long without it." – Chelsea Collier, founder of Digi.City

Exhibit 73: 5G is scalable to an extreme variation of Smart City requirements

Based on target requirements for the envisioned 5G use cases



Source: Qualcomm

The need for speed: 1G to 5G

The "G" in wireless networks refers to the generation of the underlying wireless network technology. As the generation advanced from 1G (introduced in 1981, analogue cell phones), to 2G (first digital-signal based network deployed in 1992), to 3G (enabling video signal transfer, deployed in 2001), to the current 4G, data transfer speed (2.5G network data rate of 114kbps vs 3G network of up to 3.1Mbps and 4G network of up to 100Mbps), quality (better call quality, video streaming, etc), and security have significantly improved. 5G will increase network capacity (peak speeds of 1-10 Gbps initially), has low latency (<10ms) and more flexibility to enable many different use cases for Smart Cities.

Exhibit 74: Evolution of wireless networks

1G	• Voice signal only • Analogue cellular phones • NMT, AMPS
2G	• Voice & data signals • Digital fidelity cellular phones • GSM, CDMA, TDMA
2.5G	• Enhanced 2G • Higher data rates • GPRS, EDGE
3G	• Voice, data & video signals • Video telephone/Internet surfing • 3G, W-CDMA, UMTS
4G	• Enhanced 3G/Interoperability protocol • High speed & IP-based • 4G, LTE
5G	• Expanded data capacity (suitable for IoT) • Smart connection, connected devices • No standard set yet

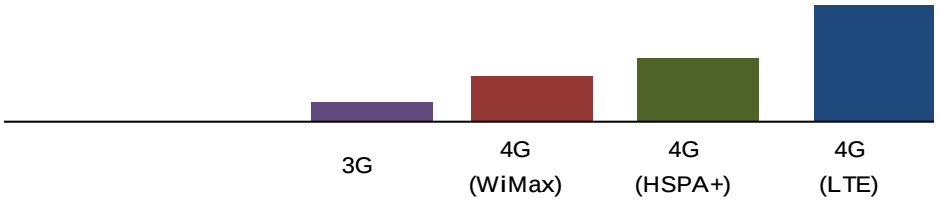
Source: BofA Merrill Lynch Global Research

4G/LTE to 5G: long-term tailwinds

The most recently deployed 4G was introduced under Mobile WiMAX standard in Korea in 2007 (and later in a faster form of LTE standard in 2009). WiMAX-enabled smartphones became available from 2010, and LTE-enabled smartphones from 2011. There are still many regions globally – mainly EMs – where 4G has not yet been actively adopted; China as of 2014 had a <10% 4G penetration rate, Brazil <5%, and India 0%. We believe the rate at which 4G will be deployed, especially among EMs, will rise rapidly from 2016.

Exhibit 75: 4G speeds and margins different

REAL 4G STANDARDS	3G	4G (WiMax)	4G (HSPA+)	4G (LTE)
Peak Rate	3 Mbps	128 Mbps	168 Mbps	300 Mbps
Real World Dow nload Speeds	0.5-1.5 Mbps	2-6 Mbps	1-10 Mbps	10-100 Mbps
Real World Upload Speeds	0.2-0.5 Mbps	1-2 Mbps	0.5-4.5 Mbps	5-10 Mbps



Source: BofA Merrill Lynch Global Research

5G rollout from 2020E: better data capacity for the IoT in Smart Cities

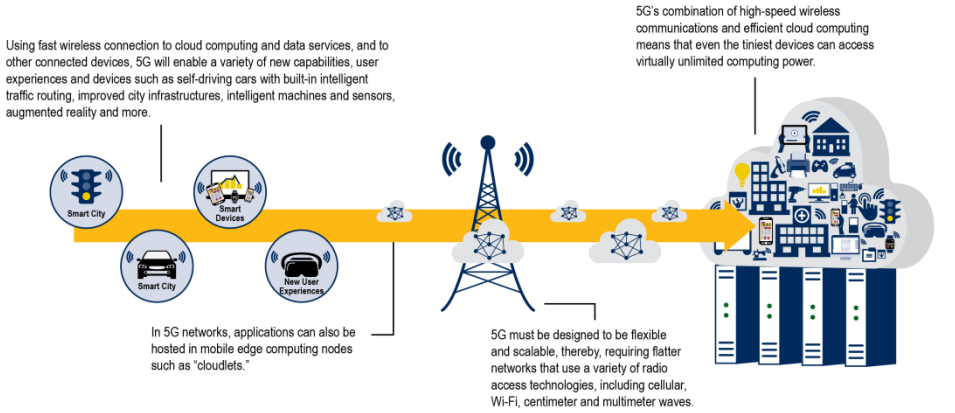
The next generation of mobile network, known as 5G, is expected to be rolled out from 2020E. In addition to simply providing faster speeds, the 5G network will allow significantly larger data capacity – enabling simultaneous and unlimited connections to the network. This will meet the demand of new uses of the IoT in Smart Cities. 5G's key elements (beam forming, massive MIMO, fibre, spectrum) will enable multiple advantages.

- **Higher speeds of up to 100x faster than current 4G** while handling traffic volumes of up to 1,000 higher, thus allowing instantaneous wireless exchange of unprecedented amounts of data.

- **More connections**, thus enabling wireless connectivity in unprecedented locations, ranging from street lights to sewer holes.

- **Quicker, more adaptive response times** that support time-sensitive applications, such as vehicle-to-vehicle communications; and ultra-low-power connections, such as sensors for leak detection in water mains, since, in many cases, the replacement cycle is directly related to battery life (source: Accenture Strategy 2017).

Exhibit 76: 5G will help support the massive growth of the IoT in Smart Cities, enable devices to communicate with one another, and will diffuse intelligence from connected devices to data centres



Source: Intel

Key technologies shaping the path to 5G

According to our US Semis team (US Semiconductors: MWC highlights: life in the fast lane with 5G mobile; Buy CAVM 28 February 2017),, an industry-wide effort (Non-Standalone 5G NR or New Radio) plans an intermediate step that will utilize existing 4G LTE radio and evolved packet core network as an anchor for mobility management and coverage while adding a new 5G radio access carrier to enable certain 5G use cases starting in 2019. The "cost" of 5G however will be a more complex architecture involving new modulation formats (64 QAM); multi-carrier aggregation for both downlink and uplink; advanced antenna designs (massive MIMO, beam-forming including support for ~100 antenna elements at each location); wider per channel bandwidths (100 MHz vs 10-20 MHz today); dependence on higher frequency (<6 GHz, mmWave) bands; denser placements of more cost-effective base stations, and greater use of cloud architectures.

Higher spectrum complexity & network topology

According to our BofAML Telecom Equipment team, 5G carriers need to license more spectrum, most likely in the 3-6GHz bands, potentially followed by millimeter wave bands beyond 2020. 3.4 - 3.8GHz seems most likely to be used globally as it has the most availability across major regions. 4.4 - 4.99 GHz is available in Japan and China only, potentially creating a local 'flavor'. In addition the 28GHz spectrum may become a band for fixed-wireless broadband providers piping data into the home with SK Telecom, Verizon and Samsung all engaged in trials currently

- **5G will initially be deployed as a complementary 'overlay' to existing 4G macro networks** in capacity hot spots. Several carriers argue that small cells will not have sufficient capacity/size to process 5G traffic. Larger 'Semi-macro' cells might be needed to densify 5G networks. 5G macro cell sites will require more (MIMO) and smarter antennas that support Beam-forming and Beam-tracking features.

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- **Only certain parts of the 5G radio access network will be centralized/moved to the cloud** (C-RAN), as this will increase latency. Fiber backhaul is required for all 5G access points.

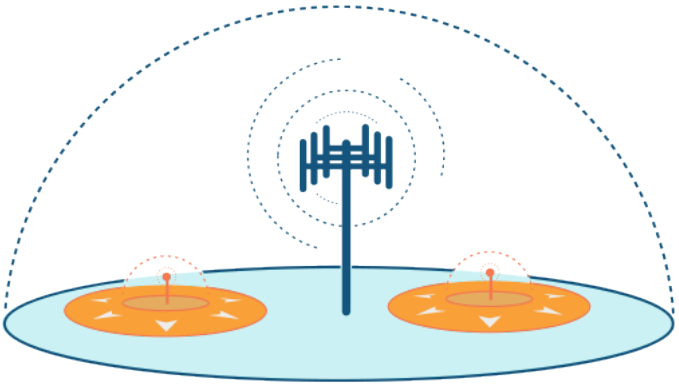
- **A key 5G feature evolving is network slicing**. This allows dynamic allocation of 'slices' of network capacity/resource tailored to different use cases such as ultra-low latency, many devices & high throughput/ultra-broadband. Network function virtualization (NFV) of Telco networks is a key enabling technology for Network slicing.

5G builds starting from 2018 should turbocharge operator small cell roll-outs

According to our BofAML Telecom Equipment team, use of higher frequency spectrum (3.4-3.8GHz) leading the first 5G deployments makes the use of small cells incrementally likely. Demand for indoor coverage also adds to this number but is more difficult to ascertain. European Tower companies Inwit and Cellnex have also expressed aspirations of significant future growth with similar double digit IRR targets. There is still some debate as to whether operators majority co-build on small cells or look for greater differentiation by through own-builds.

Exhibit 77: Small cells supplement the macro network and allow high frequency spectrum use

Illustration of how smaller cells can supplement bigger (macro) cells for telcos



Source: BofA Merrill Lynch Global Research

"Frugal 5G" could be used to connect the Bottom Billions, the world's poorest 4.5bn people who are largely unconnected:

- **It is possible to use the unused Television Band Channels (the so called White Spaces) in the VHF and the UHF Bands** to provide fixed, nomadic and mobile, high throughput, long range communications

- **Applications includes remote and rural broadband internet access, Frugal 5G for e-Education, e-Health, e-Banking**, ship to shore communications, homeland security, border protection and surveillance, environment monitoring, smart grid applications as well as low latency applications (source: IEEE 2017).

5G capex cycle likely more muted than 4G but higher margin

According to our BofAML Telecom Equipment team, capex spend may be more linear/drawn out than 4G, as 5G is not a 'rip and replace' cycle as 4G was, but should be higher margin. Some of the installed 4G equipment, such as basebands, can be

reused/upgraded, while other elements such as radio heads & antennas will likely need to be replaced. In the run up to 5G, fiber density will need to increase further as all 5G access points will require full fiber connections to backhaul the high data volumes. Meanwhile investments into 4G capacity upgrades will need to continue well into the 2020's.

Case study of benefits of 5G for the Energy & Utilities sectors:

- **Better forecasting of energy needs** via allowing many unconnected, energy-consuming devices to be integrated into the grid through low-cost 5G connections.
- **Reduced electricity peaks and reduced costs** via connecting devices using a smart grid, demand-side management.
- **More efficient infrastructure spending and reduced downtime** via capturing this data through 5G connections.
- **Precise, real-time diagnosis** in the event of power failure, down to a specific pole or transformer affected.
-
- **Finally, 5G is itself more cost effective and energy efficient than past generations of wireless** (source: Accenture Strategy 2017).

Economic benefits of 5G: US$275bn in infrastructure & up to 3mn jobs

Beyond the benefits of pervasive Smart City technology, the potential gains from the deployment process for 5G technology are also significant since telco operators are expected to invest approximately US$275bn in nextgen wireless infrastructure, with US$93bn expected to be spent on construction, with the remainder being allocated for network equipment, engineering, and planning. This could create up to 3mn jobs – across construction, suppliers and other partners – and boost GDP by US$500bn (source: Accenture Strategy 2017).

5G will mean opportunities for fibre companies, tower companies and installers vs. threats of broadband overbuilding and for cable companies and wireless companies.

Table 21: Smart city technology & 5G are expected to benefit all community sizes

	Saratoga, CA 29,900 Pop	Beaumont, TX 118,000 Pop.	Metro Chicago, IL 9,472,000 Pop.
Jobs Created	300	1,000	90,000
GDP Growth	$50M	$180M	$14B
Network investment	$20M	$100M	$8B
Smart grid & transportation benefits	$10M	$70M	$5B

Source: Accenture Strategy 2017

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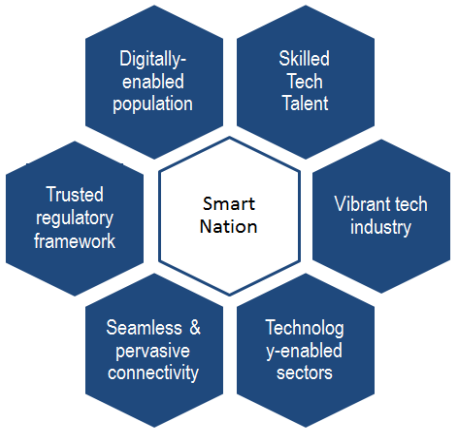
Singapore “Smart Nation” case study: a new wave of telco opportunities

Our BofAML ASEAN Telcos team has explored the impact of Smart Cities for telcos in their “Smart nation” report: Telecommunications - ASEAN: The Future is Smart 18 January 2017

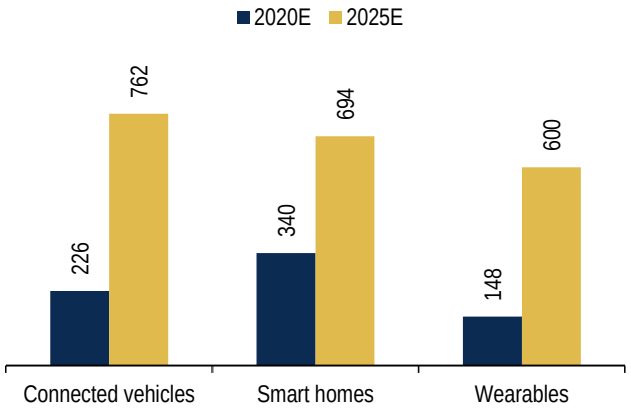
Singapore’s Smart Nation (SN) capabilities are likely to be the cornerstone of its next phase of economic growth and transformation. Our BofAML ASEAN Telcos team estimates SN-led initiatives will drive at least another S$2bn of revenue opportunity for the telcos by 2025E, and, in turn, boost the telcos’ revenue growth and diversity over time, though the gains may not be equally split.

Exhibit 78: Overview of a Smart Nation - Singapore



Source: BofA Merrill Lynch Global Research

Chart 31: Potential revenue (S$ mn) for SG telcos from connected devices



Source: BofA Merrill Lynch Global Research estimates

S$2bn-plus greenfield revenue opportunity for telcos

Revenue upside for the telcos could add up to S$2bn, led by connected vehicles, smart homes and wearables with over S$600mn potential in each. On a conservative basis, these could contribute to 34% of EBITDA for mobile and connectivity services by 2025E. There could be more upside from others eg public safety, cyber security etc, which are not included yet. SN’s revenue potential will be driven by the high volume of connected devices. The revenue per device could range from S$5-100, depending on the nature of the application. EBITDA margins could exceed 30% over time due to large-scale deployments and absence of device subsidies.

Telco network connectivity is at the core of SN

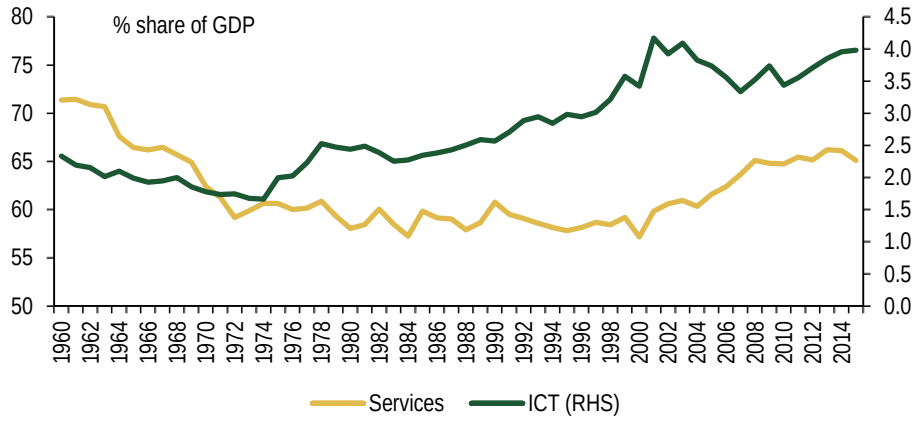
SN requires aggregation and transfer of substantial amount of data from sensors using a mix of fixed, wireless and narrow-band (NB) networks. The local telcos are in different stages of overlaying their macro network with a NB network to create a Heterogeneous Network (HetNet). The private networks, along with the government-owned network (in selective areas), will form the core of the SN architecture. Data from these networks will be used by different agencies and enterprises to offer relevant services.

Catalyst for economic gains and a trigger for automation

The SN initiative is a key thrust behind Singapore’s national strategy towards a ‘knowledge-based innovation-driven economy and society’. SN can help address structural challenges arising from aging population, rising urban density and increasing transport and energy demands. The information and communication (ICT) sector which currently makes up around 4% of GDP has the potential to reach a 5% share by 2025. SN could also lift labour productivity as the economy continues to become more reliant

on services as opposed to manufacturing. Autonomous vehicles for transport and logistics could be one such option to improve overall efficiency and road-safety.

Exhibit 79: ICT services have consistently increased contribution to Singapore's GDP



Source: BofA Merrill Lynch Global Research, CEIC

Smart City technologies transforming traditional infrastructure: new water, waste and food & ag solutions

Smart City technologies are playing an increasingly important role in allowing cities to tackle infrastructure challenges around themes like water, waste and agriculture, which are closely correlated to rates of urbanisation and income levels. Smart City technologies have the potential to minimise usage of water and production of waste, as well as water leakage and municipal costs and develop more sustainable food production.

- **The smart water market is estimated to grow to US$20.1bn by 2021E** (vs. US$8.5bn in 2016, a 2016-21E CAGR of 18.9%). This encompasses advanced water meters (meter type & meter read technology), solutions (network monitoring, advanced pressure management, SCADA (supervisory control and data acquisition) systems, advanced analytics, residential water efficiency) and services (source: MarketsandMarkets 2016). Actors in the smart water space include: ABB, GE, IBM, Itron, Schneider Electric, Suez, and Veolia, among others.

- **The smart waste management market is estimated to grow to US$2.4bn by 2021E** (vs. US$1.1bn in 2016, a 2016-21E CAGR of 16.9%. This encompasses managed services and analytics and reporting (source: MarketsandMarkets 2016). Actors in the smart waste management market include: Big Belly, Enevo, IBM, SAP, Republic Services, Suez, Veolia, and Waste Management, among others.

- **The smart agriculture market is expected to grow to US$18.45bn by 2022E** at a CAGR of 13.8% between 2016-222E (source: MarketsandMarkets). The market encompasses sensor monitoring, systems integrators. Actors in this space include Deere & Co, and AGCO among others

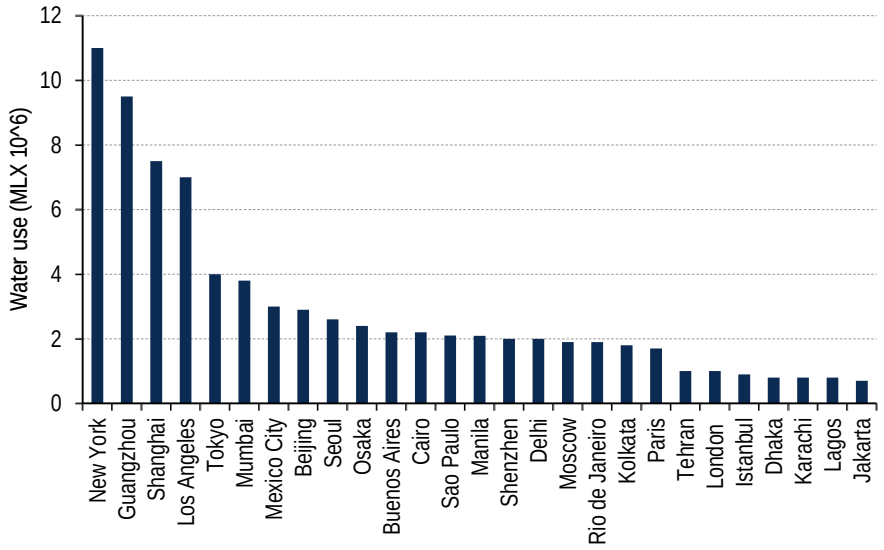
Smart Water: up to US$12.5bn in annual cost savings for Utilities

Globally, utility companies which apply smart water solutions could save between US$7.1- 12.5bn p.a. from using smart water solutions (source: SENUS 2012). These potential savings could be achieved through the use of smarter leakage and pressure management techniques of water networks, interpreting data which enables strategic capital expenditure management, smarter water quality monitoring and smarter network operations and maintenance in the water cycle (source: UK DBIS).

Fully integrated system

- A smart water network is a fully integrated system where products and systems are integrated to enable water utilities and customers to:
- **Remotely and continuously monitor and diagnose** problems, to take pre-emptive measures to manage maintenance;
- **Use remote sensors** to optimise performance;
- **Comply with waste water regulation** and conserve water;
- **Reduce supply disruptions** and improve customer service;
- **Manage water consumption more proactively** and maintain price stability; and
- **Provide users with intelligent information** which enables them to make choices about their water usage (source: UK DBIS).

Chart 32: Municipal water use including line losses



Source: PNAS

Smart Waste: enhanced efficiency of collection and separation

Smart technology employed within the waste management industry focuses on enhancing the efficiency of collection and separation. The main driver behind these technologies has been cost reduction and the need for many cities to improve their recycling performance (source: UK DBIS).

Enhanced efficiency of collection and separation

Smart waste management focuses on enhancing the efficiency of waste collection and separation:

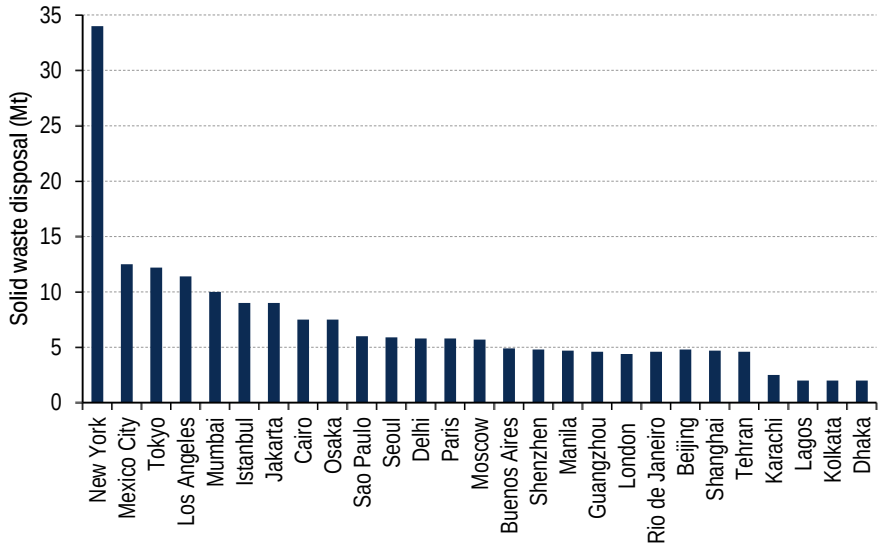
- **Smart garbage/refuse bins** including self-contained compactors powered by solar power which hold more waste than average street bins and alert collection contractors when 85% full (e.g. Big Belly Solar).
- **RFID tagging** on waste bins facilitate use of pay-by-weight mechanisms, and smart meters and wipe card access help monitor waste outputs and measure the effectiveness of reduction efforts.

- **Waste collection vehicle GPS tracking** enabling operators to track their vehicles with regards to their location, speed and historical routes – enabling the most efficient collection routes and diversion of vehicles to locations requiring immediate attention.
- **Automated waste collection** consists of a number of waste inlet points, linked together by a network of pipes that can transport waste to a central waste collection station for compaction and temporary storage (source: UK DBIS).
- **Apps enhance customer intelligence** and connectivity.

Sensor provider Enevo offers internet connection for waste bins in cities in Finland, the Netherlands, UK, Belgium, Canada and the US, and runs a Twitter feed – "Trashcan Life":

- "I am 26% full"
- "My current internal temperature is 24C"
- "I expect to be full on Wednesday" (source: Enovo, press sources).

Chart 33: New York City is the world's most wasteful city (Mt, 2011)
Municipal solid waste production (Mt, 2011)



Source: PNAS 2015

Smart Agriculture: urban farms already produce 15% of our food

With 70% more food production needed to ensure Food Security by 2050 for the c.7bn-strong global urban population, we think smart, urban agriculture will play an increasingly major role in feeding the world. Up to 15% of our food already originates in metropolitan areas (source: University of Florida). We outline a sample of case studies from this space in cities below.

- **GrowUp Urban Farms (London) -** produces sustainable fresh fish, salad produce and herbs in cities using a combination of aquaponic and vertical-farm growing technologies. Unit 84 in Beckton is the UK's first aquaponic, vertical urban farm. Its 6,000 square feet of growing space produces more than 20,000kg of sustainable salad produce and herbs (enough for 200,000 salad bags) and 4,000kg of fish each year (source: GrowUrban).

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- **Sky Greens (Singapore) –** is the world's first commercial, hydraulic-driven vertical farm making use of the company's patented technology, 'A-Go-Gro', to grow lettuce, spinach and many other leafy greens. In this system, vegetables grow on 9-metre tall 'A-shaped' towers, each hosting 38 tiers of growing troughs. Each tower uses only 1 litre of water, which is collected in a rainwater-fed overhead reservoir. Costing S$3 per month to run each tower, the power system has a very low carbon footprint, needing the energy equivalent to illuminating a 40-watt light bulb. Sky Greens produces 1 ton of vegetables every other day (source: Sky Greens).

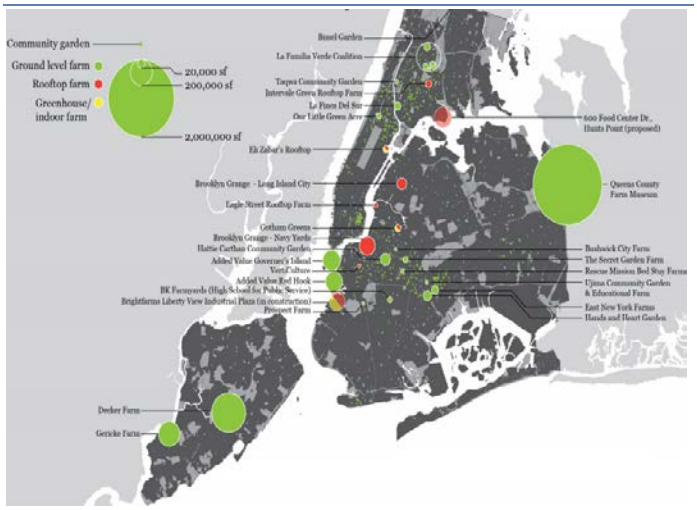
- **AeroFarms (New York) –** the company is planning to build the world's biggest vertical farm in Newark, New Jersey at 70,000 square feet that will produce 2 million pounds of food a year. The company claims that the facility will produce 75% more yield than an outdoor farm the same size and use 95% less water. Soil is not used while LEDs will provide the light (source: AeroFarms).

- **New York City –** there are over 1,000 community gardens in NYC, 15-30 of which are "farms", generally defined as over 2,000 square feet of growing area and focusing on growing food for consumption by people other than the farmers/gardeners. Most of NYC's farms and community gardens are in the neighbourhoods of East New York, Brownsville, Crown Heights, Bedford-Stuyvesant, and Bushwick in Brooklyn, the Lower East Side and East and Central Harlem in Manhattan, and Morrisania, Claremont Village, East Tremont, and Belmont in the Bronx. However, there is almost 5,000 acres of vacant land likely to be suitable for future urban farming in the five boroughs, 6x the area of Central Park. New York has 38,256 acres of available rooftop space that could be utilised for farming (source: Urban Design Lab, Columbia University).

Exhibit 80: What smart, urban farming could look like in the future
Sky Greens, Singapore

Source: Sky Greens

Exhibit 81: Food production in New York City



Source: Columbia University

Urban resilience: infrastructure needs to survive growing stresses and shocks

When it comes to infrastructure, Smart Cities need to be looking to build up their urban resilience – which 100 Resilient Cities, a city-based network – defines as the capacity of individuals, communities, institutions, businesses and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience.

City-resilience framework: infrastructure & environment

Developed by Arup with support from the Rockefeller Foundation, The City Resilience Framework (CRF) provides a lens to understand the complexity of cities and the drivers that contribute to their resilience. In terms of infrastructure and the environment, it focuses on the man-made and natural systems that provide critical services, protect, and connect urban assets enabling the flow of goods, services, and knowledge:

- **Providing and enhancing protective natural and man-made assets:** maintain protective natural and man-made assets that reduce the physical vulnerability of city systems. This includes natural systems like wetlands, mangroves and sand dunes or built infrastructure like sea walls or levees.

- **Ensuring continuity of critical cervices:** actively manage and enhance natural and man-made resources. This includes designing physical infrastructure such as roads and bridges to withstand floods so that people can evacuate, as well as ecosystem management for flood risk management. It also includes emergency response plans and contingency plans that may coordinate airports to function so that relief can be lifted in and out during a crisis.

- **Providing reliable communication and mobility:** provide a free flow of people, information and goods. This includes information and communication networks as well as physical movement through a multimodal transport system (source: 100 Resilient Cities).

Future-proofing: cities are looking to become more resilient

More cities are implementing resilience strategies and putting into action plans to help prepare them for the next century. As of January 2017, 20 cities have released resilience strategies with 56 cities now having Chief Resilience Officers to address challenges such as flooding and security (source: 100 Resilient Cities).

New York City's resilience strategy – 'One New York: The Plan for a Strong and Just City':

- Our Growing, Thriving City: affordable housing, 21st century commerce, job growth, training in high-growth industries, innovation economy etc.
- Our Just and Equitable City: lift 800k out of poverty, raised minimum wage, education, reduce premature mortality and domestic violence.
- Our Sustainable City: minimise environmental footprint, reduce GHGs by 80% by 2050, zero waste to landfill by 2030, remediation.
- Our Resilient City: upgrade public and private buildings, adapt infrastructure to withstand extreme weather events, strengthen coastal defences.

Climate-resilient infrastructure: 1.3bn people & US$158tn in assets at risk by 2050E

One of the most pressing examples of resilience stresses and shocks is that the world's largest cities are already facing increasing risks from climate change – with 85% dealing with temperature increases/heatwaves, 82% frequent/intense rainfall, 49% drought, 46% sea level rises, and 44% storms and floods. Fifty-three percent of cities report these risks as serious and near term (source: C40 Cities). This reiterates the need for cities to invest in climate-resilient infrastructure with US$375bn needed to 2020E and US$1tn for the C40 Cities alone (source: C40 Cities-Arup 2016).

We continue to view Climate Change as one of the defining issues of our time.

- **2016 was the hottest year since records began in 1880, 16 out of the 17 warmest years have occurred since 2000** (source: UN, NASA).
-
- **Global temperatures have risen above 1.1°C (2°F) compared to pre-industrial times, and the last time the world was this warm was 115,000 years ago** (source: WMO, NASA).

By 2050E, climate change-related natural disasters will put 1.3bn people and assets worth US$158tn (double the total annual output of the global economy) at risk without preventative action, according to the World Bank 2016 Global Facility for Disaster Reduction and Recovery

Expansion of urban populations increasing climate change exposure

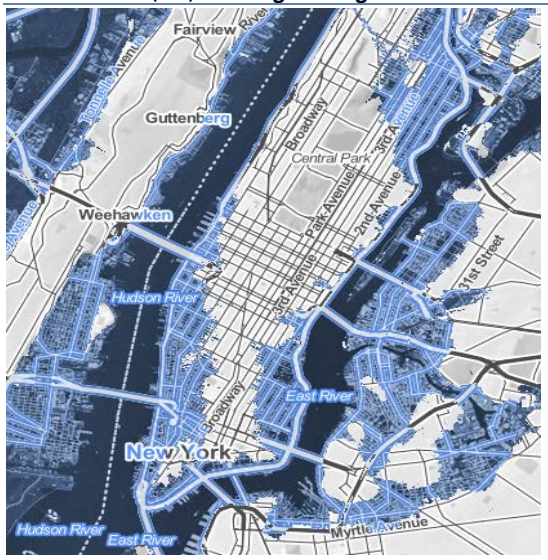
According to the World Bank 2016 Global Facility for Disaster Reduction and Recovery, expansion of urban population increases climate change exposure either through increased density, as cities build upward, or by outward expansion, as the increasing population spreads over a wider area and causes changes in land use. The urbanisation of unstable slopes or reclaimed land (often susceptible to flooding and liquefaction) leads to a disproportionate increase in exposure.

World's top 10 most vulnerable cities from flooding: Guangzhou, Mumbai, Kolkata, Guayaquil, Shenzhen, Miami, Tianjin, New York-Newark, Ho Chi Minh City and New Orleans (source: Nature Climate Change 2013)

The 136 largest coastal cities worldwide will see average global flood losses increase to US$52-63bn p.a. by 2050E (vs. US$6bn in 2005). (source: Hallegatte et. al. Nature Climate Change 2013)

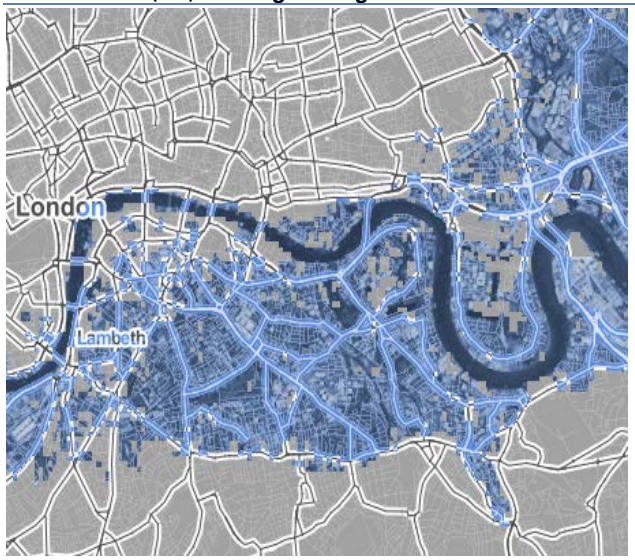
- **Urban GDP exposed to once-a-decade floods increased significantly between 2010 and 2050 in all regions**. Urbanisation can change disaster risk significantly. Evolution of flood risk varies regionally, but also differs in urban and rural contexts. The global flood model GLOFRIS (Global Flood Risk with IMAGE Scenarios) was used to estimate regional urban and rural population at risk of flooding and found a significant increase in urban population at risk of flooding for the whole world, EMs, and each World Bank region (source: World Bank GFDRR 2016).

Exhibit 82: 4°C (7°F) warming flooding scenario effect on New York



Source: Climate Central

Exhibit 83: 4°C (7°F) warming flooding scenario effect on London

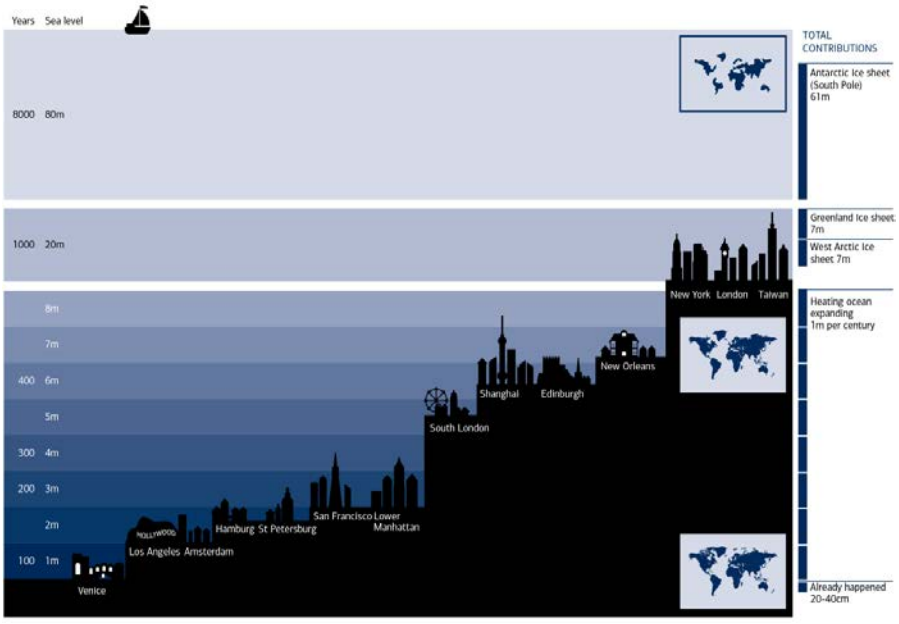


Source: Climate Central

- **Increased exposure in coastal cities is an important driver of risk**. These cities are already among the most populous in the world and have a huge amount of infrastructure exposed to coastal flooding and storm surge. These cities are also some of the most rapidly growing in terms of population. Coupled with the effects of evolving coastal hazards, this swift increase in exposure makes cities such as Mumbai, Karachi, Jakarta, and Lagos key areas in which to address evolving disaster risk (source: World Bank GFDRR 2016).

Exhibit 84: The last time ocean temperatures were as warm as 2017, sea levels were up to nine metres higher than they are today

Estimated rise in sea levels and impact on cities



Source: Hoffman et. al. Science 2017, InformationIsBeautiful, David McCandless sourced from IPCC AR3, NASA data

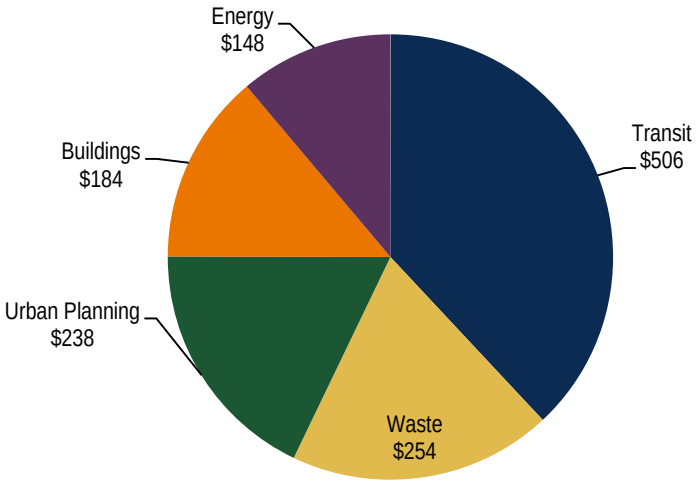
C40 cities alone need $375bn to 2020E and US1tn to 2050E

From 2016 to 2050E, over US$1tn investment is required across all C40 cities to meet the ambition of the Paris Agreement through new climate action. C40 cities comprise 80+ megacities with 600mn+ people accounting for 25% of global GDP. Some US$375bn of this investment is needed over the next four years alone. Depending on

the power structure in cities, this commitment must come from city administrations themselves, or other stakeholders, such as utilities, the private sector, or indeed tax payers (source: C40 Cities-Arup 2016).

Cities have the boldest plans to deliver a sustainable future: "Cities are where the future happens first. It has been the same throughout history and it is true once again as we face the unprecedented threat of climate change. If we cannot rely on the leadership of nations in these crucial four years, then mayors, chief executives, scientists, entrepreneurs and citizens will bear the burden instead. The consequences of failure are too dire and the opportunities for us to succeed are simply too great." – Letter to the Editor, FT 23 January 2017 by Anne Hidalgo, Mayor of Paris and Chair of C40 et. al.

Chart 34: Breakdown of US city investment pipeline between 2016 and 2050E (US$bn)

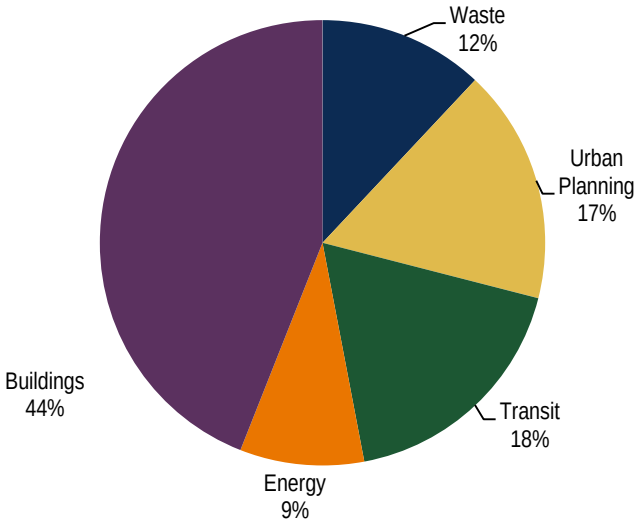


Source: C-40 Cities-Arup 2016

44% of climate actions in buildings: growing action on transport to 2020E

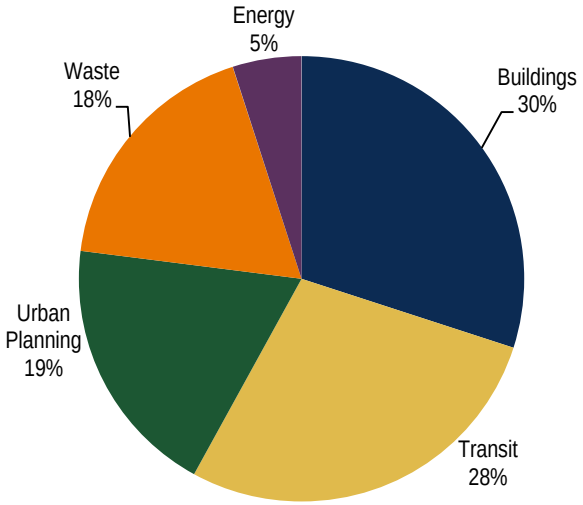
The majority of current climate actions are in the buildings sector. However, between 2016 and 2020E, action in the transit sector should expand, while the proportion of action in the buildings sector should reduce. All sectors, however, see a growth in action across C40 cities (source: C40 Cities-Arup 2016).

Chart 35: Climate actions already underway in C40 cities from 2015 to 2020E



Source: C-40 Cities-Arup 2016

Chart 36: Buildings will account for 30% of climate actions and transport 28%by 2020E



Source: C-40 Cities-Arup 2016

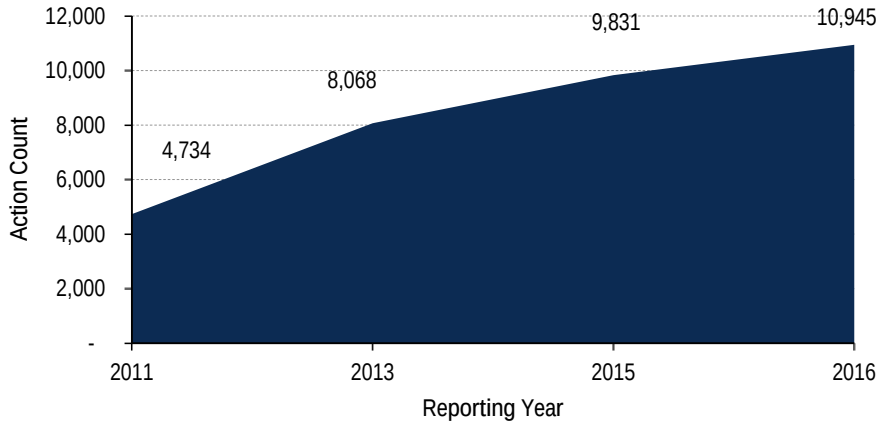
US C40 cities: already leading the way on climate action

Preliminary estimates from C40 Cities indicate US C40 cities (accounting for 30% of US GDP) have already invested on average US$2.91bn per city on climate action, compared with non-U.S. cities' US$2.16bn per city. This has unlocked 2,382 individual climate actions since 2011 or 22% of total C40 actions (source: C40 Cities-Arup 2016).

US cities with the most solar power installed (2016): Los Angeles (215 MW), San Diego (189 MW), Phoenix (147 MW), Honolulu (146 MW), San Jose (141 MW), Indianapolis (124 MW), San Antonio (108 MW), NYW (84 MW), Albuquerque (65 MW) (source: Environment America 2016)

Chart 37: Close to 11,000 climate actions were carried out by C40 cities in 2016

Increase in reported action in C40 cities since 2011

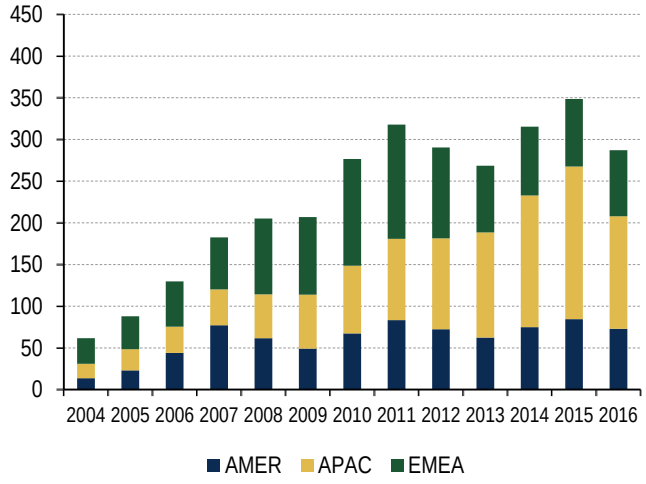


Source: C-40 Cities-Arup 2016

US$287.5bn in new cleantech investment in 2016: cities leading the drive

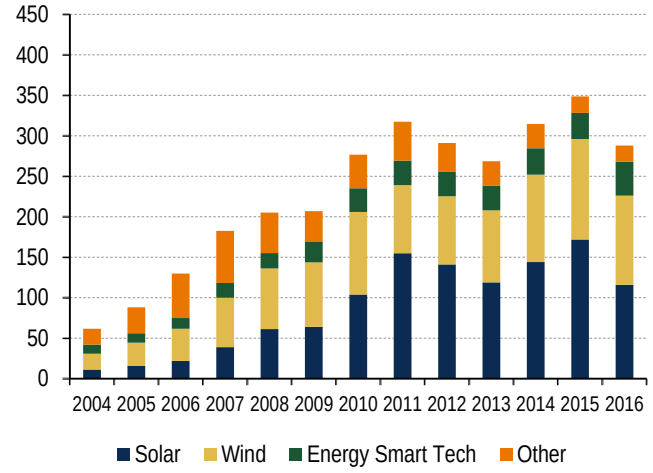
New investment in global clean energy was U$287.5bn in 2016 (-18% vs. record investment of US$348.5bn in 2015) (source: BNEF 2017). The 2016 'setback' in global investment is not necessarily a bad thing regarding cities' climate resilience, given that it partly reflected sharp falls in equipment prices: cost-competitiveness improvements in solar and wind power mean that more MW can be installed for the same price.

Chart 38: New investment in clean energy by region, 2004-16 ($bn)



Source: Bloomberg New Energy Finance 2017

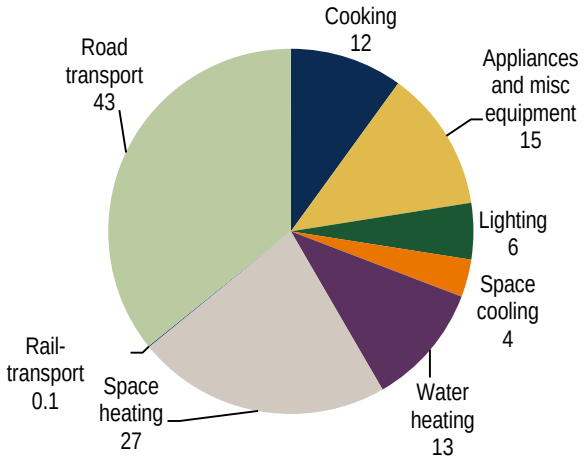
Chart 39: New investment in clean energy by sector, 2004-16 ($bn)



Source: Bloomberg New Energy Finance 2017

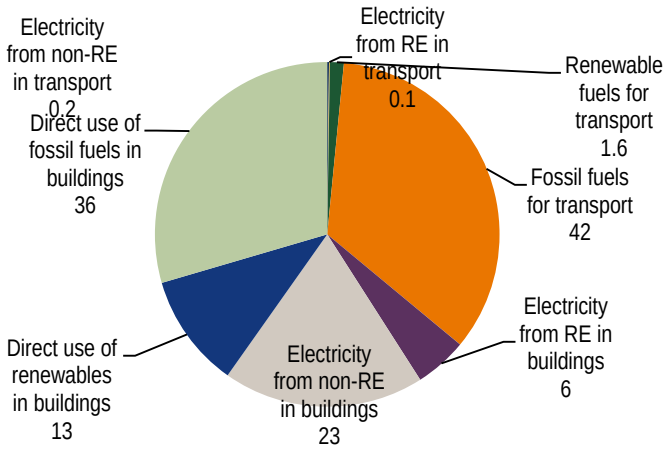
- **Renewables currently supply about 20% of energy for transport and buildings in cities** and there is an opportunity to significantly increase this share (source: IRENA 2016).

Chart 40: Urban energy use in buildings (2013, PJ/year)



Source: IRENA 2016

Chart 41: Urban energy use in transport (2013, PJ/year)

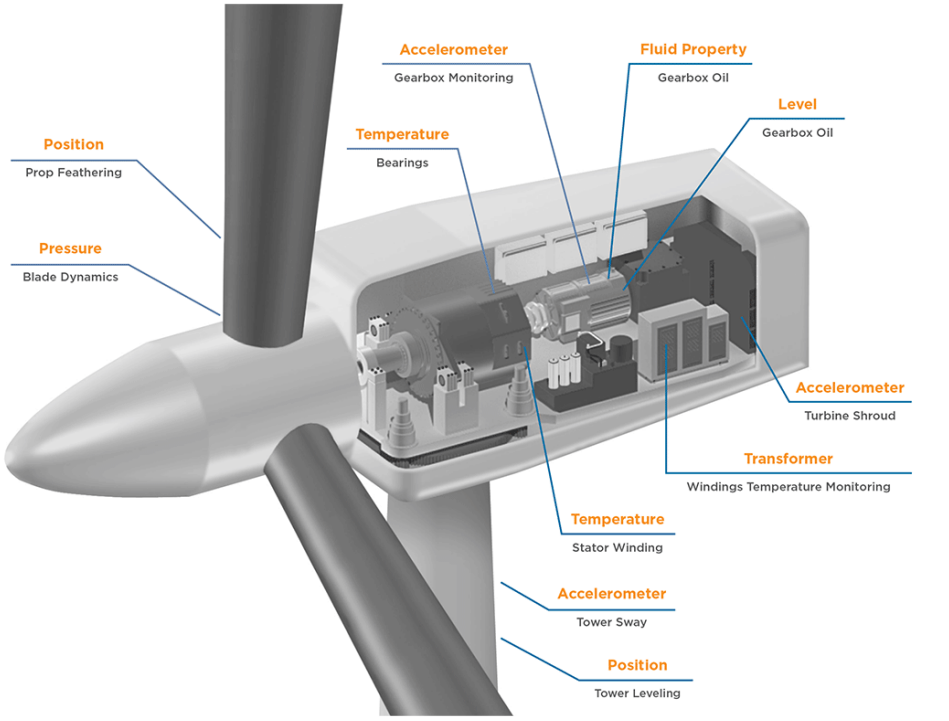


Source: IRENA 2016

- **Cities committing to 100% renewables include Copenhagen, New York, Oslo, San Francisco Stockholm, Sydney and Vancouver** (source: ICLEI-go100re).
- **Todays' cleantech is Smart City-friendly**: The cleantech industry has stepped up to the Smart City challenge with the wind industry actively integrated nextgen

materials (carbon fibre), software, sensors, and remote monitoring and diagnostics based on smart data.

Exhibit 85: Today's wind turbines contain multiple sensors



Source: TE Connectivity

Transformative financing options need to be pursued: green bonds & more

There is a need to pursue multiple routes for supporting climate-related projects and programs, including

- **Green Bonds where the market has risen substantially from US$0.8bn in 2007 to US$152bn as of Sept 30th 2016 and could cross the US$200bn mark in 2017** (source: BofAMLe, Moody's).
- **US municipals / cities are also making a push in this space**. For instance, the New York Metropolitan Transportation Authority issued US$1.4bn worth of green bonds in 2016 to fund low carbon public transport. The San Francisco Public Utilities Commission (SFPUC) has been issuing green bonds too with use of proceeds going towards water infrastructure for remedying the drought in California.
- **Other mechanisms include emissions trading schemes, international financial institutions (IFI) and agency finance, international and regional climate funds** e.g. The Green Climate Fund), city government-backed funds, and equity capital.

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Smart Safety & Security: fear fuels growth

Cities are especially vulnerable from a safety and security perspective whether it is crime, accidents, infrastructure, natural disasters, or terrorist attacks. There is a clear correlation between the size of a city and its crime rate: 80% of recorded crimes occur in cities that account for 50% of the world's population (source: Siemens). This creates a need for smarter countermeasures to protect lives and property.

High crime rates and violence are a top concern for citizens worldwide. Up to 60-70% of urban residents have been victims of crime in EMs with rapid urban population growth (source: UN-Habitat 2016). Americans are more concerned about crime and violence today than they have been for 15Y, with 53% of US adults saying they personally worry "a great deal" about it (source: Gallup 2016). While perceptions do not always reflect reality, this will ramp up the stakeholder pressure on governments to act in both DMs and EMs.

Crime across G7 countries has largely been on the decline since the 1990s. In the US, between 2008 and 2015, violent crime and property crime rates fell by 19-29% and 22-23%, respectively (source: Pew Research 2016). The US violent crime rate remains near the bottom of the nation's 30-year levels (source: Brennan Center for Justice 2016). DM cities have made the greatest progress: violent crime in the biggest US cities has fallen 64% since 1990 (vs. 32% nationally) (source: The Economist 2013 based on various sources).

There have been 150,000 terrorist attacks since 1970 and attacks on cities are on the rise. Approximately 30,000 people lost their lives to terrorism in 2015, the majority of which in current war zones (source: Global Terrorism Database 2016, Start GTD, IEP 2016). Cities are bearing the brunt of terrorist attacks, with so-called ISIL/Daesh attacking 252 different cities in 2015 (source: IEP 2016). While terrorism cost the global economy US$86.6bn in 2015, it is important to contrast this with the 437,000 homicides every year – more than 13x the number of deaths from terrorism (source: IEP 2016, 2015).

Most cities are unprotected and unprepared for cybersecurity risks. The Internet of Things (IoT) – comprising billions of connected devices and associated services and infrastructure – is at risk from cyber criminals, cyber activists, and nation states. We think it is only a matter of time before attacks on city services and infrastructure become commonplace. The US DHS has stressed the risks to critical infrastructure, public safety and, potentially, national security. Experts see smart grids as the most exposed to cyber risks, while 98% of government IT professionals see Smart Cities as having no protection against cyberattacks (source Tripwire 2016). Cybersecurity and privacy are also major inherent risks in the roll-out of disruptive technologies.

Smart Cities are integrating an increasing number of ICT-enabled measures to improve safety and security and the Safe City market will see US$226bn in revenues from 2015-2021E (source: Homeland Security Research Corporation - HRSC). Growth areas include CCTV, incident detection, crowd monitoring and control, adaptive lighting, emergency alerts and notifications, environmental monitoring, disease surveillance and epidemic monitoring, and smart care and assisted living, among other areas. Key drivers and enablers include: Big Data, integrated systems, multi/inter-agency collaboration, situational awareness, video data & analytics, automated processes, and improved strategic and tactical decision-making (source: Hitachi Insight Group, IBM, IFSEC Global).

Smart homes will be a key driver of security management: the market is expected to grow from US$1.6bn in 2015 to US$42bn in 2025E (2015-30E CAGR of 28%) (source: AT Kearney). Eighty-seven percent of consumers say smart home technology makes their lives easier and 90% cite safety & security as the #1 driver for adoption (source: Coldwell Banker, iControl). The #1 smart security feature for consumers is being able to use smartphones to monitor, arm and secure their homes (source: Comcast Xfinity).

Smart video and analytics are set to drive a US$71bn market by 2022E, at a projected CAGR of 16.6% from 2016-22E (source: IHS Markit). An estimated 350mn surveillance cameras were installed worldwide as of 2016, and the commercial market and APAC are expected to see the fastest growth (source: IHS Markit). Smart Cities are set to drive growth for cloud services and video surveillance as a service (VSaaS) (i.e. hosted cloud-based surveillance), as well as software including video analytics and management (source: EY, IFSEC). AI/deep learning are also key drivers.

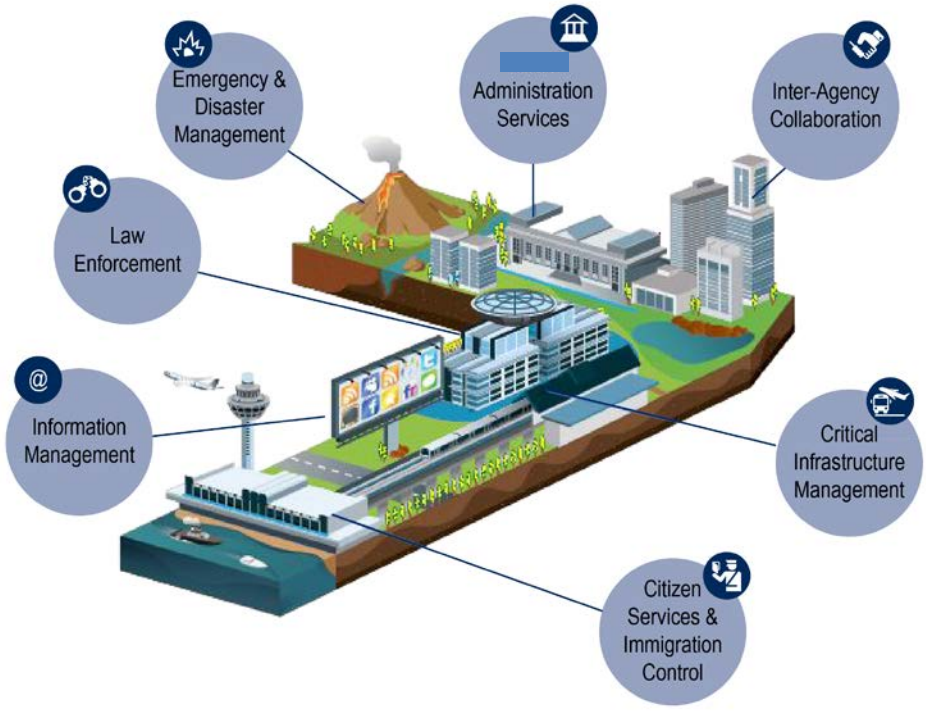
The global biometrics market is expected to reach US$41.5bn by 2020E, a 22.7% 2015-20E CAGR (source: BCC Research). Smartphones have been the mainstream gateway with c.1bn biometric smartphones in use today (source: Acuity Market Research), while governments are driving broader usage. Automated fingerprint systems currently dominate the market, while face, iris, vein and voice recognition are seeing the fastest growth (source: BCC Research). Going forward, biometrics can help to secure the IoT ecosystem at the heart of Smart Cities, and biometric data is set to become “gold dust" for city planners and governments as it increases understanding of how people behave and respond to the environment around them (source: bioconnect, Accenture).

Smart Cities technologies are a double-edged sword for the US$240bn (2020E) security services market (Freedonia 2017). Technology is threatening to disintermediate the largest parts of the value chain – human security guards and guarding services. Positively, Smart Cities will drive electronic security growth (i.e. networked, IP-connected systems), with the market reaching US$16bn in the US by 2019E (source: Freedonia 2015). The industry is also set to see a raft of new competitors vis-à-vis the Cloud, robots, and drones. Security drones alone are a potential US$11bn addressable market today (source: PwC).

Smart Cities cannot exist without smart, secure airports, which will drive US$13bn in Airport 4.0 spend by 2020E and see the passenger screening market grow to US$11bn by 2022E (source: Arthur D. Little 2015, Freedonia 2017). A major macro driver will be the estimated 7.2bn passengers that will travel by air in 2035E, a near doubling of the 3.8bn air travellers in 2016 (3.7% 2016-35E CAGR) (source: IATA). Digital technologies are becoming the main focus of efforts to balance security and efficiency and we anticipate rapid growth for advanced imaging systems, additional digital screening technologies, biometrics, and maintenance.

Safety and security in Smart Cities will continue to drive debates about the role and limits of governments in exploiting technology for surveillance (i.e. so-called “electronic panopticons”). Stakeholder concerns are largely centred around privacy factors, as data-sharing flows are operating vertically between citizens and government on an unprecedented sale.

Exhibit 86: Enhanced safety and security in Smart Cities



Source: NEC

Insecure cities: urban centres are highly vulnerable

Cities are especially vulnerable from a safety and security perspective given their large and dense populations, whether it is crime, accidents, infrastructure, natural disasters, or terrorist attacks. This requires smarter countermeasures to protect lives and property. It is also critical from an economic perspective. The World Bank estimates the cost of crime at as high as 25% of GDP in some EMs, while the European Commission calculates that it corresponds to 5%+ of EU GDP.

There is a clear correlation between the size of a city and its crime rate: 80% of recorded crimes occur in cities that account for a total of 50% of the world's population (source: Siemens).

"If city planners fail to guarantee safety, security, and supply, investors look elsewhere and highly qualified workers move to where they can expect the highest quality of life" Enzo Peduzzi, Director of Industry Affairs, Siemens Building Technologies, and President of Euralarm.

High crime rates and violence: a top concern for citizens worldwide

Crime and violence are pervasive in cities and among the top concerns for citizens. One study showed that 60-70% of urban residents have been victims of crime in those developing or transitional EMs where rapid urban population growth is at its highest (source: UN-Habitat 2016).

Most violent cities in the world: San Pedro Sula, Caracas, Acapulco, João Pessoa, and Distrito Central (source: Mexico Citizens Council for Public Security 2016).

Most violent cities in the US: St. Louis, Memphis, Detroit, Birmingham, and Rockford (source: FBI 2015).

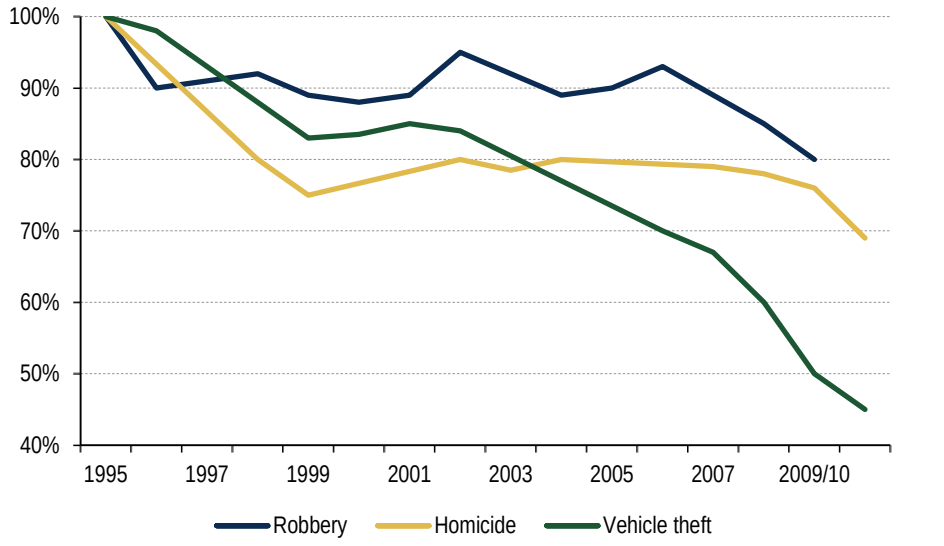
Crime perceived as being on the rise: doesn't always reflect the realities

Most surveys indicate that people around the world perceive crime to be on the rise. In the US, citizens' level of concern about crime and violence is at its highest in 15Y. 53% of US adults say they personally worry "a great deal" about it – the highest figure since 2001. The worries cut across all major cohorts, with higher levels for those with no college education, those earning US$30,000-75,000 p.a., and visible minorities (source: Gallup 2016). While perceptions do not always reflect reality, they will be an important driver of stakeholder pressure on governments to act in both DMs and EMs.

Crime across G7 countries has been on the decline since the 1990s: crime against the person and against property began to fall in the US in 1991, the UK in 1995, and France in 2001.

Cities have seen the greatest progress: in the biggest US cities, the number of violent crimes has fallen 64% since 1990 (vs. 32% nationally) (source: The Economist 2013 based on various sources).

Chart 42: Crime in G7 countries is on the decline (1995=100)



Source: The Economist 2013 based on Eurostat, FBI, Statistics Canada, Statistice Japan

57% of Americans say crime getting worse: but double-digit declines

57% of Americans believe that crime has increased since 2008. However, official government crime statistics paint a different picture. Between 2008 and 2015, US violent crime and property crime rates fell 19% and 23%, respectively, according to the

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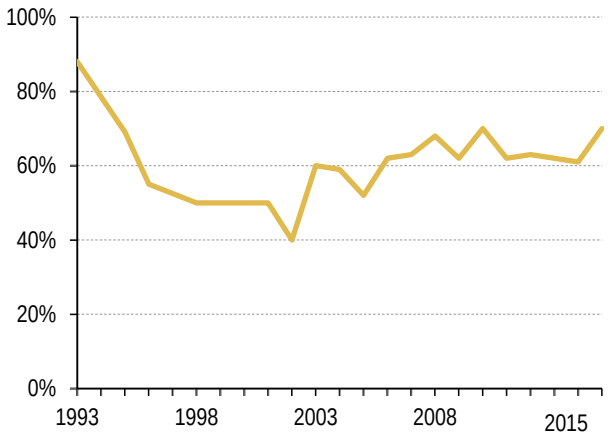
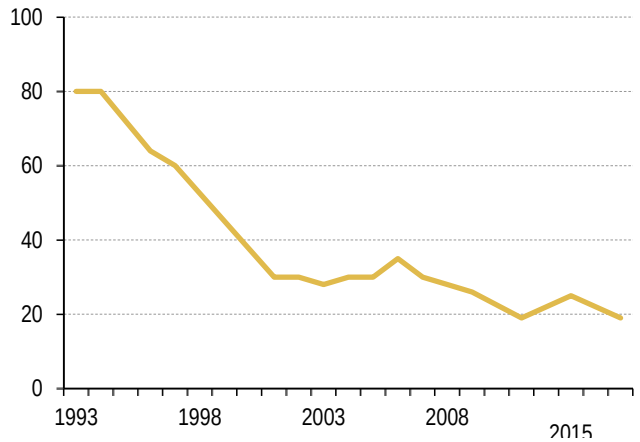
FBI's Uniform Crime Reporting Program – and 26% and 22%, respectively, according to the Bureau of Justice Statistics (source: Pew Research 2016).

Chart 43: US public perception of crime rates at odds with reality
% saying there is more crime in the U.S than a year ago



Source: Pew Research Center 2016 based on Gallup, Bureau of Justice Statistics

Chart 44: US public perception of crime rates at odds with reality
Violent crimes per 1,000 persons ages 12 and older



Source: Pew Research Center 2016 based on Gallup, Bureau of Justice Statistics

The US violent crime rate "remains near the bottom of the nation's 30-year downward trend" (source: Brennan Center for Justice 2016).

State of crime in the US (2015): 15,696 murders, 90,185 rapes, 327,374 robberies, and property crimes resulted in US$14.3bn in losses. Firearms were used in 71.5% of the nation's murders, 40.8% of robberies, and 24.2% of aggravated assaults (source: FBI 2016).

Table 22: FBI 2016 Crime in the United States

Years	Violent Crime	Murder	Rape*	Rape	Robbery	Aggravated	Property	Burglary	Larceny-theft	Motor	Arson
2013/2012	-5.4	-6.9	-	-10.6	-1.8	-6.6	-5.4	-8.1	-4.7	-3.2	-15.6
2014/2013	-4.6	-6	-10.1	4.6	-10.3	-1.6	-7.5	-14	-5.6	-5.7	-6.5
2015/2014	1.7	6.2	1.1	9.6	0.3	2.3	-4.2	-9.8	-3.2	1	-5.4
2016/2015	5.3	5.2	3.5	4.4	3.2	6.5	-0.6	-3.4	-0.8	6.6	-1.1

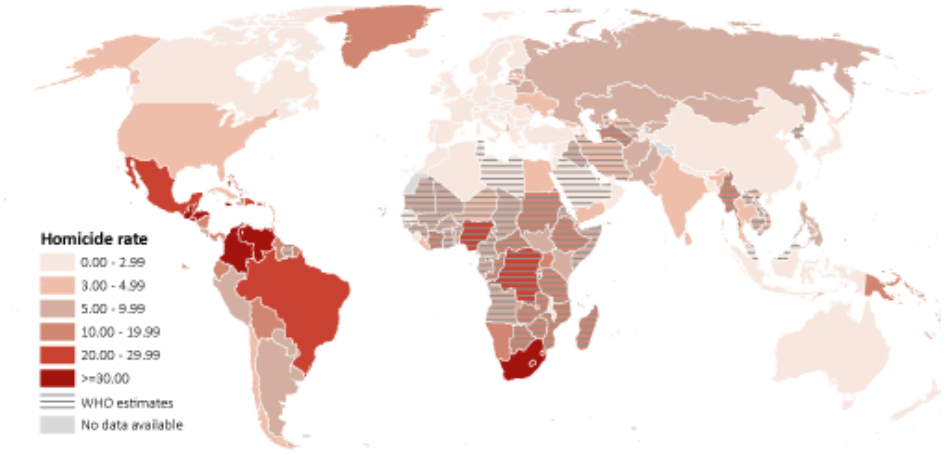
Source: FBI 2016 Crime in the United States
* Revised definition

Crime around the world: murders, burglaries, assaults

- **Murder: since 2003, on average, homicide rates have slowly decreased both in upper-middle-income and high-income countries** and have remained fairly stable in low-income countries (source: UN 2013).

Homicide rates are closely linked to income inequality: countries with the highest Gini index (i.e., the greatest income inequality) display 6-9x greater intentional homicide rates than countries with a low index (source: UN 2013)

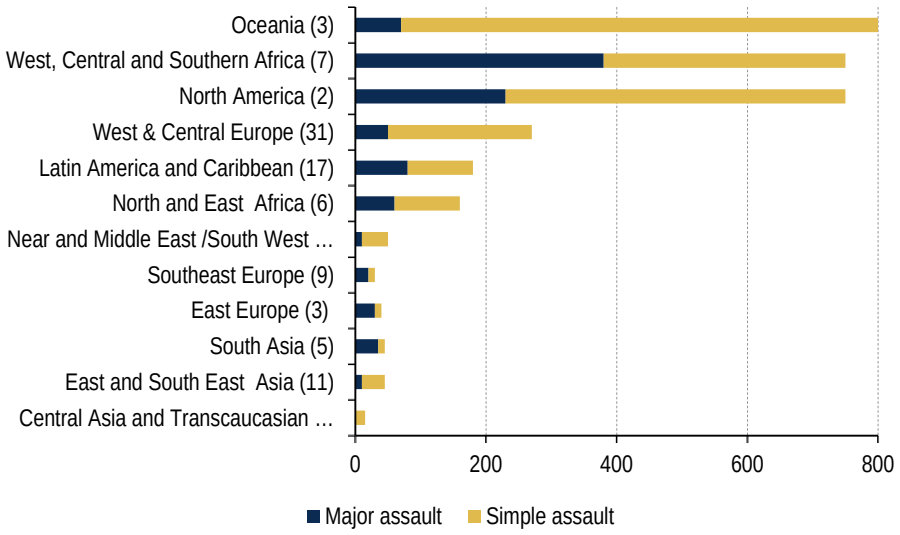
Exhibit 87: Global homicide rates (per 100,000 population)



Source: UN Global Study on Homicide 2013

- **Police recorded "traditional crimes" (recorded property crimes, burglaries and motor vehicle thefts) have decreased**. Rapes and robberies have slightly increased, and assaults have risen considerably. The average level of kidnappings has not changed. The large differences in crime between regions and countries can partly be explained by diverging criminalisation, efficiency of the criminal justice systems and recording practices (source: UN 2013).

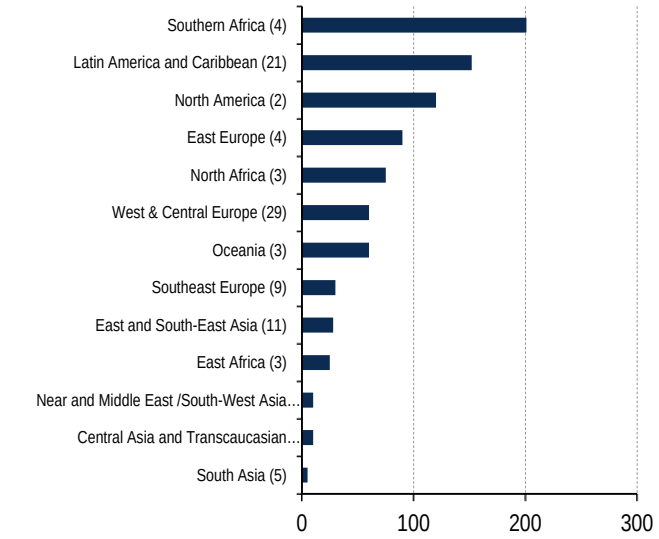
Chart 45: Major and simple assaults per 100,000 population by region



Source: European Institute for Crime Prevention and Control – International Statistics on Crime and Justice 2010

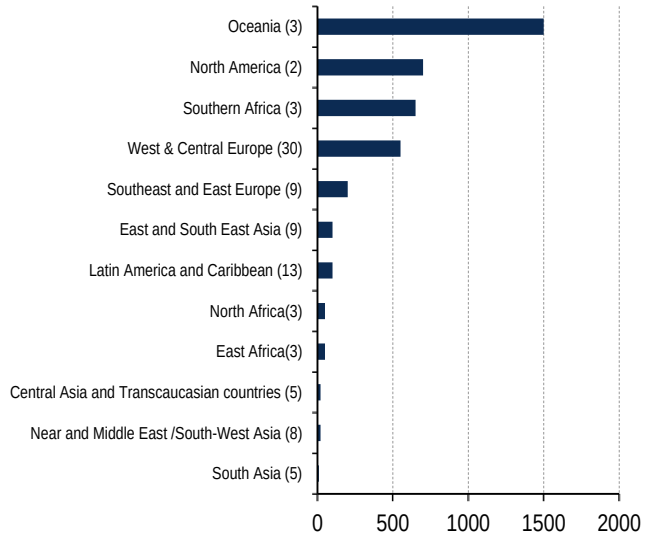
Bank of America Merrill Lynch

Chart 46: Robberies per 100,000 population by region (# of countries)



Source: European Institute for Crime Prevention and Control – International Statistics on Crime and Justice 2010

Chart 47: Burglaries per 100,000 population by region (# of countries)



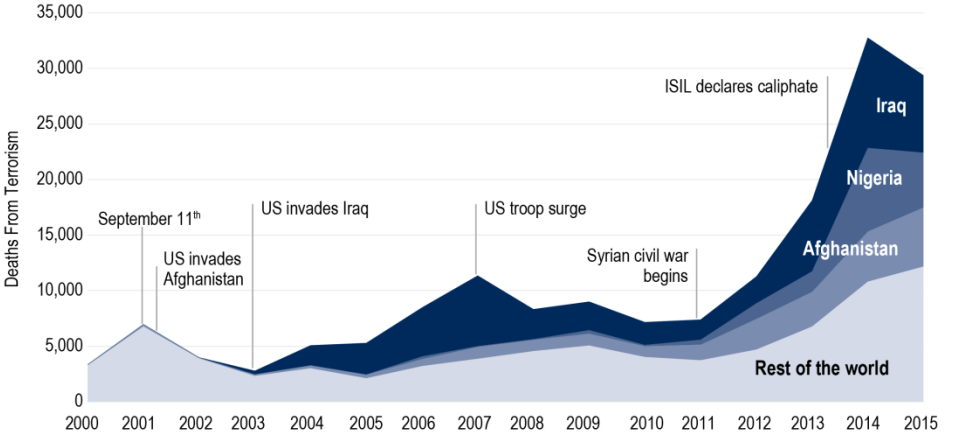
Source: European Institute for Crime Prevention and Control – International Statistics on Crime and Justice 2010

Terrorism: 150,000 attacks since 1970, attacks on cities on the rise

There were an estimated 150,000 domestic or international terrorist attacks from 1970-2015. Approximately 30,000 people lost their lives to terrorism in 2015, the majority of which in current war zones (Iraq/Syria and ISIS, Nigeria and Boko Haram, Afghanistan/Pakistan and the Taliban, Ukraine and ethnically Russian separatists/special forces) (source: Global Terrorism Database 2016, Start GTD, IEP 2016). 2016 was also the deadliest year ever for suicide bombings, with 469 attacks in 28 countries killing 5,650 people (source: Tel Aviv University's INSS 2017).

- **Cities are bearing the brunt of terrorist attacks. Berlin, Brussels, Nice, Orlando, and Paris all suffered major attacks in the last 18 months. EM cities are at greatest risk.** ISIL/Daesh carried out attacks in 252 different cities in 2015 (with 6,141 deaths) and Pakistan alone, with 429 different cities experiencing a terrorist attack in 2015 (vs. 17 in 2000) (source: IEP 2016).

Exhibit 88: Deaths from terrorism (2000-2015)



Source: START GTD, Institute for Economics and Peace (IEP) calculations 2016

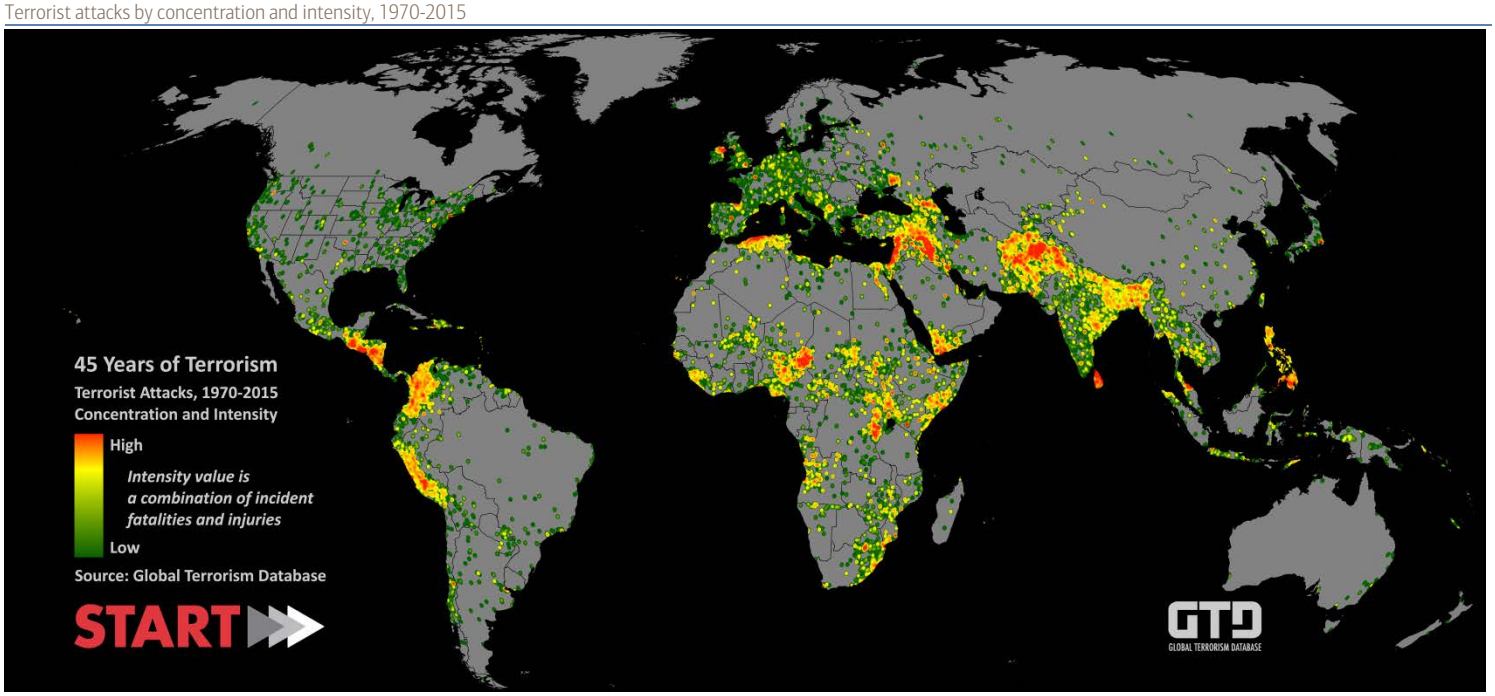
- **State power is progressively being weakened in some large cities**. Urban centres can harbour lawless enclaves that are exploited by criminals, terrorists,

militants, and bandits. In so-called feral cities such as Mogadishu, Caracas, Ciudad Juárez, and Raqqa, governments have lost their ability to govern or maintain the rule of law. In order to build up more resilience in cities, the UN launched the Strong Cities Network (SCN) in September 2015 (source: IEP 2016).

Terrorism cost the global economy US$86.6bn in 2015, which is 1% of the US$13.6tn in economic impacts of violence (source: IEP 2016).

Exhibit 89: 45 years of terrorism

Terrorist attacks by concentration and intensity, 1970-2015



Source: Global Terrorism Database

437,000 homicides take place every year, which is more than 13x the number of deaths from terrorism (source: IEP 2015).

Table 23: Number of Americans killed annually (at 2014)

Islamic jihadist immigrants	2
Far right-wing terrorists	5
All Islamic jihadist terrorists (including US citizens)	9
Armed toddlers	21
Lightning	31
Lawnmowers	69
Being hit by a bus	264
Falling out of bed	737
Being shot by another American	11,737

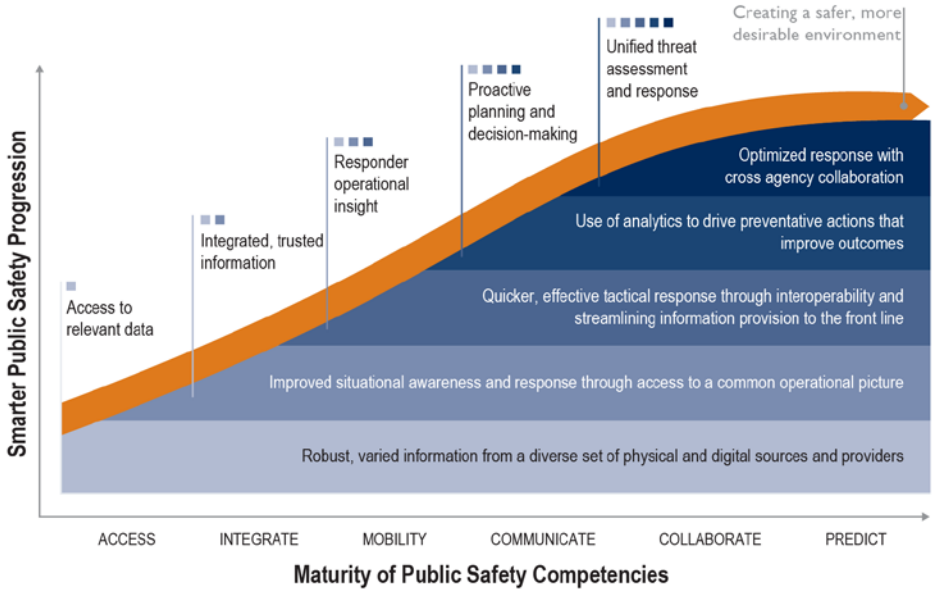
Source: Huffington Post based on various sources including CDC, NOAA, Security Data

Towards smarter public safety

While there is no definitive model for making cities safer, Smart Cities are integrating an increasing number of ICT-enabled measures which we explore further below – including CCTV, incident detection, crowd monitoring and control, adaptive lighting,

emergency alerts and notifications, environmental monitoring, disease surveillance and epidemic monitoring, and smart care and assisted living, among other areas.

Exhibit 90: A smarter approach to public safety



Source: IBM

Key elements of safe cities: ICT-enabled integration

Key elements that Smart Cities are acquiring as they move to smarter public safety and security include overcoming reliance on too many disparate systems and moving to an ICT-enabled integrated approach:

- **Big Data:** having access to relevant real-time data, integrating the data into trusted information bases, and delivering insights from the data to front-line officers and responders.
- **Integrated systems**: a shared infrastructure with common sensors connected by a shared network (vs. a disparate set of sensors with no interoperability).
- **Multi/inter-agency collaboration:** moving beyond shared infrastructure to sharing intelligence, operational procedures and planning to improve coordination and facilitating a unified threat assessment and response.
- **Situational awareness**: real-time information, with traffic data, sensor positions, resource locations, weather and other city intelligence.
- **Video data & analytics:** information collated from an array of city sensors and public and private databases combined with video analytics, licence plate recognition (LPR), biometric ID and recognition, behavioural analysis etc.
- **Automated processes**: all video feeds, event data and other sources such as social media are generated on one screen, alerts are registered, and the right operational procedure is generated.
- **Improved strategic and tactical decision-making:** anticipating problems and deploying appropriate resources to prevent them (source: Hitachi Insight Group, IBM, IFSEC Global).

Smart, safe city case studies

Charleston (South Carolina) worked with Verizon to find better ways to coordinate the efforts of its police:

- Teamed with Getac and IRSA to install systems in police cars that let officers quickly access police records.
- Helped Charleston connect to a consolidated dispatch centre that enables the police department to communicate more easily with law enforcement teams in various jurisdictions.
- Officers have greater access to current information that helps them increase situational awareness and handle events more quickly and safely.

Durham (North Carolina) worked with IBM to reduce the amount of violent crime in a two square mile region by over 50% from 2007-11:

- Based on historical data, they created an intelligent database, where they could access and visualize data that established relationships across people, places and other entities.
- The project uses data to pinpoint true trouble spots, and then uses targeted policing and community outreach to address the root causes.

San Francisco worked with GE and ShotSpotter on intelligent street lights to detect gunfire and alert authorities and reduced gun crime by 50%:

- The technology listens for gunfire, and its real-time analysis can pinpoint the location of the shots, notifying emergency dispatchers and officers in the area in less than a minute (source: companies).

FirstNet is Congress mandated initiative to build a US wireless broadband network exclusively for use by emergency first responders with AT&T as build out partner

- Congress has allocated $7bn to jump-start construction of the network.

Smart Cities will also pose their own set of security challenges

While we are positive on Smart Cities' ability to improve safety and security, they also pose new challenges including: a large and complex attack surface (more systems and "systems of systems", fast-evolving technological transformation), insufficient oversight and organisation (complex systems needing stronger management and governance), and political impacts (oversight function for safety and security coordination) (source: Securing Smart Cities).

Case study on how Smart City technology could make US military bases safer and more secure via technologies such as AI, the IoT, machine automation and robotics, and data analysis, to name a few:

- **Smart military bases' networked cameras and license plate recognition sensors** can single out new visitors and direct them to entry gates with tighter security.

- **The Army's smart energy program has reduced costs by nearly US$150mn**.

- **A geothermal power plant at a Navy weapons station in California contributes c1.5mn MWh** of electricity to the grid each year.

- **Army and Navy bases in Georgia recently opened smart energy solar plants** that allow them to operate independent of the local power grid, a critical capability in an emergency.

- **Fort Bragg is experimenting with autonomous vehicles** to transport wounded soldiers across base to rehab appointments.

- **Additive manufacturing technology**, like the Navy's Print the Fleet project, allows bases to use 3-D printing for quicker and cost-effective repair and replacement parts that can be produced on site (source: Ted Johnson, retired commander in the US Navy where he focused on cyber policy and operations, defense and national security research manager at Deloitte's Center for Government Insights, Wired 2017)

Rise of cyber threat: most cities are unprotected

Smart City infrastructures develop faster than security tools, leaving ample room for the activities of both curious researchers and cybercriminals (source: Securing Smart Cities). Insecurities around the IoT in cities and Smart Cities – including billions of connected devices and associated services, sensors, public data, mobile apps, servers, cloud infrastructure, city management systems, ICT-enabled terminals and payment systems etc. – are already being exploited in ways that affect safety. The technological and operational interdependencies that exist in cities mean that attacks can cascade quickly. In our view, it is only a matter of time before attacks on city services and infrastructure become commonplace.

Cyberattacks are the #1 source of economic assaults against governments, and the #1 source of IP theft for corporates. Cybercrime extracts up to 20% of the value created by the internet, meaning that as much as US$3tn of the global economic value could be at risk by 2020E.

The city San Diego (USA) experiences an average of 1mn cyberattacks per day (7.4 per resident) via its 11,000 employees, 24 networks, and 40,000+ endpoints (source: Gary Hayslip, CISO for the City of San Diego).

"Squirrel threat" to Smart City critical infrastructure: Squirrels, birds, rats and snakes have been responsible for more than 1,700 power cuts affecting c5mn people with squirrels topping the list with 879 "attacks",

mostly on power cables (source: Cyber Squirrel 1 2017).

Rise in attacks against Smart City elements: connected cars to utilities

The last 12-24 months have seen multiple, major attacks against many elements of Smart Cities including CCTV cameras, smart meters (Puerto Rico), power grids (Ukraine), connected cars (FiatChrysler, Tesla), traffic lights and signs, track switching (San Francisco), public utilities (Ontario), and major corporates. The cyber threat is exacerbated by the increasingly complex attack surface, lax encryption and access control, sensors being hacked and fed fake data, vulnerable legacy systems, cyber skills shortages, lack of security testing, lack of effective oversight and organisation, lack of an effective response plan, constrained budgets, and government bureaucracy.

There are >200,000 vulnerable traffic control sensors installed in cities across the world, including New York, Washington D.C., and London (source: Cesar Cerrudo, CTO of IOActive)

Cyber threats: cyber criminals, cyber activists, nation states

There is no shortage of potential "bad guys" when it comes to cyberattacks, but the Control Risks Group identifies three key cyber threat actors:

- **Cyber criminals**: Criminal actors are looking to create or purchase and deploy self-propagating malware. These "worms" can acquire easily commoditised and highly profitable information (e.g. healthcare information, social security numbers and banking credentials). If they are able to highjack ICT systems, they could use them for extremely powerful distributed denial of service (DDoS) attacks on grids or to hold an entire city to ransom in extortion attacks.

- **Cyber activists**: As cyber activist groups grow increasingly capable and, in some cases, more radical, Smart Cities will provide them with an attack surface enabling graffiti-like attacks on billboards through to targeting grids. Many cyber activist groups are also supporting physical protesters by launching cyberattacks.

- **Nation states**: The underlying network of Smart Cities will encompass most aspects of city life, and compromising the network would give them unfettered access to a target individual or organisation. Private sector firms and their executives and IP are attractive targets for state-owned competitors and actors – and the sharing of data with Smart Cities exacerbates this threat. Beyond traditional espionage operations, the large-scale destruction or disruption of physical infrastructure via ICT systems could become a technical reality with the advent of Smart Cities (source: Control Risks Group).

Cyber-physical threats to Smart Cities = new risks to public & national security

According to the US Department of Homeland Security (DHS), Smart Cities and the implementation of cyber-physical systems into critical infrastructure networks introduce a new set of risks to public safety and, potentially, national security. Historically, cyber and physical systems have operated fairly independently of one another, but today cyber-physical infrastructure directly links or integrates both domains. In addition to physical incidents creating physical consequences, exploited cyber vulnerabilities can have physical consequences (source: DHS 2015).

Greater connectivity is expanding the potential attack surface for malicious actors: the interconnectedness of devices introduces cyber-physical technologies that connect cyber systems to physical systems, thereby removing the barrier between the cyber and physical worlds (source: DHS 2015).

- **Electricity**: Smart power generation, plants, smart T&D, and advanced metering infrastructure (AMI) are creating challenges: advances in bottom-up innovation and distributed generation technology are complicating how utilities operate, smart technologies are increasing networking and automation of generation, and smart grids are introducing a large number of hard-to-secure physical devices with networked connectivity and expanding the attack surface.

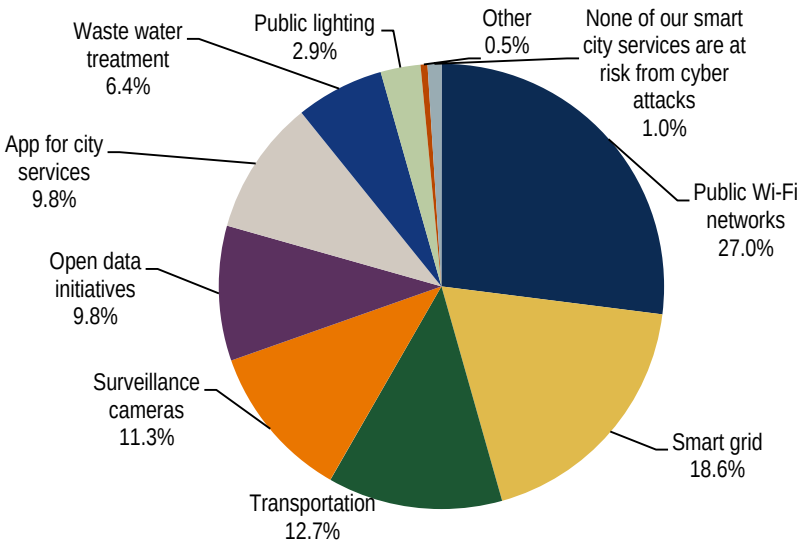
- **Transportation**: Autonomous vehicles, positive train control, intelligent transportation systems, and vehicle-to-vehicle and vehicle-to-infrastructure are creating challenges – the sheer scale and complexity of transportation networks, the large number of system access points, the burden of ensuring smooth interface/ communication/security among multiple independent systems, demand for non-stop access to real-time data, and the logistical and security hurdles of physically accommodating large volumes of passengers and freight.

- **Waste and Water**: Smart water treatment, smart water distribution, and smart water storage are creating challenges – the difficulty of securing cyber-physical technology onto existing ageing physical infrastructure, the complexity of ensuring smooth interface/communication/security among multiple independent systems, and the isolated or hard-to-access locations of certain water infrastructure (source: DHS 2015).

Smart grids are seen as most exposed to cyber risks

Smart grids are seen as most exposed to cyber risks, according to 38% of 200 professionals working for state and local governments surveyed by cybersecurity solutions provider Tripwire in 2016. 26% considered transportation to be more vulnerable. Other services include surveillance cameras, wastewater treatment, etc. Eighty-eight percent of respondents said “yes” when asked if a cyberattack targeting critical city infrastructure posed a threat to public safety.

Chart 48: Which Smart City services are most at risk from cyberattacks?



Source: Tripwire 2016

Smart Cities have no cybersecurity say 98% of government IT professionals

Ninety-eight percent of IT professionals see Smart Cities as having no protection from cyberattacks and 55% blame the cities for not focusing on cybersecurity resources. Cybersecurity is being left out of the conversation, with 61% citing budgets as the reason and 60% political interference (source: Tripwire 2016).

Cities are taking action: securing Smart Cities

Cities are beginning to collaborate to take action including the 2014 creation of Securing Smart Cities, a global non-profit initiative established by IOActive, Kaspersky Lab, Bastille, and the Cloud Security Alliance, with the purpose of better defining the security challenges of Smart Cities and finding workable solutions. Individual cities are also moving, such as Los Angeles Mayor Eric Garcetti's Executive Order creating a Cyber Intrusion Command Center to lead cybersecurity preparation and response efforts across city departments.

Cyber opportunities for cities: zero percent employment & high salaries

As we discussed in our Cybersecurity Primer, the world is facing a major cyber workforce shortage with an estimated 1mn job openings in 2016. By 2019E, the demand for cybersecurity professionals is expected to increase to 6mn globally with the shortage of trained professionals projected to be 25% of 1.5mn jobs unfilled (source: Cybersecurity Business Report, Palo Alto Research Center). With cybersecurity unemployment dropping to zero percent in major markets, cities need to step up their efforts to attract and retain such highly paid talent, which has important positive economic benefits for cities.

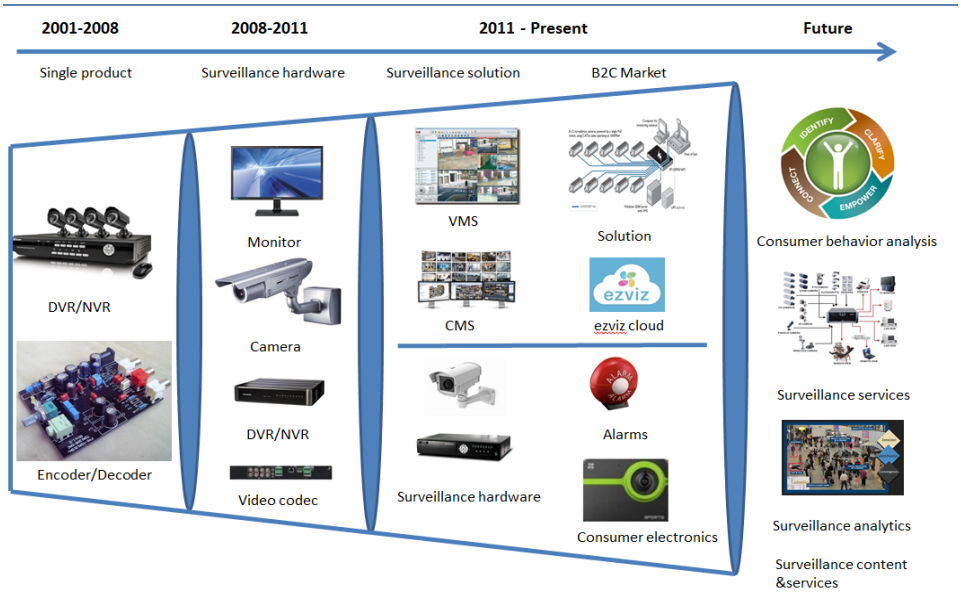
Cities need to win the battle for high-paying cybersecurity jobs with cyber specialists in San Francisco topping the unadjusted annual salary list at US$149,744. In the adjusted annual salary category, specialists in Minneapolis were on top with US$127,757 (source: Tech Republic)

More than CCTV: smart video and analytics to drive US$71bn mkt by 2022E

Surveillance using closed-circuit television (CCTV) – the use of video cameras to transmit a signal to a specific place – is a common safety and security strategy in many parts of the world with an estimated 350mn surveillance cameras installed worldwide as of 2016 (source: IHS). The cameras are used for crime prevention, industry, traffic monitoring, transport safety, sporting events, monitoring employees, schools, and home security, among other uses. Nextgen CCTV is seeing rapid growth off the back of ICT integration, although CCTV continues to generate significant debate about balancing its use with individuals' right to privacy even when in public.

The aim of Smart Cities is to provide shared security presence and real-time surveillance with the use of video cameras. The cameras collect data in image or video format which may be monitored from a central location, and allow first responders to act instantly in an emergency situation (source: EY).

Exhibit 91: Transformation of Hikvision's surveillance business – from single product to ICT-enabled surveillance solutions



Source: Company data and BofA Merrill Lynch Global Research

Video surveillance camera base: c.350mn cameras in 2016

The worldwide installed base of video surveillance cameras continues to rise, but the rate of increase is slowing according to IHS. The highest increase from 2015 to 2016 was in HD CCTV at +85.3%, while the lowest was in analogue cameras at +2%. 65% of cameras were installed in Asia. Among the leading vendors are Hikvision and Hanwha Techwin (ex-Samsung Techwin), while Axis Communications is the leading network camera vendor by installed base (source: ISH 2016).

Table 24: Global surveillance camera installed base by product type (000s, y-o-y growth)

	2012	2013	2014	2015	2016	Diff
Network Cameras	19,316.9	31,794.7	51,606.1	80,156.7	117,812.1	98,495.2
		64.6%	62.3%	55.3%	47.0%	
Analog Cameras	137,230.0	164,888.5	187,668.4	204,641.0	208,736.5	71,506.5
		20.2%	13.8%	9.0%	2.0%	
HD CCTV	243.3	1,416.0	5,267.5	12,572.1	23,299.4	23,056.1
		482.0%	272.0%	138.07%	85.3%	
Total	156,790.2	198,099.2	244,542.0	297,369.9	349,848.1	193,057.8
		26.3%	23.4%	21.6%	17.6%	

Table 24: Global surveillance camera installed base by product type (000s, y-o-y growth)

Source: IHS 2016

US$71.3bn video surveillance market by 2022E: 16.6% 2016-22E CAGR

The total video surveillance market is expected to reach US$71.3bn by 2022E, at an estimated CAGR of 16.6% between 2016 and 2022E. The market for the commercial sector as well as the APAC region is expected to see the fastest growth (source: MarketsandMarkets 2016). While demand for equipment is likely to continue growing rapidly in 2017, price competition will remain intense and competition will not make it easy for vendors to grow revenues and margins (source: IHS Markit). The global market is highly diversified, with the top 15 vendors accounting for only 55% of the global market (source: Hikvision).

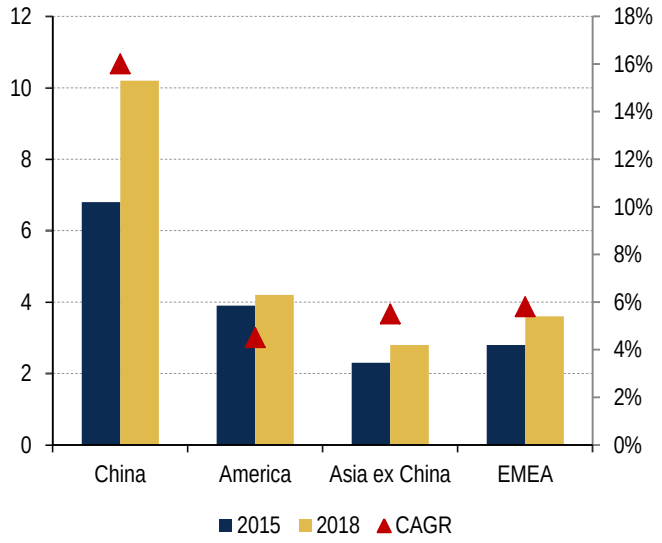
Key video surveillance drivers for the near term include:

- **Video surveillance cybersecurity**
- **Deep learning/AI** revolution
- **Body-worn cameras and live streaming**
- **Security drones** (set to take off)
- **The evolution of video management system** (VMS) user interfaces
- **HD CCTV in China**
- **Diversification by Chinese vendors** (source: IHS Markit)

Solid surveillance demand outlook in China: 15%+ revenue CAGR

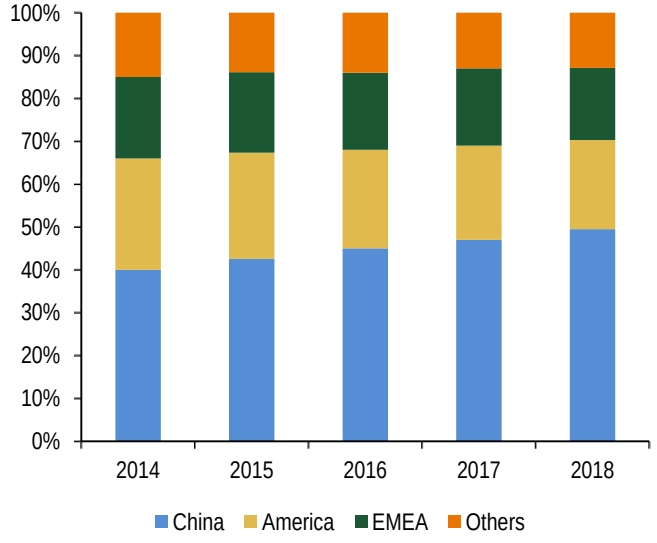
Our APAC Tech Hardware team expects Hikvision, the surveillance market leader in China, with about 20% share, to be the main beneficiary of the country's booming surveillance demand (market revenue CAGR (2016-18E) of 15%+, outstripping the global rate of 10%). China's surveillance TAM is expected to reach US$10bn by 2018 (45%+ of global TAM) from US$5.7bn in 2014 (40% of global TAM).

Chart 49: Surveillance market forecast by region – China to outperform



Source: IHS and BofA Merrill Lynch Global Research estimates

Chart 50: Surveillance market breakdown by region – China the biggest



Source: IHS and BofA Merrill Lynch Global Research estimates

Software and cloud-based services: key growth drivers

The software and service segment is expected to lead the growth of the video surveillance market.

- **US$3.4bn cloud services and video surveillance as a service (VSaaS) market by 2021E** (source: Technavio 2017). Hosted cloud-based video surveillance is playing an increasingly important role in the video surveillance system. Commercial and retail are expected to see rapid growth. Advantages include real-time alerts to call attention to events, content-based indexing, advanced facial recognition/people search, cost efficiency, and increased system performance.

- **Software components include video analytics and video management software**. Analytics is the capability of automatically analysing videos to detect certain objects, behaviour, spatial and temporal events (source: EY). IFSEC's 2016 survey of security professionals showed that 54% regard video analytics as one of the most important features of their video security needs. Heat mapping was the most sought-after analytics tool followed by crowd density, people counting, automatic number plate recognition, people-tracking and facial recognition (source: IFSEC Global). Systems are also increasingly using AI/deep learning via the use of neural networks and algorithms in the biometric surveillance system.

Home surveillance - See Smart Home section.

Too many cameras useless: need to avoid sleepwalking into surveillance society

The UK government's surveillance commissioner is on record as stating that too many surveillance cameras are useless. He has advocated cities carrying out annual reviews of their CCTV capacity (i.e. ineffective cameras, redundant cameras, those situated in the wrong place, damaged, analogue), and called for greater public debate and regulation to ensure cameras do not proliferate unnecessarily. The connected nature of smart CCTV also raises cybersecurity concerns, with multiple instances of hacking in 2015 and 2016.

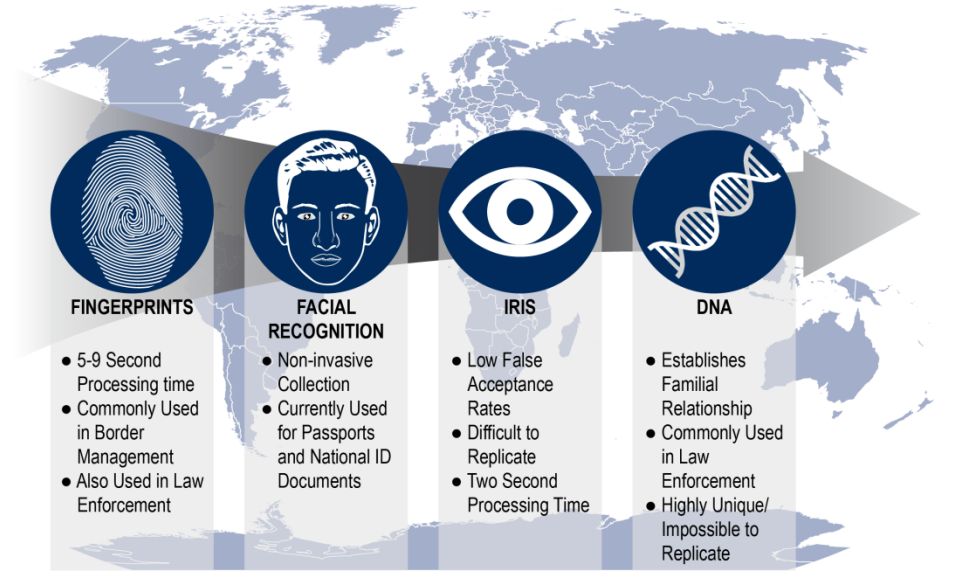
> **"You can still maintain the balance of excellent surveillance but not have a propagation of surveillance that is actually useless.** Surveillance can be an extremely good thing and run well, it's a useful tool for society.

But to quote a former information commissioner, 'we should not sleepwalk into a surveillance society'." – Tony Porter, UK Surveillance Camera Commissioner

Biometric verification & ID: US$41.5bn market by 2020E

We believe that Smart Cities will make growing use of biometric verification – which is any means by which a person can be uniquely identified by evaluating one or more distinguishing biological traits (i.e. fingerprints, hand geometry, earlobe geometry, retina and iris patterns, voice waves, DNA, signatures et. al.). Smartphones have been the mainstream gateway with c.1bn biometric smartphones in use today and 100% penetration by 2022E (source: Acuity Market Research). There is wide-scale take-up by governments (i.e. voting, ePassports, drivers' licences, IDs, passenger screening, border management etc.), but there is scope for applications across sectors given the potential improvements in accuracy, convenience, and safety. But like smart CCTV, biometrics pose privacy and cybersecurity concerns.

Exhibit 92: Biometrics offer Smart Cities multiple advantages



Source: Washington University in St Louis

Smart City residents will experience multiple benefits from biometrics:

- Unique individual ID that is 100% accurate & difficult to forge
- Identifiers that are always with you
- The end of passwords
- Subtle, discreet and convenient passenger screening
- More convenient and secure ATMs, banking and payments
- Lower healthcare fraud

Biometrics will be key to Smart Cities: securing them & Big Data

Biometrics will play a growing role in Smart Cities, in our view, including:

- **Securing the IoT ecosystem which lies at the heart of Smart Cities**. Biometrics offer the ease and convenience users want and the verification that enterprises and manufacturers require for IoT, because it is able to verify the true identity of the

user of the application. From smart homes, to cars, banking, and healthcare, there will be a growing number of applications in multiple industries (source: bioconnect).

- **Biometric data is set to become "gold dust" for Smart City planners**. Biometric data will increase understanding of individuals, in terms of how they relate to a city and how they perform themselves as kind of human machines, but also how they react with their physical environment (source: Accenture Intelligent Cities Initiative).

US$15bn market today, growing to US$41.5bn by 2020E

The global biometrics market is expected to record a 22.7% CAGR from 2015 to 2020E, taking it to US$41.5bn (source: BCC Research).

- **North America is currently the largest market but APAC is expected to grow fastest** at a 22% CAGR over the same period (source: Allied Market Research).
- **Automated fingerprint identification systems and fingerprint technologies dominate the market**, and are expected to continue to do so, growing to US$24.4bn in 2020E (vs. US$8.8bn in 2015) (source: BCC Research).
- **Face, iris, vein and voice recognition are seeing the fastest growth** at a 23% 2015-20E CAGR and should reach US$11.9bn by 2020E (vs. US$4.2bn in 2015 (source: BCC Research).

Security services: Smart Cities technology is a double-edged sword

The security services market continues to grow largely on the back of urbanisation, with: traditional guarding growing in line with GDP; rapid growth of technology-driven security solutions in DMs; customers looking for complete, cost-efficient security solutions; and the increasing complexity and scale of customers' security requirements (source: Securitas). Smart Cities are, however, a double-edged sword for the industry, with safety and security one of the primary concerns of urban residents. Meanwhile disruptive technology is threatening to disintermediate certain parts of the value chain, such as human security guards and guarding services.

> **"Due to the high rate of technological development, the security industry is in a state of fundamental change**. Improved connectivity between hardware, software and people is creating growth opportunities in the form of better infrastructure." (source: Securitas)

US$240bn market for security services by 2020E: EM growth, DM volumes

Worldwide demand for security services will reach US$240bn in 2020E (source: Freedonia 2017). Guarding services represent the majority of all revenues, although the growing availability of lower-cost alarms will support rising market penetration of alarm monitoring services. Security integration and consulting will post the fastest gains. Major actors in the space include Allied Barton, G4S, Prosegur, and Securitas.

EMs seeing fastest growth with "ChIndia" doubling: DMs have largest contracts

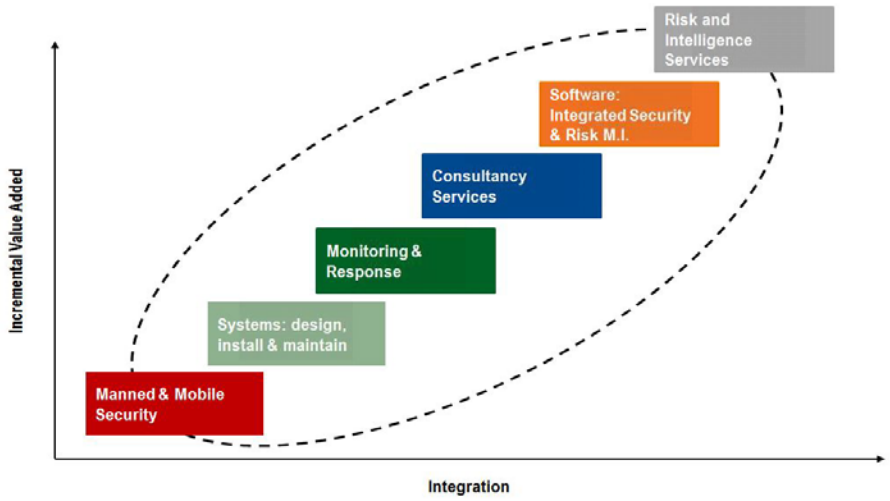
The predominantly mature security markets in North America and Europe are growing at the same pace as GDP, while growth rates in EMs in Latin America, Africa, the Middle East and Asia still tend to outpace GDP (source: Securitas). China and India will exhibit the fastest national gains through 2020E, with revenues in both countries roughly doubling in size (source: Freedonia). While growth is generally higher in EMs, volumes and large contracts are still limited to relatively mature markets (source: Securitas).

The proliferation of technologically advanced security systems will have a mixed effect on demand for security services in DM markets. The increasing complexity and interoperability of these systems will fuel greater need for monitoring, systems integration, and security consulting services. However, these security systems functionally compete with basic manned security personnel (source: Freedonia 2017).

Technology to drive electronic security growth: US$16bn mkt in US by 2019E

Demand for electronic security products is being driven by Smart City-related technological advances. Networked, IP-connected systems that provide inter-operability between various electronic security systems and building automation systems continue to promote growth of higher-value devices. New builds and perceptions of crime are also driving an industry shift towards: digital, IP-capable video surveillance systems; the incorporation of video analytics software at the OEM level; the use of mobile and other offsite monitoring; and Cloud-based storage. Interoperability as well as innovations in mobile monitoring will boost consumer demand for alarms, personal emergency responsive service alarm (PERS), and home automation more broadly. US demand for electronic security products is projected to rise 7.0% annually through 2019E to US$16.2bn (source: Freedonia 2015).

Exhibit 93: Integrated security solutions offering greater value added

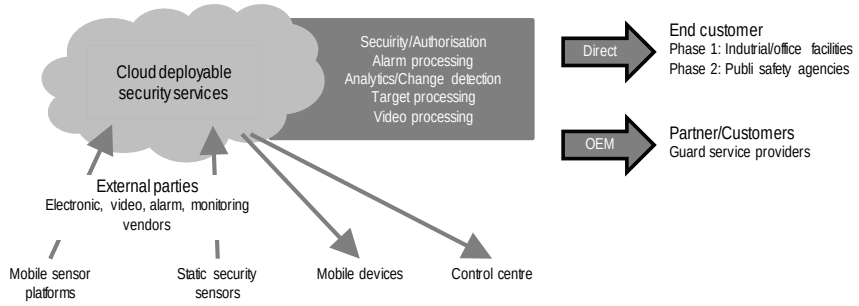


Source: G4S

New competitors entering the field: cloud-deployable services

A raft of new competitors is entering the security space. These are in a position to disrupt a market that has hitherto relied very much on bodies (i.e. security guards) and static sensors (ie traditional security systems). For instance, our EMEA Capital Goods team has focused on the growing business of Hexagon, which is approaching the market with partners (e.g. Microsoft Azure cloud capabilities).

Exhibit 94: The Hexagon approach to security industry



Source: BofA Merrill Lynch Global Research, company data

Long robots, short humans: robots may replace human guards

Robo-security may have a significant impact on the market for security guard services in the coming years, in our view. As in all industries, robotic systems are well suited to jobs that are dangerous, dull or repetitive – which can characterise certain aspects of the security services value chain. Robo-security guards exist today and are being rented out for as little as US$7/hour or US$60,000 per year (source: Knightscope).

- **Knightscope has launched a 136kg (300lb) robot security guard** for residential and commercial premises, which it calls an Autonomous Data Machine (ADM). The 152cm (60 inch) tall and 91cm (30 inch) wide robot can travel up to 29km/h (18mph) and uses 360° video cameras, 16 microphones, thermal imaging, LIDAR and 30 sensors to gather real-time data from sites, which it transmits back to security professionals to monitor. Each robot generates >90 terabytes of data per machine, every year, operates on wireless or cellular networks, and can be remotely monitored. After patrolling for a couple of hours, it can autonomously find and dock itself to a charge pad for 10-20 minutes.

Exhibit 95: Knightscope K5

Source: Knightscope.com

Security drones could be a game changer: US$11bn addressable market today

Both human and robot security guards could face growing competition from security drones, in our view, because of their speed, size, manoeuvrability, coverage, and ability to stay beyond the reach of people on the ground. PwC put the potential addressable market for security drones at US$10.5bn annually in 2016, or 8% of the total US$127.3bn addressable drone market. Drones are already being used in cities to

document accidents, monitor sites, and support first responders. In time, millions of connected drones could be navigating autonomously in Smart Cities.

Flying city services: competitive edge over alternative security services

Drones have a competitive edge over security alternatives such as stationary cameras, as intruders cannot easily step out of sight, and they can cover areas that are normally out of reach. They will create systems enabling mass surveillance, where potential threats can be identified and data is immediately transmitted to response teams (source: PwC).

- **Monitoring lines and sites:** Drones can monitor roads and highways, rail, traffic, pollution, environmental hazards, coasts and borders, as well as sites. They are also expanding beyond monitoring to ensuring the safety of critical infrastructure (buildings, roads, bridges etc.), and monitoring and assessing the scale of accidents and repairs (source: PwC).

Exhibit 96: In 2016, Nokia and United Arab Emirates GCAA entered into a strategic partnership for a drone traffic management system

Source: Nokia

- **In the future, data gathered by drones will be instantly processed in the cloud, providing complete scene recognition** supplementing human supervision. Thanks to machine-learning software, drones will not only recognise unauthorised entry to a site, but also identify precisely who the intruder is, thanks to motion sensing and biometrics-based behaviour analysis, as well as facial recognition (source: PwC).

Increasing number of companies involved: home security, first responders, etc

Big aerospace and defence was an early mover in security drones including Boeing, General Dynamics, Kratos, and Lockheed Martin. However, a number of other companies are innovating in the security drone space such as: Aerovironment's Qube drone designed as a quick tool to deploy for law enforcement and first responders; Alarm.com and Qualcomm partnering to develop home security drones; and Sunflower Labs' new security system that uses a drone combined with smart lights and sensors to detect and investigate possible threats outside the home, which it live streams to a smartphone.

Exhibit 97: Combined with smart lights and sensors, drones analyse suspicious activity and stream a video directly to your smartphone

Source: SunFlower Labs

Airports 4.0: US$11bn security screening market by 2022E

Smart Cities cannot exist without smart, secure airports that fully exploit the power of new technologies, including sensors, processors, mobile apps, gamification and behavioural analytics (source: Comarch). An increased focus on security will be critical given the anticipated near doubling of airline passengers from 2016 to 2035E (source: IATA). Many of the elements we discuss in this report (including automation, biometrics, and mobile app solutions) are needed to address growing safety threats.

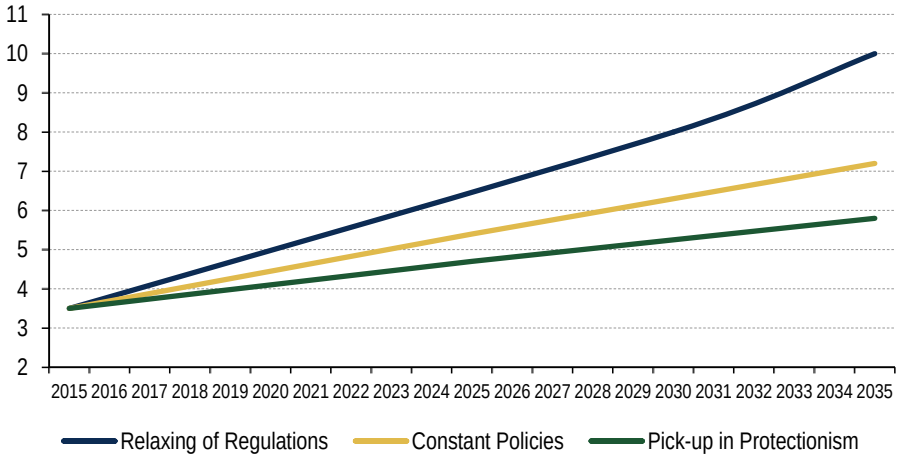
Near doubling of air travel worldwide: 7.2bn passengers by 2035E

The International Air Transport Association (IATA) expects 7.2bn passengers to travel in 2035E, a near doubling of the 3.8bn air travellers in 2016 (3.7% CAGR).

The fastest-growing markets in terms of additional passengers per year to 2035E are expected to be China (+817mn to 1.3bn), US (+484mn to 1.1bn), and India (+322mn to 442mn) (source: IATA 2016).

Chart 51: IATA expects 7.2bn passengers to travel in 2035E (3.7% 2015-2035 CAGR)

But increased trade protectionism has potential to damage growth prospects



Source: IATA 2016

Airport ecosystems are key to economic development

Cities worldwide are realising how airports and strong transportation infrastructure assets have an economic multiplier impact on the cities and regions they serve. As a result, many major cities which top the Smart City rankings are served by more than one airport, typically to avoid congestion, and where there may be factors preventing expansion to existing airports. In other cities, multiple airports may be built to cater for specific uses, such as between international and domestic flights.

- **New York metropolitan area has 7 airports within 125km (78 miles of the city)**: JFK, LaGuardia, Long Island MacArthur, Newark Liberty, Stewart International, Trenton-Mercer, Westchester County.

- **Greater London has 6 airports within 69km (48 miles) of the city**: London City, Gatwick, Heathrow, Luton, Stansted, Southend.

Table 25: World's busiest airports (total passenger traffic, 2015)

			Passengers	
Rank 2015	Rank 2014	Airport City / Country / Code	(Enplaning and deplaning)	Percent change
1	1	ATLANTA GA,US (ATL)	101,491,106	5.5
2	2	BEIJING, CN (PEK)	89,938,628	4.4
3	6	DUBAI, AE (DXB)	78,010,265	10.7
4	7	CHICAGO IL, US (ORD)	76,949,504	9.8
5	4	TOKYO, JP (HND)	75,316,718	304
6	3	LONDON, GB (LHR)	74,989,795	2.2
7	5	LOS ANGELES CA, US (LAX)	74,937,004	6.1
8	10	HONGKONG, HK (HKG)	68,283,407	8.2
9	8	PARIS, FR (CDG)	65,766,986	3.1
10	9	DALLAS/FORT WORTH TX, US (DFW)	64,072,468	0.9
11	13	ISTANBUL, TR (1ST)	61,836,781	9.2
12	11	FRANKFURT, DE (FRA)	61,032,022	2.5
13	19	SHANGHAI, CN (PVG)	60,053,387	16.3
14	14	AMSTERDAM, NL (AMS)	58,284,864	6
15	18	NEWYORKNY, US (JFK)	56,827,154	6.8
16	16	SINGAPORE, SG (SIN)	55,449,000	2.5
17	15	GUANGZHOU, CN (CAN)	55,201,915	0.8
18	12	JAKARTA, ID (CGK)	54,053,905	-5.5
19	17	DENVERCO, US (DEN)	54,014,502	1.0
20	22	BANGKOK, TH (BKK)	52,902,110	14.0

Source: Airports Council International (ACI) 2016

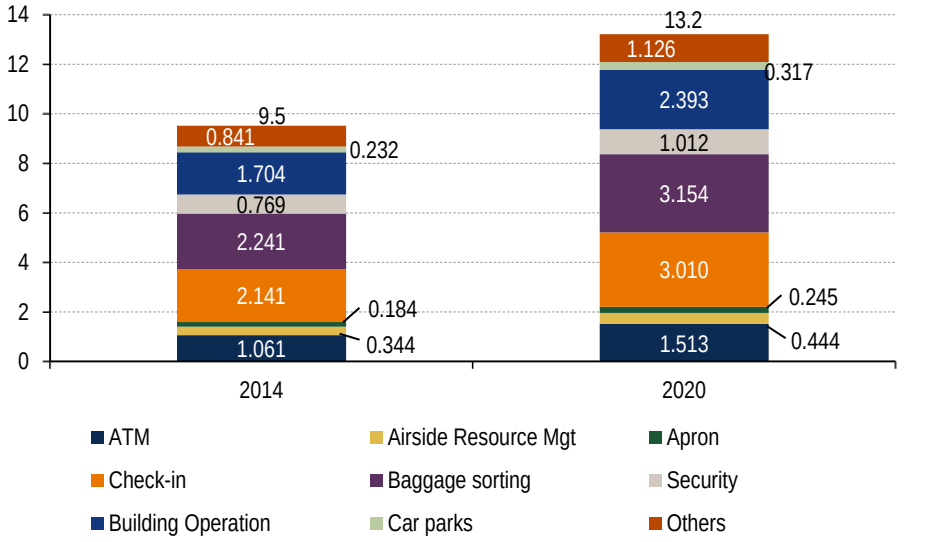
Good airline service is key to economic development

The economic impacts of airports on cities are significant, encompassing everything from time-sensitive manufacturing and distribution, to hotel, entertainment, retail, convention, trade and exhibition complexes, right through to office buildings. Economists have reached a general consensus that airports do share a relationship with economic development. Richard Green finds associations between airport passengers and both the metro population and employment growth, while Jan Brueckner notes a close connection between airline passengers and regional employment growth (10% increase in passengers generates a 1% increase in regional employment). Knowledge and service-based businesses are thought to be particular beneficiaries.

Smart airport spending: US$13bn by 2020E including US$1bn+ on security

Airports' smart spending – ie into digital-based solutions – should grow by c.40% to 2020, with the objective of better customer experience and improved, safer operations (source: Arthur D. Little 2015).

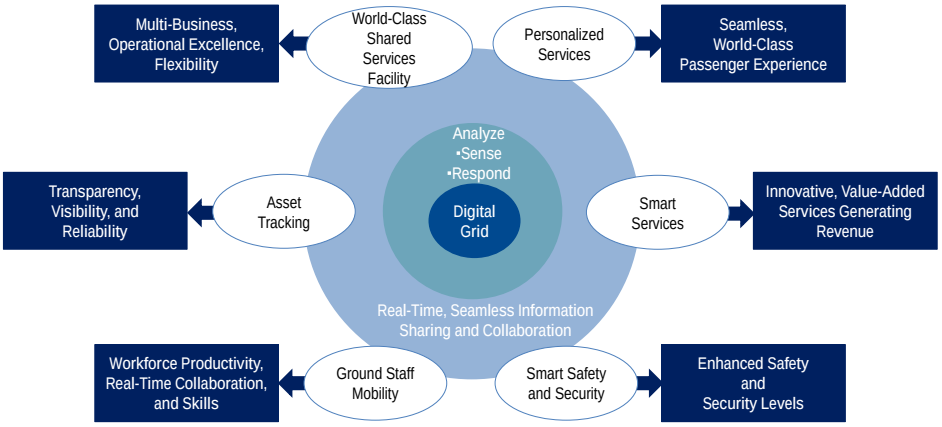
Chart 52: Smart airport spending to grow at 39% CAGR from 2014 to 2020E (US$bn)



Source: Arthur D. Little 2015

Airport 3.0 comprises "smart airports" that fully exploit the power of technology with advanced and pervasively deployed sense-analyse-respond capabilities. Systems are built around a "digital grid" which enables the exchange of real-time information, deep cross-silo collaboration, and airport-wide process integration – and significantly improves operational efficiencies, passenger services, and advanced security capabilities (source: Cisco).

Exhibit 98: Airports 3.0: smart airport vision



Source: Cisco

Passenger screening market: Terrorism #1 driver, US$11bn market by 2022E

Terrorism remains the #1 driver, sustaining the global passenger screening market, which is expected to grow from US1.74bn in 2016 to US$11bn by 2022E on the strength of futuristic products, as well as system maintenance and upgrades (source: Frost & Sullivan 2016).

- **North America remains the largest market, accounting for 35% of market spend** – while the top 5 passenger screening market participants contributed over 80% of total market revenue in 2015.
- **Key company actors in the space include** L-3 Communications, Morpho Detection, Rapiscan, and Smiths Detection (source: Frost & Sullivan 2016).

The Australian government has a goal of automating 90% of air traveller processing by 2020E. Passengers will soon be processed by biometric recognition of their faces, irises or fingerprints.

In July 2016, the TSA and American Airlines collaborated on a joint initiative on new passenger and baggage screening technology, including computed tomography (CT) scanners and automated security screening lanes at selected domestic and international airports in the US (source: Technavio)

Digital technologies are becoming the main focus

Digital technologies are becoming the main focus of efforts to strike a balance between security and efficiency. These include:

- **Rapid growth for advanced imaging systems or whole/full body imaging systems**. These advanced systems – e.g. millimetre wave technology – can spot non-metallic objects and explosives that could not be detected by security personnel using the current hand-held or walk-through metal detectors (source: Technavio 2016).
- **Additional digital screening technologies and mechanisms** such as automated passport control (APC) kiosks, automated border control (ABC) or eGates, and mobile passport apps.

- **Implementation of biometric technologies** in a variety of commercial markets for use at checkpoints and border control stations. Apps that make use of biometrics have significant potential as screening devices.

- **Service providers that can ensure quick parts replacement** during maintenance checks given growing and challenging passenger rates vis-à-vis screening systems (source: Frost & Sullivan 2016).

Big picture predictions for passenger screening:

- It will evolve into a subtle process whereby travellers are unaware they are being screened.
- Pre-screening will become a normal part of travel planning and will take place at the point of sale.
- Unique physical features will be used as identity factors for passenger screening (source: Frost & Sullivan 2016)

Smart Homes: home is where the smart is

A Smart Home is defined as one equipped with network-connected "smart devices" for controlling, automating and optimising household functions from lighting to heating and cooling to entertainment to safety. Demand for smart homes is being driven by the convergence of four broad themes in the home: (1) safety and security; (2) energy efficiency; (3) health & wellness; and (4) convenience, entertainment and connectivity.

Smart Homes look set to become a mainstream consumer trend and 2020E is set to be the inflection point for large-scale uptake, in our view. The raft of smart home products and launches at CES 2017 (Consumer Electronics Show) showed how smart homes are becoming increasingly popular. However, only 28% of Americans (close to 50% for Gen Y) have this technology in their home today (source: Coldwell Banker). The number of Smart Homes is expected to double in North America and treble in Europe between 2016 and 2019. Fifty percent of North American households are expected to own at least one Smart Home device by 2020 (source: Deutsche Telecom, Strategy Analytics). There could be more than 500 connected devices per Smart Home by 2022 vs 8.6 in 2015 and 2.4 in 2008 (source: Gartner).

The average cost of Smart Home features for US homeowners is US$1,268 with most homeowners spending between US$564-2,260, and the high end of spend estimated around US$4,500 (source: HomeAdviser 2017). However, the overall cost of outfitting a Smart Home is falling dramatically (e.g. Amazon Echo US$179/Echo Dot US49, Nest Thermostat US$249/smoke and CO detector US$99/camera US$99 et. al.) (source: company, Amazon.com).

The global market for Smart Homes is projected to grow to US$405bn by 2030E, at a 25% CAGR from US$14bn in 2015. All regions are forecast to develop rapidly but the fastest pace is expected Asia at a 27% CAGR, followed by Europe and North America at 24% (source; AT Kearney). Our APAC Telecoms team estimates that the Smart Home market in Singapore alone (a leader in the Smart City space and known as a "Smart Nation") could be worth S$694mn by 2025E – a S$2bn-plus greenfield revenue opportunity for telcos. By 2030E, Asia is expected to be the largest Smart Home market (US$116bn), overtaking both North America (US$113bn) and Europe (US$102bn) (source: AT Kearney).

A "Big 4" group of companies is pulling away from the pack on Smart Homes (Alphabet, Amazon, Apple and Samsung) based on these companies' product development, breadth of device partnerships, success of their adopted business model, level of innovation, and marrying the software/hardware aspect of the smart home with close third-party partnerships (source: Juniper Research). We believe that the "owners" of the smart hub in homes could be major beneficiaries of consumers pending going forward. But that said, an increasing number of companies across multiple sectors – including capital goods, consumer durables and retail – are competing across multiple verticals in the fight for the Smart Home.

"Convenience and comfort" is the largest Smart Home vertical and is expected to grow to US$188bn by 2030E (vs. US$9bn in 2015). This category encompasses the majority of everyday home appliances and devices. Security is, and will remain, the #2 vertical. Overall, all segments of the Smart Home are expected to grow quickly in 2015-30E. Health & Wellness (31% CAGR) is expected to lead the way, followed by Energy (30%) and Security (28%) (source: AT Kearney).

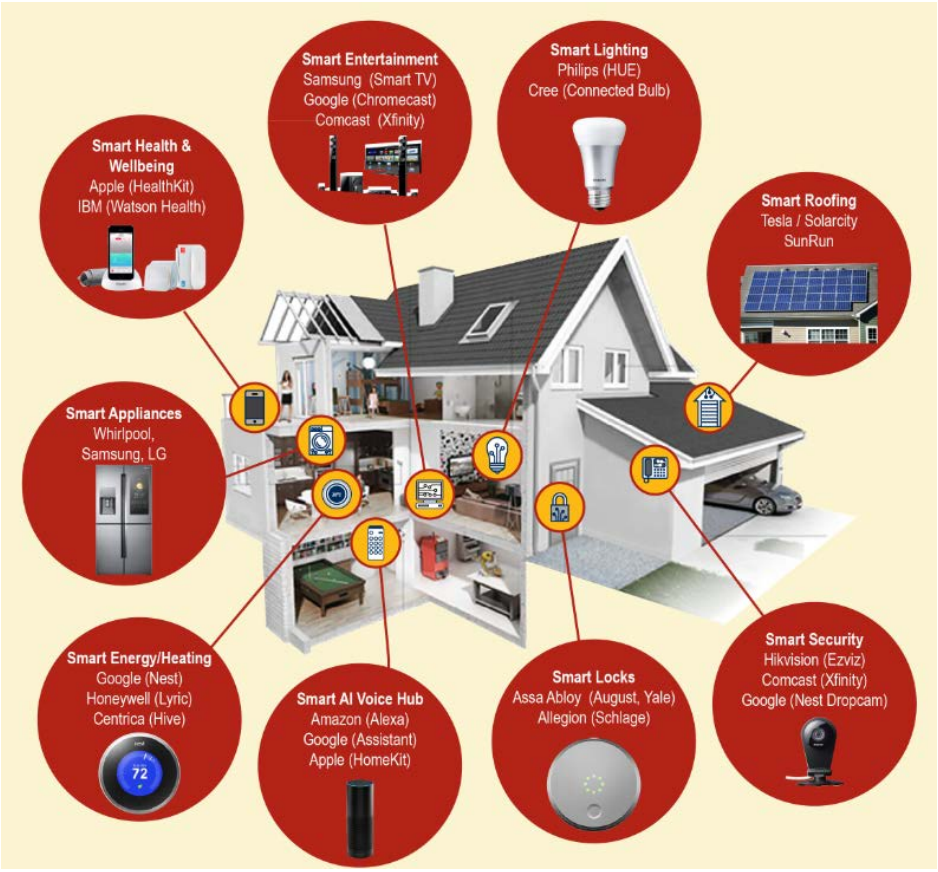
87% of consumers say Smart Home technology makes their lives easier and 90% cite safety & security as the #1 driver for adoption, followed by energy efficiency (70%) and entertainment (46%) (source: Coldwell Banker, iControl). This makes sense given that a home burglary happens every 18 seconds in the US and that 60% of convicted burglars say they would target a different home if they knew a security system was in place. In terms of energy cost, Smart Homes could save households 10%

on their energy bills (source: EcoFactor). The ROI of renovating ageing housing stock (about thirty nine years in the US) is also becoming an incentive to go smart; installing rooftop solar increases resale value by an average of US$15,000 per home (source: US DoE). Our US Hardlines Retail team has found that people who were extremely or highly likely to buy a home in the next two years were fairly interested in adding or improving Smart Home features. The Sharing Economy is also a driver with 60% of Airbnb guests willing to pay more for a rental with Smart Home features and smart TVs, smart security, touchscreen appliances, and App-controlled locks ranking highest in terms of appeal (source: August Home 2016).

Artificial intelligence (AI) is making homes smarter with voice assistants already becoming the hub of the smart home ecosystem. Tractica estimates that 40mn homes will use a voice-activated digital assistant by 2021. The question is who will come to control this market as 45% of consumers prefer a single vendor to manage their smart home (29% prefer multiple vendors) (source: GfK). CES 2017 demonstrated that Amazon Alexa is currently leading the race for the living room. However, other companies such as Google (#1 in AI, machine learning) and IBM (Watson is #1 provider of IoT-based AI) cannot be discounted given the growing importance of software as a key differentiator.

Cybersecurity, privacy and costs remain the key challenges for smart home adoption. Consumers say their #1 concern about the Smart Home is the possibility of a data breach; 71% of US consumers fear their personal information may be stolen (source: Proofpoint). Consequently, some stakeholders believe this may become a privacy nightmare in the making with the smart home sitting on troves of data. Affordability is also a constraint. Forty-eight percent of US consumers think connected products are too expensive (source: Deloitte) – meaning that the Smart Home could exclude many in DMs and EMs.

Exhibit 99: A Smart Home in a nutshell



Source: BofAML Global Research based on company reports

Smart Home 101

A smart home is a one that is equipped with network-connected products for controlling, automating and optimizing functions such as temperature, lighting, security, safety or entertainment, either remotely by a phone, tablet, computer or a separate system within the home itself. The home must have a smart security feature or a smart temperature feature in addition to a reliable internet connection. It then must include at least two features from a list of smart options, including appliances, entertainment, lighting, outdoor sensors, and safety detectors (source: Coldwell Banker). However the concept of a "smart home" is not new per se. For decades already, there have been many demonstrations of future homes, and multiple commercial offerings have been brought to market envisioning a higher degree of automation in homes

Connected home vs smart home

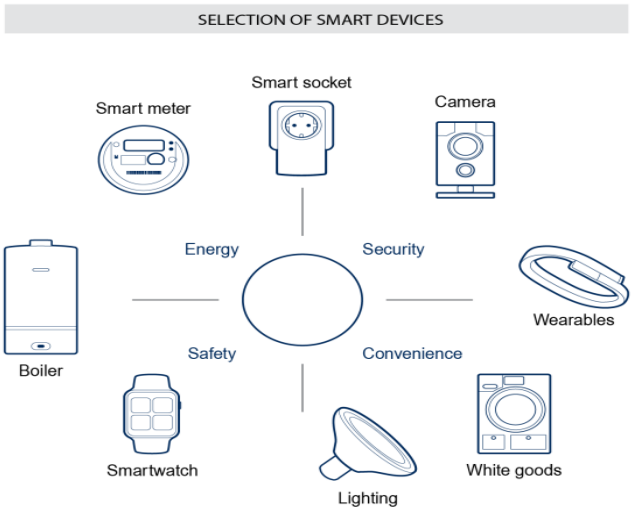
It is important to distinguish the "connected home" from the "smart home". The connected home simply has internet and a limited number of IoT-enabled devices e.g. smartphones, laptops, tablets etc. A smart home has smart devices such as appliances, lighting, electronics (TVs, computers and entertainment systems) and security/camera systems that are capable of communicating with one another usually through a hub and/or can be controlled remotely by phone or the internet. The desire for smart homes is increasingly driven by the convergence of four broad themes: (1) safety and security; (2) energy efficiency; (3) health & wellness and (4) convenience, entertainment & connectivity

Table 26: From consumer to connected to smart homes

Consumer Homes	• Include connected and non-connected homes • Non-connected homes are homes without built-in connectivity capability
Connected Homes	• Homes with built-in connectivity capability to communicate with each other and/or other devices and/or consumers
Smart Homes	• Automated homes requiring little human intervention and integrating built-in connectivity, advanced capabilities in sensing, analytics, integrated with supporting online services

Source: Euromonitor

Exhibit 100: Sample of smart home devices

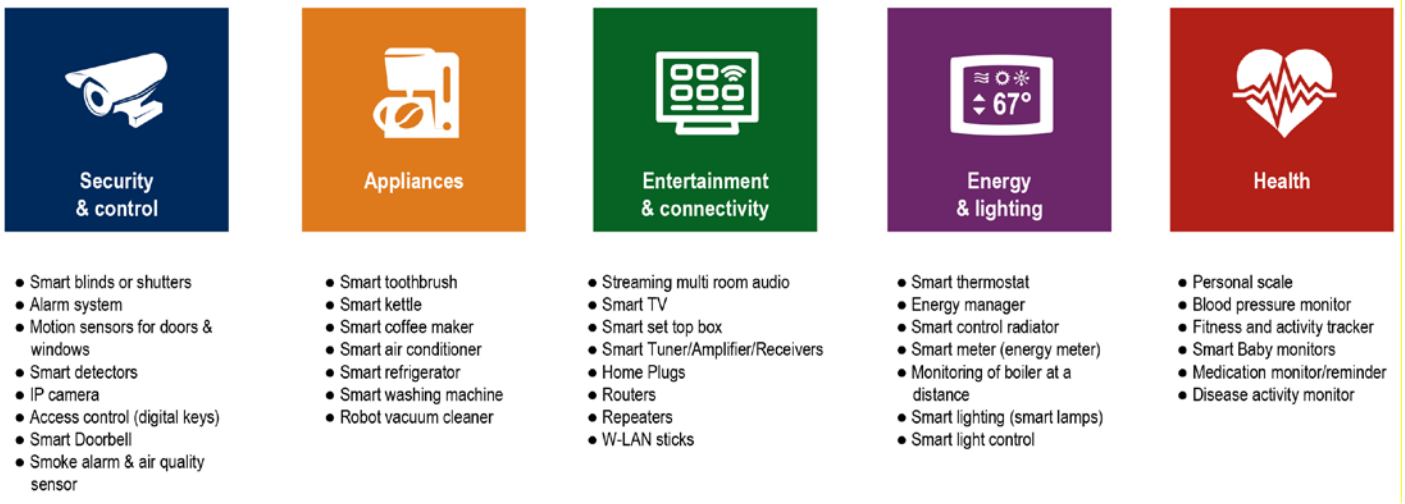


Source: Deutsche Telecom

Connectivity and the IoT: a game changer

However, what is new today is the increasing connectivity of households. Some 102.5mn US households have broadband and an average of 8.6 connected devices per home in 2015 (source: ITU, Gartner). Household devices are becoming "undumbed" thanks to the IoT and sensors, and we think households will represent one of the earliest and easiest Smart City market opportunities as consumers increasingly retrofit different parts of the home.

Exhibit 101: Different features of the smart home

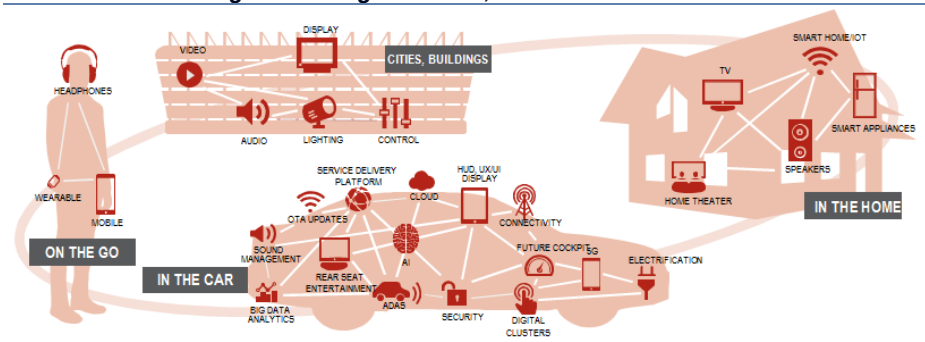


Source: GfK

"Smart living": smart homes are opening up Smart Cities to consumers

We think smart homes are integral to Smart Cities as they demonstrate and enable "smart living", ie, citizens are connected wherever they are. For instance, the smart home lies at the intersection of our Smart Cities and Future of Mobility themes. This is illustrated by Samsung's recent acquisition of Harman (connected car theme) combined with its earlier smart home acquisitions (SmartThings and AMX). The company is increasingly looking to capitalise on smart living trends. Samsung has stated that its plans to have 90% of all its products connected online by the end of 2017.

Exhibit 102: Smart Living is connecting smart cities, cars and homes



Source: Samsung

Smart home goes mainstream: 500 connected devices per smart home by 2022E

CES: AI a major catalyst for smart home developments

Retailing - Hardlines: CES 2017 takeaways; On the doorstep of a smart home revolution? 09 January 2017

The annual Consumer Electronic Show (CES) has been a catalyst for smart home developments in recent years. Although many of the products have failed to go mainstream, we think the 2017 CES could prove to be a game-changer because new AI software is making it easier for devices to interact with householders. We think 2017 could be the start of a five-year smart home revolution. Our US Hardlines Retail team makes the following observations following the most recent CES:

- **Smart homes were cited as "the most popular means of IoT engagement"** according to the Consumer Technology Association (CTA) which runs the annual CES.
- **Smart home technologies are forecasted for unit growth of 63% in 2017,** with the other high-growth categories being digital assistants like Amazon Alexa (52%), according to the CTA.
- **40% of consumers were interested in purchasing a smart home product** in 2017, according to Scripps Networks.
- **55% already own a smart home detector for smoke / carbon monoxide** followed by motion lights (32%) and monitored security (21%).
- **44% were interested in purchasing a smart home energy monitor** as the #1 item on the list, followed by lighting automation (43%) in second place (source: Scripps Networks).

Bank of America Merrill Lynch

Chart 53: Smoke or carbon monoxide detection systems 55%; Motion lights 32%; Monitored security system 21%; Sprinkler automation and controls 19%; HVAC automation and controls 19%

Source: Scripps Networks interactive, UNDER ONE ROOF community 2016

Chart 54: Home energy monitoring systems 44%; Lighting automation and controls 43%; Controlling house systems with smartphone/tablet 40%; Doorbell camera 39%; Controlling house systems with computer 38%

Source: Scripps Networks interactive, UNDER ONE ROOF community 2016

Kitchen is #1 focus area for consumers: Millennials focus more on living room

The kitchen was the #1 smart home area to which consumers want to add features, according to Scripps Networks. Meanwhile, Millennials show a strong preference to make their living rooms smarter and Boomers are focused on the front porch.

Table 27: Area of the home consumers would most like to add smart-home features

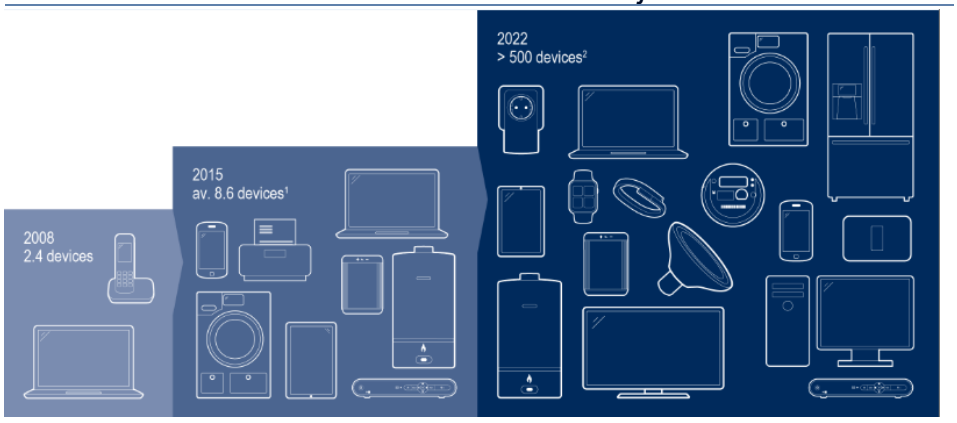
	Homeowners	Millennials	Gen Xers	Boomers
Kitchen	25%	27%	28%	23%
Front entryway or front door	15%	7%	13%	14%
Living room	13%	20%	16%	12%
Specialty room (home office, hobby space)	7%	7%	6%	9%
Garage	4%	3%	3%	4%
Bedroom	4%	10%	6%	3%

Source: Scripps Networks interactive, UNDER ONE ROOF community 2016

>500 smart devices per smart home by 2022E

The number of smart devices in smart homes is expected to surge in the next five year. Gartner estimates that there could be >500 connected devices per home by 2022E growing from an average of 8.6 in 2015 and 2.4 in 2008.

Exhibit 103: Number of connected devices in smart homes set to skyrocket



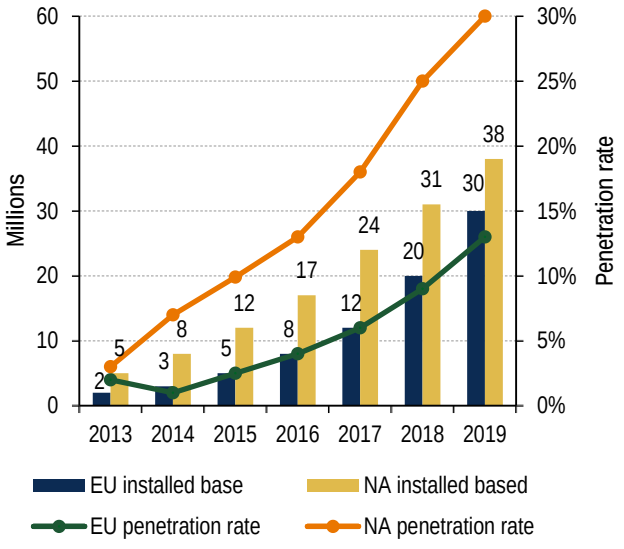
Source: Deutsche Telecom, Strategy Analytics, Gartner

Number of smart homes doubling in North America, trebling in EU by 2019E

Smart home penetration remains low but looks set to skyrocket in the coming years. For instance, the smart home installed base in North America is expected to more than double from 17mn in 2016 to 38mn by 2019E – increasing from a 12% to 28%

penetration rate. However, European smart homes are expected to grow even faster as they more than treble in number over the same period from 8mn to 30mn or from 4% to 13%. In Western Europe, Germany will be the largest single connected home market (with 11.6mn households), followed by the UK (7.7mn), France (7.3mn), Italy (6.3mn) and Spain (4.5mn) (source: Deutsche Telecom, Strategy Analytics).

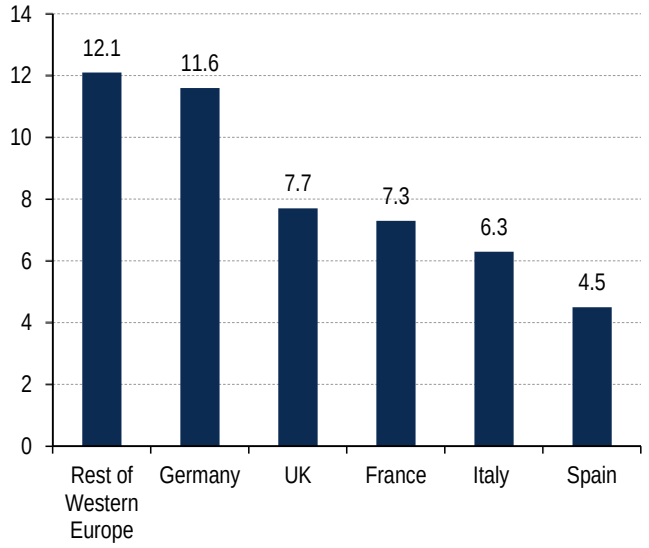
Chart 55: Connected home installed base and penetration EU and NA (North America) 2013-19



Source: Deutsche Telecom, Strategy Analytics, Gartner

Chart 56: The Number of connected home households is significantly rising

Household (mn) for the year 2019



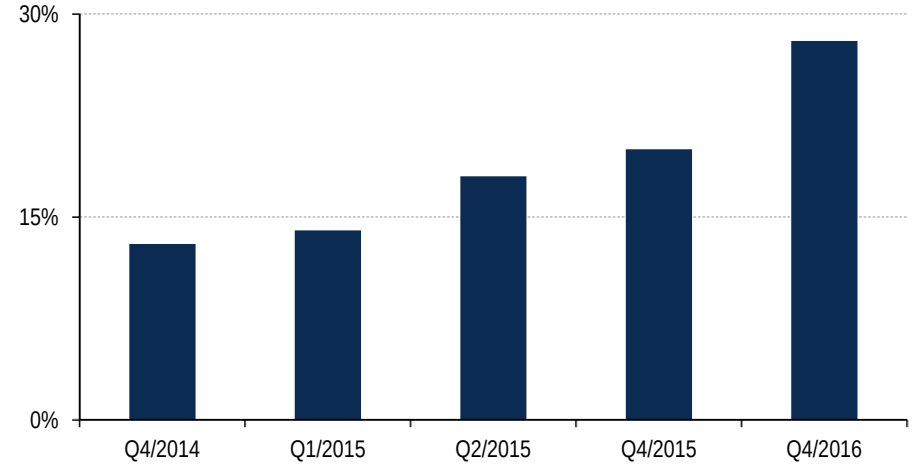
Source: Deutsche Telecom, Strategy Analytics, Gartner

1/2 NAm broadband households to own 1+ smart home device by 2020E

Being connected online is a pre-requisite to "power" the smart home and 26% of US broadband households own a smart home device as of 4Q16, which is a 7% increase over 2015 (19%), and double the penetration rate from two years ago in 4Q14. By 2020E, 50% of North American broadband households could have a smart home device (source: Parks Associates).

Chart 57: Smart Home Device Ownership (2014-2016)

U.S. Broadband Households

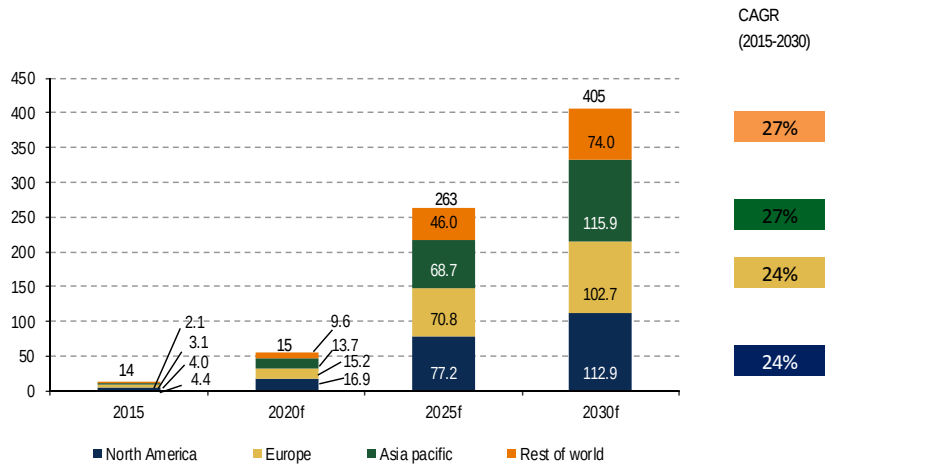


Source: Parks Associates

US$14bn smart home market in 2015; US$405bn by 2030E

The market for smart homes is projected to be worth US$405bn by 2030, up from just US$14bn in 2015, according to AT Kearney. All regions are expected to grow quickly in 2015-30, but Asia is expected to expand the fastest (27% CAGR) followed closely by Europe and North America (24%). Overall, Asia (US$116bn) is expected to overtake Europe (USS$102bn) by 2027 and North America (US$113bn) by 2030 to become the #1 smart home regional market, accounting for 30% share (source: AT Kearney).

Exhibit 104: Smart home market size by region (US$bn, 2015-2030E)

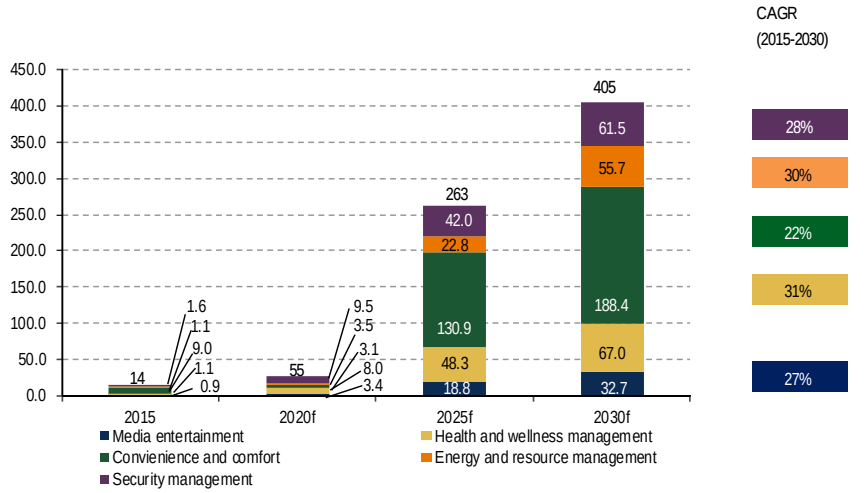


Source: AT Kearney

Largest smart home vertical: Convenience and comfort

The largest smart home vertical market is expected to remain Convenience and Comfort which will account for nearly half of the market (46%) by 2030E, worth an estimated US$188bn (vs US$131bn in 2025E vs US$9bn in 2015) (source: AT Kearney).

Exhibit 105: Smart home market size by application category (US$bn, 2015-2030E)



Source: AT Kearney

Rapid growth across segments: health & wellness #1, energy #2, security #3

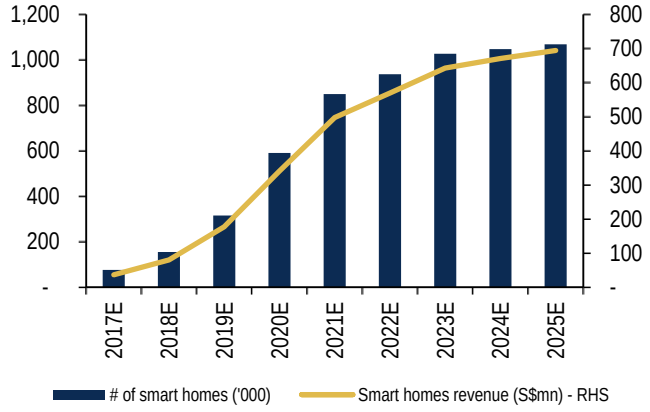
All segments of the smart home are expected to grow quickly. Health & Wellness (31%) leads the way followed by Energy (30%) and Security (28%). The rise in smart health at home is expected to be driven by an Ageing population's desire to age in place and the continued shift towards home health – as well as Millennials' focus on physical activity.

Case study on Singapore "Smart Nation": S$694mn smart home market by 2025E

Telecommunications - ASEAN: The Future is Smart 18 January 2017

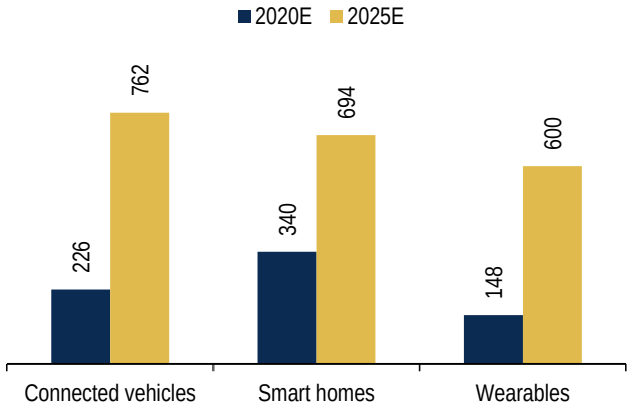
Our APAC Telecoms team estimates that the Singaporean smart home market alone is expected to reach S$340mn by 2020E and S$694mn by 2025E, as penetration rises to 70-80% of public housing households and private property households. This could result in S$2bn-plus in greenfield revenue opportunities for telcos.

Chart 58: Smart homes – estimating the opportunity



Source: BofA Merrill Lynch Global Research estimates

Chart 59: SN – revenue potential (S$ mn)



Source: BofA Merrill Lynch Global Research estimates

- **Singapore's government extended smart home solutions trials to 3.200 households** in Yuhua estate in April 2016 following an initial trial by 10 households in July 2015 (source: Channel News Asia).
- **Singapore telecom companies were already initiating smart home product trials in late-2015, and the pace appears to be picking up**. Singapore Telecoms launched its smart lifestyle solution in October 2016 and offers the service through a monthly subscription-based model.

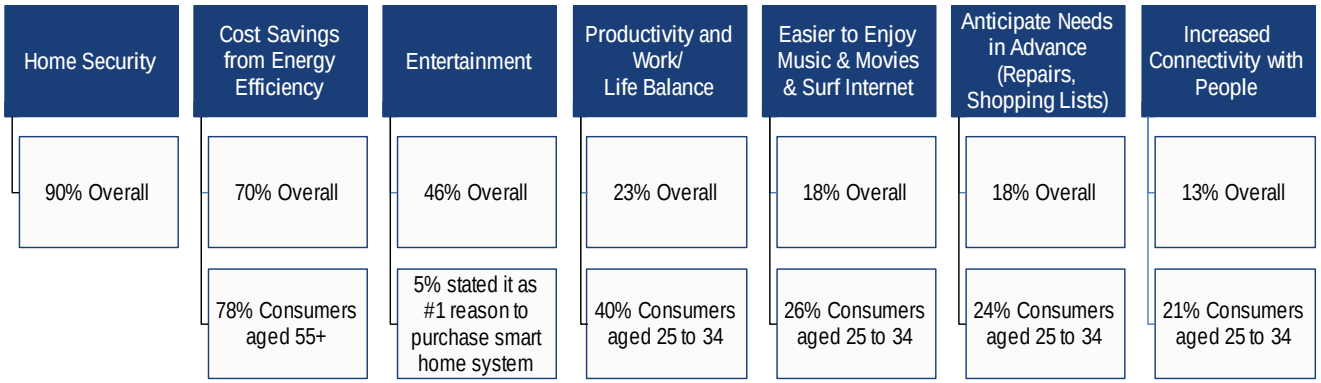
Safety: 90% of consumers say it's #1 reason to go smart

Safety & security is the #1 reason for US consumers to upgrade to a smart home, followed by saving on energy costs and convenience & entertainment. In a survey by iControl

- **90% of consumers say security is one of the top reasons** to purchase a smart home system.
- **70% say they are excited about the energy cost savings** from efficient monitoring of their usage.
- **46% cite entertainment as a main driver** for adopting a smarter home with 5% stating it as the #1 reason to purchase a system.

A home burglary takes place about every 18 seconds in the US; a household member is only present for 28% of burglaries; and 60% of convicted burglars would target another home if a security system was present (source: FBI, DoJ)

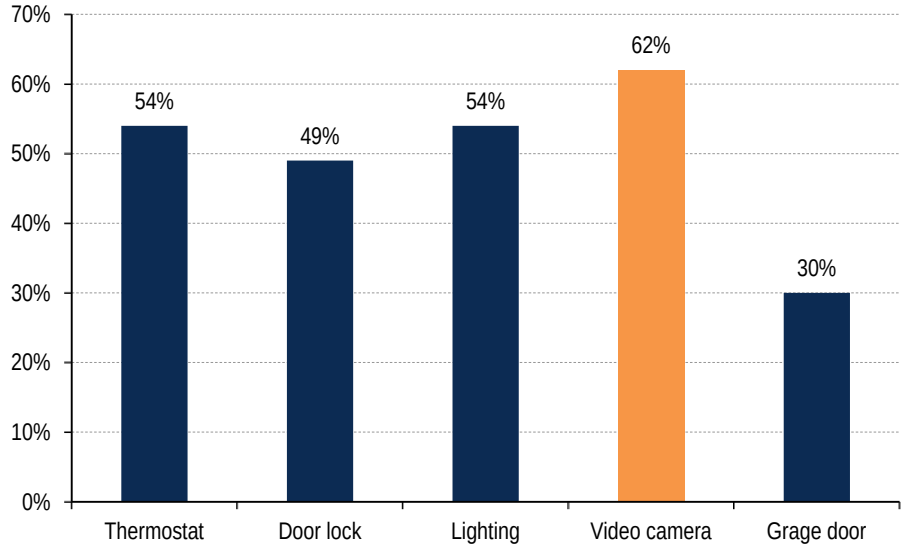
Exhibit 106: Key market drivers in smart home adoption



Source: iControl, FBIC

- **The #1 smart security feature for consumers is being able to use smartphones to monitor, arm and secure their homes** according to a Comcast Xfinity survey.
- **A popular product category for current smart home adopters is internet-connected cameras** (62%), with more than 6/10 smart home households using this technology.
- **Lighting (54%), thermostats (54%) and smart locks (49%) also proved popular** among respondents, while app-controlled garage doors were one of the least popular choices – just 3/10 smart home households (source: Comcast, Xfinity).

Chart 60: Which device are you most interested in controlling with smartphone (Top Three Choices, by percentage)



Source: Comcast Xfinity

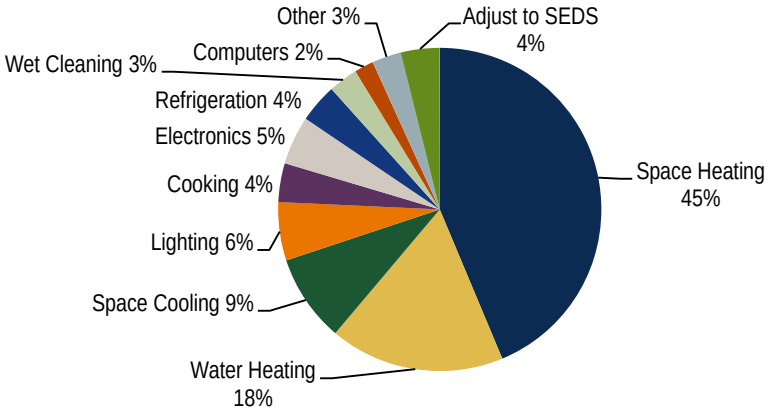
Energy efficiency: smarter homes could save 10% on household bills

Consumers are also recognising the growing associated benefits of smart homes from energy efficiency, energy costs, and convenience perspectives. Households account for 21% of total energy consumption in the US according to the DoE. The average US household spends US$2,024 on residential energy annually (including heating, cooling, water heating, appliances, lighting, and electronics) - and US$1,340/year on electricity alone. Within US homes, the DoE estimates 55% of the electricity consumed is for

space heating and cooling alone. Reducing energy consumption due to heating and cooling systems within homes can have a great impact on energy savings.

Smart homes could save 10% on household energy bills or US$100 per year on average – EcoFactor

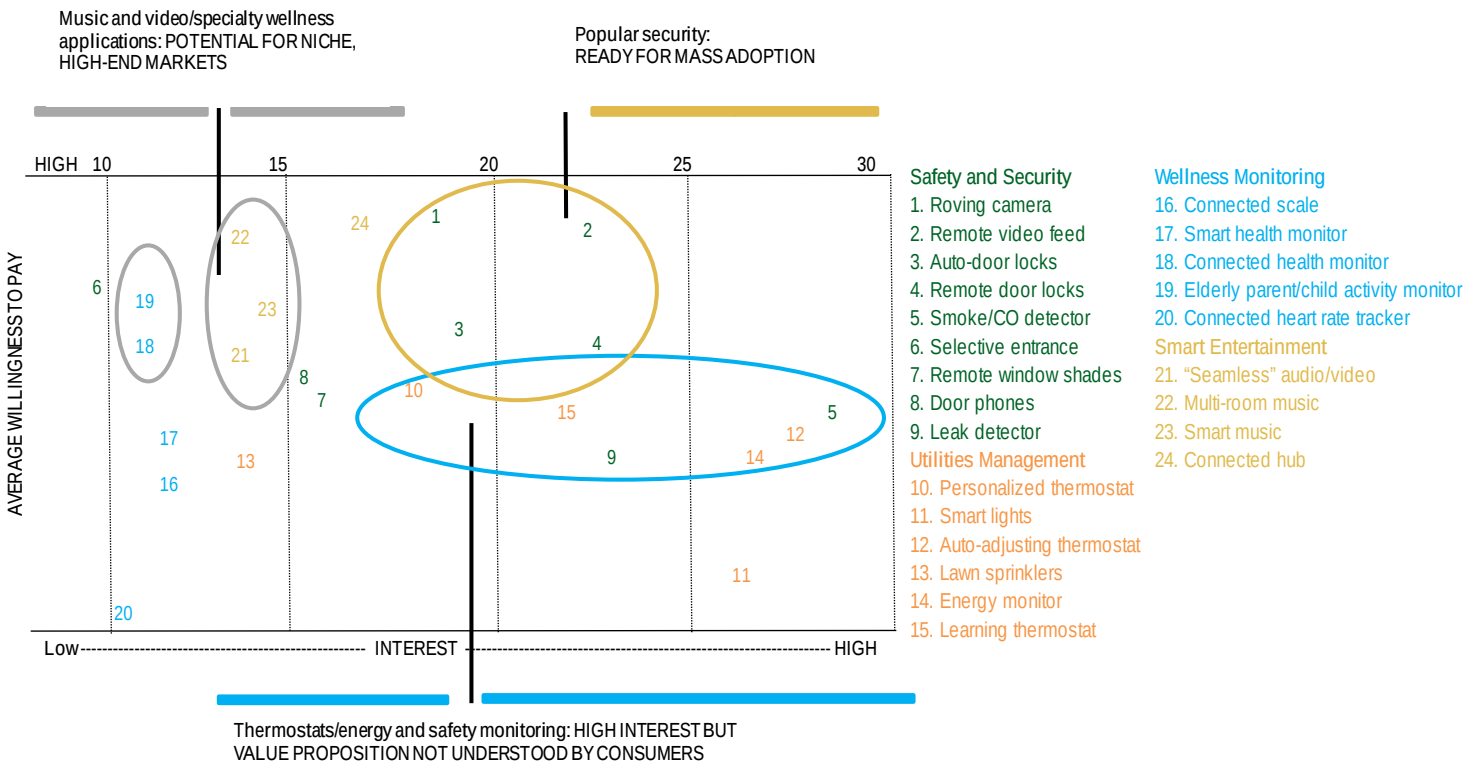
Chart 61: Residential Site Energy consumption by End-Use



Source: NYSEDRA

- **Consumer interest in smart thermostats (learning, personalising and auto-adjusting) and energy monitors is high** but generally the value proposition compared to security products is low as consumers are less willing to pay for utilities management products (source: McKinsey).

Exhibit 107: Consumer interest in smart homes



Source: McKinsey

- **There is evidence to suggest that the provision of real-time consumption information by smart meters changes consumers' behaviour patterns and leads to lower energy consumption** (source: UK DECC). Studies in several countries have shown a range of average energy savings (2-9%), although the savings are smaller for gas than electricity. All of the trials concluded that an in-home display is vital to prompt behavioural change. The DECC's cost-benefit analysis conservatively uses a 3% reduction for electricity and 2% for gas. The planned rollout of smart meters to all households by 2020 could therefore chip away at domestic demand.

Table 28: Reduction in energy consumption caused by smart meters

Study	Country	Electricity	Gas
Kema	Holland	-6%	-5%
ACEEE 1	9 countries	-9%	
ACEEE 2	USA	-4%	
ESMIG	All-Europe	-9%	
EDRP	UK	-4%	-3%
DECC model	UK	-3%	-2%

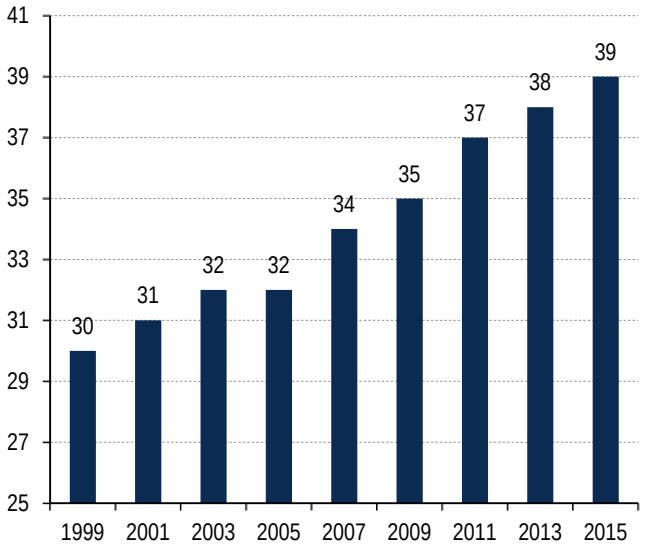
Source : DECC, BofAML Global Research

"Renovation nation": strong ROI case to smarten ageing homes

As of 2015, the average age of a US home was 39 years, up from 32 years before the housing downturn in 2008 (source: US Census Bureau). Older homes are more expensive to maintain and require more upgrades. In addition, the size of American homes has increased from an average of just over 1,500 sq ft in 1973 to about 2,500 sq ft as of 2015, which also implies higher spend on repair and maintenance. Both factors support the case for making homes smarter. In the UK, the DECC estimated that a smart home could increase the value of houses by 13% on average and up to 38% in some parts of the UK.

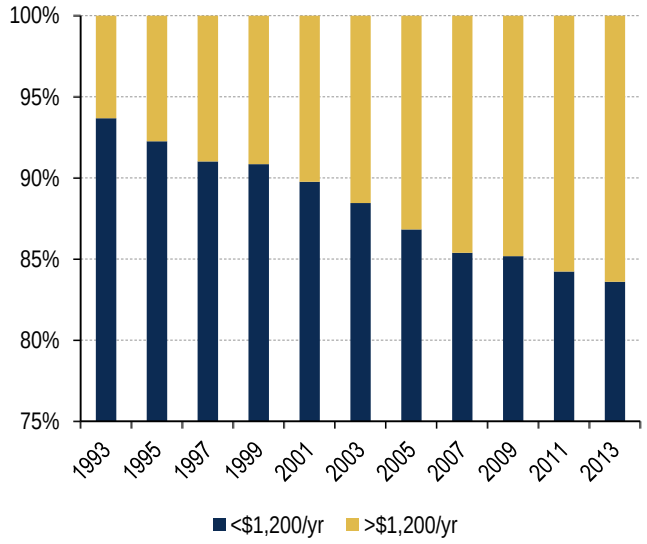
Installing rooftop solar can increase your home's resale value by US$15,000 – US Department of Energy

Chart 62: The median housing age has increased 22% since 2005



Source: US Census Bureau

Chart 63: Routine maintenance costs per year*



*Excludes respondents who did not report their costs
Source: US Census Bureau

Millennials and Boomers demanding smarter homes for age-specific reasons
Both Boomers and Millennials are driving demand for smarter homes, albeit for different reasons.

- **US consumers aged 55+ exhibit a higher level of excitement around the cost-saving benefit of the smart home** at 78% vs 70% of consumers overall.

Smart home technology has the potential to help seniors live happier, easier lives, and can be a great resource for family members to keep an eye on their ageing parents. In a survey by iControl, 72% of 25-34 year old consumers say they would sleep better at night if their parents or grandparents had smart home technology

Table 29: Generational interest differences in smart homes

Traditionalist	Urban Dweller	Family First	Affluent Nester	Social Climber
Income ~$35K per year	Income ~$40K per year	Income ~$40K per year	Income ~$75K per year	Income ~$100K+ per year
Age 45–64 years old	Age 25–34 years old	Age 25–44 years old	Age 45–64 years old	Age 25–44 years old
Interests Security 18% Utilities 10% Entertainment 3%	Interests Security 30% Utilities 26% Wellness 26%	Interests Security 32% Wellness 19% Entertainment 17%	Interests Security 27% Utilities 24% Wellness 19%	Interests Utilities 40% Security 39% Wellness 32%
Top Devices	Top Devices	Top Devices	Top Devices	Top Devices
Connected Thermostat Lighting Connected Smoke Detector	Connected Thermostat Energy Tracking Connected Smoke Detector	Remote Video Feed Connected Lock Connected Smoke Detector	Connected Thermostat Energy Tracking Connected Smoke Detector	Connected Thermostat Connected Lock Remote Video Feed
Key Barriers	Key Barriers	Key Barriers	Key Barriers	Key Barriers
Lowest awareness of any segment Most deterred by price Concerned over setup and usability Concerned over privacy and hacking	Skeptical that products work well High concerns over price Deterred by current suite of available products	Most concerned that devices will be difficult to install and use High concerns over price	Lack recognition of need for products Believe that technology is still developing Concerned over privacy and hacking	Most likely to believe that technology is still developing Concerned about product setup and usage

Source: McKinsey

- **US Millennial consumers aged 25-34 express a higher level of excitement around the productivity and convenience benefits of the smart home**. 40% of older Millennials said smart homes enabled greater productivity and ability to manage work-life balance (vs 23% of consumers overall) (source: iControl). Eighty-three percent of Millennials would be discouraged from signing up if they were unable to obtain a seamless experience for additional products and services from their provider (source: Accenture).

AI voice assistants: increasing competition to be the hub of the smart home ecosystem

Internet/e-Commerce: CES 2017: Automation making waves for the future
09 January 2017

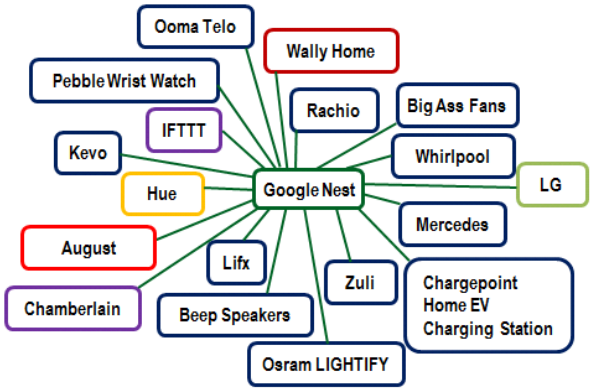
Artificial intelligence (AI) is making homes smarter with voice assistants already becoming the hub of the smart home ecosystem, in our view. Currently most smart homes are controlled via smartphones but we believe the focus will shift towards digital AI assistants such as Amazon Alexa and Google Home. Hence, we think forming product partnerships will be key to building the smart home of the future.

The key takeaway from CES 2017 was that a successful smart home needs to connect the software (digital assistant) and hardware (connected devices) to enable a seamless experience for the consumer

- **45% of consumers preferred a single vendor to manage their smart home** vs 29% who prefer multiple vendors (source: GfK).
- **40mn homes will use a voice-activated digital assistant by 2021E** according to Tractica estimates.

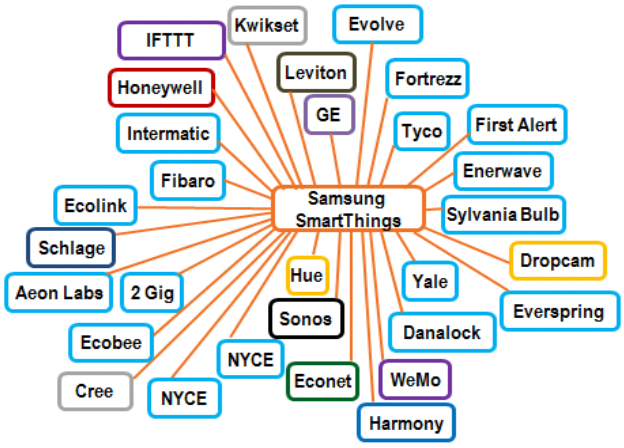
- **Eighty-five percent of connected home solutions expected to be linked to a "certified ecosystem",** eg, compatible with Amazon Alexa, Google Nest, Apple HomeKit, shifting away from the current service-based solutions (source: Gartner).

Exhibit 108: Google Nest compatibility



Source: NYSERDA

Exhibit 109: Samsung SmartThings compatibility



Source: NYSERDA

CEO Facebook Mark Zuckerberg's Smart Home: In 2016, Facebook CEO Mark Zuckerberg built his very own "Jarvis" (digital assistant made famous in the Ironman film) to power his smart home, voiced by actor Morgan Freeman speaking both English and Mandarin. The assistant is programmed to never play Nickelback but play more of the Red Hot Chili Peppers, according to Zuckerberg's music tastes

Traditional home automation actors being disrupted by AI

AI is disrupting traditional smart home incumbents. Our US Tech teams point out that the proliferation of smart devices from Amazon Echo and Google Home is a megatrend that may increasingly marginalise higher-price home automation solutions companies such as Control4. As the Amazon Echo and Google Home ecosystems grow, they become competitive rather than complementary. Echo and Home underscore the broader transition to screen-less devices and reliance on proprietary AI and voice recognition technology. Additionally, like smartphones, integration with the ecosystem and app stores may ultimately drive success, putting home-automation tools at a sharp disadvantage due to a much smaller developer base.

Amazon Alexa has a head-start in the living room: killer app for smart homes

2017 could be a breakout year for Amazon Alexa (an intelligent PA) in consumer households as the "killer app" to power smart homes seamlessly. At CES 2017, Amazon Alexa integration was a big theme, incorporated into a range of products including printers, air purifiers, refrigerators, smartphones, baby monitors and self-driving cars. Amazon Alexa's open platform and AWS API have allowed multiple OEMs and developers to quickly integrate voice control from Alexa into their products giving them an early lead in the IoT space over other personal assistants like Apple Siri and Google. Amazon notes that music is one of the most popular uses for the Alexa-enabled Echo devices.

10,000: the number of 3rd-party skills available for Alexa in Q1-17 (source: Statista).

Top 5 skills Echo owners have used at least once: set a timer (85%), played a song (82%), Read the news (66%), set an alarm (64%), checked the time (62%) (source: Experian)

Questions and commands that Amazon Echo can respond to:

- Alexa, lower the room temperature by 1 degree
- Alexa, make the room lighting a brighter hue
- Alexa, what is the S&P's latest price?
- Alexa, how much wood can a woodchuck chuck?
- Alexa, why did the chicken cross the road?

Exhibit 110: Amazon Alexa's and selection of app compatibility

Source: Amazon

Early traction gives Amazon four key advantages over competitors

Early traction provides Amazon four key advantages: (1) more data and use cases to drive Alexa improvements; (2) a bigger ecosystem to build as a standard for personal assistants and voice control; (3) more AWS usage as companies seek to build Alexa-compatible products; and (4) stronger integration of Amazon products and services. According to Amazon, it sold millions of Alexa devices worldwide over the 2016 holiday season, with Echo family sales up more than 9x vs last year's holiday season. There are about 250 devices that are certified to work with Amazon Alexa, whilst Apple's HomeKit has about only 100 devices.

Table 30: Amazon Alexa was rated smarter than its rivals at CES 2017

CES 2017 "smartness" scoreboard

"Smartness"	Amazon Alexa	Apple HomeKit	Google Home
Actually smart	8	3	5
Sure, okay	21	14	5
Why?	4	1	0
Total	33	18	10

Source: CNET

Don't write off Google Home: dominance in AI & Android

However, we think Google's leadership in AI, big data from search engine and Android as #1 mobile OS gives it an edge in being able to adapt to user's unique, personal requirement in the smart home. For instance, if Google Home and Amazon Echo are asked "What is the capital of Thailand?" both of them will answer "Bangkok." However if the next question is "How many people live there?" only Google Home will be able to understand that "there" refers to Bangkok (source: Insider Monkey). At the Mobile World Congress (MWC) 2017 the company announced that Google Home was set to be launched in the UK in June of that year (it's currently only sold in the US).

Table 31: Virtual assistant Jeopardy

How four digital helpers performed when asked trivia from the official "Jeopardy" practice questions

Virtual Assistant (Score out of 20)	Alexa (5)	Siri (17)	Cortana (16)	Google Now (16)
"What is atomic number 98?"	Says: "Hmmm, I can't find the answer to the question I heard."	Shows a periodic table illustration of Californium.	Bing search results include Californium Wikipedia entry, if you scroll down a screen. No point scored.	Says: "…Californium is a radioactive metallic chemical element with symbol Cf and atomic number 98."
"What was the name of Mozart's last symphony	Gives the wrong answer. "Symphony No. 49 in D Major."	Shows search results, the first of which is "Mozart's Last Symphony: The Giant 'Jupiter."	Shows search results, the first of which is "Mozart's Last Symphony: The Giant 'Jupiter".	Says: "…the work is nicknamed the Jupiter Symphony."
"Who played Daisy in the movie 'The Curious Case of Benjamin Button	Says: "Benjamin Button's actors are Brad Pitt and Cate Blanchett "	Says: "The Curious Case of Benjamin Button' stars Brad Pitt, Cate Blanchett	Bing search results includes Cate Blanchett link.. way down the list. No point scored	Says: "… Cate Blanchett, who plays Daisy Benjamin's great love."

Source: WSJ , Company

IoT platform's like Alarm.com are important in connecting the smart home

Alarm.com: Leading IoT platform for the smart home; initiate at Buy and $21PO 21 July 2015

IoT platforms like cloud-based Alarm.com are also important in supporting various connected devices and communications protocols (Z-Wave, Wi-Fi and ZigBee, cellular, broadband), resulting in seamless integration and automation of many devices. The platform helps powers the smart home through several solutions integrated in a single user experience: interactive security, intelligent automation, video monitoring, and energy management. The Alarm.com platform processed 20bn+ data points in 2014 from 25mn connected devices utilising its highly scalable analytics engine. Proprietary analytics allow the platform to generate actionable insight. As of March 2015, the Alarm.com mobile app had been downloaded more than 1mn times each for both iOS and Android.

Exhibit 111: Alarm.com's Cloud Platform

Building a comprehensive smart home platform takes years of investment

OLUTRON	Schneider Electric	CHAMERLAN	SCHLAGE	Kwikset
Yale	DSC	2 GIG	Interlogix	Qolsys
verizon	at&t	T Mobile	vodafone	Telefonica

Source: Company

IBM Watson is #1 provider of IoT-based AI

AI is likely to be the key differentiator for any smart home product and the rollout of IBM Watson IoT is also starting to take shape. For instance, Whirlpool is using Watson to make 'smart' appliances; this will take sensor data and overlap it with individual consumer behaviour. Panasonic is focusing on home safety and security and using Watson to analyse data from security cameras and sensors to detect if doors or windows are opened or disturbed. Finally Nokia is using wearables and smart devices to aid with home care for elderly patients (source: IBM).

Exhibit 112: IBM Watson IoT in smart homes

At Home	Whirlpool	Using Watson to make 'smart' appliances, which will overlap sensor data with consumer data
At Home	Panasonic	Focus on home safety and security with Watson analyzed data from cameras and home sensors
At Home	Bragi	Smart earphones that can measure an individual's vital signs and improve interaction
At Home	Nokia	Wearables and smart devices to aid with home care for the elderly

Source: IBM, BofA Merrill Lynch Global Research

Growing smart home opportunity: "Big 4" pulling away but attracting companies from all fields

There are an increasing number of companies entering the smart home space from many sectors. However, the "Big 4" are pulling away from the pack: Alphabet, Amazon, Apple and Samsung. This is based on product development, breadth of device partnerships, success of their adopted business model, level of innovation and marrying the software/hardware aspect of the smart home with close partnerships, according to Juniper Research.

Table 32: Smart Home Ecosystem Map

Smart Home Platforms							
Smart Gateways	**Smart Home Platforms**			**Home Energy Management**			
Alarm.com	Samsung	IBM	Apple Homekit	EnergyHub	C3 IoT	Bidgely	Tendril
wink	SmartThings	Watson		Opower	Ecova	Silver Spring Networks	Opower
Samsung SmartThings	Ayla Networks	Comcast Xfinity		Hive (Centrica)	Google nest		
Honeywell			Amazon Echo				
Control4	Alarm.com	Google Home					
OEMs & Device Suppliers							
Climate Control				**Security and Access**	**Lighting**	**Fire & Life Safety**	**Appliances**
Honeywell	Energate	EcoFactor	EnergyHub	Bosch	GE Lighting	Honeywell	Haier
Schneider Electric	Alarm.com	ecobee	Google Nest	Lockstate	Philips Lighting	Bosch	LG
				Alarm.com	OSRAM	Birdi	Whirlpool
In- Home Display		**Smart Plugs**		Honeywell	CREE	Tyco	GE
Rainforest automation	HAI by LEVITON	EnergyHub	Zuli	Panasonic		Google Nest	Samsung
2GIG BY Linear	CEIVA energy	VISIBLEENERGY	ThinkEco	Canary		Halo Smart Labs	
Schlage		INSTEON	Embertec	Google		Roost	
		Belkin		Dropcam			
Retailers & Service Providers							
Retailers	**Service Providers**						
Staples	**Security**	**Solar/Inverter**	**Select Telcos, Broadband & Cable**				
Loew's	Alarm.com	SMA	Deutsche Telekom	AT&T	HUAWEI	Time Warner Cable	
Best Buy	ADT	SolarCity/Tesla	Comcast	KPN	Telefonica	Vodafone	
B&Q	xfinity	SunPower	Verizon	Orange	BT	Swisscom	
Tesco	Yale (Assa Abloy)	Vivint Solar					
Sears							
Home Depot							
Amazon							
Walmart							
Target							

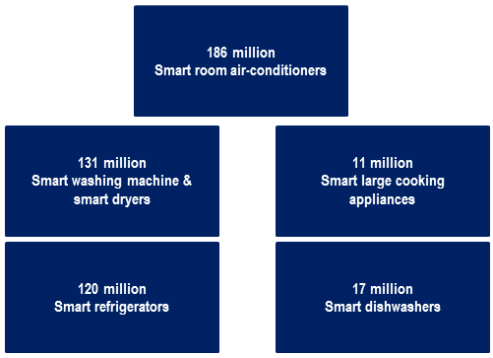
Source: Harbor Research

Smart home in practice: from security to appliances to thermostats to entertainment to toilets

Smart Appliances: 470mn connected appliances & US$443bn market by 2020E

We think the US$382bn market for consumer appliances (growing to US$443bn by 2020E) is ripe for technological disruption. According to Euromonitor, this market includes: dishwashers; food preparation appliances; heating appliances; home laundry appliances; irons; microwaves; personal care appliances; refrigeration appliances and vacuum cleaners. We think all of these items can be made smarter. IHS Technology forecasts 470mn connected smart appliances by 2020E, expanding at a 179% CAGR from 1mn appliances in 2014. China is expected to account for roughly half the manufacturing followed by the US at one-tenth.

Exhibit 113: Connected home appliance by 2020E



Source: IHS IBM company presentation

Bank of America Merrill Lynch

Smart toilets: engineers in Japan are working on a toilet capable of telling whether you might be ill or sick. The technology involves running a complete urinalysis after a homeowner uses the toilet. Based on that analysis, the toilet's software could detect the possibility of all sorts of conditions, including diabetes. Researchers are also looking at stool analysis and its potential for early detection of colon cancer (source: Life Hack)

Smart laundry; Panasonic recently invested US$60mn in its Seven Dreamers' laundry robot. With the average person spending 9,000 hours, or 375 days, folding laundry in a lifetime, the company claims the machine can fold a shirt in 10 minutes thus saving a huge amount of chore time for the household

- **At CES 2017, Whirlpool launched a new smart kitchen, laundry features and a smart all-in-one washer/dryer**. WHR also launched a new partnership with Amazon Alexa, which will be integrated into Whirlpool's smart appliances (including models released before this year). In our view, this is an important step for Whirlpool to become a bigger player in smart appliances given that it instantly leverages the size and scalability of Amazon.
- **Home Depot, Lowe's and Bed Bath & Beyond are developing their own smart home businesses, and will play a key role in driving smart home adoption** and helping consumers get past many of the aforementioned challenges. This includes being able to present the technology in an unintimidating way that simply showcases how the technology can provide solutions to improve the quality of life in the home. As an example, Lowe's has added store-in-store concepts to a number of locations that have experts and product demonstrations. Bed Bath & Beyond be particularly well positioned through Geek Squad.
- **Select Comfort publicly unveiled its new 360 smart bed line** at CES 2017 which replaces the company's existing product line. 360 will come to market through 2017 starting in Q2. All Sleep Number beds will have the SleepIQ smart bed feature and the 360 line provides automatic firmness adjustment, snore detection and a smart alarm, all driven by biometric sleep tracking. Select Comfort won a best of innovation award at CES for its advances in smart bed technology but the product offering remains niche, as a means to gaining a wider customer audience.
- **Samsung/LG/Panasonic, the traditional Asian players, are also increasing their offering of smart appliances** from Samsung's "Family Hub" fridge being able to order fresh groceries when it senses the internal contents are low through to LG's "InstaView" fridge, unveiled at CES 2017 which incorporates Amazon Alexa.

Figure 1: Smart screen, connected home

Source: BofA Merrill Lynch Global Research

Figure 2: Panasonic smart fridge

Source: BofA Merrill Lynch Global Research

Smart thermostats: US$5.9bn market by 2020E at a 32% CAGR

Smart thermostats learn from the home temperature schedule, auto-program, and can be controlled from a phone. Overall the smart thermostat market is expected to grow from US$585mn in 2014 and reach US$5.9bn by 2020E, at a CAGR of 32% (source: Markets&Markets).

- **Google Nest is widely seen as the leader in this space**. Google/Alphabet acquired Nest for US$3.2bn in January 2014. The company develops high-tech home devices like thermostats and smoke detectors that can learn from user behaviour and are connected to the internet.
- **Centrica's Hive is another well-known player in this space** where the company claims that energy savings are up to ~25% for average users. Centrica has pledged to invest c.£500mn in building a presence in this area and adding wider capabilities to its Hive thermostat by 2020E.

Table 33: Smart thermostats

Product	Up front cost, £	Who's behind it?
Nest	249	Google/Homeserve/nPower
Hive	249	British Gas
Tado	199	Homeserve
Eve	60	Smart valves
Wave	239	Worcester Bosch
Netatmo	199	
Momit	99	
iT500	112	Salus
EvoHome*	248	Honeywell
Heat Genius*	249	
Climote*	299	ScottishPower
Neo*	199	Heatmiser

Source: TrustedReviews.com, PC Advisor, BofAML Global Research

Table 34: Smart thermostat economics

Without Hive		With Hive	
Average gas consumption (therms)	408	Saving on bill	128
Average retail price per therm (SVT, p)	126	Saving in therms	102
Average gas bill, £	514	New demand (therms)	306
Wholesale costs per customer (42%, £)	216	Fixed costs per customer - as before	298
Wholesale cost per therm (p)	53	Fixed costs per therm (p)	97
Fixed costs per customer (£, inc margin)	298	Fixed recovery gap, £	-74.24
Fixed costs per therm (p)	73	Increase in tariff required for full fixed cost recovery	19%
		Smart thermostat cost	250
		Implied sales margin to break even on energy loss	30%

Source: BofAML Global Research.

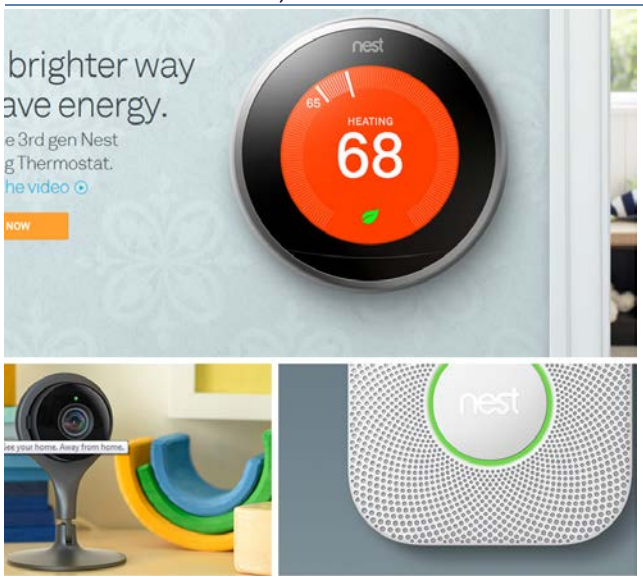
Smart smoke alarms

Smart smoke alarms give early warnings, they light up yellow and speak with a human voice (they can tell where smoke is or when carbon monoxide levels are rising) before turning on a loud alarm. For instance, Google Nest Protect senses smoke and Nest Cam will automatically record a clip. When the Nest Thermostat is set to 'Away', Nest Cam can turn on automatically. Nest also works with third-party devices to communicate with

Bank of America Merrill Lynch

Nest products under the "Works with Nest" program. The compatible products include Philip HUE, August smart lock, and Whirlpool's washer dryer among others.

Exhibit 114: Nest thermostat, smoke alarm and Nest Cam



Source: Google

Smart Lighting: could reduce energy costs by up to 90%

Philips Lighting: Inexpensive, innovative, proactive 25 January 2017

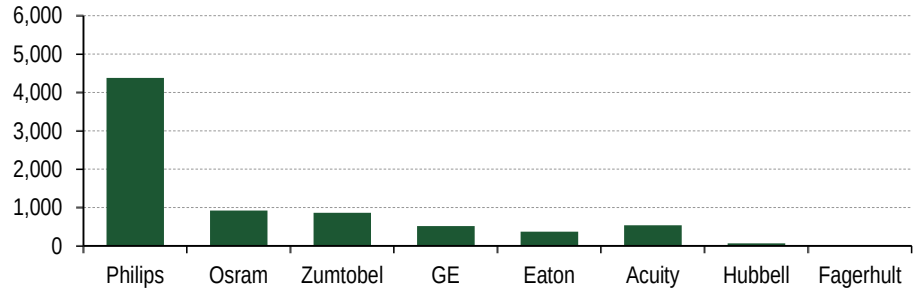
According to Energy Star, the cost of lighting a home is around US$264 per year. Gartner estimates that smart lighting alone could reduce the associated energy costs by up to 90% through a combination of installing efficient LEDs and optimising lighting as a service through monitoring usage.

Philips Lighting at the forefront

Philips Lighting is at the forefront of this trend, driven by the greater capabilities offered by LED-driven luminaires and the possibilities of remote-controlled light sources and interactive lighting systems. Philips Lighting developed the first connected lighting system for the consumer market when it launched Philips HUE in 2012 and launched connected systems for the professional market with CityTouch in 2015. The digitalisation of lighting is critical to the development of smart connected homes where Philips Lighting has the strongest IP portfolio in the industry, in particular with regard to LED & Lighting Control related products.

Chart 64: Philips has one of the strongest IP portfolios vs peers in disruptive technologies

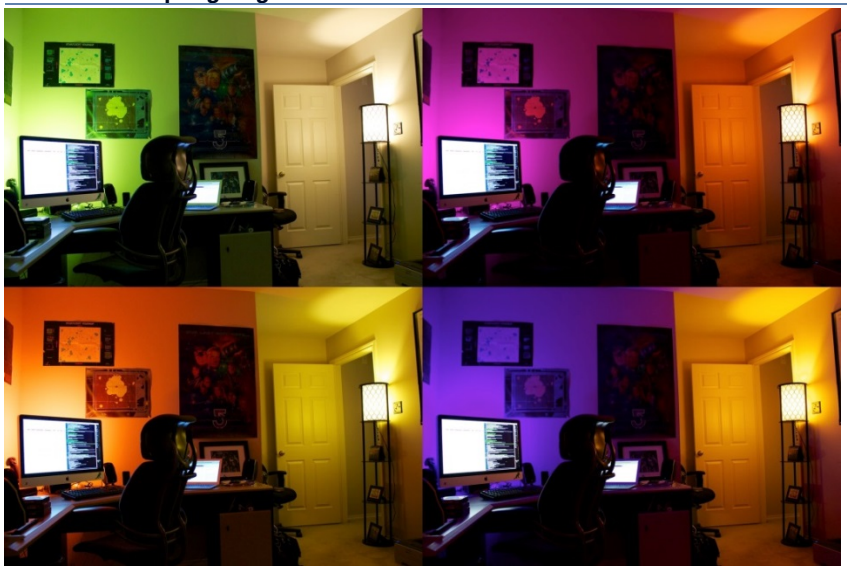
Lighting Control & Systems (patents)



Source: Company data, BofA Merrill Lynch Global Research estimates

The company's "HUE" bulbs are personal wireless LED lighting where variations in colour range from standard white to over 16mn different colours. It was the world's first commercially available internet-enabled home lighting system when launched – and users can quickly and conveniently control lights from anywhere with the HUE App. HUE motion sensors connected to the Bridge via the App automatically turn on the lights when the user enters a room. The user can choose in the app which scene or light setting should be triggered when motion is detected. The lights will turn off automatically when motion is no longer detected. It is also possible to set different light settings for day and night.

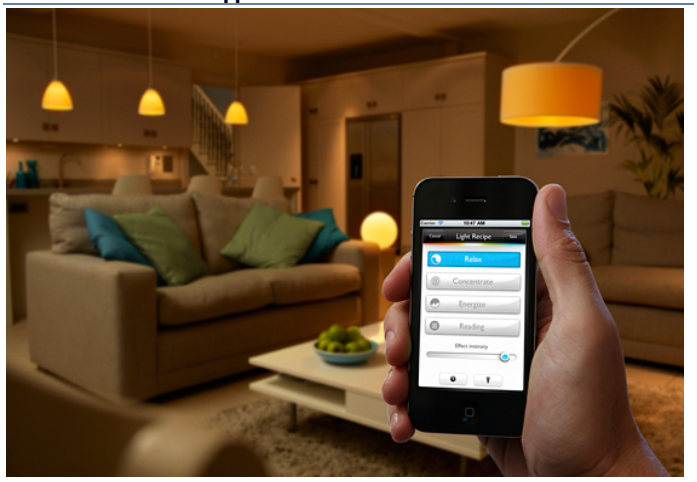
Exhibit 115: Philips Lighting HUE's different colour schemes



Source: Arstechnica

HUE offers three types of smart lights that come in different shapes, sizes and models: (i) HUE White for easy control and comfort, (ii) HUE White & Ambiance for relaxing warm white light to cool daylight to support daily activities, (iii) HUE White & Colour Ambiance for a more immersive experience. They all work together to make homes smart, comfortable and energy efficient.

Exhibit 116: The HUE App



Source: Company website

Exhibit 117: HUE Products

Source: Company website

Philips Lighting collaborates with several innovative brands such as Amazon Alexa, Apple Homekit, Google Products, IFTTT, Logitec Harmony and Nest.

Table 35: Philips HUE's benefits

	White and color ambiance	White ambiance	White
Smart control	✓	✓	✓
Away-from -home control	✓	✓	✓
Light Schedules	✓	✓	✓
Comfort Dimming	✓	✓	✓
Create your Ambience	✓	✓	
Wake-up	✓	✓	
Wellbeing	✓	✓	
Paint with Light	✓		
Sync with Music	✓		
Sync with Movies	✓		

Source: Company website

Smart Roofing: boosts home values on average by US$15,000

We also think solar roofing and energy storage will be integral to smart homes as they shift towards being "off the grid" and reap strong ROI in the long term. As highlighted in our Future of Mobility report, we think charging points for electric vehicles (EVs) at the owner's home will be important but also an opportunity for homeowners to monetise the energy captured and stored. We believe the merger between Tesla (Powerwall & EVs) and SolarCity (residential PVs) to build out the "world's only vertically integrated sustainable energy company" model is what the future smart home will increasingly look like from an energy perspective.

Installing rooftop solar can increase your home's resale value by US$15,000 – US Department of Energy

Exhibit 118: Solar roofing powering home and charging EVs

Source: Tesla

- **Powerwall 2, the new version of Tesla's residential home battery priced at US$5,500, packing 14 kWh in capacity**. This is an upgrade from Tesla's previous Powerwall which came in two sizes: US$3,500 for 10 kWh unit cost and US$3,000 for 7 kWh unit cost.

- **Solar Roof: Tesla recently launched new solar tiles that seamlessly blend into the roof of a house** without being an eyesore – a trait associated with traditional solar panels. The tiles also come in different textures and colours to appeal to consumer choice (source: Tesla).

Exhibit 119: Tesla's solar shingles / roof tiles

Source: Tesla

Smart Security: #1 driver for smart homes, US$62bn market by 2030E

With safety as the #1 driver for smart home adoption, we think surveillance equipment such as cameras that can be controlled remotely will increase in uptake. Despite a limited contribution in the short term, home surveillance could be a long-term growth theme for the smart home once IoT connectivity and applications proliferate. Smart home surveillance is expected to gain significant traction over the next few years as a key consumer IoT application. Overall the smart home security market is expected to increase from US$1.6bn in 2015 to US$62bn by 2030E at a CAGR of 28% (source: AT Kearney).

Exhibit 120: Current home surveillance product offerings

Company	Ezviz	Xiaomi	ZTE	Netgear	Nest	D-link
Model Name	C6	YI-Smart	C520	VMS3130-100NAS	NC1102ES	DCS-5020L
Image						
R.P.	960P	720P	1080P	1080P	1080P	720P
Field of view	Horizon 340° Vertical 140°	Horizon 93° Vertical 45°	360°	130°	130°	77°
Video standard	H.264	H.264	H.264	H.264	H.264	H.264
Smart alarm	Yes	Yes	Yes	Yes	Yes	Yes
Working temperature	-20~60°C	-5~40°C	-25~65°C	-20~45°C	-20~45°C	-20~45°C
IP camera	Yes	Yes	Yes	Yes	Yes	Yes
Price(RMB)	599	135	499	1155	1184	633

Source: Hikvision

- **Hikvision rolled out its consumer/home surveillance brand, Ezviz, in late 2013**. The company focuses on mainstream models with ASPs of US$549-600 for pure cameras, and it works closely with a few internet/e-commerce vendors like Alibaba (and TMall), Baidu, JD and LeTV for sales channel/software applications. Customers can obtain access to the data recorded from Ezviz cameras through Aliyun and Baiduyun, which could provide value-added services like Big Data analysis.
- **Google Nest acquired Dropcam in June 2014 for US$555mn**. Dropcam was later rebranded as Nest "Cam" and was introduced in June 2015, selling at US$199. Nest Cam is a Wi-Fi video streaming camera that provides live video accessible through a web or mobile app. It sends an alert when it detects unusual sounds and motions. Nest Cam is nicely integrated with Nest's other products.

DoorBot "smart doorbell" – live streams the front door to a user's

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smartphone whenever someone rings the bell, eg, parcel deliveries. If the user is not at home, it has the functionality of remotely unlocking the front door to allow delivery of the item or for the user to communicate that they want the item left with a neighbour

Smart locks are also emerging as a key essential of the smart home

Smart locks are gaining traction; Kwikset's Kevo is one of the first on the market. Its touch-to-unlock feature makes it one of the easiest to use. All the user has to do is approach with their smartphone or Kevo keyfob in your pocket; and a simple tap unlocks the lock.

Exhibit 121: Smart locks and other security products

Source: NYSERDA

Smart Entertainment: US$33bn market by 2030E

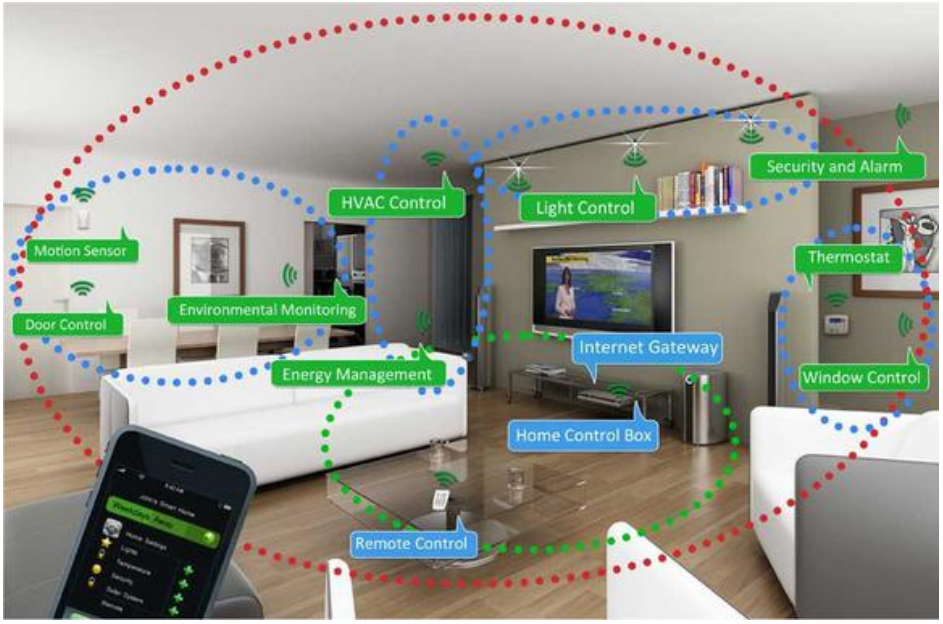
Smart entertainment is emerging as an additional driver for smart home adoption. Smart entertainment can be defined as the synchronisation of a home's entertainment system, eg, TV, speakers etc. These systems can also work in conjunction with the lights and curtains in a house. So, if a user wants to watch a movie, the lights dim automatically and the curtains draw shut once the user turns on the entertainment devices (source: FBIC). The smart home media entertainment market is expected to grow from US$1bn in 2015 to US$33bn by 2030E at a CAGR of 27% (source: AT Kearney). According to an iControl survey, interest in smart entertainment has surged by 55% since last year's survey when only 29% listed this as a top benefit of the smart home. Forty-eight percent of respondents say they are excited about the potential convenience in programming home settings, maintenance and automation.

- **Smart TV** – is essentially a TV integrated with Internet features and functions more akin to a PC. It can therefore perform tasks such as stream Netflix and play YouTube videos. The smart TV acts as the hub of the smart entertainment system at home.

- **Home Cinema** – is designed to simulate a movie theatre experience and ambience at home, integrating a large smart TV with surround-sound smart speakers.

- **Smart Speakers** – are increasingly taking shape in the form of Amazon Alexa, Google Home etc. However, we think vis-à-vis entertainment the next step is to expand this into multiple speaker offerings in the living room. For instance, Samsung's recent acquisition of Harman which has a portfolio of JBL, AKG and Infinity professional speakers represents a step in this direction with its integration into the "SmartThings" ecosystem. In addition, Sonos is often seen as the pioneer in this space where the first device was launched at CES 2004 and today incorporates functionality with the leading music streaming players, such as Spotify, Apple Music and Amazon Music.

Exhibit 122: Smart entertainment inside the living room



Source: EECatalog

Smart Health & Wellness: #1 fastest growing vertical, US$67bn market by 2030

[Healthcare: Automatic for the people; the intersection of Tech and Health Care 24 March 2016]

With an Ageing population that wants to age in place, smart health devices for homes are expected to become one of the fastest-growing verticals of the smart home.

- **Smart home health helps lower costs and thus is well positioned to benefit from the emerging shift away from volume- to value-based care,** by providing lowest costs and reducing wasted healthcare spend, which is also becoming a dominant theme.

- **Smart home health will allow for remote monitoring and consultation, and could enable more accurate diagnoses with next-gen technologies and personalised healthcare treatments** from analysis of a patient's data over time. Smart health devices will increasingly enable homes to take over traditional diagnostics and potentially treatment that is commonly taken at hospitals or surgeries.

- **For instance, Apple HealthKit is compatible with several health devices** ranging from smart scales to smart blood pressure monitors. The diagram below depicts the different measurements that can be tracked in Apple Health and examples of technologies that generate the data and that are integrated with Apple's HealthKit.

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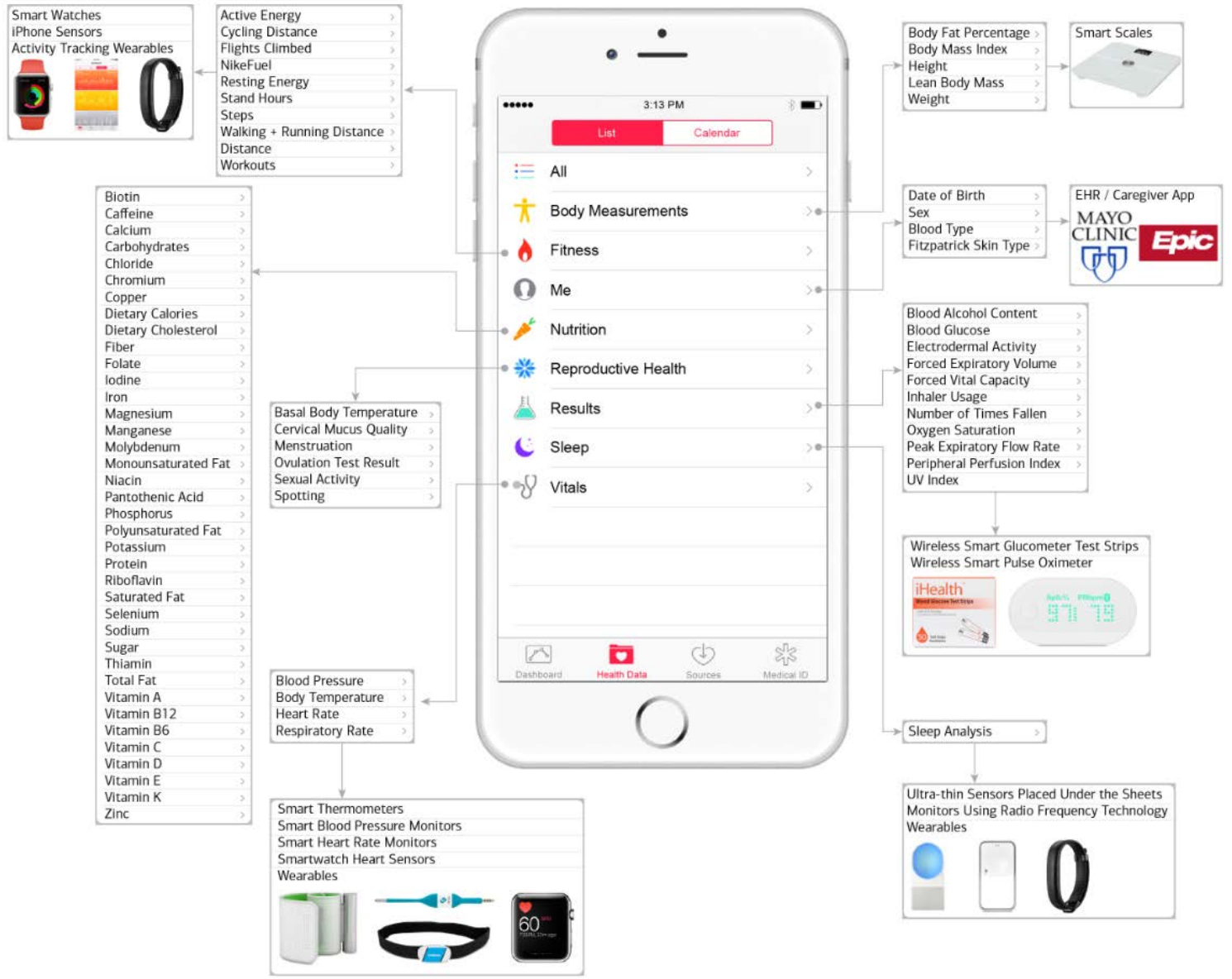
Figure 3: Examples of how 3rd party smart devices can integrate with Apple HealthKit at home.



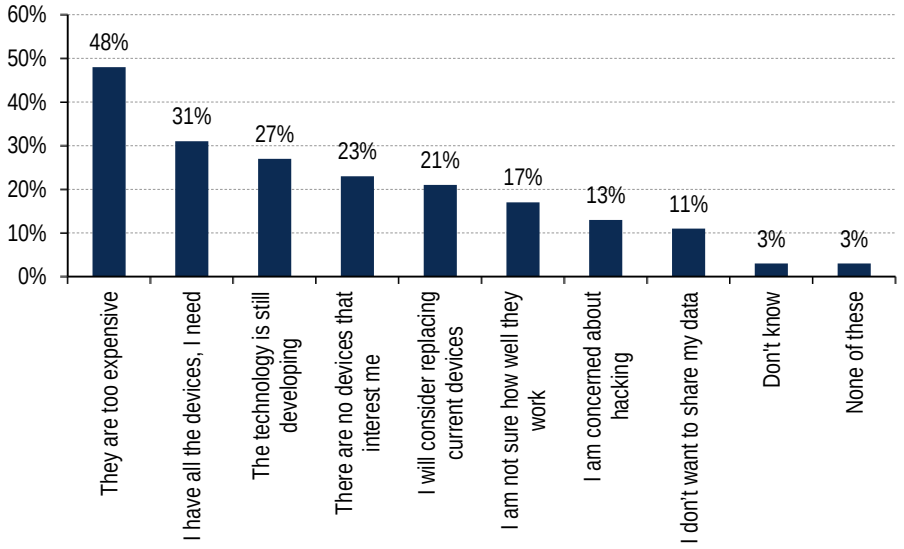
Source: BofA Merrill Lynch Global Research, Apple company website

Cybersecurity & privacy and costs: still key challenges

However, there remain challenges and barriers to adoption vis-a-vis purchase of smart home products that hinder greater consumer uptake, namely cost and cybersecurity, According to a Deloitte survey:

- **48% of consumers think connected products are too expensive** and this rises to 53% for cash-strapped Millennials.
- **26% think the technology still needs to evolve** with 30% of Gen X saying the technology is still developing.
- **21% would consider replacing current devices with connected products** once they are worn out. The 55-64 year old cohort is the most likely to replace aged appliances.

Chart 65: Barriers to purchase of Smart Home products



Source: Deloitte 2016

70% of the most commonly used IoT devices contain vulnerabilities (source: HP)

Being hacked is the #1 safety fear of consumers today

Perhaps the most worrying prospect for growth in the smart home is that newly connected / smart devices could be hacked. A recent report by ProofPoint found that in 2013-14 nearly 100,000 connected devices sent more than 750,000 malicious emails. More worryingly, 25% of these emanated from everyday household appliances, such as smart TVs and refrigerators. Although attacks launched by smart TVs and fridges do not at this point threaten people's lives, they do compromise privacy which can be unsettling for the victims.

- **Consumers say their #1 concern about the smart home is the possibility of a data breach** with 71% sharing the fear that their personal information may be stolen. Consumers say they are more worried about this than the cost of the technology. Sixty-four percent of consumers fear their data will be collected and sold online while 57% fear their smart home technology will have too many bugs (source: iControl).

Smart home is a low priority compared to other low-cost home improvements

According to our US Hardlines Retail team's survey, smart home features remain largely an afterthought in the home improvement space, ranking 12th among projects at 9.9%, after basement, plumbing and electrical.

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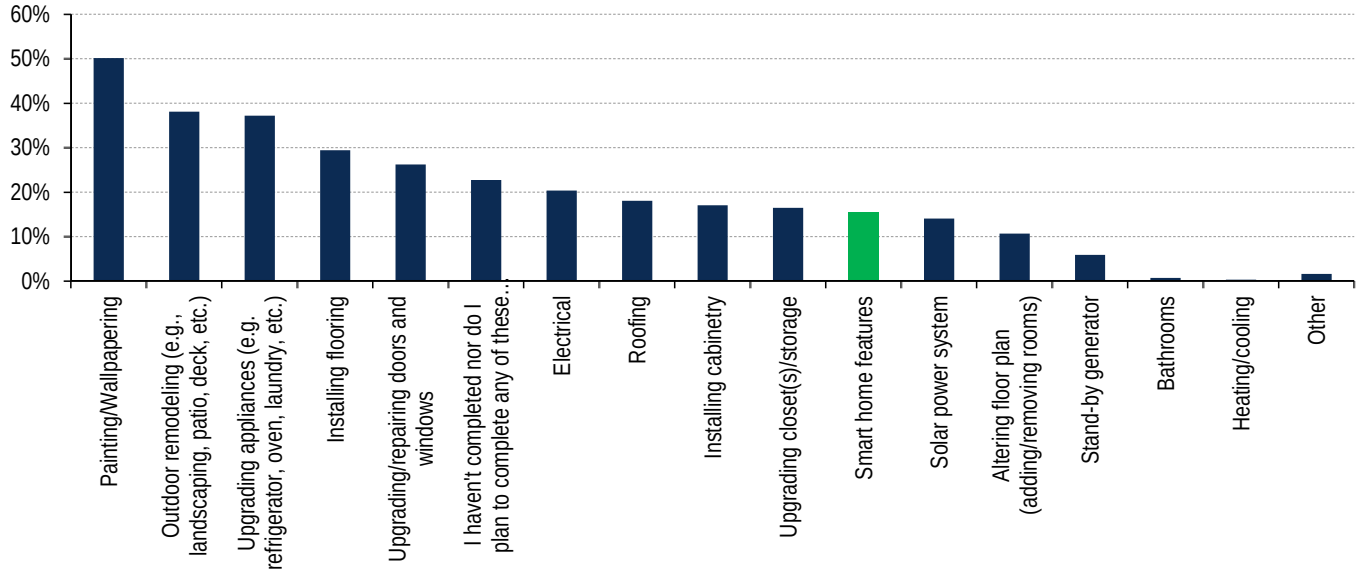
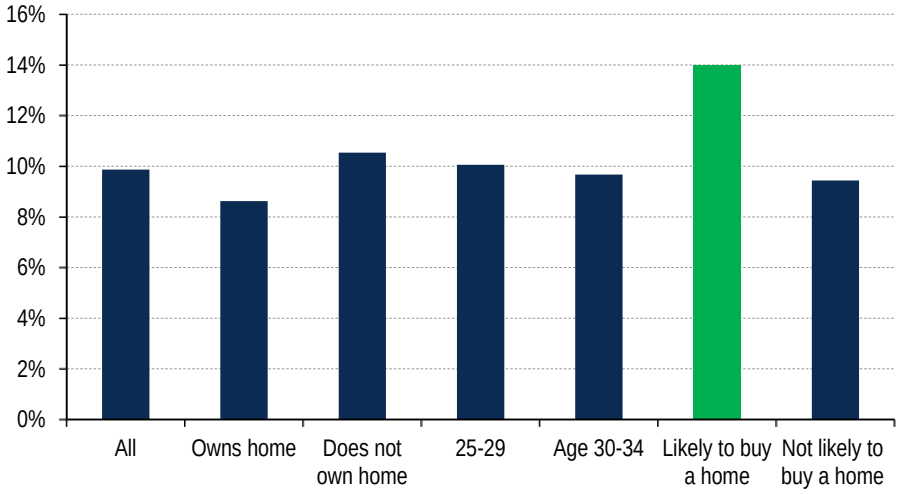
Chart 66: When looking at completed home improvement projects, lower-cost projects such as painting jobs dominated



Source: SurveyMonkey, BofA Merrill Lynch Global Research

People who are extremely, or highly likely to buy a home in the next two years, however, are fairly interested in adding or improving smart home features. Smart home systems tied for 6th (14%) place with living room, closets/storage and windows/doors in terms of priorities. For people who already owned a home, smart home features ranked 14th (8.6%), below solar power systems.

Chart 67: Smart Home features ranked as a low priority investment across the board



Source: SurveyMonkey, BofA Merrill Lynch Global Research

Smart Buildings: the building blocks of cities

We spend 90% of our time in buildings and they account for c.40% of energy, 25% of water, and 40% of resource use, and one-third of GHG emissions globally (source: EPA, Honeywell). However, most buildings are characterised by an increasingly complex array of systems which exist in silos (eg, lighting, ventilation and cooling, utilities, and security), leading to inefficiencies in energy consumption, building usage, and lower quality of services. Buildings are also at great risk of manmade and natural adversities, putting human lives and assets in danger (source: Honeywell).

Only 10% of US buildings have even basic smart system technologies installed and the average Smart Building score in the US was only 35 out of 100 (source: PNNL, Honeywell). With the global building stock expected to grow from 152bn m² in 2014 to 172bn m² in 2024E, this reiterates the need to move to smart buildings – aka automated or intelligent buildings – or those that incorporate "smart" technologies (source: Navigant Research 2016, ICE). Smart Cities envisage efficiencies in urban infrastructure and utilities, smart communication and data networks, and comfortable environments for work and daily life. All of these will enable smart and productive users. Smart Buildings are a critical enabler of such comfort and productivity (source: Honeywell).

Building automation systems (BAS) provide a foundational technology for Smart Buildings while the IoT and AI are making buildings intelligent and intuitive. BAS includes pre-programmed features such as automated control of heating, cooling, lighting and security. Building automation can drive energy savings of up to 30%, with associated paybacks of 0-10Y (source: ABB, Siemens). However, we are also at the cusp of a post-BAS Smart Building revolution where we can incorporate disruptive technologies such as the IoT, Big Data and AI to bring buildings "alive" by shifting away from performing pre-programed, automated tasks to more intelligent, intuitive tasks. Hence, technology companies are becoming increasing competitive threats for traditional building automation players.

The global Smart Building market is expected to increase from US$58bn in 2013 to US$101bn by 2021E (source: Navigant Research). From an investment perspective, our BofAML European Industrials, Building & Construction teams have mapped out several opportunities across the building chain. These include Building Producers (cement, bricks, insulation, glass, flooring, steel) to Capital Goods/Building Technologies (lighting, elevators, heating, ventilation and air conditioning – HVAC). With the shell/envelope of the building (c.60% of costs) remaining relatively unsophisticated from a "smart" perspective (cement, bricks etc), we conclude that c.40% of a building can be made "smarter", most of which in the interior.

We believe there are multiple parts of a building that stand to benefit from high growth from smart technologies. These include: smart building automation systems, smart HVAC (US$17bn market by 2024E), smart elevators (US$23bn market by 2020E), smart lighting (US$19bn market by 2022E) and smart glass (US$8bn market by 2022E). The most mature market is smart security features (eg, access control, CCTV, fire safety) (source: IFSEC), while smart energy management via the IoT tends to be a low-hanging fruit, and can easily be utilised for a diverse set of other business initiatives, including building efficiency, portfolio management, and business operations.

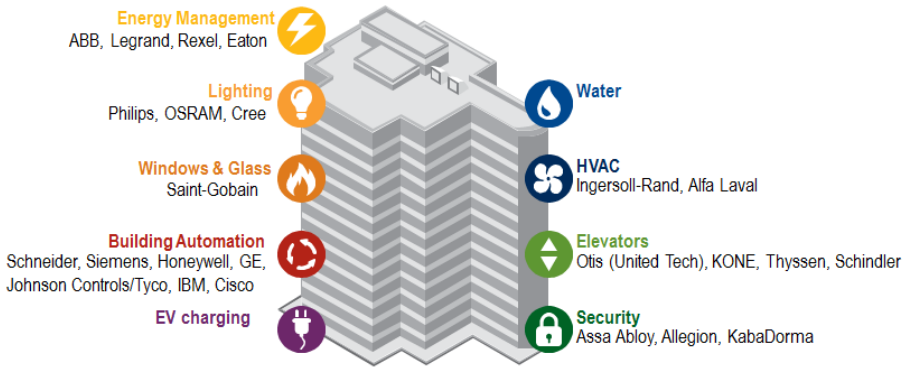
The triumvirate of energy efficiency, productivity, and health, safety and security (HSE) is driving the adoption of Smart(er) Buildings. Energy consumption in buildings accounts for 40% of global energy use and 30% of CO2 emissions (source: IEA). One worker dies every 15 seconds from a work-related accident globally, equating to 6,300 people every day or more than 2.3m deaths every year (source: ILO). Some 160mn people have work-related diseases such as "sick building syndrome" (SBS) making them the most prevalent occupational risk. The estimated potential annual savings and

productivity gains of tackling these risks are US$6-14bn from reduced respiratory disease, US$1-4bn from fewer allergies and asthma, and US$10-30bn from reduced SBS symptoms (source: College of Estate Management, Fisk 2000)

Smarter buildings make for smarter, more productive and satisfied workers. Occupants in high-performing, green-certified office environments score 26% higher on cognitive function tests, have 30% fewer symptoms of SBS, and 6% higher sleep quality vs those working in high-performing but non-certified buildings (source: Harvard TH Chan School of Public Health). And, according to JLL, comfortable, well-ventilated, well-lit, and safe workplaces increase productivity by as much as 16% and job satisfaction by as much as 24% while also reducing absenteeism.

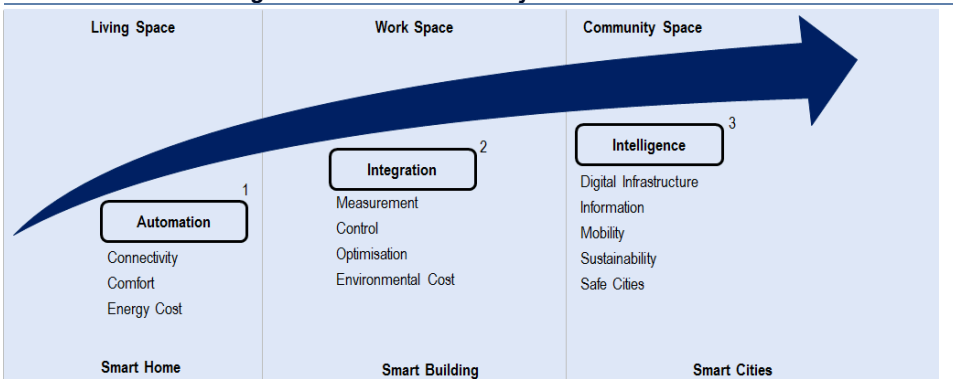
We also think Smarter Buildings can attract Millennial workers and potentially unlock long-term value in real estate. Gen Y workers are driving landlords to remodel their properties to meet their desire to work in offices inspired by the likes of Google and Facebook, introducing co-working and work-life balance features and technologies. Moreover, real estate is frequently the second-largest expense on the income statement and the third most valuable/expensive asset in a company's portfolio (source: IBM). Smarter technologies could be a game changer with 56% of real estate stakeholders believing that they will open up new revenue streams, and 59% believing that will deliver business gains beyond energy efficiency (source: Charles Russell Speechlys).

Exhibit 123: Sample of companies involved in the Smart Building



Source: BofAML Merrill Lynch Global Research based on company reports

Exhibit 124: Smart Buildings connect the Home and City



Source: Frost & Sullivan

Smart Buildings 101

Smart Buildings are sometimes referred to as "automated", "intelligent" buildings or those that incorporate some "smart" technology (source: ICE). We think making buildings smarter matters considering that 90% of people's time is spent inside homes, offices, college campuses etc, of which c.20% is spent doing work (source: EPA). Hence, we view Smart Buildings as integral to our Smart Cities theme and enabling "smart working" for citizens (cf. "smart living" for Smart Homes).

Table 36: Smart Buildings provide a wide range of benefits for Smart Cities

Energy management	Reduce energy consumption and lower utility costs.
Portfolio management	Get a portfolio-wide view of building performance, costs, occupant comfort indicators, and much more.
Sustainability	Motivate occupants to contribute to energy savings by modifying their behavioral patterns.
Occupant comfort	Allow individual to request warm or cold air to improve the comfort level of their environment and as a result increase employee productivity.
Business Intelligence	Use big data analytics to generate useful insights across production, operations, human resources, asset planning, business forecasts, etc.
Operational efficiency	Lower maintenance costs and increase equipment uptime.
Physical security	Keep occupants safe across the property.

Source: Intel

Global building stock: 171.6bn m² by 2024E

The global building stock is forecast to grow from 151.8bn m² in 2014 to 171.6bn m² in 2024E. Most of the new growth is expected to occur in China, where c.1bn m² of space is forecast to be added to the total commercial and residential building stock every year. North America and Western Europe each represent significant portions of the total building stock as well (source: Navigant Research 2015).

9/10 buildings currently still not smart: only scoring 35/100 in US cities

The urgency for making buildings smarter is apparent, with 90% of the buildings in major US cities lacking basic smart technology such as BAS (building automation)/BEM (building energy management)/BMS (building management) systems, leaving them highly inefficient from energy and operational perspectives. The majority of these buildings are of a small/medium size (<50,000 square feet) meaning the return on investment is more challenging compared with larger buildings (source: PNNL).

Honeywell's analysis of 500 buildings across seven major US cities found that airports, government offices and hospital buildings tend to have the highest "smart" score while private offices and high-rise residential buildings often have the lowest scores.

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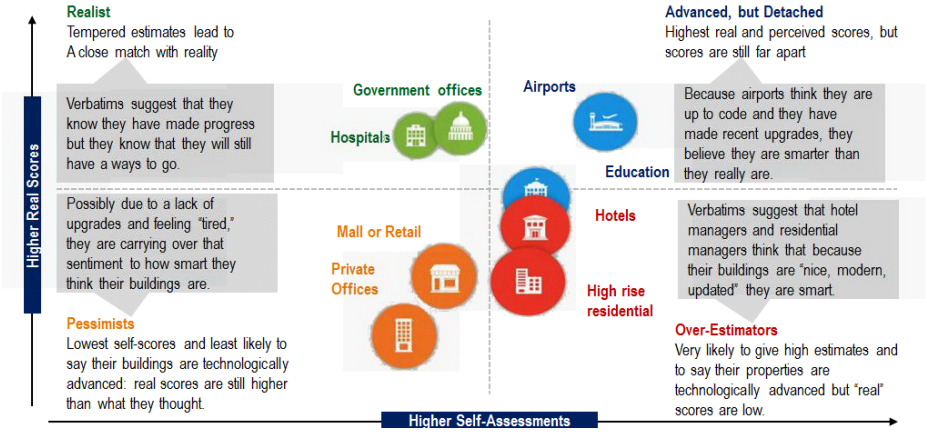
Exhibit 125: "Perception vs. Reality" – How Smart Building Types Really Are

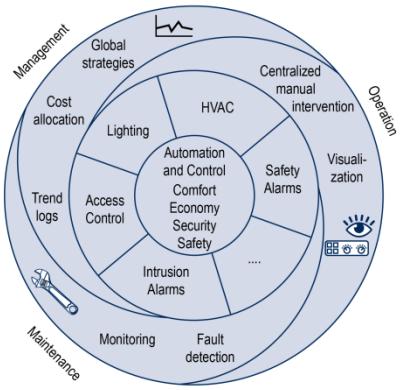


Source: Honeywell

Building automation systems (BAS) provide the foundational technology

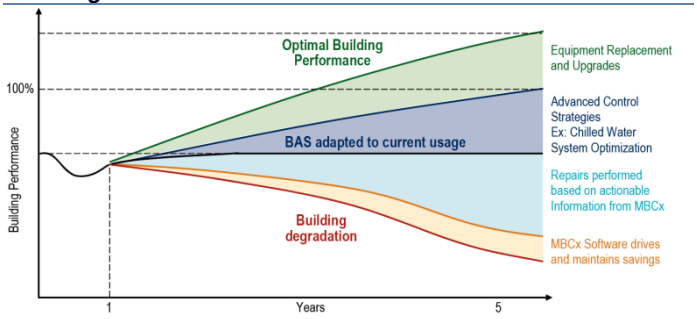
Building automation is generally defined as the monitoring and automatic control of functions within a commercial, industrial or institutional building. Through hardware and software, the control system is designed to improve operational performance through better comfort, safety, energy efficiency or process control. This is a fairly broad definition and the term building automation – including Building Management Systems (BMS), Building Energy Management (BEM), Building Automation & Control Systems (BACS) – is typically used to describe relatively basic control systems that control two or more functions, eg, coordinating heating and lighting (source: Siemens).

Exhibit 126: Functional aspect of building automation systems



Source: Citeseerx

Exhibit 127: Building energy performance with building automation technologies

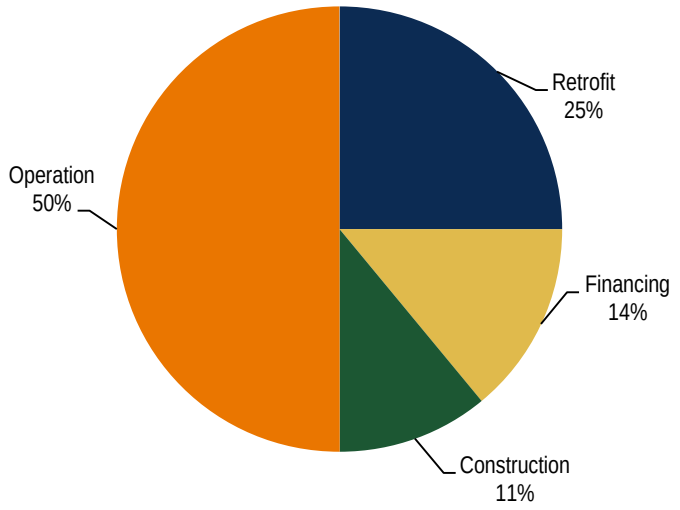


Source: Siemens

Typical lifecycle savings of up to 30% with up to 10Y payback

According to ASHRAE via Frost & Sullivan, 50% of a building's lifecycle cost over a 40Y period typically comes from operation, followed by retrofitting (25%), financing (14%) and construction (11%).

Chart 68: Building's lifecycle cost over 40 years



Source: ASHRAE, Frost & Sullivan

Table 37: Building automation can drive savings of up to 30%

Automation area	Potential savings
Room heating control	14-25%
Heating automation	7-17%
Shutter control	9-32%
Lighting control	25-28%
AC control	20-45%
Average energy savings	11-31%

Source: ABB

Siemens and ABB have both estimated that building automation (through efficiency improvement and modernisation) can generate energy savings of up to 30%, with associated paybacks of 0-10 years.

Table 38: Energy savings and payback examples

Case Study	Energy Savings	Payback Period	Technology Trade Names
State of Missouri	17% annual energy savings (post retrofit)	Payback in less than two years	Enterprise Asset Management & Building Information Management System
Kwantlen University College	30% annual energy savings compared to energy code ASHRAE 90.1 -1999		Integrated Building Automation System (BAS)
Rogers Centre	76% savings on lighting energy costs (post retrofit)	Phase One: Payback in three years Phase Two: Payback in two-and-a-half years	Energy Control System (ECS)
Providence Newberg Medical Center	26% annual energy savings compared to ASHRAE 90.1		Integrated HVAC system
The Verve – High Rise Condominiums	35% annual energy savings compared to local energy code (similar to ASHRAE 90.1)	LEED premiums Payback in seven years or less	Energy Management Systems (EMS)

Source: Cisco, Frost & Sullivan

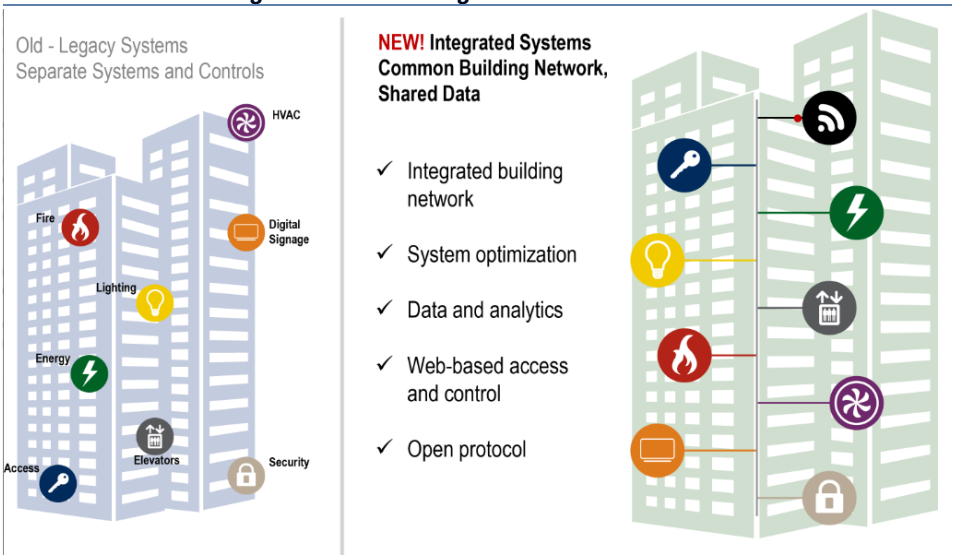
Disruptive technology: taking buildings to the nextgen level

We think the next phase, post-BAS, is for Smart Buildings to incorporate disruptive technologies such as the Internet of Things, Big Data, and Artificial Intelligence to bring the building "alive". This involves a shift from performing pre-programed, automated tasks to more intelligent, intuitive tasks such as predicting and optimising energy usage according to occupancy capacity. Features of a truly smart building may include:

- **Setting up lighting to operate on an intelligent/efficient schedule**.
- **Telling when HVAC is running both heating and cooling** to reduce utility costs.
- **Identifying who and when someone is entering and leaving** a building.

- **Coordinating components and facilities to work together** for greater efficiency.
- **Sensing emergencies** and turning off facilities that could endanger occupants.
- **Alerting cameras, recording activity, sending alarm and data** to a security team.
- **Optimising incoming air flow** to regulate air quality, temperature and comfort.
- **Detecting problems** (elevator stuck with people inside) and sending an alert. (source: Control Solutions).

Exhibit 128: Smart Buildings aka "IoT for Buildings"



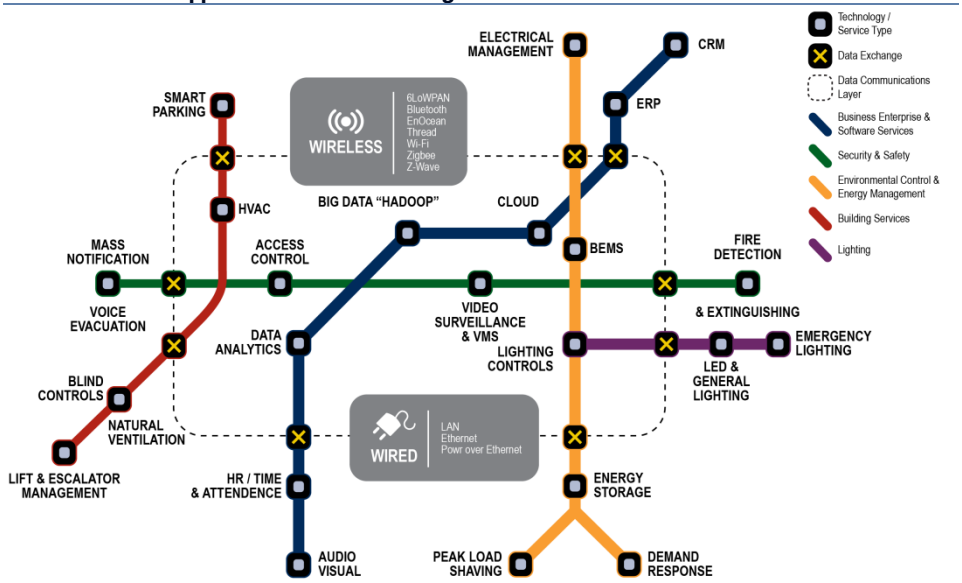
Source: JLL

Tech companies getting in on the smart buildings opportunity

As with many of our themes, technology companies are becoming more disruptive competitors and the Smart Buildings space is no different. There is growing recognition of the potential for IoT in the Smart Buildings market. For example, value-added components to meet connectivity requirements for new and existing building systems as well as corresponding demand for network hardware, data services and platforms. A company example of this is IBM Watson, which is already being putting its expertise to use in IoT vis-à-vis the Smart Buildings space:

- **PhotonStar** – creating intelligent lighting solutions based on Watson IoT moving towards smart buildings.
- **ISS** – using Watson IoT to improve its facilities management and coverage of 25,000 buildings.
- **KPMG** – building upon the IBM TRIRIGA facilities manager software offering to simplify compliance with lease accounts and find cost savings.
- **North Start Bluescope Steel** – steel producer leveraging Watson IoT to improve workers' safety.
- **City of Cambridge (Canada)** – leverage weather data from Watson IoT to improve city work management solutions (source: IBM, BofA Merrill Lynch Global Research).

Exhibit 129: IoT mapped in commercial buildings

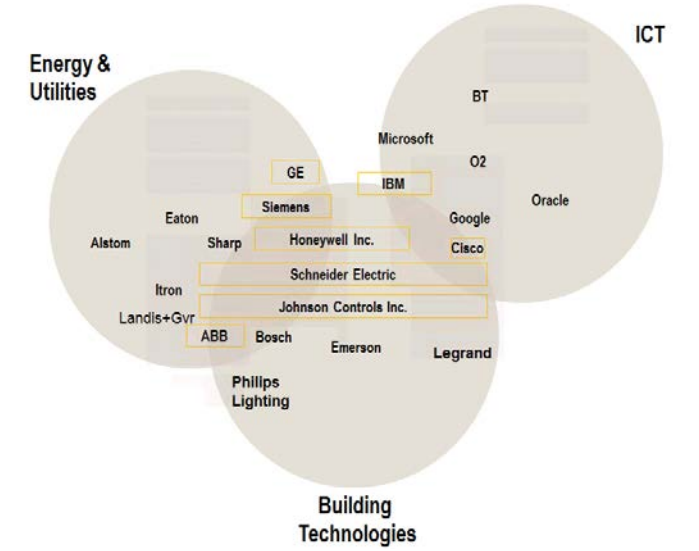


Source: Memoori

Traditional building automation players such as Siemens and Schneider have occupied this space. However, large technology companies are increasingly bringing their expertise in AI, IoT, and Big Data analytics to shift from simple automation of building tasks, such as pre-programed functions, to more intelligent roles, eg, predicting and optimising usage.

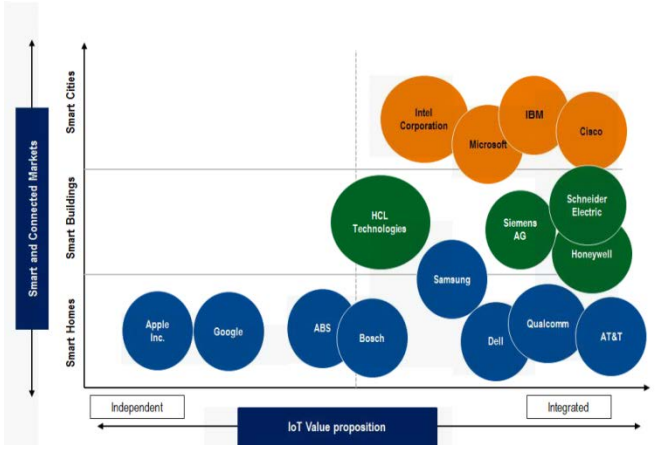
Exhibit 130: Smart Buildings Market: Key Participants and the convergence of Three Industries

Europe,



Source: Frost & Sullivan

Exhibit 131: IoT in Smart Buildings: Key participants in Smart and Connected Markets, Global, 2014



Source: Frost & Sullivan

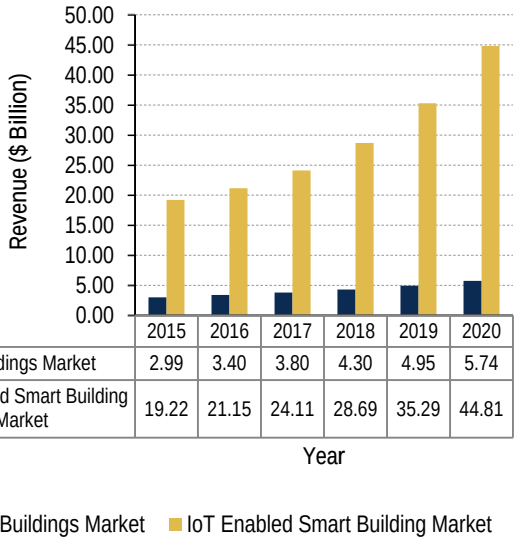
US$45bn NAm smart building IoT-enabled market by 2020E

The potential size of the smart buildings IoT-enabled market for North America alone is estimated at US$19bn in 2015 and projected to increase at a CAGR of 18.4% to 2020E to reach US$45bn (source: Frost & Sullivan).

Bank of America Merrill Lynch

Chart 69: IoT enabled Smart Building market: revenue forecast, North America, 2015-20E

CAGR: 18.4%



	2015	2016	2017	2018	2019	2020
Smart Buildings Market	2.99	3.40	3.80	4.30	4.95	5.74
IoT Enabled Smart Building Market	19.22	21.15	24.11	28.69	35.29	44.81

Source: Frost & Sullivan

Table 39: Percent revenue share by product segment, North America, 2015

BAS Hardware and Enablement Hardware	Network Communication Services	IoT Data Services
68.0%	17.0%	15.0%

Source: Frost & Sullivan

Note: All figures are rounded. The base year is 2015.

Case study on architect Stefano Boeri's plan to build "forest cities" in China:

- **The initial plan is for Nanjing to have two neighbouring towers coated with 23 species of tree and >2,500 cascading shrubs**. The structures will reportedly house offices, a 247-room luxury hotel, a museum and even a green architecture school, and are currently under construction, set for completion in 2018.

- **Boeri describes his "vertical forest" concept as the architectural equivalent of a skin graft**, a targeted intervention designed to bring new life to China's polluted cities. Boeri claims the buildings will suck 25t of CO2 from Nanjing's air each year and produce about 60 kg of oxygen every day.

- **Boeri has been asked to design an entire city with 100-200 buildings of different sizes**, all with trees and plants on the facades, and China could have its first "forest cities by 2020E (source: Stefano Boeri architetti, press sources).

"Building" the investment case: US$101bn by 2021E

We think the overall long-term investment case for the Buildings space is compelling given that:

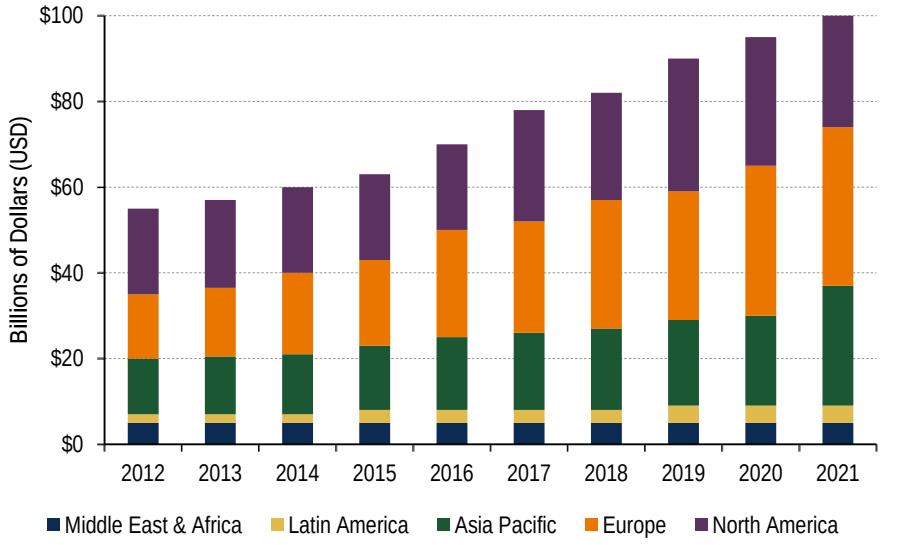
- **The global building stock is expected to grow to 172bn m² by 2024E** from 152bn m² in 2014 and the market is forecast to grow at 4.2% per annum (source: Navigant Research).

- **China is adding around 2bn m² of buildings every year**. By 2024, China will have 58bn m² of building space, which will make up more than a third of the world's total (source: Navigant Research).
- **Fifty percent of the buildings are yet to be built to support the 300mn+ city dwellers in China** by 2030 (source: Vision 2050, World Business Council for Sustainable Development).
- **In the US building operations contribute around US$235bn to GDP**, support 17.5mn jobs and generate US$67bn in new earnings, contributing c.30% to the economy each year (source: ARM).
- **Globally, smart building technology could reduce emissions by 1.68 GtCO2e**, create £201bn of energy savings and slash carbon costs by £31.1bn by 2020 (source: IFSEC).
- **Global construction output will grow by 85% to US$15.5tn by 2030E** with three countries – China, the US and India – leading the way and accounting for 57% of global growth (source: PwC).

Global BAS market to grow from US$58bn in 2013 to US$101bn in 2021E

The global commercial building automation systems (BAS) market is expected to increase from US$58.1bn in 2013 to US$100.8bn in 2021E (source: Navigant Research). The commercial BAS market is driven by new and retrofit commercial building construction and by the energy efficiency requirements applied to this construction. The sector continues to evolve from point solutions built from proprietary products towards open and integrated systems, based on modern digital information technologies. Integrated by new building management systems (BMS), the automation of HVAC, lighting, fire & life safety, and security & access controls is increasingly forming the foundational infrastructure for advanced energy management products and services (source: Navigant Research).

Chart 70: Commercial building automation revenue by region, 2012-21E



Source: Navigant

- **North America –** the US and Canada are pioneers in the smart buildings market. Global market leaders such as IBM, Dell, and Echelon have implemented smart building projects in North America. Technological sophistication and the recovering economy are key drivers for the smart buildings market.

Bank of America Merrill Lynch

- **Europe –** the UK, Germany, Sweden, France, and Italy are leading candidates in implementing smart buildings. The EU has invested in R&D for smart buildings, which directly helps in improving the energy performance of buildings across Europe.

- **APAC –** China, Japan, South Korea, Singapore, and India are frontrunners in bringing together the construction and ICT industries for global development. This offers immense opportunities for growth of the smart buildings market.

- **Middle East –** Smart City projects have been incorporated in the city of Masdar (UAE), Lusail (Qatar), and King Abdullah Economic City (Saudi Arabia). Smart buildings in these regions have good prospects because of strong and stable economies and high construction rates.

Many companies across the value chain involved in making the building....

The non-residential building market is large and fragmented encompassing many sectors. Our European Industrials, Building & Construction teams have mapped it out as the following: Site Preparation (including surveying); Distribution (of building products); Building Activity (contractors); Building Products (cement, bricks, insulation, glass, flooring, steel); and Capital Goods/Building Technologies (lighting, fire and security, automation, elevators, low and medium voltage products, HVAC, cables).

Exhibit 132: Who makes the building? Breakdown of key segments and companies

THEME	WHO MAKES THE BUILDING							
END MARKETS	Residential Building Construction							
	Non-residential Building Construction							
BUILDING FLOW	*Site preparation*	Distribution	Building activity		Building Products		Capital Goods	Building Tech
SEGMENTS	*Surveying* *Construction Equipment* *Rental Equipment*		Housebuilders	Contractors	Cement Bricks Flooring Insulation Glass	Steel	Lighting HVAC Medium voltage Automation Cables	Low Voltage Elevators Fire & security
COMPANIES	Hexagon Ashtead	Rexel Travis Perkins Wolsely	Barratt Bellway Berkeley Group Bovis Homes Persimmon Redrow Taylor Wimpy	ACS Balfour Beatty Eiffage Ferrovial Hochtief OHL Skanska Vinci	CRH Cie de St-Gobain HeidelbergCement Holcim Lafarge Tarkett	ArcelorMittal Salzgitter SSAB/Ruukki ThyssenKrupp	Osram Philips Melrose (Meters) Schneider Siemens ABB IMI Alfa Laval Nexans Prysmian	Legrand Assa Abloy KONE

Source: BofA Merrill Lynch Global Research, Companies data

...but up to c.40% of the building can be made "smarter"

Our Building & Construction teams estimates the cost of an average non-residential building at €46.4mn (excluding land and professional fees) where the shell/envelope of the building costs 55-60% of the total structure including products such as glass walls, steel frame and concrete. Hence, the interior costs up to 40% of the building with HVAC (10%) taking the lion's share followed by carpets/tiles (6%), elevators (4%) and lighting (3%), low-voltage products (2%), fire & security (3%), building automation systems (2%), water & drainage (1%) and sanitary appliances (1%). With the building envelope relatively unsophisticated by construction we infer that c.40% of a given building can be made smarter, most of which in the interior.

Exhibit 133: Non-Residential Building Construction cost breakdown - key global companies

Red box highlights the "smarter" areas of the building

Category	Excavation & Foundations	Steel & related	Concrete	Flooring	Roofing Products	External walls (glass)	Windows & doors	Plumbing & Drains	HVAC	Lighting	Low voltage	Fire & Security	Building automation system	Elevators
% of costs	7%	10%	4%	6%	2%	15%	1%	1%	10%	3%	2%	3%	2%	4%
Companies covered	Volvo	Arcelor Salzgiter SSAB Thyssen	CRH Lafarge Holcim Heidelberg	Tarkett	St Gobain	CRH Heidelberg Lafarge Holcim	*Windows* St Gobain *Doors* Assa Abloy	Wolseley St Gobain Travis P.	Alfa Laval Schneider ABB IMI	OSRAM Philips	Legrand Schneider ABB Siemens Rexel	Schneider Siemens Assa	Schneider Siemens Legrand	KONE Thyssen
Competitors	CAT Komatsu Hitachi New Holland JCB Bobcat CASE Doosan Kubota Bell	US Steel AK Steel Gerdau Dynamics Nucor Sumitomo JFE Steel Baosteel Angang China steel	Cemex Buzzi Italcementi Vicat Titan CNBM Anhui Jidong China Rsc. Sinoma	Shaw Armstrong Mohawk Interface Forbo Gerflor Beaulieu Balta Mannington	Braas Monier Kingspan Wienerb'ger Etex Terreal Imerys Durken Juta	Wienerberger Boral ACME Cemex Buzzi Italcementi Vicat Titan	NSG AGC KONE Agta Dorma Stanley	Polypipe Wienerb'ger Xylem Tetra Tech Sanki Roto rooter	Ingersoll R UTX Mitsubishi SANYO TRANE Lennox YORK Daikin Honeywell Yaskawa	GE Zumtobel Acuity Cree Hubbell Eaton Panasonic Toshiba Sharp Samsung	Eaton Hubbell Hager Chint Tyco Honeywell Johnson Panasonic Leviton Hubbell	United Tech Honeywell Tyco Lennox Johnson C	Honeywell Johnson Tyco United Tech	United Tech Schindler Hitachi Mitsubishi Toshiba Fuji

Source: BofA Merrill Lynch Global Research, Companies data

Triumvirate of efficiency, health & safety, and productivity driving adoption

Up to 30% energy savings and 20% lower maintenance costs can be achieved in intelligent buildings (source: ABB).

Similar to Smart Homes, the drivers of energy efficiency, health, safety and security are key. However, productivity is also a driver in the adoption of Smart Buildings, improving the workplace to maximise the output of employees. Honeywell's smart building scoring index divides 15 key building features into three buckets as follows:

- **Green/sustainable –** buildings consume less energy and fewer resources saving valuable energy dollars while cutting emissions. For instance, LEED-rated Gold Buildings consume 25% less energy, 11% less water, and emit 34% less greenhouse gases than non-LEED certified buildings, and score 27% higher on occupancy satisfaction.

- **Safer** – smarter buildings lower the cost of managing business risks, eg, terrorist, cyber attacks etc, hence protecting key assets (real estate, employees etc).

- **More productive** – in a building environment with better air quality employees are up to 5% more productive with a national workforce positive impact of potentially up to US$200bn.

According to Honeywell building operators' key priority is safety (51%) followed by sustainability/efficiency (27%) and productivity (22%).

Safety accounts for the top four smart building features

Like for smart homes, the greatest degree of smart maturity and demand appears to come from safety & security, which accounts for the four most common smart building technologies according to a recent IFSEC survey:

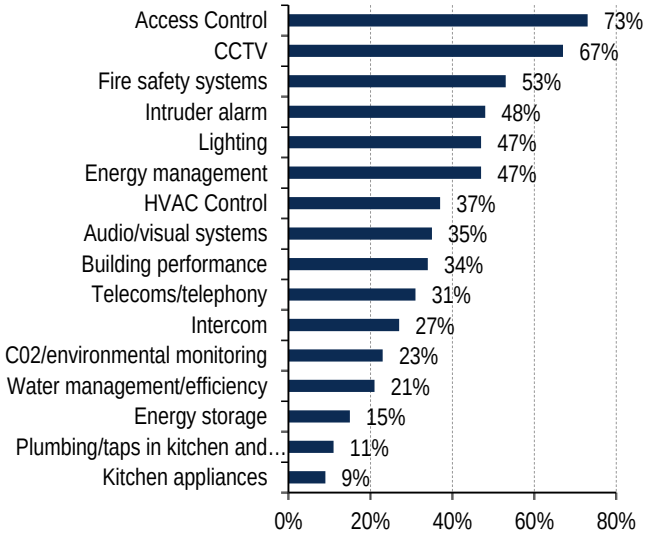
- **Access control was #1 smart building feature** (73%) followed by CCTV (67%), fire safety systems (53%) and intruder alarms (48%).

- **Conversely, among the least smart features were energy storage** (15%), CO2/environmental monitoring (23%).

- **The biggest benefits of installing smart tech in buildings were jointly "improving security" (23%) and "cutting energy usage/costs" (23%)**.

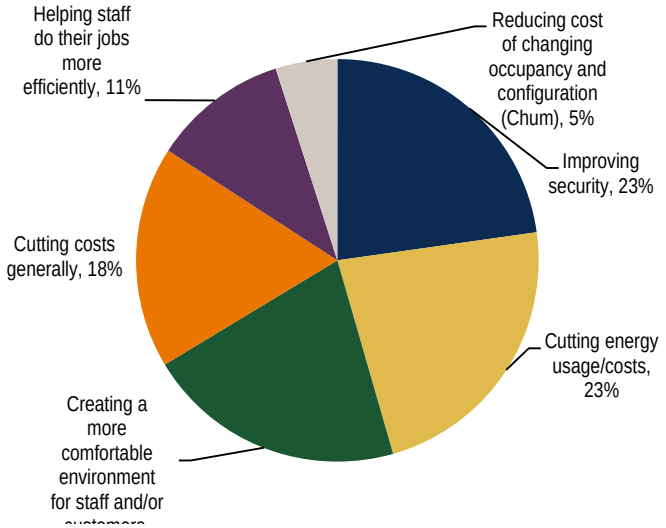
Bank of America Merrill Lynch

Chart 71: Which of your building functions would you describe as having 'smart' functionality? (answer options, %)



Source: IFSEC

Chart 72: What has been/do you expect to be the biggest benefit of installing smart technologies in your building?



Source: IFSEC

"3-30-300" rule for greener, safer & productive buildings

The rule of thumb to approach the triumvirate is what Jones Lang LaSalle (JLL) advocates as the "3-30-300" rule for the smart building whereby organisations spend US$3 per square foot on energy, US$30 on rent and US$300 on their employees' salaries and benefits:

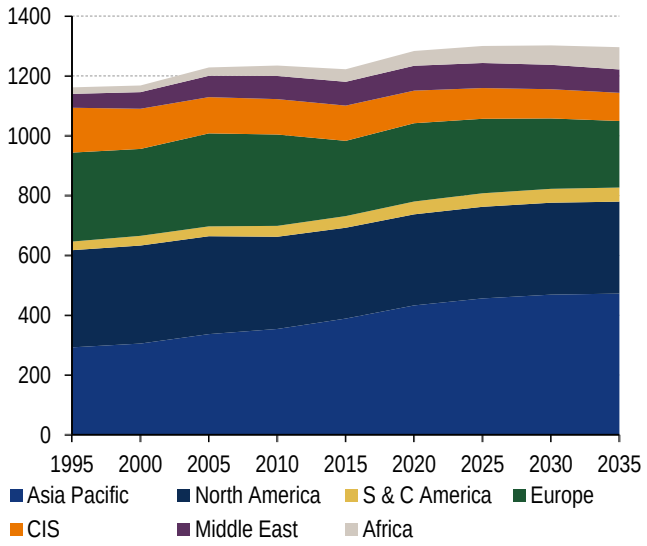
- **Using smart technology to improve a building's energy efficiency by 10% would yield US$0.30 per square foot in cost savings**.
- **Using smart sensors to gather occupancy data and inform workplace strategy safety decisions to increase space occupancy by 5% would yield cost savings of US$1.50 per square foot**.
- **The ability to customise and control the office environment from a smartphone – improving productivity by 2% – would yield cost savings of US$6 per square foot in increased productivity**.

Energy Efficiency: buildings remain #1 energy consumer

As we have previously flagged in our Climate Change primer, the argument for greater energy efficiency in buildings is compelling. Energy consumption in buildings accounts for 40% of global energy use and 30% of CO2 emissions (source: IEA). Energy demand has been on the rise for many years with the biggest culprits being heating and cooling, which, together with lighting, can account for up to 60% of consumption. Global energy demand from buildings is expected to increase by more than 60% by 2040E, or a CAGR of 1.6% globally, and 2.7% for EMs (source: IEA).

Chart 73: Global buildings' energy consumption outlook by region

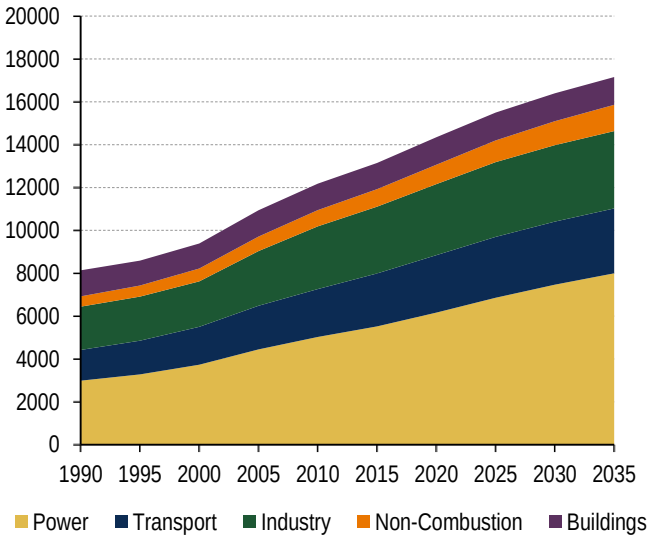
Million tonnes oil equivalent



Source: BP Energy Outlook 2017

Chart 74: Global energy consumption outlook by Industry

Million tonnes oil equivalent

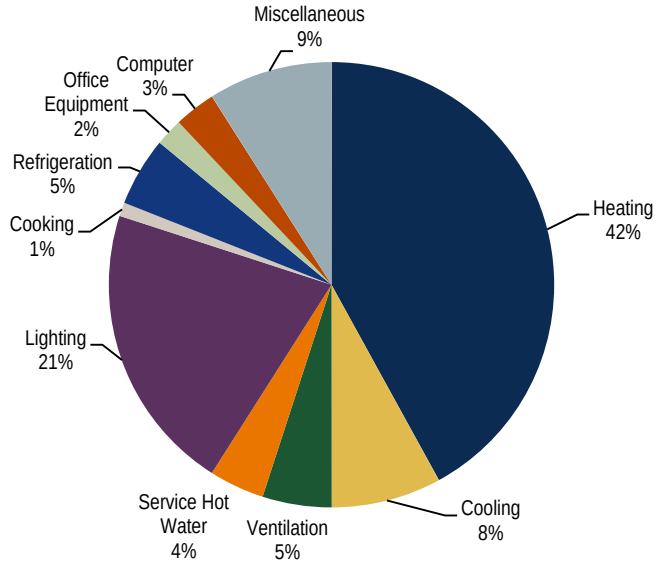


Source: BP Energy Outlook 2017

Biggest culprits: heating, cooling & lighting

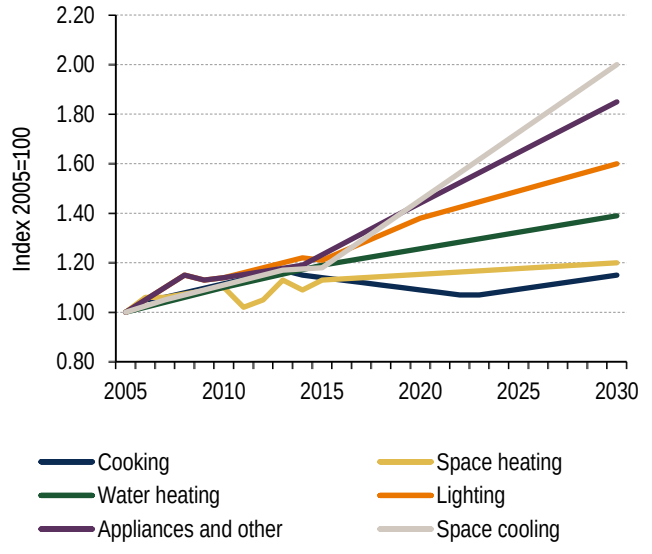
Heating and cooling, together with lighting, can account for up to 60% of a commercial building's energy consumption. Alongside tackling buildings' thermal envelopes, building automation will play an important role in reducing energy use by the targeted 30-50% by 2030-50. Space cooling energy consumption in buildings is expected to continue to rise and remain the #1 culprit; doubling by 2030 from 2005 indexed levels. Interestingly, space heating energy demand during this period will largely remain flat suggesting that occupants generally find buildings too warm rather than too cold or the earth is getting warmer (source: IEA).

Chart 75: Typical energy cost breakdown of a commercial building (50,000 sf)



Source: PNNL

Chart 76: Global buildings sector end-use energy consumption, 2005-2030



Source: IEA

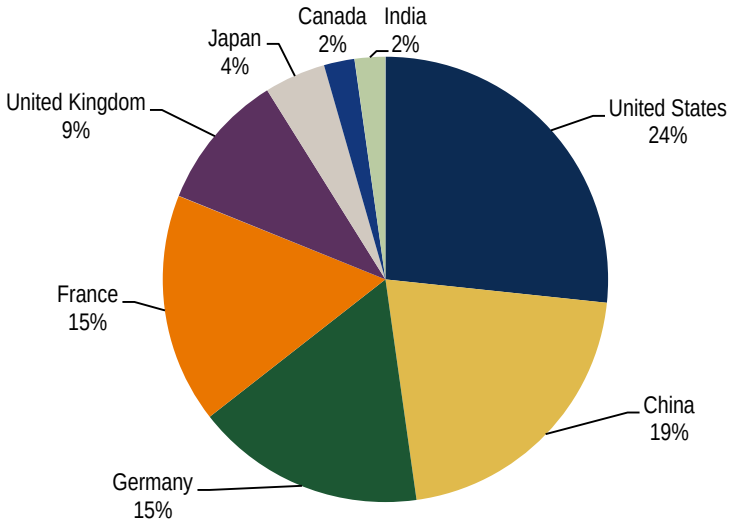
US$388bn energy-efficient buildings investment market

The IEA has identified the building sector as one of the most cost-effective for reducing energy consumption. Improved energy efficiency in this sector offers the potential to

reduce energy use by 50% and costs by 30%. The average payback for efficient building technologies is only 3Y in terms of electricity and 9-14Y for fuels. Moreover, there is significant low-hanging fruit – with 80% of the economic potential of energy efficiency in buildings remaining untapped (source: IEA).

- **Global incremental energy efficiency investment in buildings, including appliances and lighting, has been increasing and was US$118bn in 2015**.
- **Total spending on energy-efficient products and services in buildings worldwide was US$388bn in 2015**. The US, China, Germany and France accounted for more than US$86bn of this investment. Efficient buildings are still only 8.5% of total building construction spending of US$4.6tn worldwide (source: IEA).

Chart 77: Incremental energy efficiency investment in buildings by country, 2015



Source: IEA, Navigant Research

Zero-energy buildings: carbon neutral or supplying the grid

We are also seeing an emerging trend of the "zero energy building" (ZEB) where buildings are becoming carbon-neutral and/or actually generating energy and supplying this back to the grid driven by regulation demands. For instance, the EU's Energy Performance of Buildings Directive requires all new buildings to be nearly zero-energy by the end of 2020, and all new public buildings to be nearly zero-energy by 2018 (source: European Commission).

Green is not to be confused with smart: bright green buildings are the end-goal

One common misnomer is to conflate the green building with the smart building. A green building differs from a smart building but the two can overlap, defined by Cisco as a "bright green" building – intelligent, green, and profitable. This is a building that uses both technology and process to create a facility that is safe, healthy and comfortable, and enables productivity and well-being for its occupants. Bright green buildings exhibit key attributes of environmental sustainability to benefit present and future generations. Whereas green buildings may focus on carbon footprint such as reducing energy usage, intelligent buildings seek to integrate systems for greater effectiveness. However, more often than not these two goals converge, which we explore in our case study of The Edge, Amsterdam later.

Safety: protecting infrastructure, employees and data

As we highlighted in our earlier section on Smart Safety & Security, the workplace can be a hazardous place whether that be related to a cybersecurity hack or physical accidents. With recent events ranging from terrorist attacks to natural disasters,

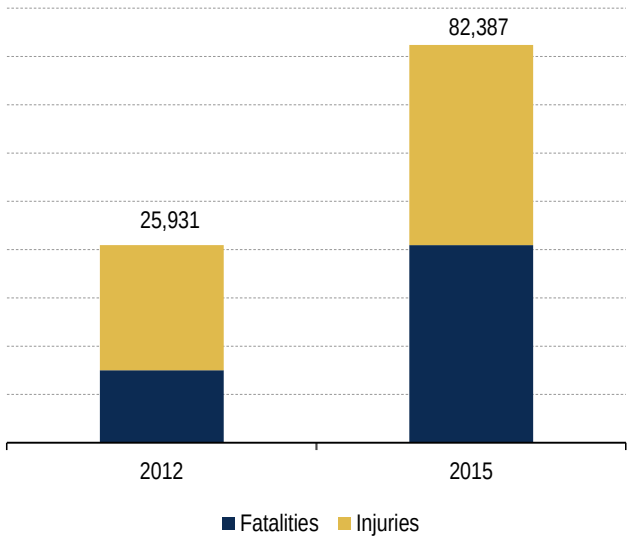
corporations are developing and implementing greater safety mechanisms for their buildings' crisis management & communication, emergency response, business continuity plans and IT/disaster recovery plans. There was an estimated US$535bn in total annual impact from terrorist attacks, malware programs, and natural disasters alone in 2015 (source: various listed below).

One worker dies every 15 seconds from a work-related accident globally, equating to 6,300 people every day or more than 2.3mn deaths every year.

The direct and indirect costs total US$1.25tn in annual GDP losses due to workplace illness, injury and deaths (source: ILO).

Chart 78: Global Terrorist Attacks

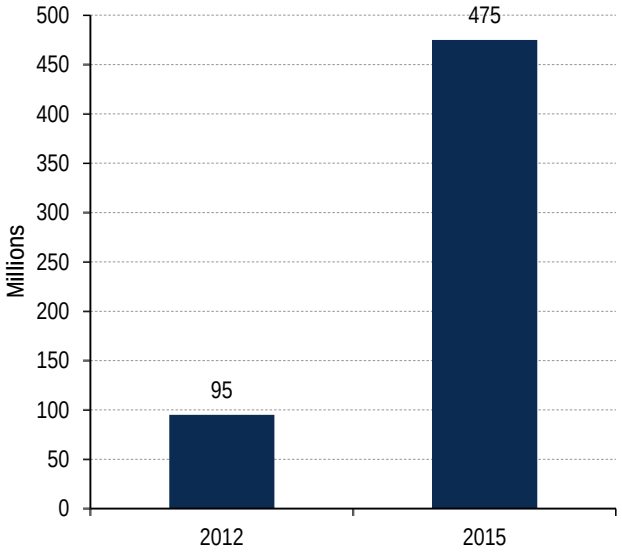
Accelerating Threats, 2012 vs. 2015: US$535bn total annual impact from terrorist attacks, malware programs, and natural disasters



Source: Company reports, Global Terrorism Database

Chart 79: Global Number of Malware Programs 2

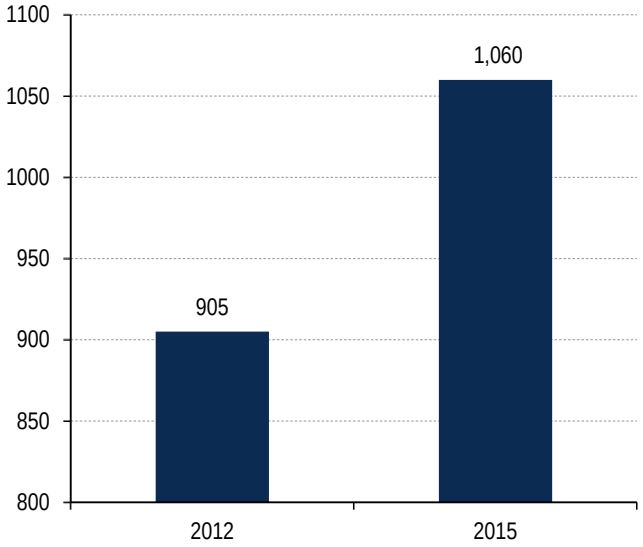
Accelerating Threats, 2012 vs. 2015: US$535bn total annual impact from terrorist attacks, malware programs, and natural disasters



Source: AV-Test Institute – "Total Malware"

Chart 80: Natural Disaster Loss Events 3

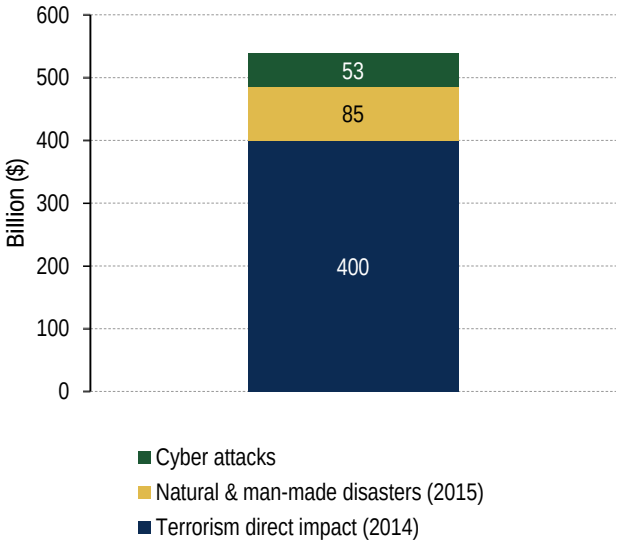
Accelerating Threats, 2012 vs. 2015: US$535bn total annual impact from terrorist attacks, malware programs, and natural disasters



Source: Munich RE – "NatCatSERVICE Loss events worldwide 1980 – 2015" and "NatCatSERVICE Loss events worldwide 2015"

Chart 81: Total Cost 4

Accelerating Threats, 2012 vs. 2015: US$535bn total annual impact from terrorist attacks, malware programs, and natural disasters



Source: Institute for Economics and Peace "Global-Terrorism-Index-2015", Swiss Re - Preliminary sigma estimates for 2015: global catastrophes cause economic losses of USD 85 billion" Lloyd's – "Cyber attacks cost companies $400 billion every year"

Long-term secular drivers for Smart Building safety & security

There remain strong long-term growth drivers for building safety including: sector trends (outsourcing, privatisation, consolidation, convergence of IT and physical security, renovation trends); socio-economic trends (terrorism, crime, cash cycle, EM middle class and urbanisation, stakeholder perception of threats); the economic environment (wealth disparities, rebound in GDP); regulation (proliferation of codes and standards); the fragmented nature of the market and increasing consolidation trends; and technological shifts with incumbent markets like "manned" guarding coming under pressure from technological solutions.

Robocop for buildings: Knightscope and SAM case studies

Knightscope is an autonomous security robot used to predict and patrol crime using a variety of sensors including video camera, thermal imaging, laser range finder, radar and a microphone. It can be programmed to operate inside or outside buildings and if it detects known criminals it will alert local authorities. The founders believed that with a unique combination of hardware and software they could reduce crime by as much as 50% in a geo-location fenced-confined area. The company claims the robot can process 300 licence plates a minute and detect any irregularities (source: Knightscope.com). Knightscope prices its robots at US$6.25 per hour – half the estimated average hourly wage the 1mn+ security guards earn in the US (source: BLS). Customers include Microsoft (uses it to patrol its Silicon Valley campus) and Uber (patrols a car inspection lot on Vermont Street in San Francisco).

Similar to Knightscope, SAM (Secure, Autonomous and Mobile) is a robot security guard drone that the maker, Robot Security Systems, claims is "the first robot that can recognize people and objects while on the move". SAM knows the floor plan of the premises, and features lots of sensors, meaning it can effortlessly pass by obstacles, take the elevator, and open (automatic) doors while making its surveillance rounds. Sodexo, G4S and Rabobank are partners that are currently using SAM, and The Edge in Amsterdam uses it for nighttime patrols.

Productivity: smart buildings can make for smart(er) workers

As highlighted earlier, we think a unique driver for Smart Buildings compared with other Smart Cities entry points is the desire for greater work productivity by unifying various features, eg, HVAC, lighting, work stations into a seamless experience for its occupants. According to JLL, comfortable, well-ventilated, well-lit and safe workplaces increase productivity by as much as 16% and job satisfaction by as much as 24% while reducing absenteeism. Furthermore, Smart Buildings can make for smarter workers. Occupants in high-performing green-certified office environments scored 26% higher on tests of cognitive function, had 30% fewer symptoms of sick building syndrome (SBS), and 6% higher sleep quality scores than those working in high-performing but non-certified buildings (source: Harvard TH Chan School of Public Health).

US$6-14bn in productivity gains from reducing sick building syndrome

Sick building syndrome (SBS) is a common issue for workers, with a range of symptoms thought to be linked to spending time in a certain building, most often a workplace, although no specific cause of the illness can be found (source: NHS). The symptoms of SBS include poor concentration, shortness of breath, fatigue and skin irritation. Anyone can be affected by SBS, but office workers in modern buildings without access to windows, poor ventilation, inadequate lighting and airborne particles are most at risk.

- **The likelihood of experiencing SBS symptoms can be higher for those employed in routine work that involves using display screen equipment**. The WHO suggests up to 30% of new and remodelled buildings worldwide may be subject to complaints related to poor indoor air quality (IAQ) and only 5% of buildings management address this issue.
- **160mn people have work-related diseases, making them the most prevalent occupational danger, outpacing fatal accidents by 4:1**. The estimated potential annual savings and productivity gains are US$6-14bn from less respiratory disease, US$1-4bn from fewer allergies and asthma, and US$10-30bn from reduced SBS symptoms (source: College of Estate Management, Fisk 2000).

Reinventing the office: Millennial workers & real estate

> Workspace: Shares price in uncertainty, but operations show no slowdown post-Brexit 09 November 2016

As highlighted by the BofAML European Real Estate team, Millennials are driving landlords to remodel their properties to match this generation's desire to work in offices inspired by the likes of Google and Facebook, introducing features such as a free snack bar, games room, sleep pods and chill rooms. The arrival of the Millennial generation into the workspace is likely to place the emphasis on innovation, and the requirement for co-working opportunities. This generation is attracted to shared work spaces, which offer networking among the like-minded: 82% of Millennials say the quality of available technology in the workplace would influence whether they would accept a job (source: Dell).

Ease of access and local amenities are key drivers

Gen Y views offices as an important consolidator and despite improvements in technology, the drive is to get people to work from the office and not from home. Thus, location becomes an important decision factor. Ease of access is a priority to attract staff. Likewise, local amenities become key to: (1) ensuring staff attend the office rather than working remotely, and (2) increasing the dwell time at the location. Cafes and social areas are deliberately made into focal points of the office, to maximise human interaction'. Space is planned so as to retain flexibility and adaptability. With major users of space seeing flexibility of space usage and networking opportunities as key

elements of a building's design, such as Google with its 1m sq ft London HQ currently under construction at King's Cross.

WorkSpace has a "Club Workspace" initiative for those who do not want the commitment of a permanent location, or who want a more dynamic environment. Club Workspace offers high-speed WiFi service, refreshments, and networking opportunities across a variety of locations. In addition, members have the option to hire a lockable desk to store larger equipment, such as monitors. At this stage, the Club Workspace offering utilises the less-attractive space in Workspace buildings, such as ground floors or basements, and therefore the Club Workspace membership fee revenue comes at limited cost in terms of rental income foregone.

Exhibit 134: "Sleep pod" inside Google's offices

Source: Google, TechCrunch

Smart Buildings can positively impact real estate

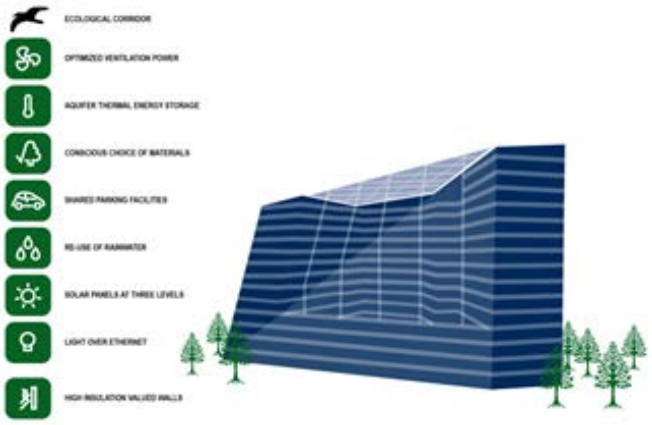
We also think smarter buildings have a knock-on impact in the real estate space by potentially unlocking long-term value with better technology installed in properties. Real estate is often the second-largest expense on the income statement and the third-most valuable/expensive asset in a company's portfolio (source: IBM).

A recent survey among real estate stakeholders by Charles Russell Speechlys found that: (1) 56% think smart buildings will open up new revenue streams; (2) 59% believe smart buildings will deliver business gains beyond energy efficiency; and (3) 38% are taking the lead, changing their behaviours and acquiring new capabilities to benefit from smart buildings. Overall, reducing the space per person via methods such as "hot-desking" and creating a more comfortable environment can achieve 30-40% reductions in real estate costs (source: JLL).

Case study: The Edge, Amsterdam, #1 smart building in the world

The Edge in Amsterdam (occupied by Deloitte) has been cited as the greenest and smartest building in the world. According to British rating agency BREEAM, The Edge has the highest sustainability score ever awarded at 98.4%. We outline a sample of innovative features the building is pioneering in this space which we think could be adopted by other buildings and shape how new builds may function in the future (source: Deloitte, The Edge Amsterdam).

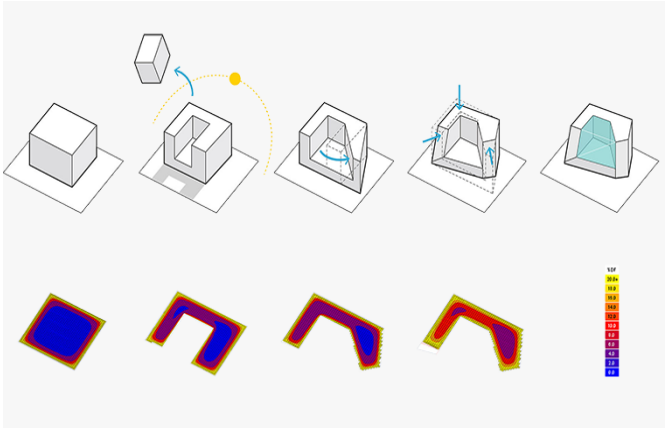
Exhibit 135: The Edge, Amsterdam features



Source: Deloitte

Exhibit 136: Building form shape vs daylight analysis

The Edge is aligned and shaped to maximise sunlight



Source: PLP

- **Smartphone app** – passport to the building, eg, use it to find colleagues, adjust the heating
- **Solar powered/aligned** – southern facing wall of solar panels and windows. The Edge uses 70% less electricity than the typical office building, and recently installed panels on rooftops mean it now produces more energy than it consumes.
- **Underwater aquifer** with two 129 meter deep wells to provide ambient temperature for the building all year round
- **"Hot desking"** – 2,500 Deloitte workers share 1,000 desks meaning desks are allocated to workers when they are required rather than giving each their own desk.
- **Lighting** – nearly 6,500 connected LED luminaires to create a "digital ceiling" in the building's 15 stories with integrated sensors in 3,000 of these luminaires. This amounts to €100,000 in expected savings in energy costs and €1.5mn in space utilisation costs.
- **Ceilings** – embedded with 28,000 sensors measuring temperature, light, motion and humidity.
- **Dashboard –** collecting gigabytes of data on how employees interact.
- **Electric vehicle/parking** – number plate recognition for automated entry.
- **Security Robot** – nighttime security drone guard SAM that patrols the building.
- **Toilets** – connected bathroom lets the cleaning staff know when it is ready for cleaning.
- **Gym –** some of the exercise stations harness the energy from employee's workouts and use it to power the building.
- **Coffee machines** – are also connected to the internet, meaning facilities staff can see which are getting low and refill them before someone finds it empty.

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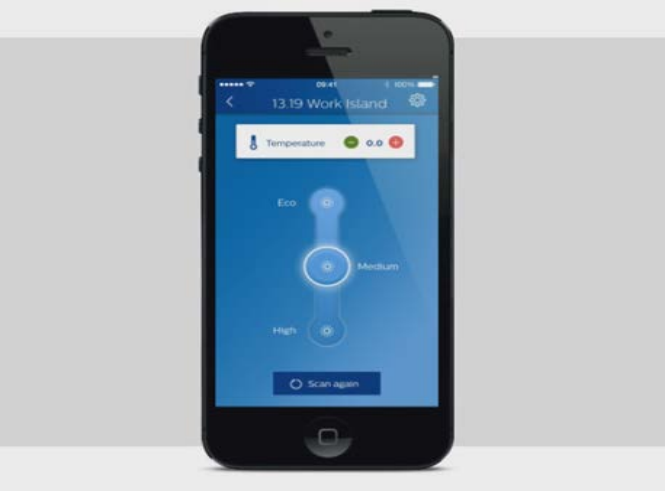
Exhibit 137: Smartphone app to control temperature in The Edge



Source: Deloitte

Exhibit 138: SAM security guard drone

Source: Deloitte

Table 40: Other "smart buildings" across the world

"Cheesegrater", London	AKA 122 Leadenhall Street. The building has 293 energy meters installed to monitor light usage. The square-mile 'hot-spot' also boosts low-flow water fixtures and fittings, and the external glazing features vents every seventh floor to let air circulate freely, reducing the need for AC systems.
Capital Tower, Singapore	Is one of the oldest smart buildings in the world. The building features a state-of-the-art fully integrated intelligent building management system (IBMS) for its services and facilities. The 254-metre Capital Tower boasts highly intelligent car park management with real-time status display at the entrance.
David Brower Centre, California	Offices are designed to receive daylight, removing the need for artificial light. A system of photovoltaic panels, which doubles as a sun shade device, controls the energy needs of the building. The infrastructure has been installed with CO2 sensors that can automatically control the need for more fresh air.
Port of Portland, Oregon	Features a world-class wastewater system boasting 200,000 sq ft in size water use dropped 75% by utilising all wastewater generated by the building's 500 employees. The Living Machine system produces high-quality water that is reused to flush toilets and supply the cooling towers in the building.
SAP America Headquarters, Pennsylvania	Comprising 210,000 sq ft of space, the office building features ice cooling and rainwater collection. The rainwater collection feature stores up to 50,000 gallons of water in a cistern that supplies water for landscape irrigation and the flushing of toilets in some of the building's bathrooms.
Terminal B, Norman Y Mineta San Jose Intl Airport	The building displays state-of-the-art tech specs with a modern system for self-checking and bag screening. A new concept introduced in the terminal is the "Air Chair", an electronic charging station for passengers to charge their smartphones as well as a ventilation system that enables the airport to save on energy costs.
New York Times Building NYC	Features the first "high rise curtain wall" with ceramic sunscreen to be built in the US. Hundreds of ceramic tubes filled with ultra-clear low-iron glass create a curtain wall that reflects light and changes colour throughout the day.
Beijing Airport, T3 Terminal	Is packed with 25,000 monitors and sensors to ensure both security and energy-friendly use of resources in one of the most polluted cities in the world. With 10 workstations to control water, heating and air flows, the terminal's Schneider Electric automation system, supplied by IBM, boasts more than 3,000 DDC controllers, more than 900 sets of special controllers and more than 1,600 VAV fan coil units.

Table 40: Other "smart buildings" across the world

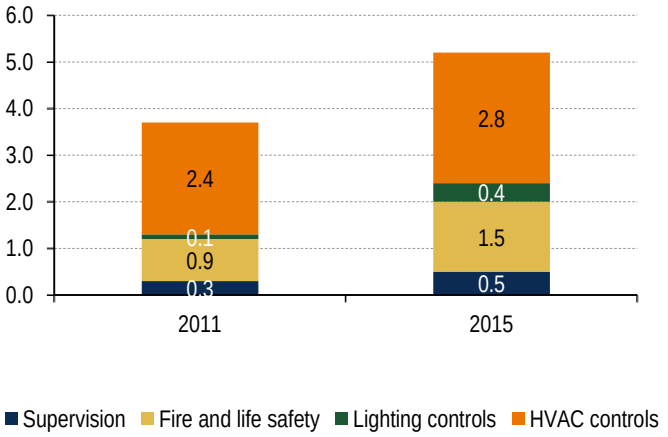
Musée du quai Branly, Paris	Features a 'green wall' covered with living plants that grow freely. The wall covers 800sqm of exterior facade and 150sqm of inside walls. It is made out of 15,000 plants, of 150 varieties from all over the world. The project was designed to improve air quality throughout the infrastructure and to reduce energy use.
The Edge, Amsterdam	Has been cited as the greenest and smartest building in the world. According to British rating agency BREEAM, The Edge has the highest sustainability score ever awarded at 98.4%.

Source: CBR Online

Smart building automation system: brains of the building

As we highlighted earlier, a good building automation system to act as the brains is of vital importance for the interoperability of a building. However, given the potential wide-ranging scope of the market and the lack of clarity on whether a product is being used in isolation or as part of a smart building, estimates for the market size of building automation vary widely. Our BofAML Industrial, Building and Construction teams have sized the market at €5-80bn, although at the top end this includes a number of adjacent products (smart metering, lift, escalator controls etc). Rexel's estimate of the size of the market is shown in the chart below, although this does not include certain areas (for example, security, lifts). Legrand below estimates the value uplift per building of using building automation.

Chart 82: Rexel- estimated size of its addressable building automation market (EUR mn)



Source: Rexel

Table 41: Legrand examples of potential Incremental spending in different segments

Application	Products	Additional products installed
Energy savings & comfort	Eco-plc, smart shedder, contractor and breakers motor operated to control energy, lighting and presence detector, dimmers, sockets, thermostats, screens	Eur6000
Aging population	Alarms, bracelets, sensors, intercoms, cameras, lighting paths, VDI, screens, webserver	Eur5000
Eco friendly-Residential	Solar panels, inverters, EV charging, smart grid, energy storage	Eur10000

Source: Legrand

Industrial companies are leaders in building automation systems

While in the Smart Home, big technology companies are increasingly gaining a head start for mindshare, traditional Industrials/Capital Goods companies remain at the forefront of pioneering the Smart Building. The main players in the fragmented building automation markets are Johnson Controls International (JCI), Siemens, Honeywell, Ingersoll Rand (Trane), Tyco, Schneider, Bosch Security, GE Industrial, Azbil and UTC. Market shares differ significantly by end-application (for example, Bosch and Tyco are leaders in Security, Fire & Safety, while Azbil, Delta Controls, Trane lead in HVAC Controls) and by product type.

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Table 42: Total Building Automation Market: Market Share Rankings of Participants by Region

	North America	Europe	Asia-Pacific	Middle East	Latin America	Africa
1	Johnson Controls	Siemens	Siemens	Siemens	Johnson Controls	Siemens
2	Honeywell	Honeywell	Johnson Controls	Johnson Controls	Siemens	Johnson Controls
3	Siemens	Johnson Controls	Honeywell	Honeywell	Honeywell	Honeywell
4	Schneider	Schneider	Schneider	Schneider	Schneider	Schneider

Source: Frost & Sullivan

Smart HVAC: getting hot, US$17bn market by 2024E

Heating, ventilation and air conditioning (HVAC) is a large segment covering everything from a basic one-room radiator control to automated systems for large industrial and office buildings and clean rooms. The total market is split between air- and water-based systems, and is estimated to be worth up to €150bn according to our BofAML Industrials, Building & Construction teams. The biggest markets are room air conditioners (c.€30bn), unitary air conditioners placed in a window or hole in a wall (c.€25bn) and heat pumps (€10bn). The Smart HVAC segment is expected to grow from US$8.5bn in 2015 to more US$17bn by 2024E or at a 10.7% CAGR (source: GMInsights).

With HVAC accounting for 40% of energy use in commercial buildings (source: IEA) and only 37% of facility managers stating that they consider their HVAC system "smart" (source: IFSEC), we think there is scope for improvement in this space. For instance, HVAC "smart chips" can be installed in <15 minutes on both commercial and residential units, which could achieve air-conditioning savings of 16-25% and heating savings of 12-18% (source: HVACSmartChip.com)

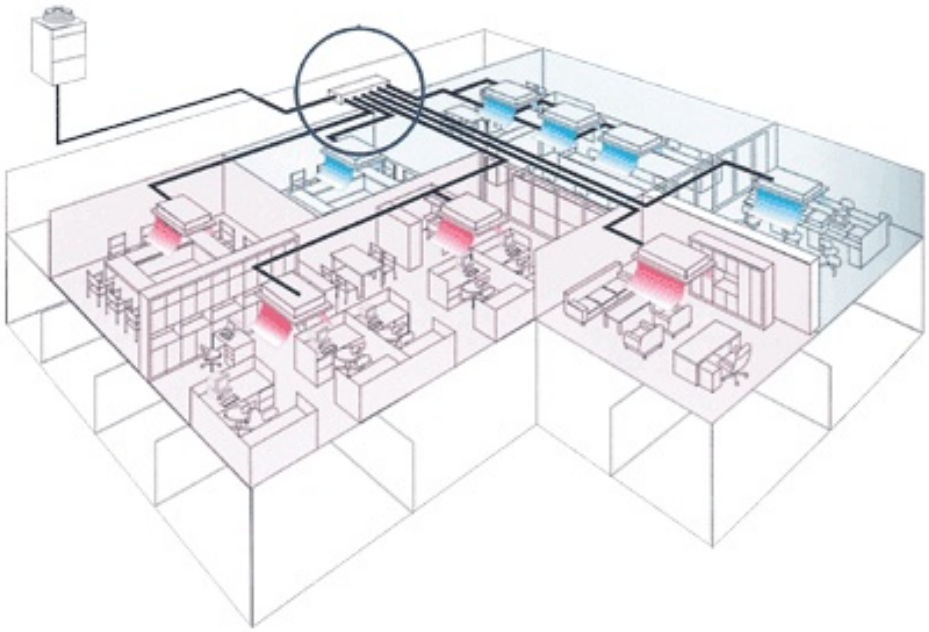
Ductless HVAC and IoT the hot topics for the industry in 2017

Industrials/Multi-Industry: AHR HVAC Expo Takeaways: Solid outlook for 2017, IoT impact accelerating, 31 January 2017

Our US Industrials team recently visited the AHR Expo in Las Vegas, NV, the largest HVACR (heating, ventilation, air conditioning & refrigeration) event in North America. It found that increasing trends of energy efficiency and environmental regulations along with the use of cloud-based technology are contributing to industry growth, particularly in retrofit markets. In particular, VRF (variable refrigerant flow) or ductless HVAC applications and IoT were topics presenting an opportunity both for more efficiency and from a simplified future installations perspective.

Ductless HVAC or VRF systems – provide heating and cooling simultaneously through refrigerant piping as opposed to ductwork. They can recover heat from spaces being cooled for use in spaces being heated and vice versa and can be controlled via IoT network or control room – Mitsubishi

Exhibit 139: How ductless / VRF for HVAC works



Source: Mitsubishi

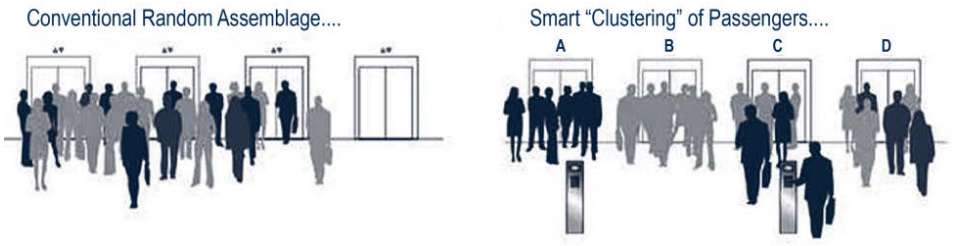
VRF is estimated to grow by 10-15% per year especially in commercial end markets, with Korean LG highlighted as a particularly aggressive market player. Many companies have incorporated cloud-based sensing capabilities into their systems to improve efficiency by more effectively heating and cooling areas of buildings that are most used. Some companies noted how earlier attempts at connected controllers failed because the technology was "too buggy" during the initial rollout about 10 years ago. However, today the feedback from AHR Expo is that this technology is finally functional and easy to control. The Internet of Things (IoT) was a prominent feature for controls and equipment in both commercial and residential applications. Exhibitors noted that the skill set of the technicians was deteriorating, but mobile applications are able to close some of the skill gap by providing better tools for collecting and analysing information.

Smart Elevators: going up, US$23bn market by 2020E

> **"If my car didn't start 4-6 times a year I'd probably change it"** – Andreas Schierenbeck, ThyssenKrupp's Elevator.

The global smart elevator market is expected hit US$23.16bn by 2020E registering a CAGR of 13.8% from 2014-20E (source: Allied Market Research). The average elevator lifespan is 30-35 years, yet on average it breaks down 4-6 times per year, implying up to 200+ maintenance repairs over its lifetime (source: ThyssenKrupp). Elevators remain highly inefficient (lost time stuck in lifts, consumption of energy) leaving huge scope to make them "smarter" whether by installing more sensors to monitor usage or designing them to be lighter and consume less energy. A recent survey by IBM using US Bureau of Labor Statistics found that:

Exhibit 140: Smart clustering at elevators

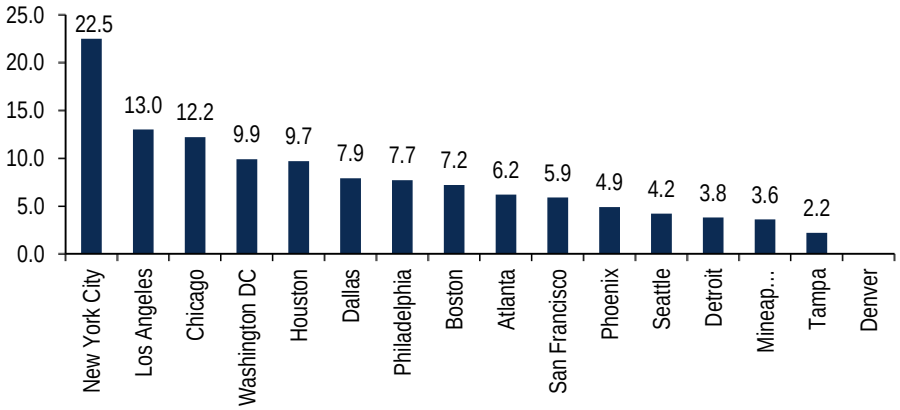


Source: Schindler

- US office workers spend a combined 92 years waiting for elevators and 33 years stuck in elevators each year.
- 1 in 4 say the elevators in their office buildings are not coordinated properly, eg, there are too few or too many at any one time and/or insufficient capacity.
- 14% of New York office workers say they have been stuck in an elevator in the past year.

Chart 83: Elevators: The Time Cost

Total amount of years all office workers spent waiting / stuck per year



Source: IBM

The charts compares the total amount of time -- measured in years -- that office workers in 16 U.S cities spent either waiting for elevator or stuck in one during past twelve months.

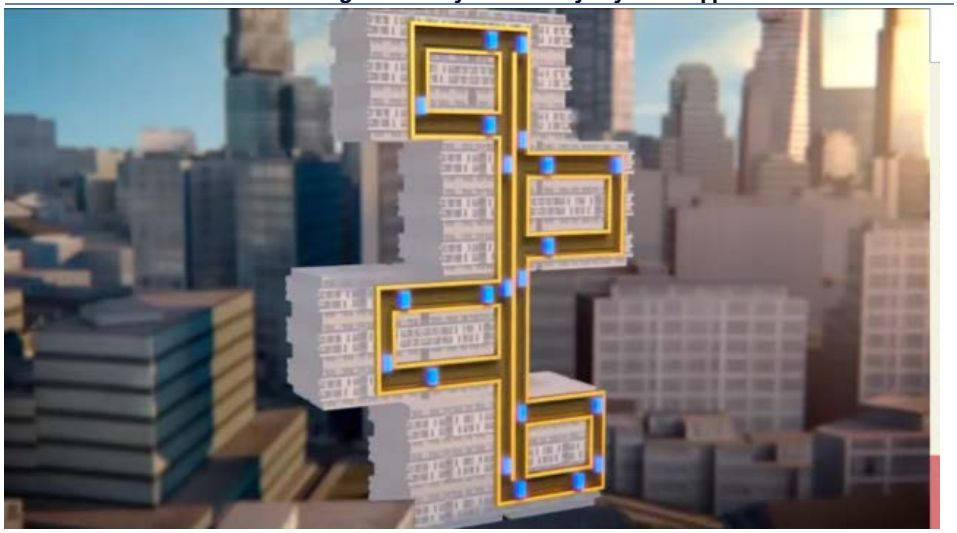
Smart, connected and "sideway" lifts

However, the traditional elevator incumbents recognise the urgency to smarten up and are increasingly partnering with tech firms to connect lifts online so that they can monitor each individually and improve the performance of the whole fleet. The opportunity is significant as our BofAML Industrial, Building and Construction teams estimate that the global elevator market is worth more than €45bn per annum, including new equipment, modernisation and maintenance.

- **Kone / IBM's Watson –** has an IoT pact where lifts are installed with sensors to monitor real life elevator rides.
- **ThyssenKrupp / Microsoft** – plans to connect 180,000 elevators to the cloud by 2018.
- **Schindler / GE –** the system the US industrial giant also deploys to monitor jet engines.
- **Otis / AT&T** – has partnered for wireless links for its elevators.

In addition, ThyssenKrupp has designed a nextgen lift system powered by magnetic levitation rather than steel rope suspension pulley. This potentially enables elevators to move sideways rather than just vertically in skyscrapers, as ThyssenKrupp states that magnetic-levitation elevators are best for buildings higher than 300 meters. The company claims that it has already received about 30 expressions of interest. These Maglev elevator systems could increase average shaft capacity by 50% and move at speeds of up to 8m/second. By the end of 2017, a prototype is expected to be installed in a 240m purpose-built tower in Rottweil, Germany, that has 12 shafts designed to test the new MagLev technology before it goes commercial costing US$43mn to complete (source: ThyssenKrupp)

Exhibit 141: Visualisation of the MagLev sideways elevator by ThyssenKrupp



Source: ScienceAlert, Thyssen

Smart Lighting: getting bright, US$19bn market by 2022E

We think building lighting can be made smarter and more personalised considering it is historically the least controlled aspect of a building with switched-on hours far exceeding inhabited hours. Lighting constitutes a substantial portion of the total energy load in commercial buildings, typically in the range of 30-35%. Up to 50% of this energy is wasted, either by inefficient lighting equipment or careless lighting habits by end-users and sometimes by both (source: US Department of Energy). The global smart lighting market is expected to reach US$19.47bn by 2022E increasing at a CAGR of 27.1% (source: MarketsandMarkets).

Demographic drivers: older workers need twice as much light as Gen Yers

The one-light-for-all principle is outdated at a time when we are all living and working longer and the workforce is more inter-generationally diverse than ever before. For instance, for everyday work tasks compared to your average 20Y old Millennial worker - those aged 45Y+ need almost 2x as much light whilst workers of 60Y+ need 5x more light (source: American Lighting Association (ALA).

Personalised, connected lighting via smartphones

As we highlighted earlier with the case study of The Edge in Amsterdam, personalised lighting controlled via a worker's smartphone can help customise brightness on the go. This not only maximises worker productivity but also saves on energy by using lighting only when it is needed and tailored to the user, where for instance:

- **Connected lighting** – via smartphone app to suit users' tasks (reading vs computer screen) and preferences even in open-plan offices.

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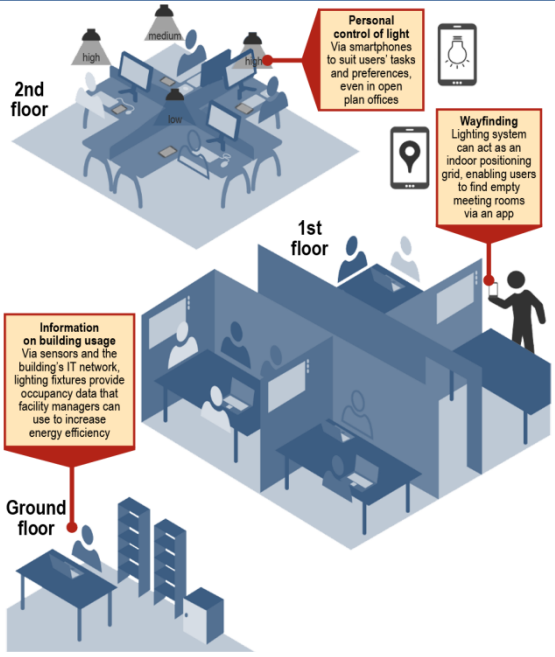
- **Wayfinding** – lighting systems can act as an indoor positioning grid, enabling users to find empty meetings rooms via an app.
- **Information usage** – sensors and the building's lighting fixtures provide occupancy data for facility managers to tweak energy settings.

Exhibit 142: Philips connected lighting for offices



Source: Philips Lighting, LEDs Magazine.

Philips case study: the smart city lighting LEDer

Philips Lighting: Inexpensive, innovative, proactive 25 January 2017

Our BofAML European Capital Goods team has highlighted Philips Lighting as a global leader in the lighting industry. It is at the forefront of connected city lighting with its "CityTouch" management system for smart public lighting built on 3 pillars integrated into one solution: software, luminaires and services. Brightness levels can be set appropriately and adjusted easily when needed and when a light bulb is out "CityTouch" will send a notification with location for a quick response and repair.

- **CityTouch has been deployed across multiple cities worldwide** including among others: London, Singapore, Toronto, Los Angeles and Buenos Aires
- **CityTouch can reduce energy use by more than 70% as well as significantly lower CO2 emissions,** according to the company, allowing cities to adapt public lighting to changing conditions and situations
- **The system can also improve citizen's sense of security by up to 10%** by illuminating "dark corners", individual roads and streets, and increasing light levels at junctions and pedestrian crossing (source: company).

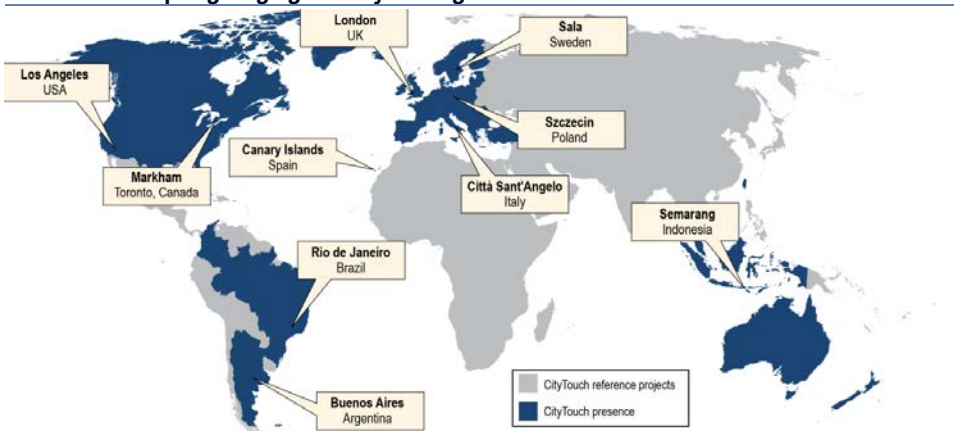
SmartPole project with PG&E and Ericsson

Furthermore Philips Lighting also has an ongoing "SmartPole" Project in San Jose, California. As part of the initiative in collaboration with Pacific Gas and Electric Company (PG&E) and Ericsson, the companies are seeking to pilot and potentially scale

up a transformative for smart cities globally: The project is aimed for zero traffic deaths, smart street lighting, zero signal dropouts and safe streets:

- **50 SmartPoles with 750 RoadFocus luminaires** from Philips are housed with Ericsson's LTE small cell technology.
- **Philips collaboration with PG&E will measure the electricity consumption** of the mobile network thanks to the installed bi-directional metres on top of SmartPole.
- **SmartPoles will also provide connected street lighting, increased data capacity, and improved data coverage** for the citizens of San Jose.

Exhibit 143: Philips Lighting's global city coverage



Source: Philips

Smart Glass: window of opportunity, US$8bn mkt by 2022

The smart glass market is expected to grow to US$8.13bn by 2022E at a CAGR of 19.2% from 2016-22 (source: MarketsandMarkets). Glass and windows in buildings can also be made smarter. The glass industry is developing new, more technical, products. For instance, Saint-Gobain's triple-glazing is more energy-efficient than a wall, regardless of the direction it faces. Noise-insulating glass is of particular importance in towns, and the market includes glass for safety and security, as well as fire protection, which is more significant for commercial buildings. Key structural trends in the market beyond energy efficiency are:

- **Larger glass panels** – an architectural trend towards increased sunlight, resulting in larger glazed facades and roofs in buildings. Advanced solar glass products can also allow the sunlight in while keeping the heat out.
- **Regulation** – building regulations in many countries now require double glazing as standard. Window-labelling systems have also been established to promote energy-saving glass to consumers.
- **Renovation & Retrofit** – there is a greater need in developing countries for renovation of windows, due to poor initial building quality.

Table 43: Different types of windows

Technology	Energy savings	Cost	Overview	Barriers
Electrochromic windows	<19-26% of cooling loads, <45-65% of lighting energy	High	Adjust light transmission properties of glazing to minimise solar heat gain & maximise natural lighting	High initial cost: incremental costs are US$1000/m² ($93/ft²) of glazing
High performance windows	39% of heating & 32% of cooling energy	Med.	2nd gen low-e coatings, high insulation technologies w/ triple or quadruple panes, vacuum spaces & aerogels, retrofits possible	High initial cost: US$30-50/m² higher than standard

Source: Saint Gobain, BofA Merrill Lynch Global Research

Electrochromic glass with Saint Gobain

Perhaps one of the leading innovators in this space is Saint Gobain-owned SAGE Electrochromics, which develops electronically tintable smart glass aka “electrochromic glass”. This glass can be electronically tinted or cleared to optimise daylight and improve occupant comfort in buildings. According to the US Department of Energy’s Lawrence Berkeley National Laboratory (LBNL), SAGE's technology "has the potential to reduce building heating and air conditioning equipment size by up to 25%; and could potentially reduce overall cooling loads for commercial buildings up to 20% by lowering peak power demand and may reduce lighting costs by up to 60% while providing building occupants with more natural daylight and greater comfort."

Exhibit 144: Example of smart electrochromic glass

Source: Urban Land

Smart Energy: cities driving the cleantech revolution

We continue to view the war on Climate Change as one of the defining issues of our era. We believe that cities are in the driving seat in this fight, as well as in the transition to Smart Energy (ie, smart grid, computer-based remote control and automation, energy efficiency, wind, solar, electric and autonomous vehicles (EVs and AVs), batteries and energy storage, IoT, HVDC, and other environmentally friendly and ICT-enabled technologies). Priority areas for action for cities include cleantech in buildings, sustainable transport, and smart, integrated urban energy systems (source: IRENA).

Cities account for 71-76% of GHG emissions and 67-76% of global energy use, with the latter expected to rise to 80% by 2040E (source: The Global Commission on the Economy and Climate 2015, Shell/Booz & Company). The importance of the transition towards Smart Energy cuts across multiple Smart City segments with energy consumption from both Buildings and Mobility in cities set to rise by up to 68% from 2014-30E (source: IRENA, REMap). The worst offenders among major cities in terms of GHG emissions per capita are Sydney, Washington DC, Boston, Los Angeles and Shanghai (source: World Bank).

1.3bn people and US$158tn in assets are at risk from climate change by 2050E – and 40 of the world's leading cities alone need US375bn in climate-resilient infrastructure investment to 2020E and US$1tn by 2050E (source: World Bank 2016 GFDRR, C40 Cities-Arup 2016). Eighty-five percent of cities are dealing with temperature increases/heatwaves and 53% report these risks as serious and near term (source: C40 Cities). The world's 10 most vulnerable cities to flooding are Guangzhou, Mumbai, Kolkata, Guayaquil, Shenzhen, Miami, Tianjin, New York-Newark, Ho Chi Minh City and New Orleans (source: Nature Climate Change 2013).

We see the Smart Grid – a digitalised and connected electrical grid which encompasses cleantech – as the "holy grail" for Smart Energy in cities; and the global Smart Grid market could grow to US$400bn by 2020E (source: GTM Research). Ageing transmission and distribution (T&D) infrastructure built out in the 20th century is struggling to keep up with the challenges and demands of 21st century cities, in our view. This is evidenced by growing blackouts and data and connectivity issues – with the US cities most at risk of power outages being New York, Philadelphia, Jacksonville, Virginia Beach, and Hartford (source: John Hopkins University).

New global investments in cleantech reached US$288bn in 2016, and cities are projected to see US$137bn in cumulative Smart Energy investments from 2015-24E (source: BNEF, Navigant). Globally, US$6.2tn is expected to be invested in wind and solar from 2016-40E, accounting for nearly 60% of total energy investments (source: BNEF).

Smart Cities will be in the driving seat of the cleantech revolution as we head towards zero emissions cities by 2050E, in line with the 2016 Paris Agreement. Close to 11,000 climate actions were carried out by a group of the world's leading cities in 2016 alone with the majority focused on buildings and transport (source: C40 Cities). Globally, renewables already account for 20% of energy for transport and buildings in cities (source: IRENA) and a growing number of cities are committing themselves to ambitious renewable energy goals. Masdar City (UAE) is aiming to be one of the world's first zero carbon city, while San Francisco has committed to 100% renewables by 2030E, followed by San Diego by 2035E and Vancouver by 2050E. Copenhagen, Stockholm Malmö, Oslo, New York and Sydney have set similar targets (source: ICLEI-go100re).

US cities have taken pole position on solar and have now installed nearly as much solar power as the entire country had at the end of 2010, with 1,700MW of solar PV

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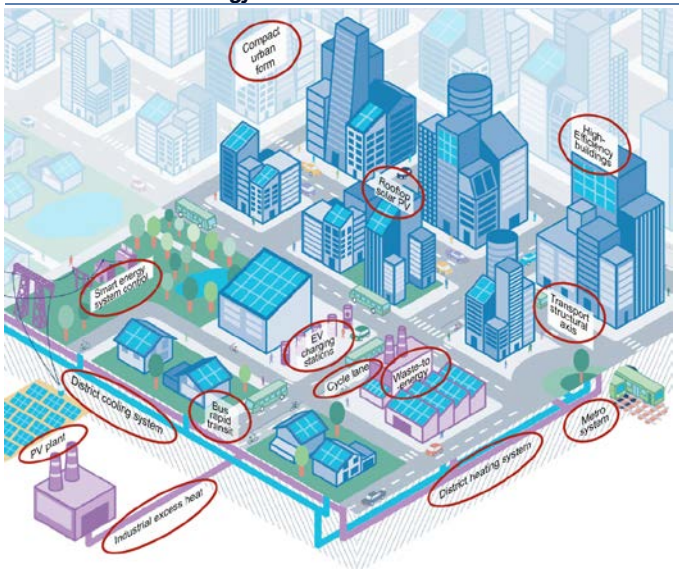
capacity. The top cities by installed capacity are Los Angeles (215MW), San Diego (189MW), Phoenix (147MW) Honolulu (146MW), and San Jose (141MW) (source; Environment America 2016). Globally, rooftop solar PV could cover 9-25% of urban electricity demand (source: IEA) and up to 60% for Los Angeles (source: NREL). Where viable, cities are also increasingly tapping into wind as a source of energy with Copenhagen (Denmark), Georgetown (Texas, US), Greensburg (Kansas, US), and Burlington (Vermont, US) among the leaders in this space.

EVs could be the near-term catalyst for Smart Grid uptake, and ultimately for Smart Energy in cities. The EV battery (cell + pack) market is projected to reach US$87bn in 2030E (vs US$11bn in 2015 growing at a 10% CAGR) (source: BofAML Global Research estimates). As we highlighted in our Future Mobility report and the Smart Mobility section of this report, the electrification of the broader road transport fleet ranging from EV two-wheelers to buses and trucks will be a key part of the equation. In addition, EV charging infrastructure is becoming less of a challenge with public and private investment leading to 1.5mn outlets in 2015. This is set to grow to 12mn+ by 2020E (source: IEA, IHS). Recent moves by O&G giants such as RD Shell and Total to add EV charging to gas/petrol stations means further improvements are likely.

Smart Meters and advanced metering infrastructure (AMI) are driving the "internetisation" of utility services with the smart electricity meter market reaching 115mn units in 2015. The market is expected to achieve an average of 85mn unit installations per year up to 2025E. China accounted for 46% of global smart electricity meters in 2015 but this is forecast to fall to 18% by 2025. As China's share gradually declines, other markets are taking share - Japan is already a key global market, and France and the UK are expected to install more than 10mn units a year to 2019E. The global smart electricity meter market was worth US$8.2bn in 2015 (source: Frost & Sullivan).

A "utility death spiral" or structural threat from potential "cord cutting" from the grid and going off-grid could occur by 2029E, according to our BofAML US Utilities team. For 2017, the team estimates that a fully off-grid system with three days of autonomy (standard for grid-equivalent reliability) for a typical US household would cost roughly US$72,000 (consisting of a US$42,000 battery at US$190/KWH and solar panels + installation and components of US$30,000). By 2029E, this falls to US$32,000 using a 10% decline rate per year for batteries and panel costs, and a modest 1% increase per year in labour, installation, and incidental component costs.

Exhibit 145: Smart Energy in a nutshell

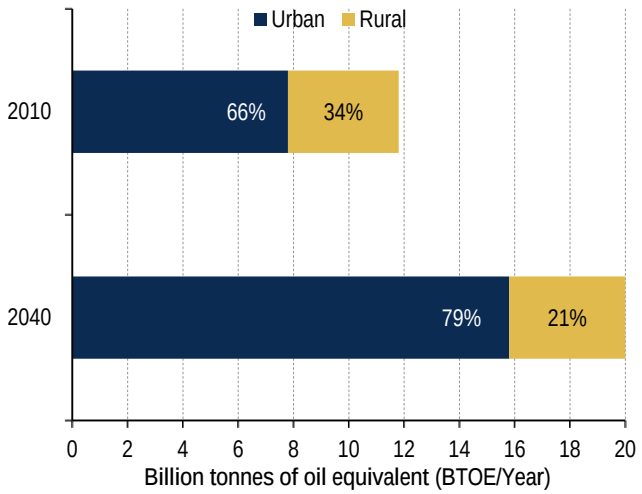


Source: IEA, OECD

War on climate change: won or lost in cities

We think the war on Climate Change and transition towards cleantech will be won or lost in cities. Cities account for 71-76% of GHG emissions and 67-76% of global energy use (source: The Global Commission on the Economy and Climate 2015), with the latter expected to rise to 80% by 2040 (source: Shell, Booz & Company). The top five cities that currently produce the most GHG emissions per capita are Sydney, Washington DC, Boston, Los Angeles and Shanghai (source: World Bank). IRENA has outlined three key priority action areas for renewable energy in cities: (1) renewable energy in buildings; (2) sustainable options for transport; and (3) the creation of smart integrated urban energy systems.

Chart 84: Urban & Rural world energy consumption



Source: Shell, Booz & Company

Table 44: World's top GHG-emitting cities

City	Country	GHG (tCO2e /capita	City	Country	GHG (tCO2e/capita)
Sydney	Australia	20.3	Singapore	Singapore	7.8
Washington	USA	19.7	Cape Town	South Africa	7.6
Boston	USA	13.3	Madrid	Spain	6.9
Los Angeles	USA	13	Paris	France	5.2
Shanghai	China	12.9	Tokyo	Japan	4.9
Toronto	Canada	11.6	Barcelona	Spain	4.2
Beijing	China	10.8	Seoul	South Korea	4.1
Bangkok	Thailand	10.7	Buenos Aires	Argentina	3.8
San Francisco	USA	10.1	Stockholm	Sweden	3.6
London	UK	9.6	Oslo	Norway	3.5
New York	USA	7.9	Rio	Brazil	2.1

Source: World Bank

Energy demand in cities set to grow up to +68% by 2030E

According to IRENA, renewables currently supply about 20% of energy for transport and buildings in cities and there is an opportunity to increase this share significantly. City residential/commercial buildings and inner-city transport's energy consumption totalled 139 exajoules (EJ) in 2014; this is set to grow by 35% to 187 EJ by 2030 in a base case scenario but potentially by up to 68% in higher estimates. The scenarios differ depending on average population density and climate change (source: IRENA, REMap).

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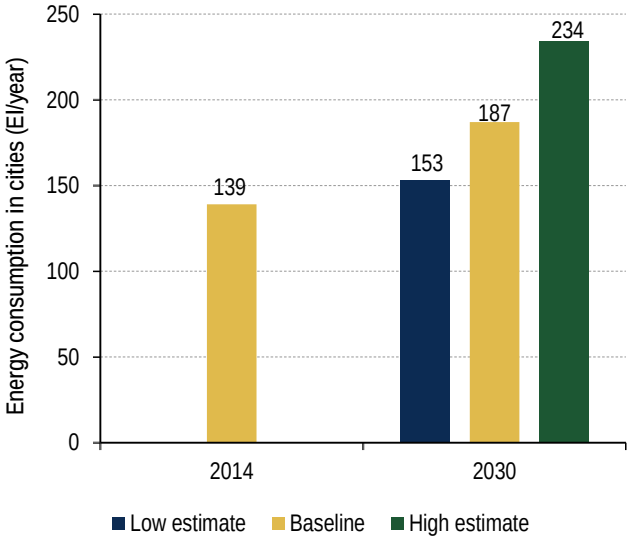
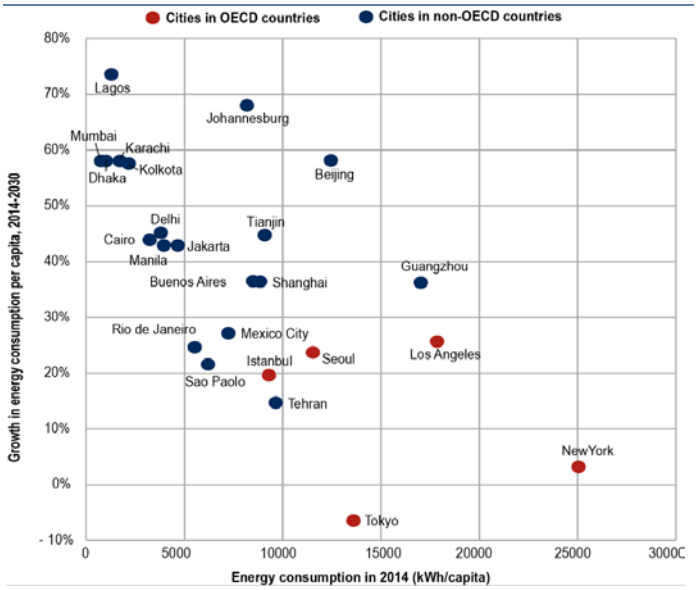
Chart 85: Energy use in buildings and for transport in cities, 2014 and 2030



Source: IRENA

Exhibit 146: Energy use and growth in energy use per capita in the world's largest cities

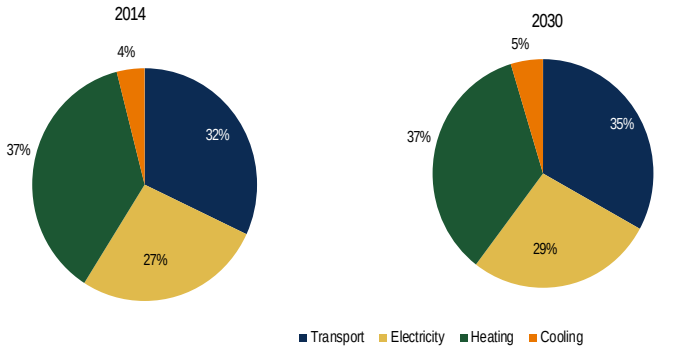
2014 – 2030E



Source: IRENA

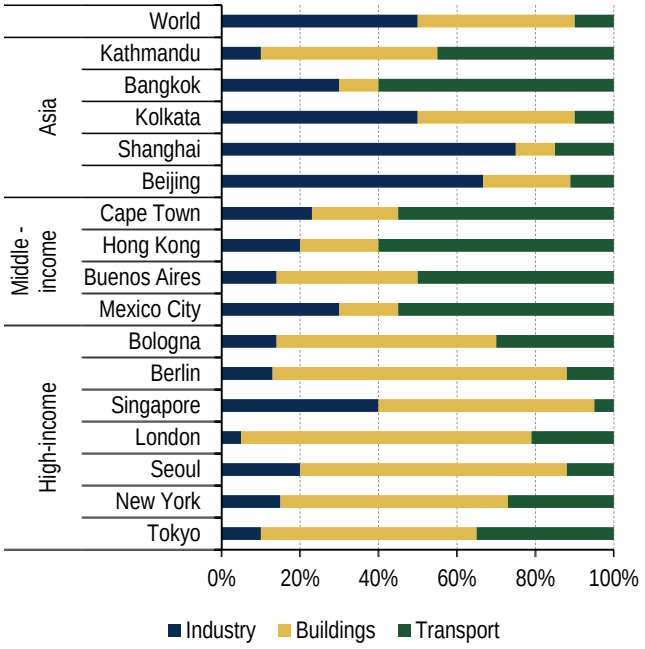
- **By 2030E, transport is expected to account for the largest share of total energy use in cities, at 35%** (up from 32% today). Half of all global passenger transport activity already takes place within city borders, and this is expected to increase. This is especially the case in cities in EMs, due to rising levels of wealth and vehicle ownership.
- **Electricity use (excluding cooling) is set to increase by nearly 50% by 2030**, with its share of total urban electricity consumption expanding from 27% today to 29% in 2030E driven mainly by rising ownership of household appliances (source: IRENA 2016).

Exhibit 147: Energy use in buildings and for transport in cities by application, 2014 and 2030



Source: IRENA
Note: includes heating and electricity use in buildings and transport energy use. Electricity excludes use for cooling.

Chart 86: Estimates of the breakdown of energy use by sector in selected cities



Source: IRENA

Smarter Energy in cities: need to rethink the entire energy system on a city-by-city basis

Making urban energy systems Smarter is not a question of simply transitioning towards clean(er) fuels, but rather of rethinking the entire energy system with all the related interactions and uses. This involves:

- **Considering the main end users**, including buildings, transport and industry;
- **Designing smart, integrated urban energy systems** that can manage variable power produced by solar panels and wind turbines, and that can take advantage of sector synergies where energy is produced and consumed; and
- **Taking all policy areas and governance levels into consideration**.

Renewables have great potential: but every city is different

While the potential for renewables is high, it varies greatly depending on each city's characteristics. Population density, growth prospects and demand profiles in cold versus hot climates all shape the opportunities to introduce renewables, including the vast potential for uses in urban buildings and transport. Accordingly, deployment strategies must be tailored to technology options and enabling policy frameworks for each city (source: IRENA).

Cities of all shapes and sizes = differing energy consumption patterns & needs

A recent study by Shell of more than 500 cities with over 750,000 inhabitants and 21 megacities with over 10mn inhabitants identified six illustrative archetypes to help frame our understanding of how different cities consume energy.

- **Urban Powerhouse (eg, Hong Kong, Singapore, New York):** Although greater prosperity means energy consumption is high, this does not impact global energy needs too much due to the relatively small number of eight urban powerhouses. The

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large professional population uses a lot of energy on heating and cooling homes and offices.

- **Sprawling Metropolis (eg, London, Rio De Janeiro, Los Angeles).** Because of their vast size, low-density housing and relative wealth, these cities use a tremendous amount of energy, amounting to 38% of the world's supply, most of which goes towards powering people's cars and homes.
- **Prosperous Community (eg, Valencia, Dubai, Amsterdam):** Largely due to high overall wealth and living standards, these cities use a great deal of energy, consuming 26% of the world's supply, most of which is used in powering people's cars and homes.
- **Developing Mega-Hub (eg, Beijing, Nairobi, Buenos Aires):** These cities are quickly becoming regional commercial hubs, but energy use is still fairly modest, mainly because most citizens are low-paid. Energy use is pretty evenly split between housing, transport and industry.
- **Developing Urban Centre (eg, Marrakech, Nanchong, Panama City).** Residents in these cities do not use a great deal of energy, as living spaces are usually small and electricity is not as widely used as in richer cities. Industry soaks up a lot of the power supply.
- **Crowded City (eg Manila, Lagos, Lima):** Energy use is relatively subdued in crowded cities due to low average incomes and underdeveloped infrastructure, with unreliable power a reality for much of the population.

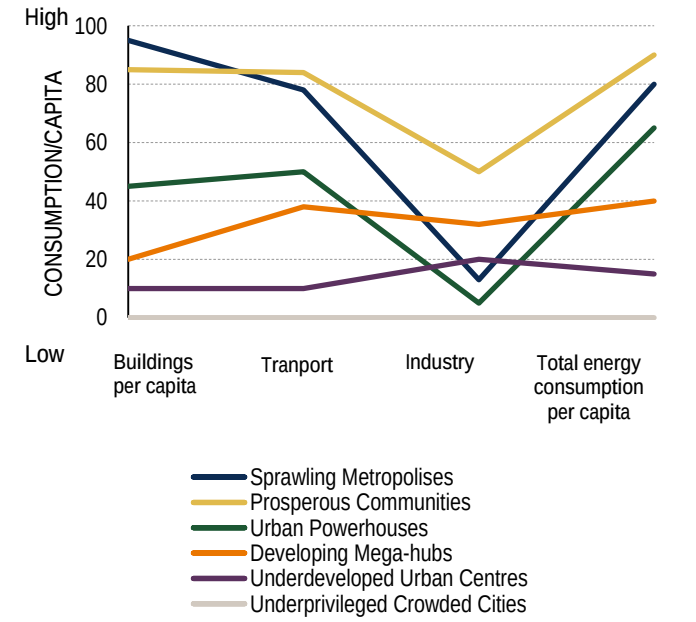
Table 45: "6 city archetypes in how they use energy"

	Under-developed Urban Centres	Developing Mega-Hubs	Under-privileged Crowded Cities	Sprawling Metropolises	Prosperous Communities	Urban-Power-houses
Total energy used (Billion tonnes of oil equivalent/ year)	0.49	0.22	0.36	1.66	1.13	0.46
Examples Including	Nanchong Kathmandu Algeries	Changqing Nairobi Hyderabad	Bangalore, Manila Kinshasa	London Rio de Janeiro Tokyo	Stockholm Calgary Dubai	Hong Kong Singapore New York
Number of city archetypes worldwide	267	26	42	41	127	8

Source: Shell

Chart 87: Energy use by archetype (2010)

Ranking by city type



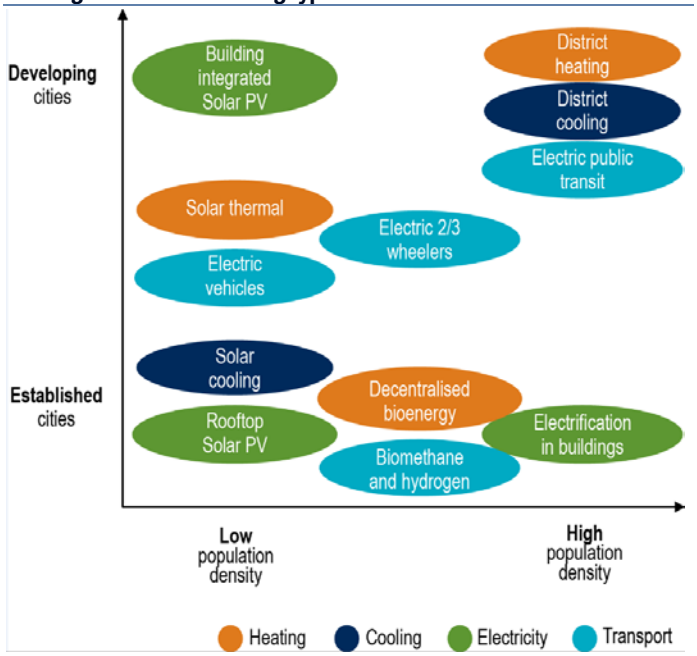
Source: Shell

Population density is a key factor: transport, electricity and cooling

Population density also has a large impact on energy use, particularly for transport but also for electricity and cooling. Cities with lower population densities consume more than 2x as much energy per capita as those with higher population densities (source: IRENA 2016).

- **Established cities**, have lower building turnover rates and largely rely on retrofits and technologies that can be added relatively easily to existing buildings, such as heat pumps and rooftop solar equipment.
- **High-population-density cities** can benefit from renewable-powered electric public transit systems and cost-effective district heating and cooling systems.
- **Low-population-density cities**, with larger rooftop areas, could benefit from highly distributed renewable energy technologies and the growth of electric cars (source: IRENA).

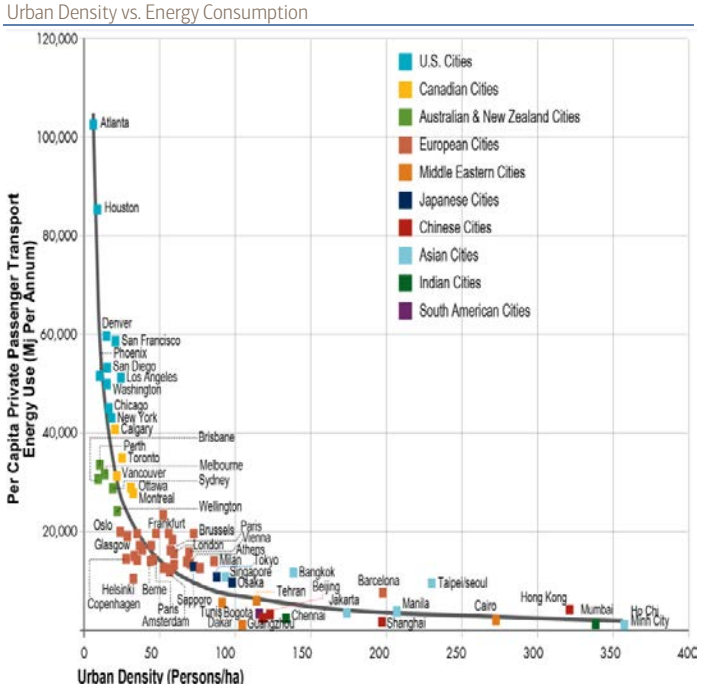
Exhibit 148: Potential for renewable energy options for transport and buildings in different building types



Source: IRENA

Exhibit 149: City density is a key factor in energy consumption

Urban Density vs. Energy Consumption



Source: IRENA

Climate also matters: cold cities account for two-thirds of energy usage

IRENA has also identified how cities with different climates (hot vs cold) can maximise efficiency of their energy use. Cities in areas with cold climates will represent two-thirds of the total energy use in cities by 2030E, mainly because they account for nearly 90% of the energy used for heating. However, in areas with hot climates, transportation and electricity for appliances dominate energy use, and cooling is more important. Currently, 37% of energy used in cities is for space and water heating. That is projected to shrink to 31% by 2030, because many of the fastest-growing cities are in hot climates (source: IRENA 2016). Below are examples of how buildings and transport can be made smarter vis-à-vis energy use.

- **Buildings:** Rooftop solar PV and solar water heating are easy to install and offer significant economic gains. Other effective technologies include renewable-based district heating and cooling systems, which are most economical in densely populated cities, and renewable sourced heat pumps, which can be easily integrated in both new and existing buildings.
- **Mobility/Transport:** Electric transport, when powered by renewable sources, reduces air pollution and is increasingly cost competitive. Electricity is already widely used to power public transport, such as tramways, metros, and other rail systems. Electric trucks, cars, scooters and bikes have also recently gained momentum and are well suited to the demands of all types of cities.

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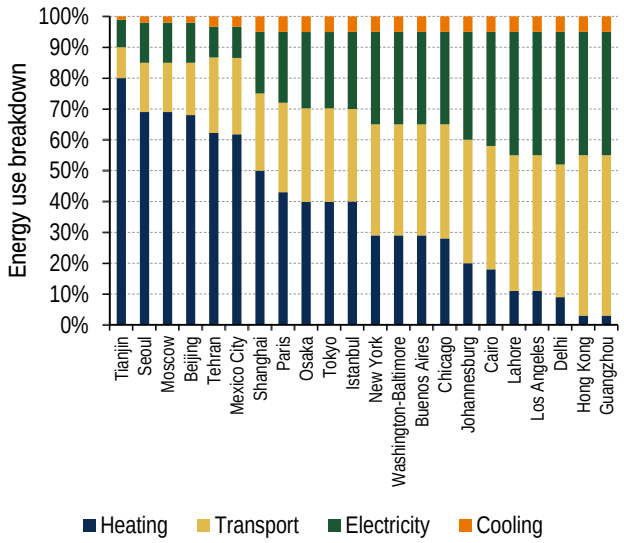
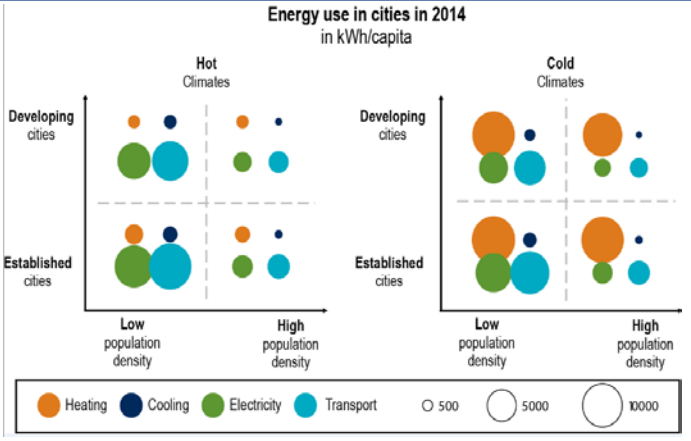
Chart 88: Breakdown of energy use in selected cities, 2030



Source: IRENA

Exhibit 150: Energy use by application in different city types



Source: IRENA

"Cities of zeros": a tale of renewable cities

Many cities around the world are recognising the multiple threats posed by Climate Change (flooding, extreme weather etc) and committing themselves to ambitious renewable goals. For instance, Masdar City, UAE is aiming to be world's first zero carbon city, San Francisco has committed to 100% renewable power by 2030E, followed by San Diego (2035E) and Vancouver (2050E). Other major cities that have also set themselves similar targets include Copenhagen, Stockholm Malmö, Oslo, New York and Sydney (source: ICLEI-go100re). We outline a sample of innovative smart energy initiatives among the world's leading smart cities below (source: IRENA):

- **Barcelona** was the first city in Europe to introduce a solar thermal ordinance, requiring 60% of the total hot water to be provided by solar thermal.
- **Paris** accounts for 80% of France's geothermal capacity, with plans to double this capacity to 100MWth to supply energy for heating and cooling.
- **Tokyo** has set itself a target for 1GW of on-site systems solar PV to be installed in the city by 2024E.
- **San Francisco** became the first major US city in April 2016 to require all new buildings (10 storeys or higher) to install rooftop solar PV.

Table 46: City examples of the use of renewable energy technologies and policies to meet energy consumption in commercial and residential buildings

Energy use	Technology/ resource		Area	Example
Space and water heating	District heating	Residual heat	Rotterdam, the Netherlands	Use of residual heat from the port is being increasingly used in the city's district heating network
		Waste	Vienna, Austria	District heating provides heat to 270 000 people in the city; waste incinerators are a main source of energy
		Bioenergy	Stockholm, Sweden	87% of district heat is provided by renewables, which include excess heat and combustable waste but also solid biomass
		Geothermal	Munich, Germany	5 additional geothermal locations planned for 2025 and a target of 100% renewables in district heat by 2040
		Solar	Crailsheim, Germany	7 300 m2 of solar thermal flat plate collectors provide 50% of the heat to 260 housing units
			Cities in Denmark	Solar district heating in Denmark increased from 100 000 m2 installed in 2010 to 800 000 m2 installed by 2015
	Decentralised boilers	Solid biofuels	Aberdeen, UK	Biomass boilers installed in various public buildings, including the City Council building, a hospital, and a primary school
	Solar thermal	Solar	Cities in China	Over 80 cities with compulsory and favourable policies for installing solar water heating systems by 2011
			Sao Paulo, Brazil	A Solar Ordinance requires new residential, commercial and industrial buildings to install SWH to cover at least 40% of

Table 46: City examples of the use of renewable energy technologies and policies to meet energy consumption in commercial and residential buildings

Energy use	Technology/ resource		Area	Example
	heating			energy used for heating water
			Barcelona, Spain	Barcelona was the first city in Europe to introduce a solar thermal ordinance, requiring 60% of the total hot water to be provided by Solar Thermal
	Heat pumps	Renewable power	Cities in Europe	The European Heat Pump Association has annual awards for cities with innovative heat pump projects. Past winners include Amstetten (Austria), Etten-Leur (the Netherlands), Viborg (Denmark), and Olot (Spain)
Cooling	District cooling	Water (sea)	Port Louis, Mauritius	The first seawater district cooling network in Africa is under development for 26 MW of power
			Honolulu, Hawaii	A USD 250 million project is under development to avoid oil imports to the island by 178 000 barrels per year
		Water (river)	Bonn, Germany	The Post Tower uses water flows from the Rhine river through 210 kilometres of piping for heating and cooling
		Geothermal	Paris, France	80% of France's geothermal capacity is in Paris, with plans to double geothermal capacity to 100 MWth to supply energy for heating and cooling
		Solar	Geneva, Switzerland	1139 m2 of rooftop solar collectors at Geneva Airport provide heating and cooling to the airport's terminals
	Solar Cooling	Solar	Barcelona, Spain	A 35 kilowatt (kW) system was installed on one of the city's public health agency buildings in 2007
			Singapore	A 1500 kW system using 3 900 m2 of collector surface at the United World College was commissioned in 2011
Electricity (production)	Rooftop solar PV	Solar	Tokyo, Japan	A target for 1 GW of on-site systems solar PV in the city by 2024
			Bangalore, India	Local and state entities leading net metering policy resulting in 14 MW of cumulative installations between 2014 and 2016
			Cape Town, South Africa	Through net metering programme city has commissioned more than 4.5 MW of grid-connected small-scale solar PV capacity
			San Francisco, US	An ordinance requires solar PV to be installed on new buildings up to 10 stories tall, the first major city in the US to do so
	Building integrated PV		Denver, US	Denver provides streamlined, same-day permit review for solar panel projects, including Electrical, Plumbing, and Zoning Permits for PV systems
			Uppsala, Sweden	Building integrated PV was integrated with a residential building housing 70 apartments in 2014
Cooking	Electric cooking	Renewable power	Cities in Ecuador	Financing support and free electricity for one month were used by the government to support induction electric cooking
			Peri-urban Bolivia and Paraguay	Solar cookstoves programme in peri-urban areas including local production, installation and maintenance, aiming to install more than 50 000 stoves in Bolivia and Paraguay. Stoves reduce fuel-wood consumption by more than 60% and generate emission reductions
	Improved cookstoves using bioenergy	Solid biomass	Cities across Africa	Various clean cookstove programmes to support scaling up access to finance and the dissemination of clean cookstoves, such as improved cookstoves in Mali, Ghana, Urganda and Kenya, among others
		Ethanol	Maputo, Mozambique	CleanStar Mozambique, a food, energy and forest protection business, seeks to leverage carbon finance to disseminate up to 30 000 improved cookstoves in urban and periurban Maputo
		Biogas	Ibadan, Nigeria	A scheme is using slaughter-house waste to produce biogas (1,800 cm methane daily) and 1 MW power generation capacity at lower than market price as well as fertiliser for low-income farmers, creating local jobs and boosting local industry
			Cities across Nepal	Nationally subsidised domestic biogas plants use daily organic wastes to produce biogas for cooking purposes in urban households since 2012

Source: IRENA

Masdar City: ambitious goal to be the world's first zero carbon city

Masdar City is attempting to be one of the world's first zero carbon cities (which is different from having 100% renewable power), meaning that it will produce and offset equal parts of carbon. It was established in 2007 with a US$15bn commitment to invest in green energy. Through its private equity arm, Masdar has invested more than US$500mn and now has a portfolio of about 4.5GW of renewable energy, equivalent to four nuclear reactors with a solar PV power plant acting as its central energy source.

Attracting major global corporates

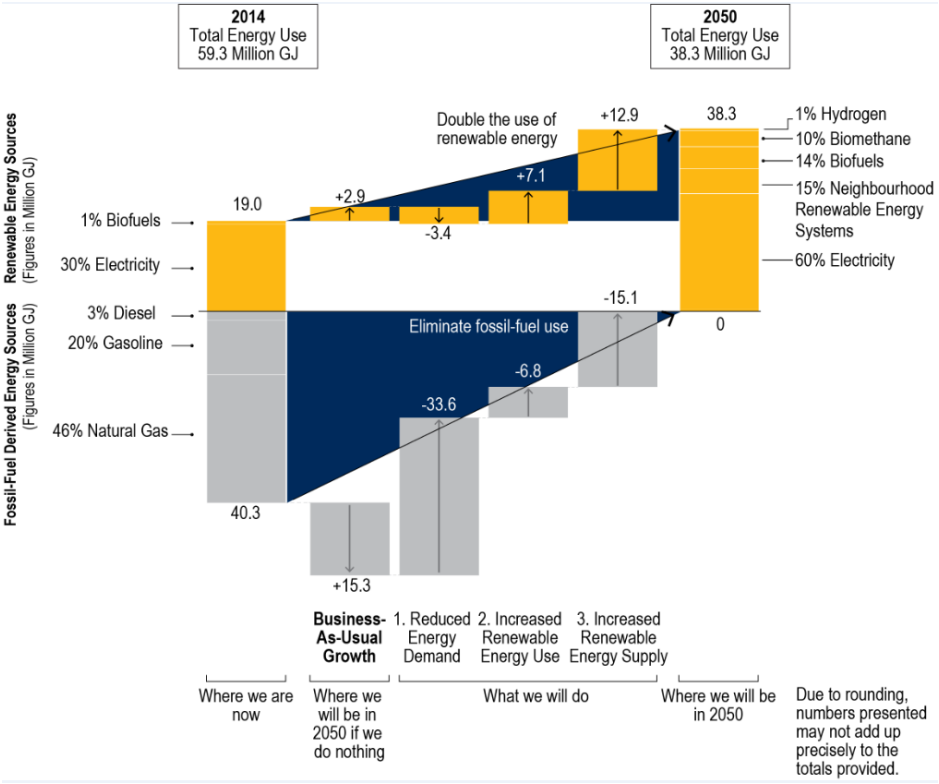
The first tenant/institution to locate was the Masdar Institute of Science and Technology. Siemens Middle-East headquarters are also based in Masdar where a 45-metre wind tower helps channel cooling breezes down a shaded street. Other tenants include Boeing's headquarters and the International Renewable Energy Agency (IRENA) (source: masdar.ae). However, Masdar remains a hugely ambitious project and is currently facing delays to construction and financing.

Vancouver: aiming to be 100% renewable by 2050E

Vancouver is another city making a push in the smarter energy space with two recently stated targets: (1) derive 100% of the energy used in Vancouver from renewable sources before 2050E; and (2) reduce greenhouse gas (GHG) emissions by at least 80% below

2007 levels before 2050E. Vancouver's energy use is 31% from renewables as of 2014 and implementing the "Renewable City Strategy" will reduce total energy use from a 2050 business-as-usual scenario by more than 50%, saving 39 million GJ of energy annually. The net impact is a reduction of one third over 2014 energy use levels, saving 21 million GJ of energy a year. Forty percent of Vancouver's buildings will have been replaced and built to carbon-neutral standards by 2050. Twenty-five percent of the city's personal vehicles will be electric using renewably generated electricity and 45% will be plug-in hybrids using renewable electricity and sustainable biofuels by 2050E (source: City of Vancouver).

Exhibit 151: How Vancouver will get to 100% renewable energy by 2050



Source: City of Vancouver

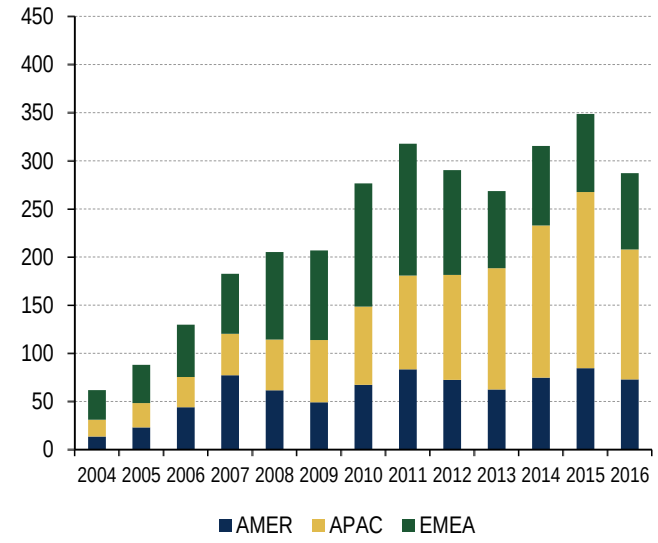
US$137bn cumulative smart energy market by 2024E

The global Smart Energy market for Smart Cities technology is expected to grow from US$7.3bn in 2015 to US$20.9bn in 2024E, implying that the segment is forecast to total US$136.9bn worth of investments from 2015-24E (source: Navigant Research).

US$288bn of cleantech investments in 2016; >US$6tn towards 2040E

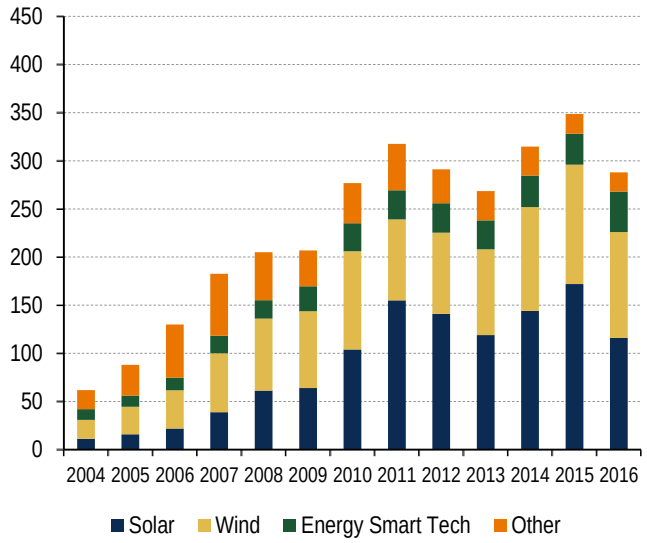
Globally, new investment in cleantech reached US$287.5bn in 2016 (-18% vs record investment of US$348.5bn in 2015) (source: BNEF). We think the 2016 'setback' in global investment is not necessarily a bad sign given that it partly reflected sharp falls in equipment prices: cost-competitiveness improvements in solar and wind power mean that more MW can be installed for the same price.

Chart 89: New investment in clean energy by region, 2004-16 ($bn)



Source: Bloomberg New Energy Finance 2017

Chart 90: New investment in clean energy by sector, 2004-16 ($bn)



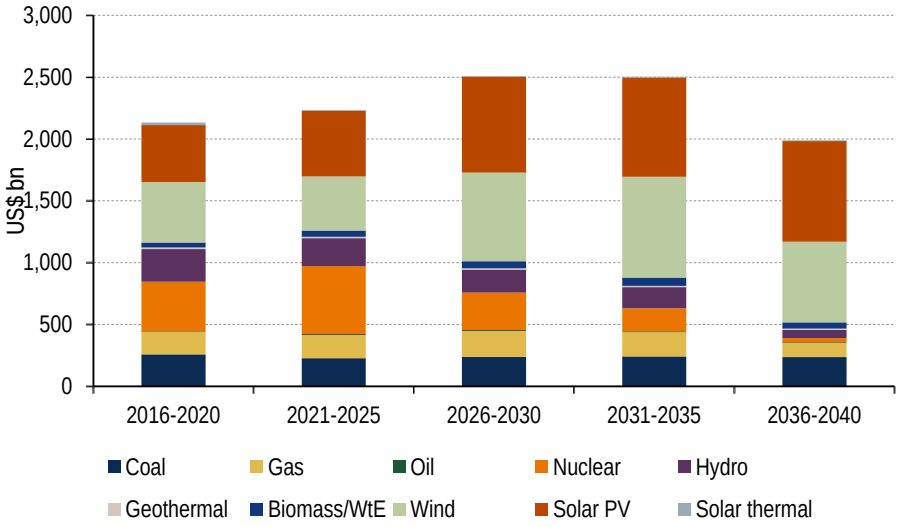
Source: Bloomberg New Energy Finance 2017

US$11.4tn in new power-generating capacity to 2040E: two-thirds renewables

Furthermore, BNEF estimates that the world will invest around US$11.4tn in new power-generating capacity over the next 25Y from 2016-40E at an average of US$454bn per year. More than two-thirds of this will be targeted at renewable energy, with solar seeing a US$3.4tn opportunity and onshore wind attracting US$2.8tn. Overall wind and solar are expected to account for c.60% of the new investments into energy during this time period (source: BNEF)

Chart 91: Wind & Solar will drive cleantech investments

5Y investment in power generation capacity by energy technology (US$ bn, 2016-40)



Source: BNEF

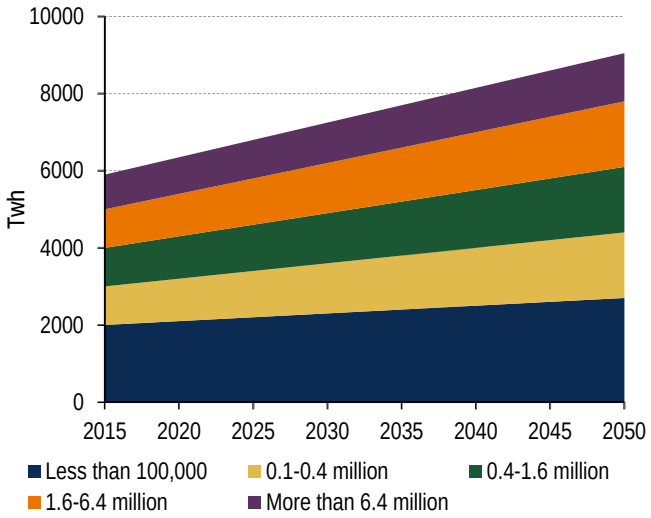
Solar booming: clean fuel for Smart Cities

We think solar will be a key fuel for smarter energy in cities as it helps them fight global warming, reduce air pollution, strengthen electric grids and grow local economies vis-à-vis job creation.

- **On average rooftop solar PV could cover 9% of urban electricity demand in the "2 Degree Scenario" but this figure could stretch to over 25% in EM cities** in India and Africa (source: IEA).

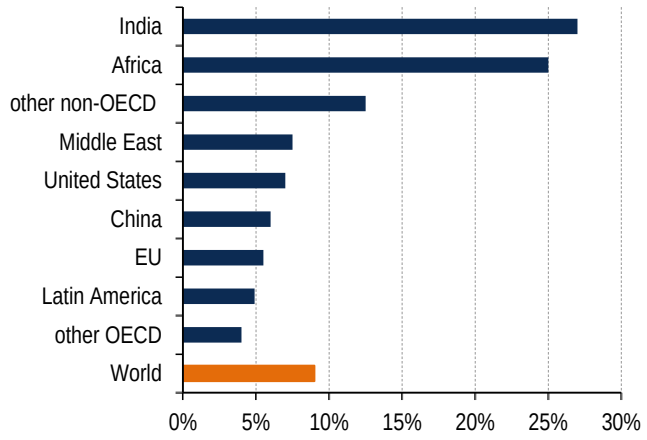
- **Population density will have a strong impact on the available rooftop area per capita** for solar energy, ranging from 100m2/cap in less-populated urban areas to 1m2/cap in high-density cities. According to IRENA, small cities with fewer than 100,000 inhabitants account for the biggest technical potential, at almost 40% of the total. However, the potential in cities with populations of 1.6mn still accounts for a sizeable c.25%.

Chart 92: Total potential for urban rooftop PV by city population



Source: IEA, IRENA

Chart 93: Share of electricity demand in cities covered by urban rooftop solar PV



Source: IEA, IRENA

US cities: currently leading the solar boom

America's major cities have played a key role in the solar revolution and stand to reap tremendous benefit. A rarity just a decade ago, solar panels can now be found on more than 780,000 US residential and business rooftops, with a new system installed every two minutes. According to Environment America, after a year of record-breaking growth in 2015, US solar capacity now exceeds 27,000 megawatts (MW), enough to power 5.4mn homes. Improvements in solar technology and rapidly declining costs are making solar energy more attractive with every passing year.

US cities with the most solar power installed (2016): Los Angeles (215MW), San Diego (189MW), Phoenix (147MW), Honolulu (146MW), San Jose (141MW), Indianapolis (124MW), San Antonio (108MW), NYW (84MW), Albuquerque (65MW) (source: Environment America 2016)

- **The top 20 cities representing just 0.1% of US land area accounted for 6% of US capacity** as of the end of 2015 at 1.5GW.

- **64 US cities have installed nearly as much solar power as the entire country had installed at the end of 2010** with over 1,700MW of solar PV capacity.

- The cities with the highest **total** installed solar PV capacity are Los Angeles, San Diego, Phoenix, Honolulu and San Jose.

- However, the cities with the most solar PV installed **per capita** are Honolulu, Indianapolis, San Jose, San Diego and Albuquerque,

Table 47: Solar in US Cities

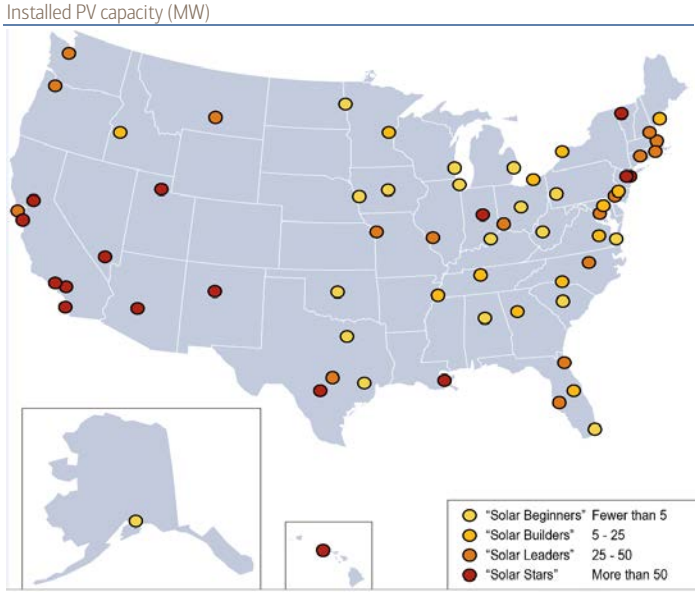
Ranking

City	State	Total Solar PV Installed (MW-DC)	Total Solar PV Rank	Per Capita Solar PV Installed (Watts-DC)	Per Capita Rank
Los Angeles	CA	215	1	55	15
San Diego	CA	189	2	136	4
Phoenix	AZ	147	3	96	6
Honolulu	HI	146	4	417	1
San Jose	CA	141	5	139	3
Indianapolis	IN	124	6	146	2
San Antonio	TX	108	7	75	10
New York	NY	84	8	10	37
Albuquerque	NM	64	9	114	5
Las Vegas	NV	58	10	94	7
San Francisco	CA	41	11	48	16
New Orleans	LA	35	12	90	8
Austin	TX	33	13	36	18
Sacramento	CA	32	14	66	12
Riverside	CA	28	15	88	9
Jacksonville	FL	24	16	28	21
Newark	NJ	21	17	75	11
Portland	OR	19	18	31	20
Boston	MA	15	19	23	24
Washington	DC	14	20	20	29

Source: Environment America 2016

Exhibit 152: Solar in US cities

Installed PV capacity (MW)



Source: Environment America 2016

Rooftop solar in Los Angeles could provide up to 60% of the city's electricity - NREL

US cities have only begun to tap their solar energy potential

Cities such as Los Angeles, New York, Chicago and San Antonio have the technical potential to generate 10-100x more solar energy than they do currently according to the NREL. Top-ranked city Los Angeles, which currently has 215MW of solar PV capacity, could host up to 9,000MW of solar PV capacity on its rooftops, providing up to 60% of the city's electricity. New York, San Antonio and Chicago could each accommodate more than 6,000MW of solar PV capacity on city rooftops. Other cities with the rooftop resources to install at least 2,000MW of solar PV capacity include Baltimore, Charlotte, Detroit, Milwaukee, New Orleans, Philadelphia and Portland. Overall rooftop solar power alone is technically capable of contributing 1,118GW of generating capacity to the national electric grid. That is enough solar energy to cover the annual electricity needs of more than 135 million homes (source: National Renewable Energy Laboratory (NREL).

- **San Francisco, US:** In April 2016, San Francisco became the first US city to require all new buildings to install rooftop solar PV. The ordinance builds on a California requirement for new buildings to set aside 15% of the roof area to be "solar ready", meaning the space should be clear and unshaded. The city says this is the first mandate of its kind, and that new buildings 10-storeys tall or shorter will have to install PV panels or solar water heaters (source: City and County of San Francisco, 2016).

- **Las Vegas, US:** The city is now powered by 100% renewable energy after a large solar array – Boulder Solar 1 – came online on December 2016 powering its 140 buildings, streetlights and other facilities. Many of the casinos have now installed

rooftop solar in an effort to go off grid. Las Vegas has installed a total of 6.2MW of solar electric capacity on 37 public buildings, community centres, fire stations and parks, including a 3.3MW generating station at the city's wastewater treatment plant.

- **Austin, US:** Austin already has an estimated 33MW of solar electric capacity within city limits. However, it is taking further steps to add 450MW of solar power capacity to its electric grid. Austin Energy, the city's municipal electric utility, already supplies over 60MW of solar energy to the local region.

- **Tokyo, Japan:** Tokyo plans to install 1 gigawatts (GW) of rooftop systems by 2024E, including 22 megawatts (MW) of PV on state-owned buildings and facilities by 2020. It aims to increase the share of renewables to 20% of total power generation by the time of the Summer Olympics in 2020 (source: Movellan, 2015).

- **Rizhao, China (Solar Thermal Systems):** The city has promoted solar water heating (SWH) in residential buildings for the past 20 years through regulations, information campaigns and subsidies. The Shandong provincial government helped finance solar research and development resulting in competitive pricing of SWH systems compared with electric heaters. As a result, by 2015, 90% of households in Rizhao had access to SWH (source: IRENA, Rizhao Government, 2015).

Wind case studies on Copenhagen and Paris

Wind energy tends to be largely generated outside of cities (offshore by the sea, onshore wind farms in rural areas). However, where viable, cities are also tapping into wind as a source of energy. Copenhagen (Denmark), Georgetown (Texas, US), Greensburg (Kansas, US) and Burlington (Vermont, US) among others are taking a lead in this space.

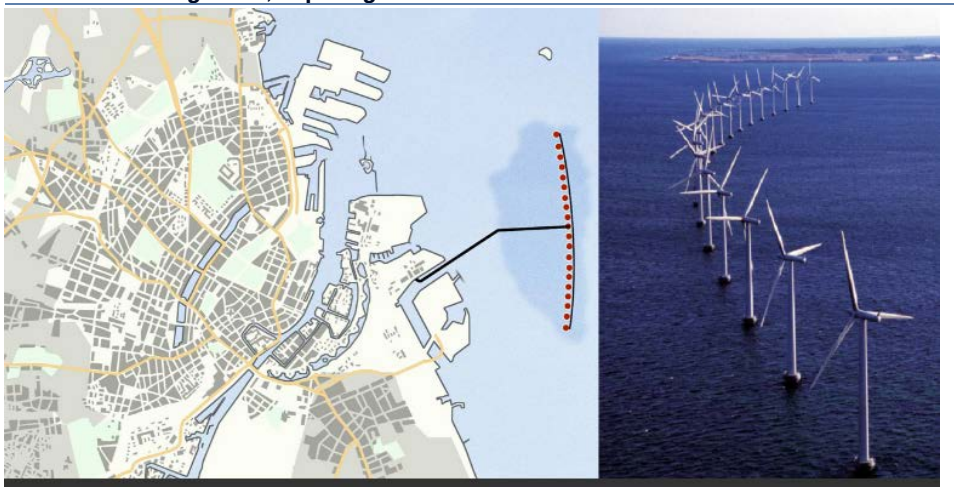
Copenhagen aiming to be carbon neutral by 2025E

Copenhagen's stated goal is to become carbon neutral by 2025. It is installing more wind turbines to help meet this goal, which is part of Denmark's plan to run entirely on renewable energy by 2050E. To achieve carbon neutrality by 2025E, the Municipality of Copenhagen needs to set up 360MW – or more than 100 – turbines. The exact number depends on the distribution of on-shore and off-shore wind turbines, wind conditions, future technological developments etc (source: InvestDK, Copenhagen City).

Middelgrunden: offshore wind farm delivers 4% of Copenhagen's electricity

The Middelgrunden is an offshore wind farm 3.5km outside of Copenhagen installed by DONG Energy. When it was built in 2000, it was the world's largest offshore farm, with 20 turbines and a capacity of 40MW delivering about 4% of the power for Copenhagen. The project is an example of community wind energy, and is 50% owned by the 10,000 investors in the Middelgrunden Wind Turbine Cooperative, and 50% by the municipal utility company.

Exhibit 153: Middelgrunden, Copenhagen



Source: MIT, Middelgrunden.dk

Paris: aesthetically pleasing "wind trees" being installed

Wind power need not be an eyesore that detracts from a city's skyline. French company New Wind recently piloted "wind trees" in Place de la Concorde in Paris. The 26-foot-tall steel structures feature 63 "aeroleaves" that operate as mini vertical turbines all around the "tree." When the wind blows, the leaf turbines rotate and quietly produce energy. The cables and generators are integrated into the leaves and branches so that the turbine operates almost silently. The "aeroleaves" can generate electricity power output of 3.1kW in wind speeds as low as 4.5mph (7km/h) and can provide enough power to supply 15 street lamps or one electrical car for 1,360km over the course of a year (source: New Wind).

Exhibit 154: "Wind Trees" in Paris

Source: New Wind

Smart Grid: modernising T&D for 21st century cities

We think the smart(er) grid is the "holy grail" for smart(er) energy in cities by managing the energy demands of 21st century cities. Most smart cities will unlikely be able to power itself in the near term hence transmission and distribution into and out of cities is of critical importance. Large-scale renewables such as solar farms (PV and solar concentration) and wind farms, as well as hydro dams that operate outside of city boundaries will need to be integrated with distribution systems within cities. This will

require smart interfaces between intermittent renewable sources and storage mechanisms to ensure a reliable supply and a stable, balanced system.

Table 48: Today's Grid . vs. Tomorrow's. Smart Grid

Characteristic	Today's Grid	Smart Grid
Enables active participation by consumers	Consumers are uninformed and non-participative with power system	Informed, involved, and active consumers - demand response and distributed energy resources.
Accommodates all generation and storage options	Dominated by central generation- many obstacles exist for distributed energy resources interconnection	Many distributed energy resources with plug-and-play convenience focus on renewables
Enables new products, services and markets	Limited wholesale markets, not well integrated - limited opportunities for consumers	Mature, well-integrated wholesale markets, growth of new electricity markets for consumers
Provides power quality for the digital economy	Focus on outages - slow response to power quality issues	Power quality is a priority with a variety of quality/price options - rapid resolution of issues
Optimizes assets & operates efficiently	Little integration of operational data with asset management - business process silos	Greatly expanded data acquisition of grid parameters - focus on prevention, minimizing impact to consumers
Anticipates and responds to system disturbances (self-heals)	Responds to prevent further damage- focus is on protecting assets following fault	Automatically detects and responds to problems - focus on prevention, minimizing impact to consumer
Operates resiliently against attack and natural disaster	Vulnerable to malicious acts of terror and natural disasters	Resilient to attack and natural disasters with rapid restoration capabilities

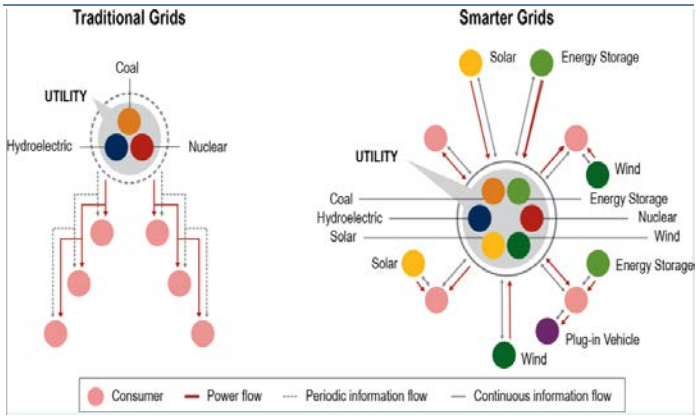
Source: US Department of Energy

Smarter T&D is key to the roll-out of renewables

Smarter transmission and distribution (T&D) networks are expected to play an important role in increasing the share of renewable energy in cities.

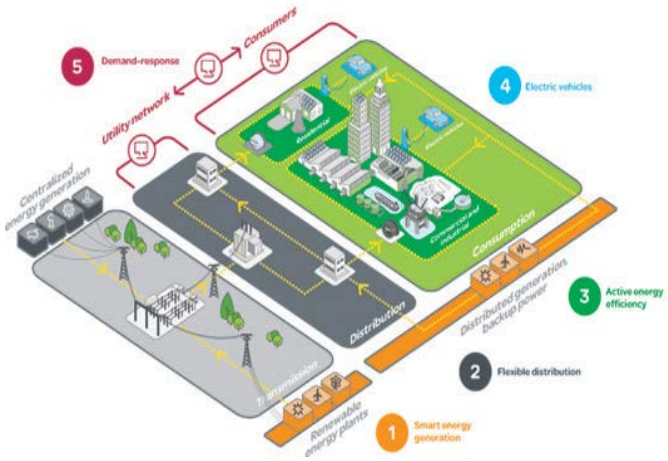
- **Electricity grids are becoming interconnected within countries and across borders, allowing for greater flexibility in managing variable renewable energy**.
- **Smaller and autonomous grids are growing in popularity** as a means of providing access to communities previously left behind.
- **Furthermore, to maximise potential, significant ICT upgrades will be needed for existing grid systems**. This includes two-way digital communication devices connected to the grid, such as power meters, fault detectors and voltage sensors. Smart grids allow a utility to increase its level of control over millions of connected devices, and to manage demand and power flows in real time (source: IRENA).

Exhibit 155: Traditional vs. Smart Grid



Source: BroadbandHomeCentral

Exhibit 156: Smart Grid illustration



Source: Schneider

Smart Grid 101: electricity network using digital technologies

According to the IEA, a "smart grid" is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying demands of end-users. Smart grids co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimising costs and environmental impacts while maximising system reliability, resilience and stability. Smart grid is a broad term that incorporates:

- **Renewable & distributed generation –** electricity from intermittent renewables or distributed solar PV near point of consumption. These may need grids to have bidirectional energy flows (vs one-way flow currently) and more flexible/robust balancing solutions.
- **Demand side response –** the action of changing electricity usage in response to incentives that reflect the real-time needs of the electricity system. This primarily involves shifting electricity demand away from peak periods.
- **Energy storage –** examples of batteries include lithium-ion, lead-acid and flywheel spinning. Storage can be:
    - a grid component to reduce the volume of balancing services required, to overcome the problem of intermittent renewables generation and to level the daily load curve;
    - combined with distributed generation, potentially allowing businesses or households to reduce their dependence on grid power.
- **Smart meters –** more advanced digital meters which can communicate with the network, providing readings at more frequent intervals and allowing for accurate monitoring, billing, real time pricing and time-of-use tariffs.
- **Electric vehicles –** EVs can be integrated into the grid to reduce daily load fluctuations or to act as storage, although the latter seems difficult to us.
- **Network 'intelligence' –** includes high-speed communication and sensors that enable the remote monitoring of equipment such as transformers and power lines.

Exhibit 157: Areas affected directly and indirectly by smart grid technologies

	Generation	Transmission	Distribution	Suppliers	Consumers
Smart Meters					
Grid Intelligence (sensors etc.)					
Demand Response					
Electric Vehicles					
Battery Storage and Distributed Generation					
Grid-scale Storage					

Area affected directly

Area affected indirectly

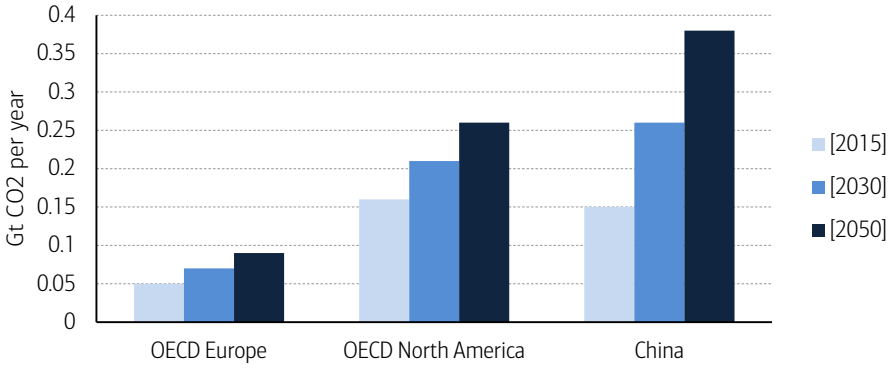
Source: BofAML Global Research

Helping cities achieve their sustainability and environmental targets

Smart grids can allow cities to meet their carbon emission reduction goals, eg, the EU's '20-20-20' target which aims to: improve energy efficiency by 20%, reduce greenhouse gases by 20% in 2020 from 1990 levels, and raise EU energy consumption from renewable resources to 20%. We view these environmental targets as the driving force behind smart grid adoption. Smart grids can help achieve sustainability targets through:

- **greater penetration of highly variable renewable energy sources** through demand-side response, system management and battery storage;
- **lower losses on transmission and distribution networks,** ie, less operating and capital expenditure; and
- **demand-side management and load adjustment** reducing the need for polluting peak power stations.

Chart 94: Regional CO2 emissions reduction from deployment of smart grid technologies



Source: IEA

Microgrids within the smart grid: up to 100GW by 2030E

A specific advancement in the area of energy management in Smart Cities is the proliferation of the "microgrid". A microgrid is defined as a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously. Hence cities, or districts within cities, are increasingly implementing microgrid architecture allowing for distributed generation (eg from rooftop solar PV or small hydropower) and can provide electricity within the autonomous grid at times of a blackout at the central utility (source: IRENA). Globally microgrids have grown to over

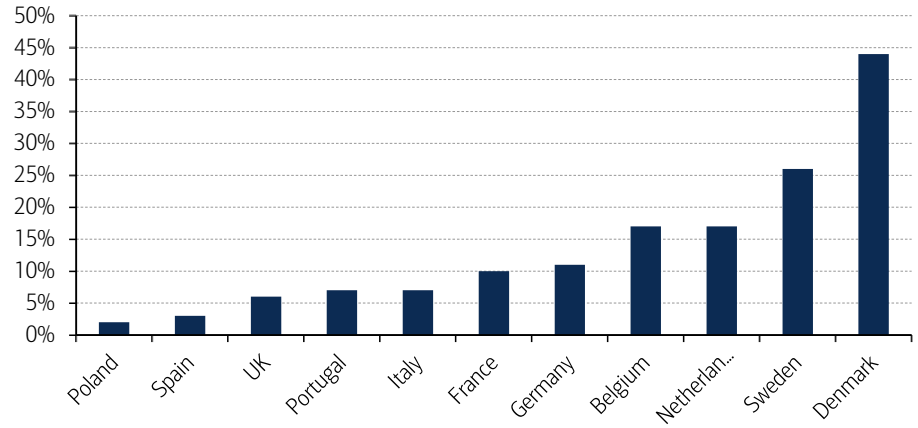
1.2GW in capacity, with projections for 20GW by 2020 and 100GW by 2030, according to Andres Carvallo at Intel. The global microgrid market is estimated to grow from US$9.8bn in 2013 to US$35.1bn by 2020 (source: Transparency Market Research).

Smart grid is not just about energy: ICT is a key enabler for interconnection

Electricity generation is no longer purely an engineering concern; it is increasingly a question of infrastructure built around and incorporating information and communications technology (ICT) according to Intel. Network Intelligence, interconnection providing connectivity infrastructure for the transfer of data, is also becoming paramount for the instalment of more sensors in the smart grid.

- **Alongside more 'intelligent' systems, transmission grids can create more inter-country transmission lines**, often high-voltage, direct current electric power transmission lines.
- **As countries invest more in renewables, interconnection can help transport energy generated by renewable plants to areas of consumption**. We thus see new transmission capacity as an important grid component in the transition to higher renewable generation.
- **Interconnection can also reduce spare generation capacity needs** as electricity can be sourced from other areas. If more electricity is sourced from other countries, it would increase price convergence, for example, between European nations.

Chart 95: Interconnection levels in Europe (% of all installed generation capacity), 2014

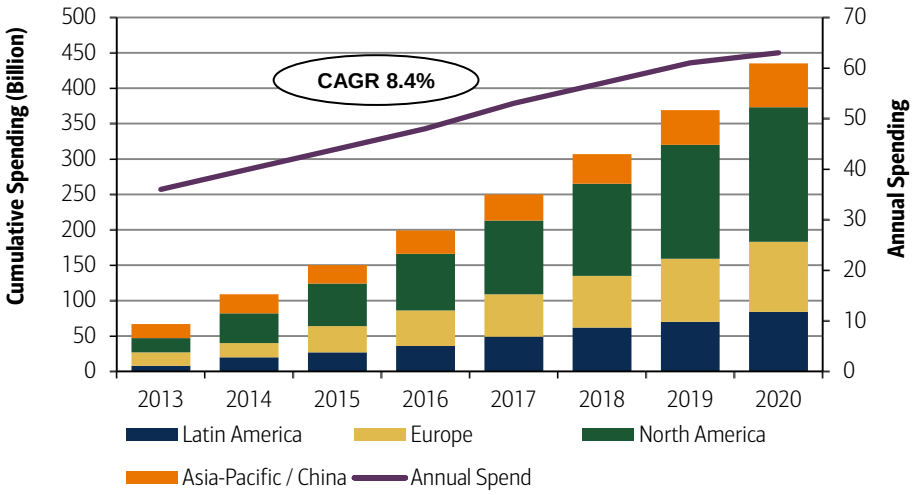


Source: European Commission

US$400bn global smart grid market by 2020E

The smart grid market is expected to grow at an 8.4% CAGR between 2013 and 2020, to exceed a cumulative value of US$400bn (source: GTM Research). The main names in the field include ABB (transmission and distribution automation), Cisco (communications), IBM (integration and consulting) and Itron (advanced metering infrastructure) (source: Frost & Sullivan, GreenTechnica).

Chart 96: Regional smart grid forecast 2013-20



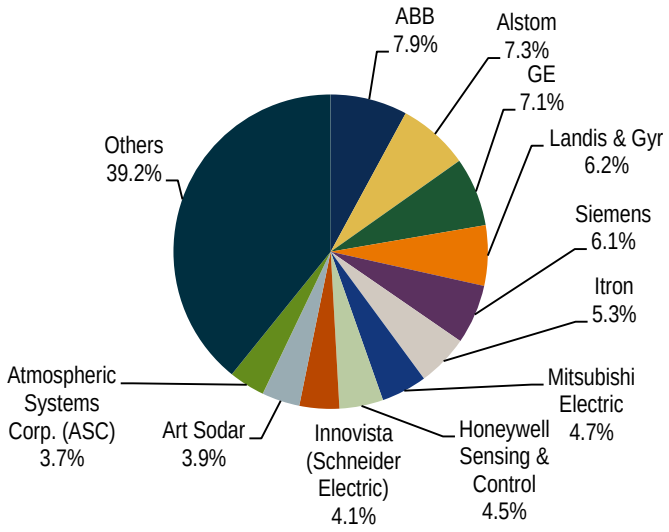
Source: GTM Research

Table 49: The Networked Grid Top 10 Vendors

Vendors	Submarket
ABB	Transmission and Distribution Automation
Cisco	Communications
IBM	Integration and Consulting
Itron	AMI infrastructure
Siemens	Transmission and Distribution Automation
S&C	Distribution Automation/Grid Support
Schneider Electric	Distribution Automation
oPower	Soft Grid
Silver Spring Networks	Communications
Tendril	Home Energy Management

Source: Greentechmedia

Chart 97: Sensors Market in Smart Grids: Percent Revenue Breakdown, Global, 2015



Source: Frost & Sullivan

Smart Grid city case studies

- **Jeju, South Korea** – a large smart grid test-bed which started operation in 2009 in line with the objective for a national smart grid by 2030E. Technologies tested include smart meters, intelligent power transmissions and distribution equipment, a real-time electricity pricing system and integrated electric vehicle charging stations.

- **San Francisco, US** – introduced a trial programme in 2015 for the smart charging vehicle concept. In times of high electricity demand, the utility alerts the car maker, which can then delay charging vehicles that are not scheduled to be used.

- **Hamburg, Germany** – a virtual power plant (VPP) development and demonstration project including dynamic simulation modelling (DSM) for buildings, combined heat

& power (CHP) plants, and thermal storage systems operated by an advanced management system.

- **Kalmar, Sweden** – 10 buildings are part of a smart heat grid, including intelligent control systems to coordinate interaction between production, distribution and consumption with plans for linking another 40 premises.

Table 50: City examples of the use of support technologies and concepts for sustainable and integrated urban energy systems

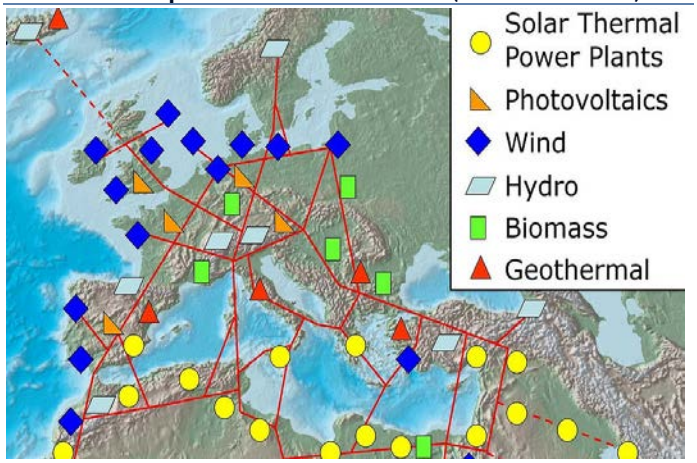
Category	Technology/ application	Area	Example
Demand side management	Vehicle-to-grid	San Francisco, US	In 2015, a trial programme for the smart charging vehicle concept started. In times of high electricity demand, the utility alerts the car maker who can then delay charging vehicles that are not scheduled to be used
	DSM for buildings / industry	Cities in the US	Transmission organization PJM runs a program that compensates customers for reducing their electricity loads during periods of high power prices or when the reliability of the grid is threatened. By May 2016, nearly 20 000 industrial, commercial, and residential users were part of the programme
		Cities in Germany	A study in Germany showed that air-sourced heat pumps can play a major role in shifting the demand for electricity; e.g. 20-30% of electricity space heating could be shifted in wintertime
Energy storage	Stationary battery storage	Cities in Germany	In Germany 20000 privately owned battery storage systems were installed in 2015
	Thermal storage	Cities in the Netherlands	Across urban areas, around 2000 aquifer thermal energy storage systems - combined with heat pumps - have been installed to date. In the next 10 years, it is estimated that this could grow to 20000 units.
Grids and networks	Smart power grids	Jeju, Republic of Korea	A large scale smart grid test bed started operation in 2009 towards the objective for a national smart grid for the country by 2030. Technologies tested include smart meters, intelligent power transmissions and distribution equipment, a real-time electricity pricing system and integrated electric vehicle charging stations.
	Virtual power plants	Hamburg, Germany	A VPP development and demonstration project includes DSM for buildings, CHP plants, and thermal storage systems operated by an advanced management system
	Smart district energy networks	Reykjavik, Iceland	The city of Reykjavik supplies 100% electricity and heat demand from geothermal energy sources including district heating
		Kalmar, Sweden	10 buildings are part of a smart heat grid - including intelligent control systems to coordinate interaction between production, distribution, and consumption - with plans for linking another 40 premises
Integrated urban planning	Building design and regulation	London, UK	A study shows that the solar irradiation of roofs could be increased by around 9%, while that of façades could grow by up to 45% with certain measures to utilise the morphology of London's neighbourhoods
		Santa Monica, US	The Municipal Green Building Ordinance demands new family homes and hotels to install solar PV systems with specific minimum total wattage dependent on the building surface (1.5 watts per square foot)
	Street lighting	Nairobi, Kenya	Kenyan Urban Roads Authority and lighting manufacturer have jointly installed solar-powered LED street lighting in Nairobi with possible expansion across the country starting in 2012
		Kathmandu, Nepal	8000 solar lamps to be installed through a funding scheme shared between government, the city and local community funds
		Nagpur, India	As the first Model Solar City in India in 2007 Nagpur installed approximately 72 000 city-wide street lights
	Landscape planning	Melbourne, Australia	Melbourne targets a tree canopy cover of 40% by 2040 - up from 22% today - to reduce air-conditioning energy consumption as well as lost business during heatwaves
	Urban agriculture	Vancouver, Canada	Vancouver promotes urban agriculture to enhance the city's food security and reduce "distance to fork"
	Waste-to-energy	Ruhr region, Germany	The interconnection between two transregional networks would allow for more industrial waste heat to be used in serving district heat to 500 000 homes
		Vienna, Austria	District heating provides heat to 270 000 people in the city; waste incinerators are a main source of energy
		New York, US	The city has run a pilot program since 2013 to produce methane from food waste
		Belo Horizonte, Brazil	In 2010 a large landfill biogas plant became operational in the city producing 28 000 MWh per year, representing the power consumption of approximately 30 000 consumers

Source: IRENA

European utilities driving smart city innovation: albeit on a small scale

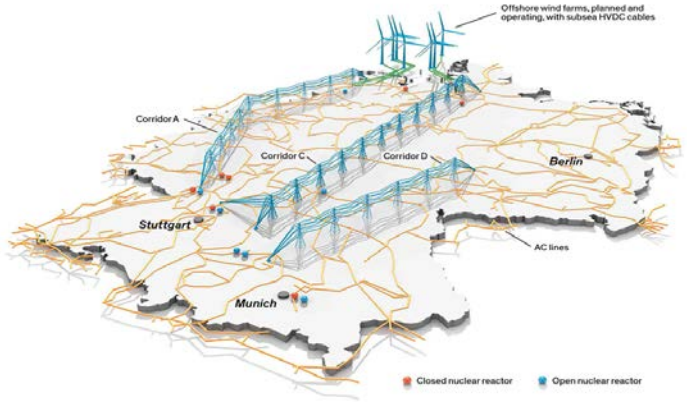
In October 2014, the European Council announced a 2020 target for member states to achieve at least 10% interconnection of their installed generation capacity, with an objective of 15% by 2030. Many countries have already reached these levels although countries on Europe's periphery, which are more isolated from the internal electricity market, are less connected. The EC estimates that c.€200bn will be required by 2020 to build necessary infrastructure to adequately interconnect all EU member states. There are also ambitions to create a European 'Super Grid', interconnecting EU countries and enabling wider use of renewables. With high costs and difficult cross-border agreements needed, we do not see such a grand plan taking shape anytime soon.

Exhibit 158: European Smart Grid Grand Vision (HDVC cables in red)



Source: DESERTEC

Exhibit 159: German HDVC Lines (from North to South)



Source: ENTSOE , Bryan Christie Design

On a city level there has also been an increasing number of greenshoots in this space:

- **Malaga, Spain (Endesa):** This is Europe's largest eco-efficient city initiative, covering 11,000 domestic and 1,200 industrial and service customers. Smart meter, network automation and smart recharging infrastructure for e-vehicles were installed. After five years, the programme led to 25% energy savings. If smart grid and smart city solutions are deployed more widely, it may be possible to reduce energy demand.

Exhibit 160: Smart distribution grid of Malaga

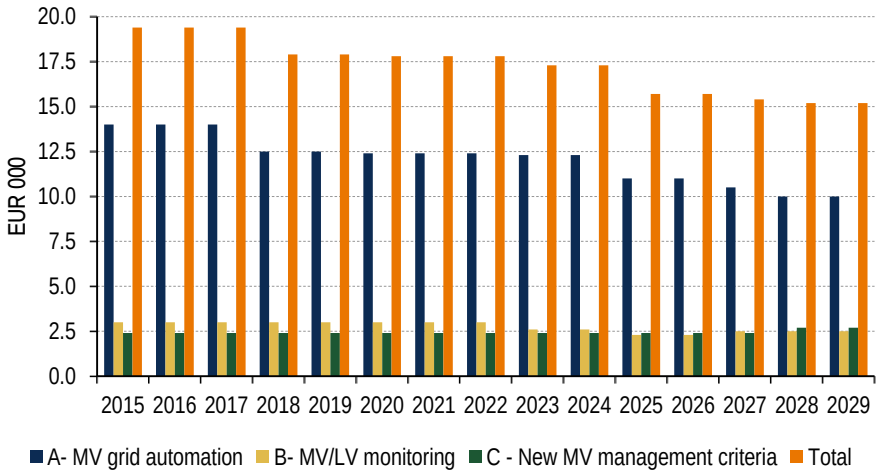
Source: Endesa

- **Malmo, Sweden (E.ON):** The company has commissioned a sustainable city development, comprising 2,000 residents and 2,000 work-places. The city is a test-bed for development of new technologies, such as distributed generation, distributed energy storage and smart homes. E.ON estimates smart technologies will deliver an energy efficiency gain of 10-20%.
- **Lyon & Grenoble (GreenLys):** France's first full-scale smart grid demo that reached 1,000 residential consumers and 40 commercial sites. This included automatic grid

reconfiguration and advanced sensors on distribution substations. The project's biggest impact came from demand-side response – this reduced consumer energy costs by 16%.

- **Rome (ACEA):** The pilot project involved smart grid implementation in the Malagrotta area of Rome, reaching 1,200 consumers, with advanced grid automation, monitoring and remote control.

Chart 98: Benefits gained annually for the Malagrotta project



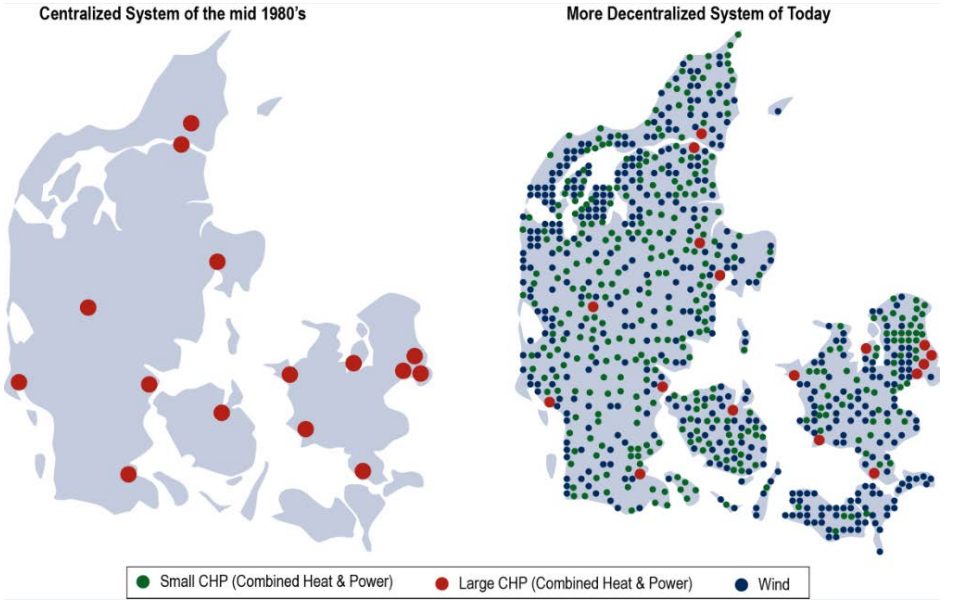
Source: European Commission

Denmark case study: quarter of all EU smart grid tests

We think countries can take a leaf out of Denmark's book as a case study in how to decentralise a country's energy system into localities. Today Denmark is home to 22% of all European Smart Grid test and demonstration projects (source: SmartGreen) and the country's energy infrastructure is hugely localised compared with the mid-1980s. We outline how this trend and the smart grid have benefited a selection of Danish cities:

Exhibit 161: Denmark's energy revamp progress over the past 20 years

Centralized in the 1980s vs. Decentralized Present Day



Source: US Department of Energy

- **Kalundborg** aims to turn energy distribution into an open platform. This means that the city's energy system will be able to incorporate solar energy, wind, biogas

Bank of America Merrill Lynch

among others and that citizens will be able to choose from a range of energy solutions in a similar way to Google's and Apple's app platforms. This approach makes the residents of Kalundborg "prosumers", which involves them functioning both as consumers of energy, but also as suppliers of electricity back into the energy grid. For instance, it is possible for citizens to control the period in which their electrical devices are recharged. For example, electric cars can be recharged at times of surplus energy or of low pressure on the electricity network – ensuring the cheapest price and the most sustainable solution (source: CleanClusterDK).

- **Bornholm.** The Danish island is becoming one of the most popular sites in the world for testing new green technologies. Because of its geographical location and well-developed water, heating and electricity systems, the island is ideal for testing electric cars, solar panels, smart buildings, and intelligent systems, all of which will play an important role in future Smart Cities. One example is the €26.8mn project, EcoGrid EU, which has helped to install computers in 2,000 households on the island, testing smart management of electricity consumption. The project actively involves the end-user in the electricity market so that it is possible to control consumption based on the price of electricity. The specific household computer makes allows the household to switch selected devices on and off based on the price (source: CleanClusterDK).

US Utilities: energy independence and mitigating blackouts for cities

The ageing US grid dating back to the 20th century is failing to keep up with the rise of its 21st century cities. According to the US Department of Energy, since 1982, growth in *peak* demand for electricity has exceeded transmission growth by almost 25% every year yet spending on R&D is among the lowest of all US industries (<2%). Nearly 75% of transmission lines and transformers are 25Y or older.

- **The pressing need to revamp the ageing 20th century grid for cities is underscored by increasing prevalence of city-wide blackouts**. According to 2013 data from the US DoE, US power grid outages have risen by 285% since records on blackouts began in 1984. For the most part these were driven by the grid's vulnerability to unusual and extreme weather events – such as the devastating Hurricane Sandy in 2012 that caused extensive power outages across the East Coast – which are becoming less unusual as the years roll on. From 2008-12, major outages caused by weather increased to 70 to 130 per year. Weather used to cause about 17% to 21% of all outages. In the past five years, it has accounted for 68% to 73% of all major outages.

- **Topping the list of cities most likely to see big increases in their power outage risk are New York, New York; Philadelphia, Pennsylvania; Jacksonville, Florida**; Virginia Beach, Virginia; and Hartford, Connecticut. This is because power grids in coastal US cities are increasingly at risk due to climate change. Cities at the bottom of the list, whose risk of outages is unlikely to change significantly, include Memphis, Tennessee; Dallas, Texas; Pittsburgh, Pennsylvania; Atlanta, Georgia; and Buffalo, New York (source: John Hopkins University).

Table 51: Top 10 Cities most likely to see big increases in power outage risk

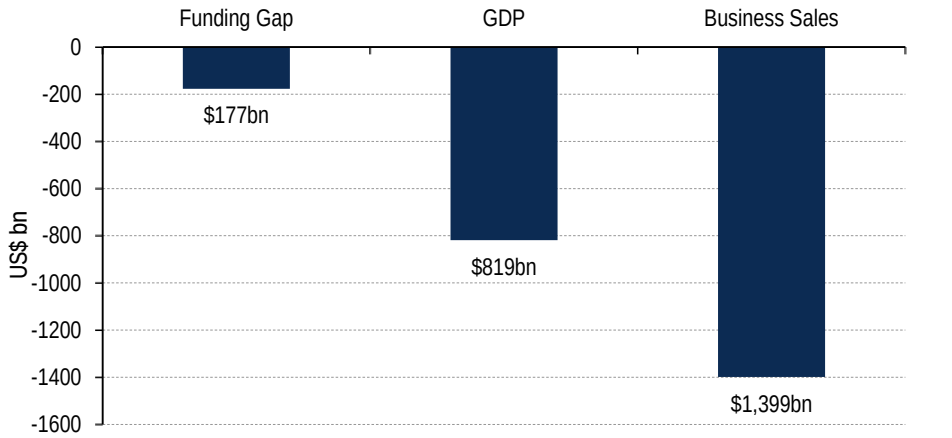
1	New York, NY
2	Philadelphia, PA
3	Jacksonville, FL
4	Virginia Beach, VA
5	Hartford, CT
6	Orlando, FL
7	Tampa, FL
8	Providence, RI
9	Miami, FL
10	New Orleans, LA

Source: John Hopkins University

- **The American Society of Civil Engineers (ASCE) estimates that the US requires US$934bn in total electricity infrastructure investment through to 2025E.** Of this, US$757bn is funded, leaving an underinvestment funding gap in America's electricity of US$177bn. In a business-as-usual scenario underinvestment in the electricity infrastructure sector could harm the US economy in the long run with a loss of business sales of US$1.4tn, reduction in GDP of US$819bn and loss of 102,000 jobs through to 2025E. The electricity sector underinvestment gap in 2025E would be 22% in generation, 24% in transmission and 54% in distribution.

Chart 99: The state of US electricity infrastructure investment

Cumulative impact - 2016-25E



Source: American Society of Civil Engineers 2016

Recovery & Reinvestment Act (2009): boost for public-private partnerships

Under the 2009 American Recovery and Reinvestment Act, US$9bn of public-private investment has led to acceleration in US smart grid deployment, in particular, greater spend on distribution automation systems. Still, smart grid technologies represent less than 10% of total network investments (average distribution system upgrades by investor-owned US utilities from 2003-12 were US$17bn annually according to EIA data). Although US investment in smart grid technology is not extensive nationally, individual projects have shown the potential savings that smart grid technology can bring multiple benefits too in addition to the savings.

In many areas of the US the only way a utility knows there's an outage is when a customer calls to report it (source: US Department of Energy).

- **EPG Chattanooga, a utility in Tennessee with 170,000 customers**, has invested significantly in smart grids. The utility has installed 1,200 automated switches which enabled EPG to restore power instantly to half of the city's residents affected by a severe windstorm in 2012. This single incident saved the utility US$1.4mn (0.23% of full year operating revenues).
- **Western Electricity Coordinating Council** has determined that it can increase energy flow by 100MW along the California-Oregon transmission line with the instalment of advanced sensors for real-time grid control. This reduces energy costs by an estimated US$35-75mn over 40 years without any new high-voltage capital investments.
- **Bonneville Power Administration** used historical phasor measurement unit data on the performance of the 1,100MW Columbia Nuclear Generating Station to validate and calibrate the plant's dynamic model. This removed the need to take the plant offline for manual tests saving US$700,000 for the power plant's operator Energy Northwest.

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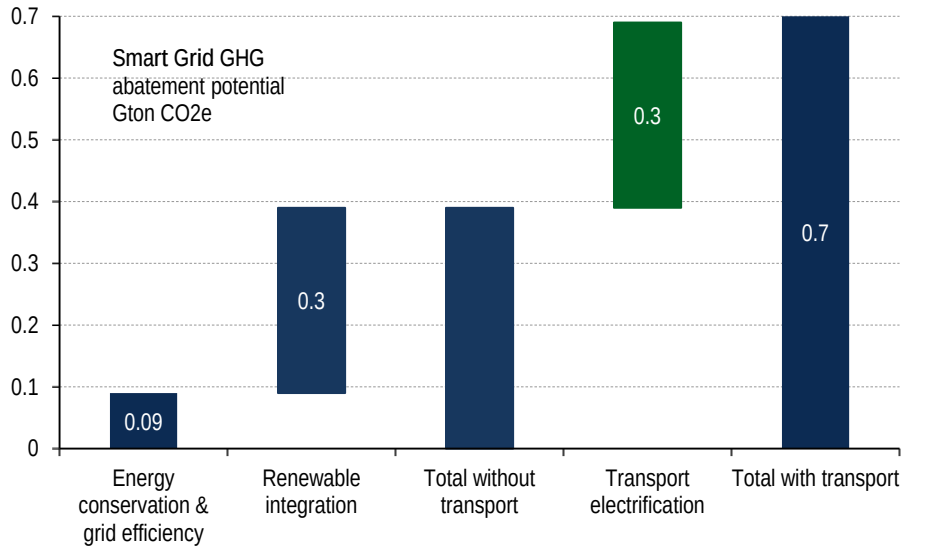
EVs: potential catalyst for the smart grid

Renewable Energy: Supercharge me – electricity demand upside scenarios from electric vehicles 16 February 2017

EV smart charging and vehicle-to-grid (V2G) have been described by experts such as Robbie Diamond from Securing America's Future Energy (SAFE) as the "killer app" for the Smart Grid and hence ultimately smart energy for cities. As we set out in our Future Mobility report, the boom in EVs should also spur a virtuous cycle of investments in the smart grid as well as proliferation of the EV charging infrastructure.

- **EVs are able both to consume and provide energy through the grid's infrastructure and hence facilitate what the power industry calls "frequency regulation".** That is, EVs, as batteries on the move, can respond quickly to the gap between power generation and demand on the grid (source: Silver Springs).
- **For electric-car owners, a smart grid will help track exactly how much electricity they are consuming, what it costs to charge their vehicles**.
- **For utilities, a smart grid will help manage demand**, preventing big power surges as well as opening the door to a variety of new services.

Chart 100: EV Greenhouse Gas Abatement potential with Smart Grid

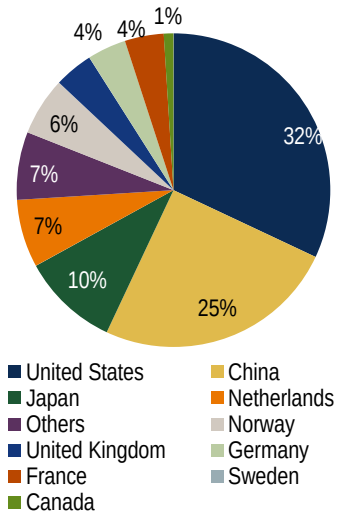


Source: Silver Spring Networks
Transport electrification involves charging Eves from renewable energy sources.

Charging infrastructure becoming less of a challenge: 12mn outlets by 2020E

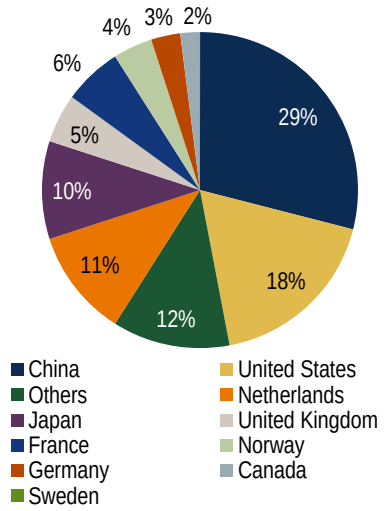
There is a shortage of EV charging infrastructure, but this is expected to change rapidly. According to IEA, in 2015 there were 1.3mn private outlets globally, with another 162k public slow outlets and 28k fast ones, for a total of around 1.5mn. This is projected to rise to over 12mn by 2020E, potentially exceeding the total number of EVs on the road (source: IHS).

Chart 101: Geographical distribution of the 2015 stock of EVSE outlets by charger type
Private 1.3 million outlets



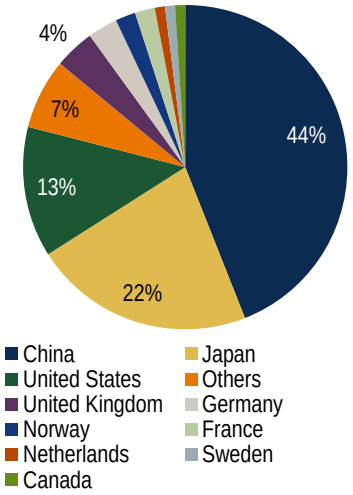
Source: IEA analysis based on EVI country submissions, complemented by EAFO (2016).

Chart 102: Geographical distribution of the 2015 stock of EVSE outlets by charger type
Publicly available, 162,000 slow outlets



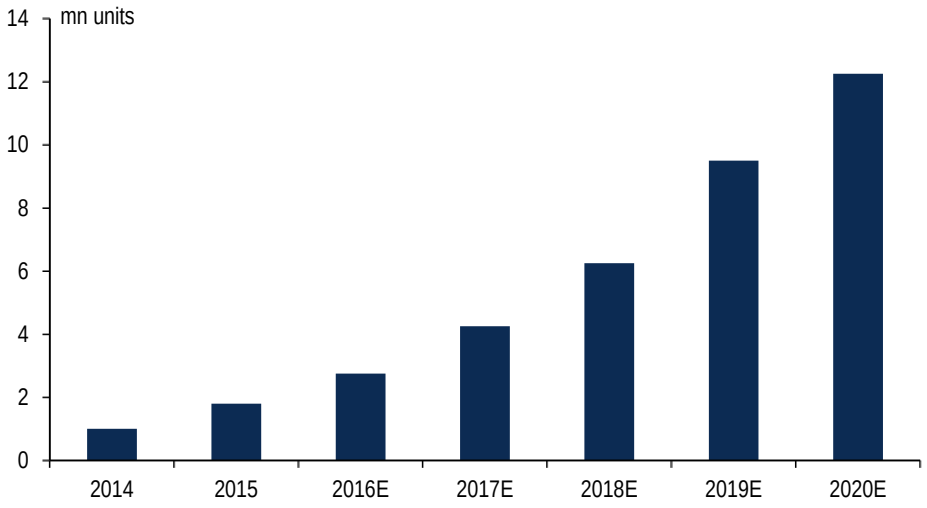
Source: IEA analysis based on EVI country submissions, complemented by EAFO (2016).

Chart 103: Geographical distribution of the 2015 stock of EVSE outlets by charger type
Publicly available, 28,000 fast outlets



Source: IEA analysis based on EVI country submissions, complemented by EAFO (2016).

Chart 104: Number of charging outlets



Source: I.H.S Automotive

Charging network schemes are growing

EVs are mostly charged at home; however, EV public charging stations have enabled EV users to charge their vehicles on the go so they can travel longer distances. The US, UK, Japan and other major countries encourage the installation of electric vehicle supply equipment (EVSE) through incentives, which cover part of the installation cost. Operation costs such as electricity and maintenance are covered by fees charged for EVSE operation.

Charging stations primarily charge customers per session, though there are also monthly subscriptions and some are offered free for a limited time (30 minutes or 1 hour). There are many EV-charging networks such as Blink Network, CarCharging, AeroVironment, ChargePoint, NRG eVgo, and SemaConnect. These networks coordinate with EV

manufacturers, hotel/restaurant owners, malls, and merchants to build extensive networks of public charging stations for electric cars, often targeting parking garages and lots.

Table 52: Charging network pricing schemes

Blink Network	AeroVironment	ChargePoint	NRG eVgo
Subsidiary of CarCharging group. In states where fees by the kilowatt-hour are permitted, it charges $0.39 to $0.79 per kWh for Level 2 and DCFC charging depending on the individual's membership status. In other states it charges based on the time used, which varies from $0.04 to $0.06 per minute for Level 2 charging, and $6.99-9.99 per session for DCFC charging, depending on membership status.	Range of Level 2 and Quick Charge equipment, but also operates its own network of chargers. Unlimited monthly access is $19.99 per month or there is the option of paying per session. The charge is $7.50/session for DC Fast Charger and $4.00/session for a Level 2 charging station	Largest network of charging stations and operates in more than 14 countries. It provides turnkey EV charging solutions for property owners, who in turn determine the terms for offering charging to EV drivers. Currently there are many ChargePoint stations that are free to use.	Offers a plan for $30 per month, with a one-year service agreement. EV drivers have access to unlimited charging, which includes Level 2 and DC fast charging. There is a $40 per month Home plan, with a three-year service agreement, which adds installation of home charging equipment but does not include electricity cost. Tesla's supercharger stations are free; Tesla users simply drive up and plug in.

Source: BofA Merrill Lynch Global Research based on company disclosure

EV/smart grid city case studies

- **Ultra-low emission zones in European cities:** Cities such as Paris and London are trying to implement stricter ultra-low emission zones for vehicles in the city, which significantly favours electric vehicles or other low-emission vehicles (hybrids) at the expense of polluting gasoline vehicles. There could be significant fines for non-compliant vehicles. Due to high pollution levels, Paris tried out the "odd-even" scheme in December 2016, which was mass implemented in New Delhi earlier.

- **Oslo, Norway** is the city with the highest density of EVs in the world. Across Norway nearly 1 in 4 four cars sold is electric, with hydropower delivering 100% of electricity.

- **Portland, Oregon (US)** was recently ranked the most favourable city for EVs in the US, with the most extensive charging network, planning and outreach, and 3x the average US battery EV sales.

- **Amsterdam, Netherlands** has the highest density of private charging stations in the world. The city aims to expand its network to 4,000 charging points by 2018.

- **Barcelona, Spain** in October 2013 hosted the world's first EV-charging station powered by a wind turbine.

- **Curitiba, Brazil** through its Biocidade Programme aims to convert all of its Bus Rapid Transit fleet to run exclusively on biodiesel (B100).

- **Calgary, Canada** has a light rail transit network 100% powered by wind energy.

- **Medellin, Colombia** metro is the only rail-based public transportation in the country to be largely powered by hydroelectricity.

Table 53: City examples of the implementation of sustainable energy transport options

Technology/ resource		Area	Example
Electric mobility	Electric public transport	Delhi, India	Solar panels were installed on stations of the metro system with plans for solar power to eventually supply all of the system's electricity
		Santiago, Chile	The Metro de Santiago, South America's second largest subway system, will be powered by 42% from solar power and 18% from wind power by 2018
		Riyadh, Saudi Arabia	Stations of the new metro system will incorporate solar panels, to reduce power consumed for cooling and lighting at stations by 20%
		Cities in China	In 2015 more than 100 000 electric buses were on the road in China; 20% of all city buses in the country
		Calgary, Canada	Calgary's light rail transit network is 100 % powered by wind energy
		Medellin, Colombia	Metro de Medellin is the only rail-based public transportation in Colombia largely powered by hydroelectricity

Table 53: City examples of the implementation of sustainable energy transport options

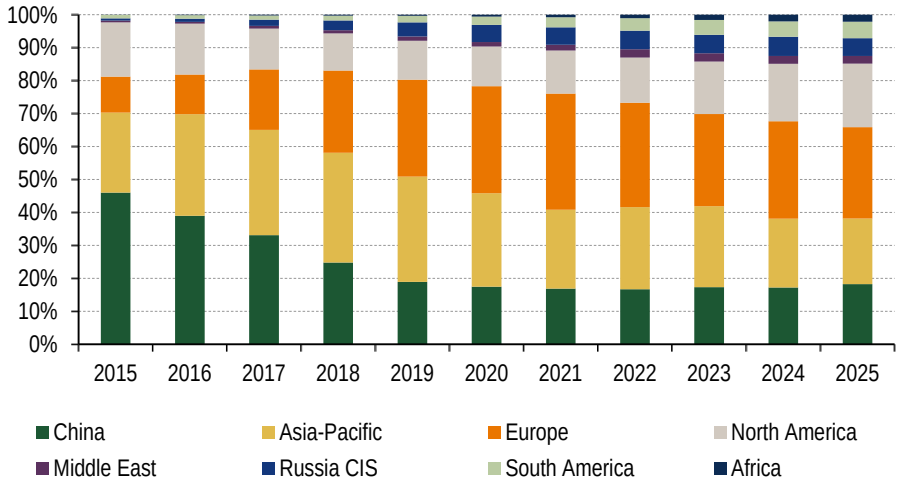
Technology/ resource		Area	Example
		Monterrey, Mexico	The city uses a biogas plant, which runs on waste, to power its metro system
	Electric vehicles (four wheelers)	Oslo, Norway	Oslo is the city with the highest density of electric vehicles in the world. Across Norway nearly one in every four cars sold is electric, with hydropower delivering 100% of electricity
		Portland, US	The city was recently ranked the most favourable city for electric vehicles in the US, with the most extensive charging network, planning, and outreach, and three times the average US battery electric vehicle sales
		Amsterdam, the Netherlands	Amsterdam has the highest density private charging stations in the world. The city aims to expand its network to 4 000 charging points by 2018
		Barcelona, Spain	Since October 2013, the city hosts the world's first electric vehicle charging station powered by a wind turbine
	Electric two- to three-wheelers	Cities in China	China is the largest two-wheeler market in the world with more than 90% of global sales. Cities have played an important role for their uptake. Due to favorable city-level policies, by 2007 more than half of all two wheelers were electric in Chengdu, compared to less than 10% in Beijing
Bioenergy and hydrogen	Liquid biofuels	Cities in China	Several Chinese cities have worked together to reverse a national corn-based ethanol ban, resulting in the approval of new maize-based ethanol production plants and 10 percent ethanol blends in some provinces
		Curitiba, Brazil	Curitiba through its Biocidade Programme aims to convert all of its Bus Rapid Transit fleet to run exclusively on biodiesel (B100)
	Biomethane	Cities in Sweden	Organic waste is used for the production of bio-methane to fuel 89 buses of the city of Linköping; in Stockholm 250 biogases buses are in operation as part of a long term vision towards a fossil fuel free bus fleet
	Hydrogen	Cities in Europe	As part of the Clean Hydrogen in European Cities project, 26 fuel cell hydrogen powered buses are integrated in cities such as Aargau (Switzerland), Bolzano and Milan (Italy), London (UK), and Oslo (Norway). In Munich, Germany, the first hydrogen car sharing program was introduced with 50 hydrogen cars available in the city center

Source: IRENA

Smart Meters/AMI – "internetisation" of utility services

Another important element of the smart grid is advanced metering infrastructure (AMI), including the rollout of smart electric, gas and water meters. Penetration rates vary widely across segments and geographies but according to Frost & Sullivan, North American and APAC combined account for 90% of global smart meter shipments. The smart electricity meter market reached 115mn units in 2015 and is expected to achieve an average of 85mn per year up to 2025E. China accounted for 46% of global smart electricity meters in 2015 but this is forecast to fall to 18% by 2025. As China gradually declines in terms of volume contribution, other markets are emerging to fill much of the gap vis-à-vis market share. Japan is already a key global market; and France and the UK are expected to install more than 10mn units a year till 2019E. Overall the global smart electricity meter market was worth US$8.2bn in 2015 but is forecasted to decline towards 2025 (source: Frost & Sullivan).

Chart 105: Global percentage regional revenues for smart electricity meters



Source: Frost & Sullivan

Competitive landscape for AMI companies

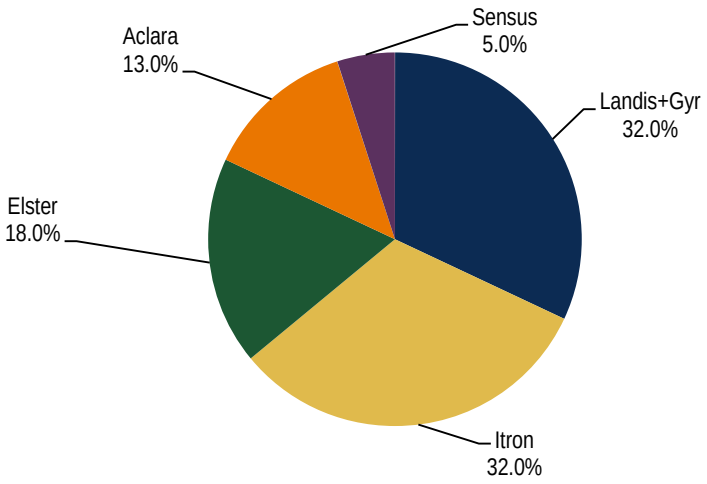
There is a variety of actors in the smart meters to smart software space, and a big and rapidly growing constellation of small and large companies entering the fray. They are all in a race to become major players in the enormous market to apply the communications, sensors, computing, and software muscle of the digital age to enable a 21st century ElectriNet:

- **Manual and AMI/AMR meter manufacturers** include General Electric, Itron, Elster (now part of Melrose), Landis+Gyr (now part of Toshiba), Sensus, Silver Spring Networks and Panasonic (partnership with Itron in Japan). On the electric meter communications front, independents include Trilliant and SmartSynch.

- **Electricity metering** players include Itron, Landis+Gyr and Elster, as well as GE, Silver Spring, and Sensus in the North American smart meter space.

Chart 106: North America Smart Electricity Meters Market: Percent share of Smart Meter Units, 2015

Total Units: 11.2 Million



Source: Frost & Sullivan

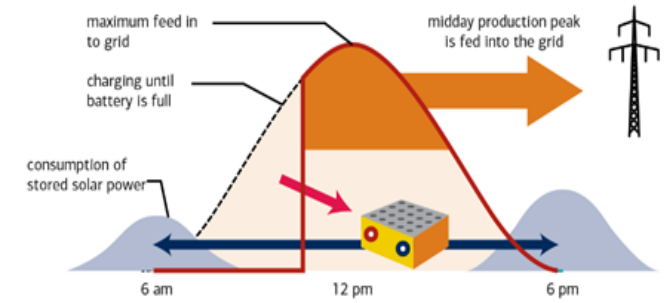
- **Gas meter market** includes the leader Elster (Honeywell) and Itron along with Dresser and Emerson at the high end, Honeywell in utilisation, and Toshiba in residential. Customer relationships in the gas segment are particularly sticky as a

result of the serious safety concerns associated with gas extraction, storage, transmission and use.

Storage and off-grid: possible in the US by 2029E

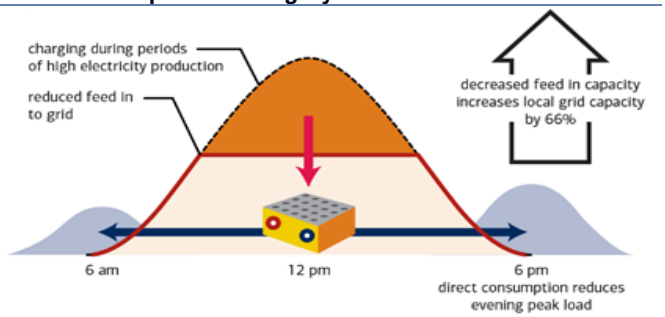
Energy storage in cities will add redundancy and flexibility to the system and contribute to city resilience and the transition to a low-carbon future. Different storage technologies can be installed at various points on the network from the point of generation to points of use. Energy storage can provide an economical, environmentally friendly and low-carbon-footprint response to fluctuations in energy demand. The storage solution enables excess electricity produced at "off-peak" hours, to be stored and used later to meet demand spikes. This reduces the need for expensive spinning reserve while using existing power plants more efficiently – often known as "peak shaving" and" load levelling of demand". When a battery storage unit is connected to the grid there could be an option to sell the excess electricity onto a "smart grid" as well (see Smart Home section).

Exhibit 162: Conventional storage systems



Source: IRENA

Exhibit 163: Grid optimised storage systems



Source: IRENA

Economics of going off-grid are becoming more compelling

The economics of going off-grid are arguably becoming more compelling: with greater KWH usage, the total system cost of going off-grid likely more than counteracts the usage effect for a typical US household. The structural threat from potential cord cutters and falling battery/panel costs is commonly referred to in the industry as the "utility death spiral". Our US Utilities team estimates that with the current falling costs of technology, "cord cutting", ie, going off-grid, might become viable in 2029. For 2017, it estimates that a fully off-grid system with three days of autonomy (standard for grid-equivalent reliability) for a typical US household would cost roughly US$72,000 (consisting of a US$42,000 battery at US$190/KWH and solar panels + installation and components of US$30,000). By 2029, this falls to US$32,000 using a 10% decline rate per year for batteries and panel costs, and a modest 1% increase per year in labour, installation, and incidental component costs.

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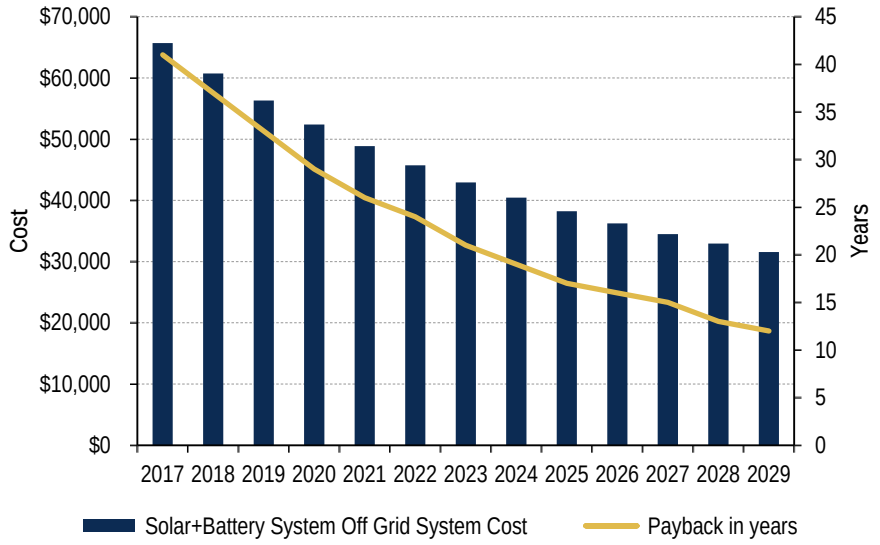
Chart 107: "Off-Grid" Cord Cutting Costs and Payback Years are Falling Rapidly



Source: BofAML Global Research, EIA.

Smart Mobility: electric, autonomous, connected, public, and shared

A comprehensive overview of the Smart Mobility challenges and opportunities discussed in this section can be found in our Future Mobility Primer: Thematic Investing: Overdrive – Global Future Mobility Primer 16 February 2017

The global transportation sector is a behemoth with US$6.8tn in annual output and a 1.2bn global vehicle parc globally, generating US$2.1tn in annual light vehicle sales and a further US$4tn+ in supplies and ancillary products (source: Roland Berger, Navigant). We believe that the sector is ripe for a defining disruptive moment as it moves towards more sustainable ways to tap into transport demand, while evolving towards next-generation solutions using limited resources.

Existing urban mobility systems are close to breakdown with 64% of all travel taking place within these environments, and the total amount of urban kilometres travelled expected to triple by 2050E. A similar trend is anticipated in urban goods distribution, with e-commerce being the fastest-growing driver of urban deliveries, which also impacts the length and fragmentation of urban logistics flows. By 2050E, urban mobility will cost €829bn per year across the globe (4x higher than in 1990), and use 173% of the planet's bio-capacities (5x more than in 1990) (source: Arthur D. Little).

Urbanisation, demographics, congestion, pollution, emissions, safety and cost are all challenging the existing vehicle ownership model. The global population will grow by 2.5bn and reach 9.7bn by 2050, 70% of whom will be living in urban areas (source: UN). Parking spaces now occupy one-third (31%) of urban land and cars generate one-quarter (23%) of all emissions. Some 95% of all cars are parked at any given point – and the 5% that are driven average only 1.2 passengers per ride (source: Kenworthy & Laube, IEA, BCG). It costs US$8,558 pa in the US to own and operate a car, while 1.2mn people die in road accidents every year, costing 1-3% of global GDP (source: Kleiner Perkins, WHO, Swiss Re). Consumer behaviour is also fundamentally changing. The percentage of 16- and 17-year-old Americans with drivers' licences dropped from 50% and 75% in 1978, respectively, to 25% and 45% by 2014 (source: Sivak 2016). At the older end of the spectrum, the 75+ population is 2.5x more likely to have a fatal car accident than those under 75 (source: Japan National Police Agency).

The Internet of Things (IoT) and artificial intelligence (AI) ecosystems have already transformed many industries and the auto sector is the next shoe to drop, in our view. There are five key trends disrupting the transport sector right now – electrification, autonomous driving, connectivity, greater use of public transport, and shared mobility. Together, they will unbundle the automobile, shift revenue pools, alter consumer mobility behaviour, and introduce new competition and cooperation. The five disruptive trends are mutually reinforcing. For instance, shared mobility can double utilisation rates, which would pull forward the parity point of EVs vs ICE vehicles from 2021E to 2018E (source: Bloomberg New Energy Finance). Higher utilisation rates reduce the lifespans of cars, accelerating the evolution towards next-gen EVs and AVs. The rule of thumb is that for every 10% increase in shared mobility, EV sales will increase by 5% (source: BNEF/McKinsey).

A shared vehicle that replaces its internal combustion engine with an electric one, and replaces its human driver with AI, will become the cheapest, fastest, and most flexible form of transport. Today, a fleet of autonomous EVs on the Tesla Network would cost around US$0.42-0.49/mile, including charging, insurance, and maintenance costs. This is 70-85% cheaper than ride-hailing, up to 50% cheaper than car ownership,

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and even 35-65% cheaper than car-sharing (source: Chen et al 2016). Many studies show that the long-term cost of robo-taxis could be as low as US$0.17-0.30/mile as infrastructure, R&D, and other start-up costs fall (source: Chen et al 2016, BCG 2016, KPMG, BNEF/McKinsey, Rock Mountain Institute). This could even be cost competitive compared with mass transit at a rate of two passengers, but with a 40% lower commute time (source: BCG).

Public transport in particular is a driver for economic growth in many cities with the market estimated at US$61bn and employing nearly 400,000 people worldwide. It also propels urban community growth and revitalisation, with the US figures very positive in this regard: every US$1 invested in public transportation generates approximately US$4 in economic returns; every US$1bn invested in public transportation supports and creates more than 50,000 jobs; and every US$10mn in capex in public transportation yields US$30mn in increased business sales (source: APTA). After a period of erosion, public transport is growing at 1.2-3.9% pa and is expected to see a doubling of market share at the expense of private transport by 2025E (source: UITP) and integration of nextgen features such as Mobility as a Service (MaaS).

We expect nextgen mobility adoption in cities to occur as a step-wise function depending on population density, income levels, consumer acceptance, and government regulation. Cities are likely to be the first movers, with around 50 urban areas with 500mn inhabitants likely to accelerate towards this new mode by 2030E. Uptake of EVs, AVs, shared mobility, and connectivity will, however, vary depending on population density and income. Dense, developed cities will likely see the greatest take-up with as much as 60% EVs and 40% AVs. Distance travelled in low-income, population-dense areas can rise as much as 86%, and 25-30% for DMs as the price of transport falls (source: BNEF/McKinsey). Total car ownership is likely to rise in EMs on the back of low absolute levels of penetration and macroeconomic growth. Ownership in DMs is projected to flatten or decline by 2030E, with areas like the US already experiencing a 6.3% decline in per capita ownership 2006-2012 (source: BNEF/McKinsey, Sivak et al)

The Future Mobility market is projected to rise to US$1.5tn by 2030E versus US$30bn today. This includes over US$450-750bn in data connectivity, apps, navigation, entertainment, remote services, and other tech-based solutions which would be created on the back of new business models (source: McKinsey). While the total size of the transport market will likely expand for the next 5-10Y, it may plateau and decline thereafter as the overall cost of transport becomes cheaper. In developed regions such as the US, the market opportunity for mobility services could be as high as US$120bn by 2025E (source: Rocky Mountain Institute). Robo-taxi services can account for 20% of these transportation revenues and 41% of the profit by 2030E. OEMs could see their profits drop by 16% and prospects could be just as bleak for other players in the ecosystem including independent retail, aftersales and financial services (source: Roland Berger)

In an extreme bullish scenario of a seamless green robo-taxi mobility system, we will move towards a "world of zeros." This includes a 59% decline in vehicle demand, 87% fewer accidents, 54% fewer parking spots and 85% lower emissions (source: BCG 2016). In even the most conservative scenario, accidents are likely to be reduced by 19%, and vehicles generate 9% fewer emissions (source: BCG 2016). While the future mobility framework will put downward pressure on auto demand, especially in developed markets, emerging markets will continue to drive demand on the back of urbanisation and macroeconomic growth. Annual vehicle sales could still rise to 115mn by 2030E vs c.90mn today, with robo-taxis making up around 10% of demand (source: IHS Automotive, McKinsey). Total volumes after 2030E will be more uncertain.

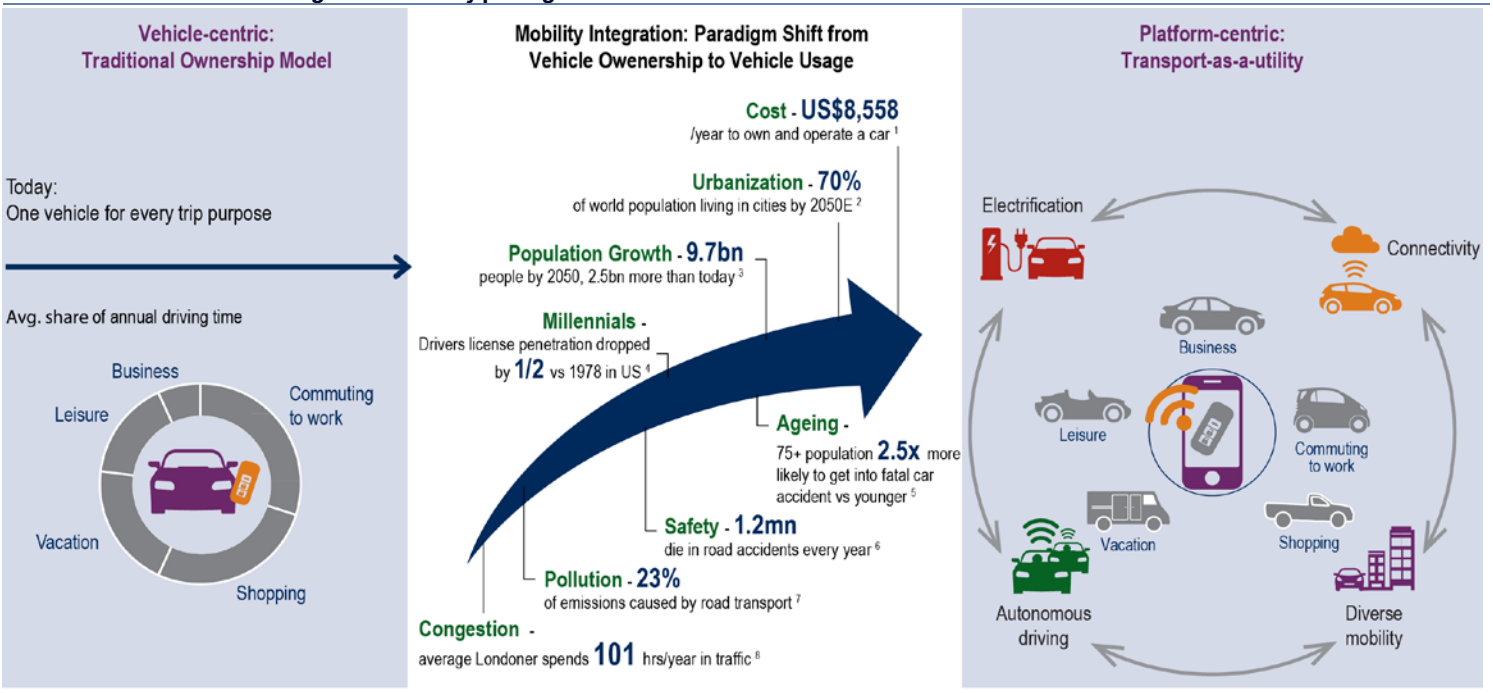
Future mobility can generate US$3.8tn of cumulative positive impact over the next decade (source: World Economic Conference 2017, Accenture). Autonomous driving

alone can create US$200bn-1.9tn of positive impact annually by 2025E (source: McKinsey). This could lead to a reduction of nearly 1Gt of annual emissions by the late 2030Es, while generating US$1tn in total cost savings in the US (source: Rocky Mountain Institute). This is around 20% of total annual emissions from the country in 2014 (source: IEA 2016).

The digital transformation of autos will bring new challengers for traditional car manufacturers, while bringing opportunities for greater cooperation. The average car will be less hardware-centric, and be a more software-based and connection-centric system, with shorter lifecycles and increasing demand for upgradability. EV and AV technology also unbundles the automobile, and lowers the barrier to entry. The paradigm shift from vehicles to mobility as a service means that mobility providers (Uber, Lyft, Grab), tech companies (Alphabet, Apple) and emerging OEMs (BYD, Tesla, Faraday Future) can become new competitors (source: McKinsey 2016). Many tech giants also have the cash war chest to fund R&D. For instance, Apple has more cash on its balance sheet than the US energy, autos, manufacturing companies combined (source: Bloomberg).

OEMs are increasing their focus on software, Big Data, AI, cloud analytics, and sensor data collection through rising R&D spend and acquisitions. Automakers will need to play catch-up, on average spending three-quarters (75%) of their capex on hardware vs tech players who spend 50% of capex on software development and another 30% on customer-focused applications (source: BNEF/McKinsey). Investments in ride-hailing and other transportation start-ups have totalled around US$32bn since 2011 (source: BNEF/McKinsey). Acquisitions have been heating up, with major OEMs such as GM, Ford, Daimler, BMW and Volvo each purchasing or investing in 6-16 auto and auto technology companies since 2011 (source: CB Insight). While 2016 brought record sales and profitability to the sector, automakers are also at risk of falling into the success trap. They are each aiming to avert the Kodak/Nokia moment, to catch the crucial inflection point towards the next phase of autos.

Exhibit 164: Macro factors driving shift in mobility paradigm



Source: 1 Kleiner Perkins; 2 UN; 3 UN; 4 Sivak 2016; 5 Japan National Police Agency; 6 WHO; 7 IEA; 8 INRIX 2016

Source: BofA Merrill Lynch Global Research based on cited sources

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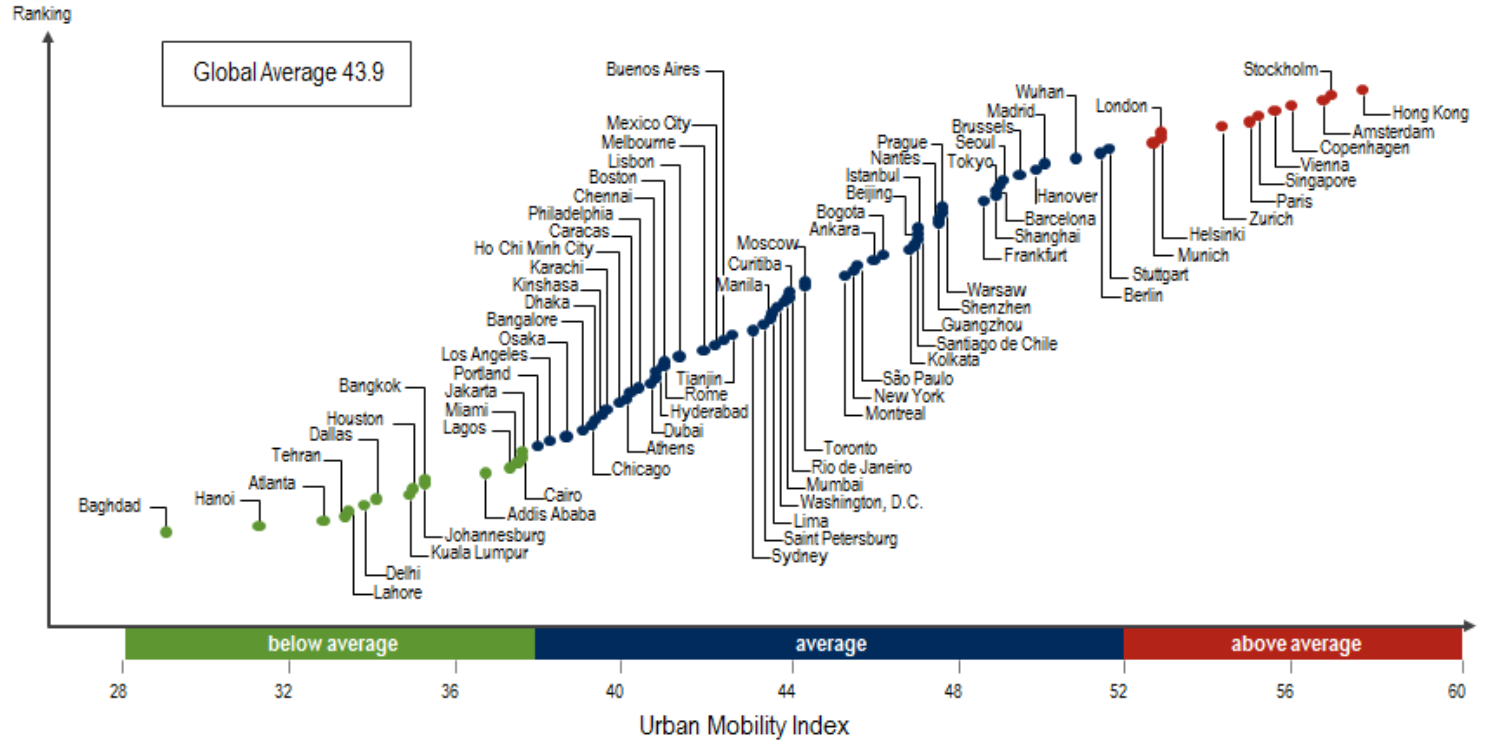
A perfect storm of events: driving disruption in urban transport

Existing mobility systems are close to breakdown and by 2050E, the average time an urban dweller spends in traffic jams will be more than 106 hours pa, 3x more than today. Delivering urban mobility will also require greater resources. In 2050E, urban mobility will cost €829bn per year across the globe (4x higher than in 1990), and use 173% of the planet's biocapacities (5x more than in 1990) (source: Arthur D. Little).

Exhibit 165: Urban mobility performance ranking of major cities worldwide: Hong Kong, Stockholm, Amsterdam, Copenhagen & Vienna lead the way

Rated on a scale of 1-100 (with 100 representing the top performance*)



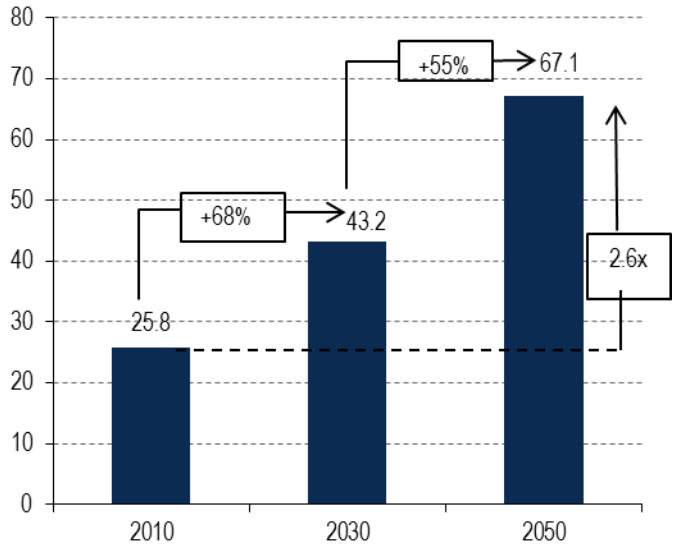
Source: Arthur D. Little 2014

* The Index assesses the mobility maturity and performance of 84 cities worldwide using 19 criteria ranging from public transport's share of the modal mix and the number of cars per capita to average travel speed and transport-related CO2 emissions

Urban mobility demand skyrocketing: passengers and goods

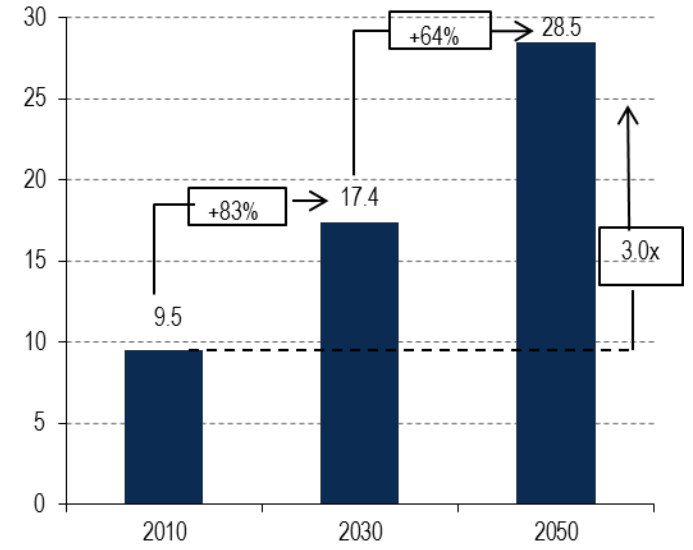
Today, 64% of all travel takes place within urban environments, and the total amount of urban kilometres travelled is expected to triple by 2050E. A similar trend is anticipated in urban goods distribution, with e-commerce being the fastest-growing driver of urban deliveries, which also impacts the length and fragmentation of urban logistics flows (source: Arthur D. Little).

Exhibit 166: Urban passenger mobility demand explodes
Urban passenger mobility demand, 2010-50E [trillions person-km pa; %]



Source: UITP 2015 based on UN, World Bank, OECD, ITF, Schäfer/Victor 2000, Congrove/Cargett 2007, Schäfer 2007, Arthur D. Little

Exhibit 167: Urban goods mobility demand explodes
Urban goods mobility demand, 2010-50E [trillions of ton-km pa; %]



Source: UITP 2015 based on UN, World Bank, OECD, ITF, Schäfer/Victor 2000, Congrove/Cargett 2007, Schäfer 2007, Arthur D. Little

We are running out of urban space and running into congestion

As we discuss throughout the report, we are living in an increasingly urbanised world and 70% of the population (including 86% in DMs) will live in cities by 2050E (source: UN). Increasing population density, coinciding with rises in household wealth, tends to lead to more traffic and congestion.

Big cities are seeing growth in urban density: 68.2 inhabitants per urban hectare in DM cities in 2012 (vs 64.5 in 2001) (source: UITP)

Exhibit 168: Mapping all of the 170mn annual taxi trips in NYC (pick-ups in yellow, drop-offs in blue)

Source: HubCab

- **31% of urban land is used for parking, 30% of all traffic is looking for spots….** Parking accounts for 31% of the central business districts in global cities (source: Kenworthy & Laube). For cities like LA, 59-66% of land is car-related, consisting of either sidewalks, streets, or parking (source: Transportation and Parking for Tomorrow's cities, Smith). In urban areas in Illinois, Indiana, Michigan, and

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Wisconsin, this averages 2.5-3.0 non-residential parking spaces per car (source: Davis et al 2010). In fact, 30% of all traffic flow in urban centres across the world is looking for parking spots (source: Shoup et al). Furthermore, 40% of fuel in cities is wasted looking for parking (source: Casualty Actuarial Society). Liberating space otherwise wasted on parking via replacement by fewer AVs could allow more people to live in city centres.

- **Traffic congestion for the US alone cost US$300bn in 2016, an average of US$1,400 per driver** (source: INRIX 2017). Globally, Los Angeles is the most congested city in the world with 104 peak hours spent in congestion, followed by Moscow (91), NYC (89), San Francisco (83), Bogota (80), Sao Paolo (77), London (73), Atlanta (71), Paris and Miami (65) (source: INRIX 2016 Traffic Scorecard 2017).

Los Angeles commuters spent over 100 hours a year in traffic jams in 2016, more than any other city in the world. The US accounts for 11 of the top 25 cities with the worst traffic congestion.

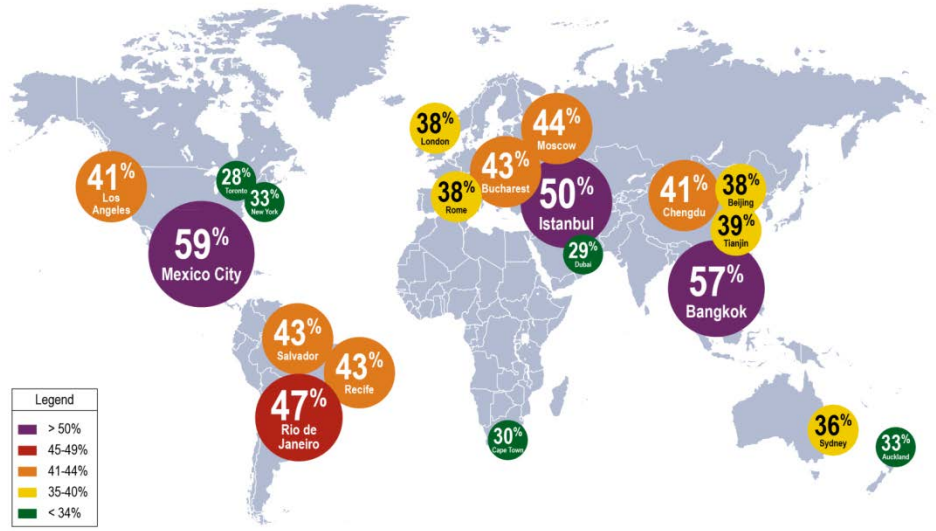
Most congested US roads in 2016: I-95 Westbound (NYC, Exit 6 to 2), I-90/I-94 Northbound (Chicago, exit 53A to 34B), I-95 Eastbound (NYC, exit 70A to 7A), I-93 Northbound (Boston, Exit 5A to 16), and I-10 Eastbound (LA, Exit 3A to 12).

Dublin is the slowest moving major city – slower than a horse and cart - at 7.5kph (4.7mph) during congested periods, with peak hour speeds at 5.5kph. Humans walk at 5kph (3.1mph) (3.4mph) (source: INRIX 2016 Traffic Scorecard 2017).

Yearly congestion costs for commuters travelling during peak times: Washington DC (US$1,834), Los Angeles (US$1,711), San Francisco (US$1,675), NYC (US$1,739) (source: INRIX 2015 Traffic Scorecard)

Congestion can cost around 2-4% of GDP in lost time, wasted fuel, increased cost of doing business (source: BNEF Finance, McKinsey)

Exhibit 169: Congestion level of world's cities (extra travel time)



Source: BofA Merrill Lynch Global Research, TomTom Traffic Index 2016

Table 54: Traffic profile of world's cities

	Berlin	Cape Town	London	Moscow	Pittsburgh	Riyadh	Toronto
Congestion level (Extra travel time)	28%	30%	38%	44%	18%	27%	28%
World rank compared to other large cities	67/174	47/174	16/174	5/174	125/174	71/174	64/174
Highways (extra travel time)	25%	25%	19%	55%	11%	27%	25%
Non-highways (extra travel time)	30%	32%	45%	41%	24%	27%	30%
Extra travel time per day	27 min	40 min	39 min	48 min	21 min	23 min	33 min
Extra travel time per year	105 hr	152 hr	149 hr	185 hr	81 hr	88 hr	126 hr
Most congested day	Thu 08 Oct 2015	Fri 27 Nov 2015	Thu 09 Jul 2015	Thu 17 Dec 2015	Tue 06 Jan 2015	Thu 19 Mar 2015	Sat 21 Feb 2015

Source: TomTom Traffic Index 2016, BofA Merrill Lynch Global Research

Urban-policy decision-makers: cracking down on cars

Urban-policy decision-makers are increasingly looking to limit car usage in cities over the next 10 to 20 years. For example, London, Singapore and Stockholm have had congestion charges for years, and these have worked as intended, decreasing and smoothing out traffic. Other cities seeking to curb congestion and pollution are considering limiting the number of cars, for example, by restricting parking (or making it more expensive), and creating car-free zones. A number of Chinese cities, including Beijing, Guangzhou, Shanghai and Tianjin, limit the number of new cars by auctions or lotteries for new licence plates. Some Chinese cities also restrict cars with nonlocal plates (source: McKinsey).

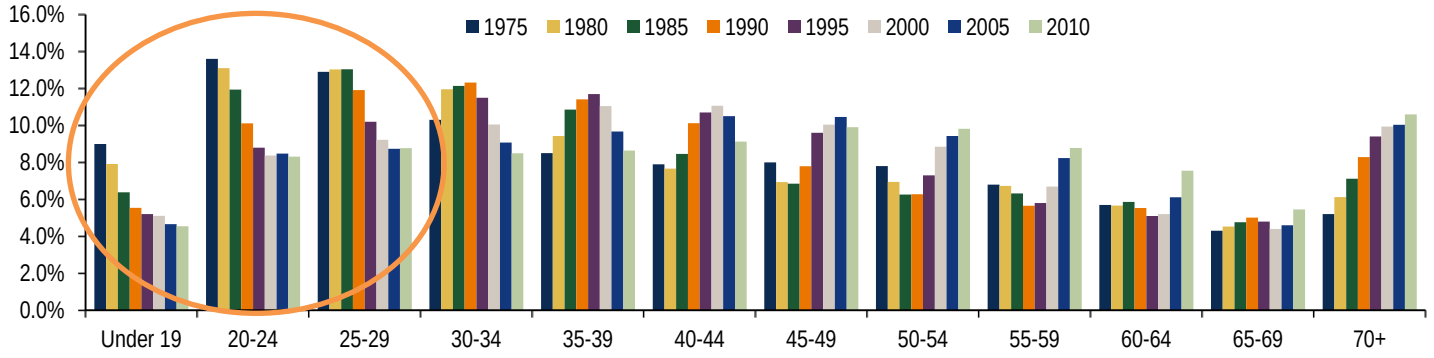
Demographics: Millennials and the elderly driving Future Mobility

Demographics – including the role of Millennials and the elderly – are a major driver for adoption of future mobility trends in Smart Cities.

Millennials in no rush to get a licence or drive

Millennials (born 1980-1997) and Centennials (born 1998-2016) account for ~60% of the world's population, and they are in no rush to get behind the wheel. The number of vehicle miles travelled (VMT) in the US has fallen 23% or from 10,300 miles a year to 7,900, from 2001-09; Millennials made 15% fewer trips by car over the same period (source: PIRG). Vehicle costs have risen, causing consumers' monthly car payments as a percentage of household income to reach 12.5% or US$503 (source: NADA). In contrast, public transportation ridership has increased 36% between 1996 and 2014 (source: S&P Ratings Service). Even in countries like Germany, car-ownership rates among 18- to 29-year-olds have dropped from 420 cars per 1,000 people in 2000 to 240 in 2010 (source: McKinsey).

Chart 108: Licensed drivers by age in US, % of total drivers (1975-2010) – sharp drop in younger population



Source: US Department of Transportation

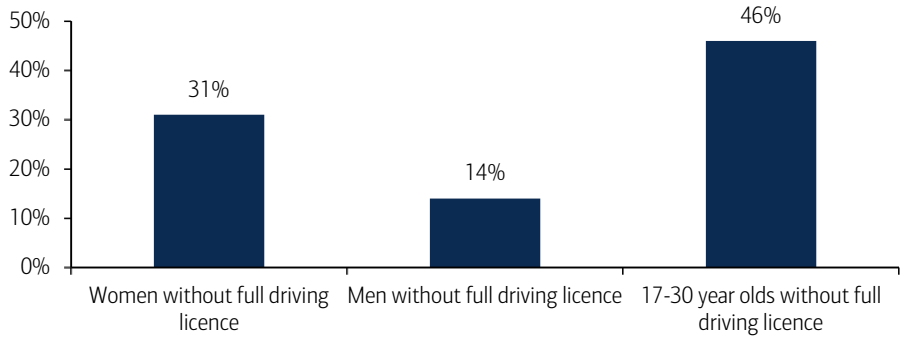
Older generations are 2.5x more likely to get into accidents than the young

Older generations are facing mobility challenges associated with the cognitive and sensory impairments that come with age. By the middle of this century, nearly one in four people (23%) will be aged 60+ (source: UN). The ageing Baby Boomer will likely have increasing needs for alternative mobility services such as ride-hailing, microtransit, or robo-taxis (source: Center for Automotive Research).

Increased access for all: physically challenged and the car-less

Beyond older persons, automated vehicle technologies could potentially improve mobility for all people, including those with disabilities, and those without a driving licence or access to a vehicle. For instance, in the UK, nearly one in three women and one in two Millennials lack a full driving licence. Self-driving cars could be a major enhancer of life quality in these cases (source: UK Department for Transport 2015).

Chart 109: UK population without a full driving licence



Source: UK Department for Transport 2015

High costs of mobility mean the sector is ripe for disruption

The rising financial, environmental, human and social costs of transport are unsustainable.

Costs of current car ownership are unsustainable

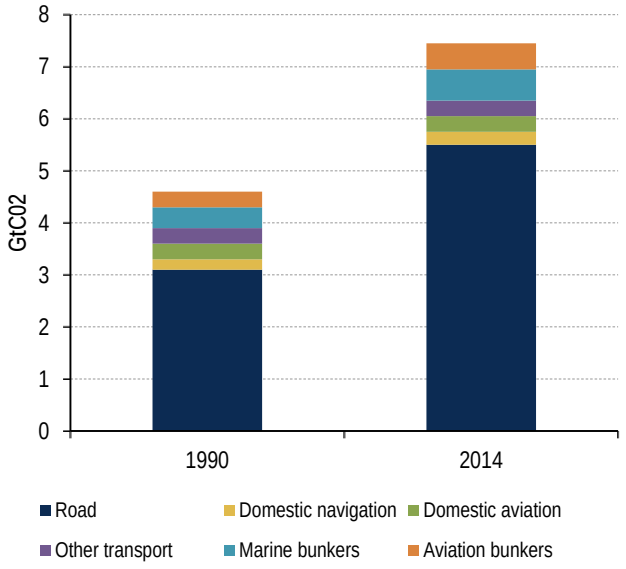
- 1.2mn people die in road accidents every year, costing 1-3% of global GDP
- US$8,558/year in the US to own and operate a car
- The US average 2.2 vehicles/household with 20% of households with 3+ cars

- Cars are parked, and unused 95% of the time
- 31% of urban land is parking spaces; 30% of urban traffic is looking for spots; 40% of fuel wasted in cities is by people looking for parking (source: WHO, Swiss Re, Kleiner Perkins, Google, Shoup 2005, Kenworthy & Laube, Casualty Actuarial Society)

Energy impacts of transport are too high

Transport accounts for nearly one-quarter of global energy-related emissions with cars and trucks representing 75% of these emissions (source: IEA). Road emissions have nearly doubled in the past 25Y, and the current path is unsustainable given the 2016 Paris Agreement's aims of holding global average temperature increases to 1.5-2.0°C (2.7-3.6°F) vs pre-industrial times, and to peak GHG emissions as soon as possible (source: UNFCC 2016). We believe that pressures on the auto sector to reduce oil consumption and CO2 emissions will only grow. The combination of legislation and consumer demand is challenging the traditional internal combustion engine.

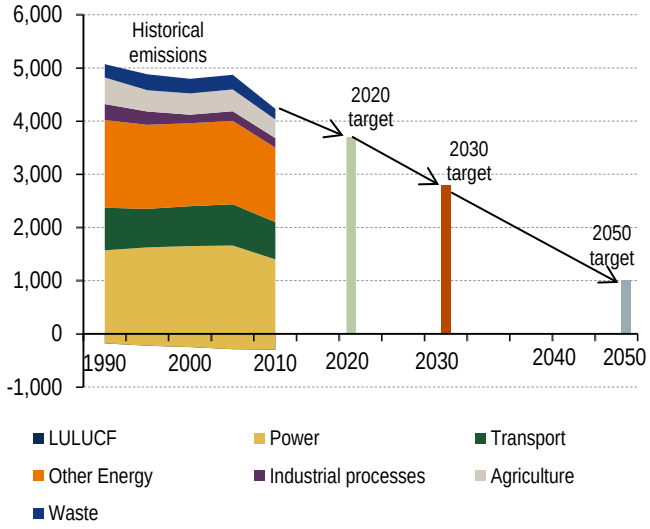
Chart 110: CO2 emissions from transport



Source: IEA 2016

Chart 111: EU28 Emissions by sector and 2020-50 target levels

MTCO2E/YR



Source: Bloomberg New Energy Finance

Five disruptive Smart City trends: electric, autonomous, connected, public, and shared

There are five Smart City trends disrupting the transport sector right now – electrification, autonomous driving, connectivity, greater use of public transport, and shared mobility. Together they will change the inner workings of the automobile, shift revenue pools, alter consumer mobility behaviour, and introduce new competition and cooperation.

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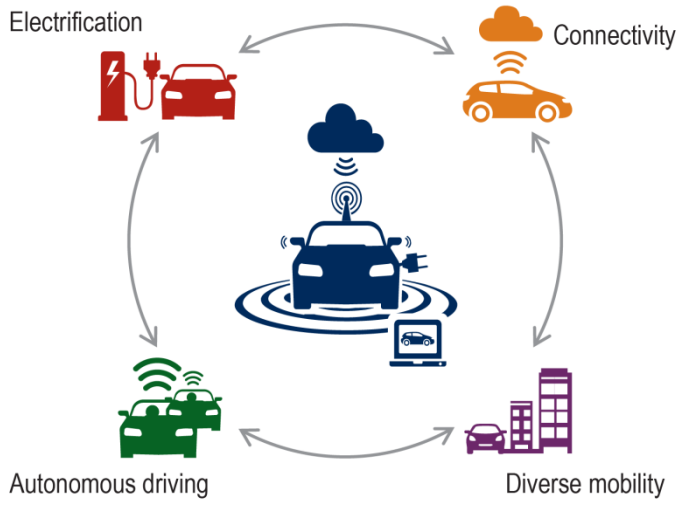
Exhibit 170: Disruptive trends in the auto industry



Source: McKinsey

Table 55: Building blocks of future mobility

Electric	Autonomous
Happening right now Removing the engine & transmission destabilizes the car industry and its Suppliers Doesn't change how cars are used (much)	5-10 years Many challenges to resolve Change where the value is Changes what cars are Changes cities as much as cars changed cities
Connected	
Underlying technology helping to enable EVs and AVs	
Shared	
On-demand accelerated by autonomous technology, and help accelerate EV uptake	

Source: BofA Merrill Lynch Global Research

Table 56: Overview of the high-disruption vs. the low-disruption Future Mobility scenario

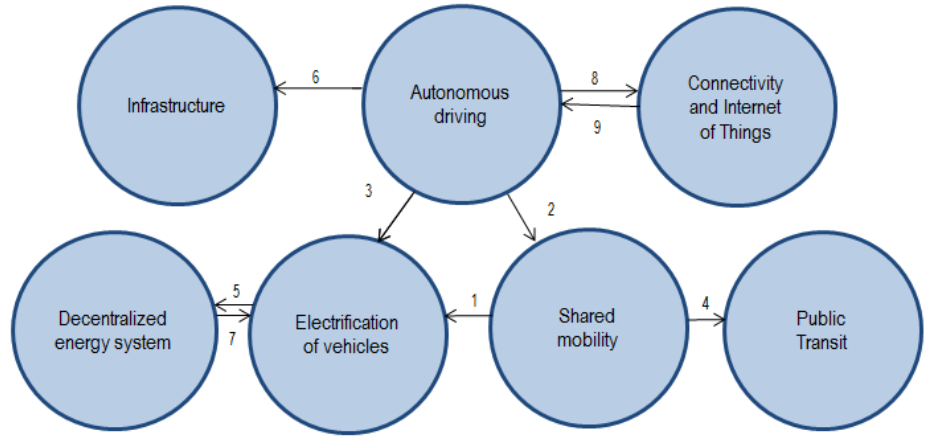
	High	Low
Shared		
City policies discouraging private vehicles	Intensified	Steady
New, on-demand business models	Prevalent	Limited
Modal shift away from car ownership to shared mobility	Significant	Limited
Autonomous		
Regulatory challenges are overcome	Fast	Gradual
Development of safe and reliable technical solutions	Comprehensive	Incomplete
Consumer acceptance and willingness to pay	Enthusiastic	Limited
Electric		
Battery prices continue to decline	Rapid	Protracted
Regulator-driven emission restrictions	Intensified	Gradual
Consumer demand for electrified powertrains	Widespread	Restrained
Connected		
Uptake of car connectivity globally	Vast majority	Partial
Consumers regularly using paid content	Mainstream	Limited

Source: McKinsey 2016

Mutually reinforcing trends

The four disruptive trends are also highly symbiotic. For instance, shared mobility can double the utilisation rate, taking it from ~10k miles per year to 20k, which would pull forward the parity point of EVs vs ICE vehicles from 2021E to 2018E (source: Bloomberg New Energy Finance). Furthermore, higher utilisation rates reduce the lifespan of cars, accelerating the evolution towards next EVs and AVs. In fact, every 10% rise in shared mobility would increase EV sales by 5% between 2015 and 2030 (source: BNEF/McKinsey).

Exhibit 171: Mutually reinforcing effects of future mobility trends for Smart Cities

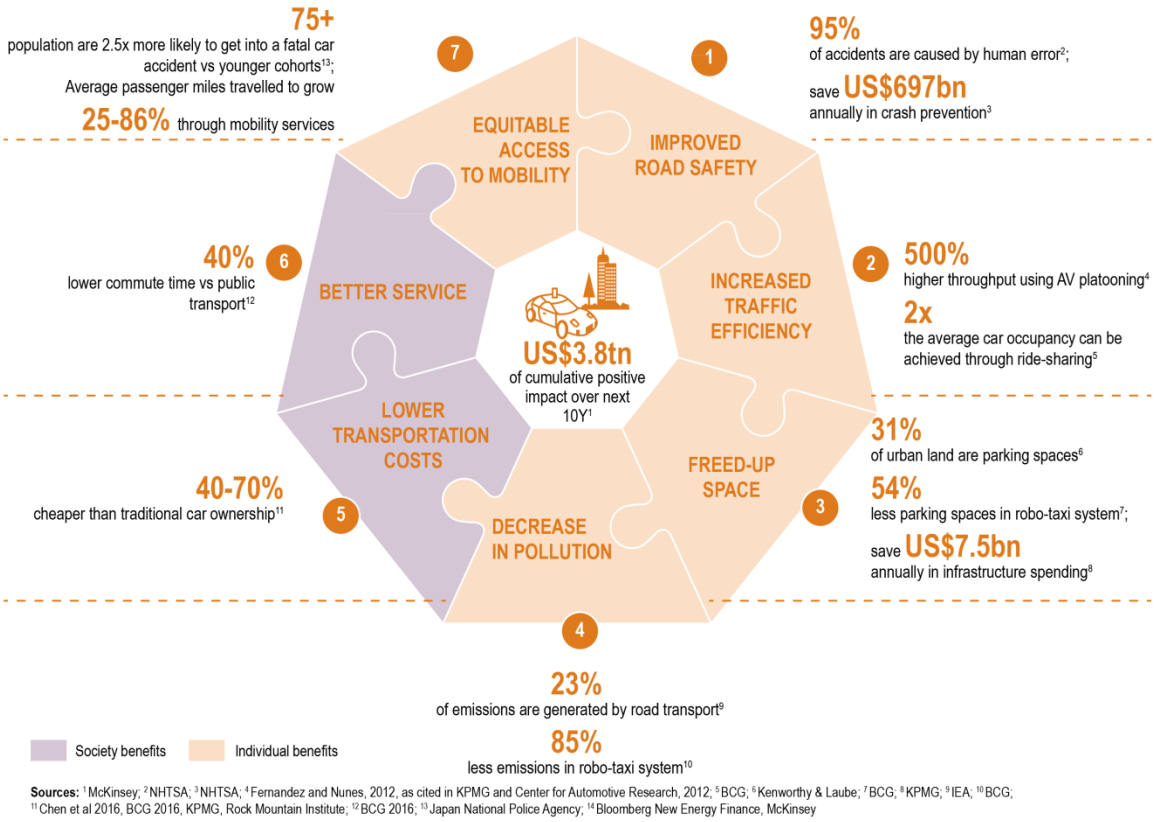


Source: BNEF/McKinsey

US$3.8tn of positive impact over next decade

Transforming the mobility sector can generate US$3.8tn of cumulative positive impact over the next decade (source: World Economic Conference 2017, Accenture).

Exhibit 172: Benefits of an integrated mobility system: US$3.8tn of positive impact over next decade



Source: BofA Merrill Lynch Global Research based on cited sources

Urban real estate could be transformed: 61bn ft² could be freed up

The real estate sector could undergo a dramatic transformation as robo-taxis free up as much as 61bn ft² (5.7bn m²) of parking space in the US alone (source: McKinsey 2015). Values for existing garages, auto dealerships, gas stations, truck stops, etc. will likely become riskier or decline in value (source: Henderson et al 2016). Roads will be able to increase capacity, while excess land could be repurposed for widened sidewalks, tree-lining, retail seating, and storm water runoff filtration. In many cases, the present value

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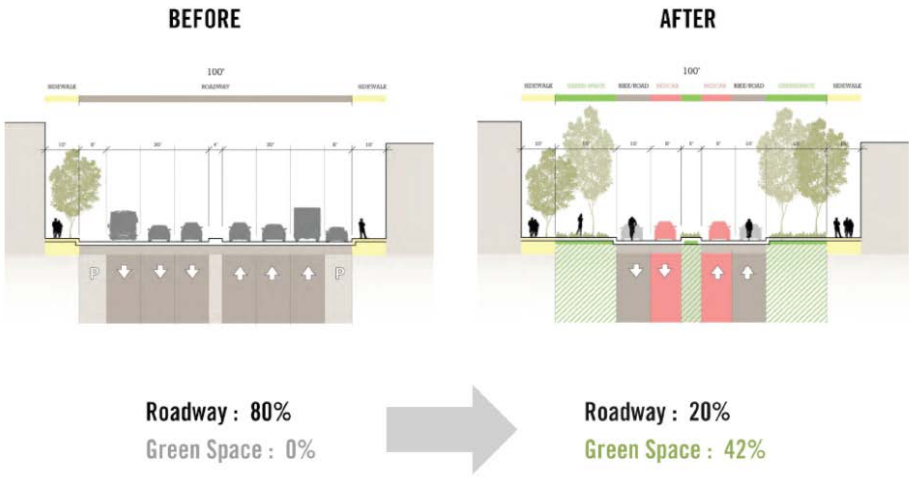
of real estate can be much higher when land is purposed for living or working rather than for parking. Such changes would also likely enhance the overall urban and suburban quality of life.

Exhibit 173: Diagram of 19th Avenue in San Francisco before and after AVs



Source: Henderson et al 2016, Perkins and Will

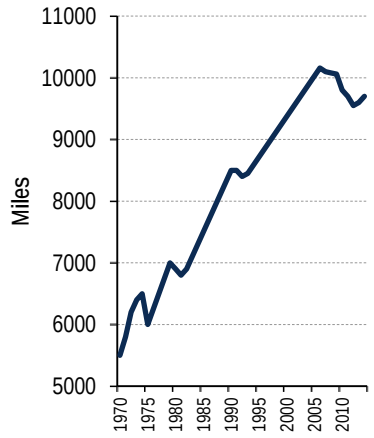
Peak car for DMs: but no slowdown in EMs (yet)

The combination of drivers described above means we are reaching "peak car" in many DMs. In the US, annual vehicle miles travelled (VMT) peaked in 2005 (source: Center for Automotive Research). Per capita vehicle ownership was down 6.3% between 2006 and 2012, with aggregate vehicle demand topping out as early as the early 2020s (source: McKinsey, Sivak et al, Rocky Mountain Institute).

The rate of motorisation in DM cities almost stopped growing between 2001 and 2012. Motorisation grew by 2.3% p.a. from 1995-2001 vs 0.5% from 2001-12 (source: UITP)

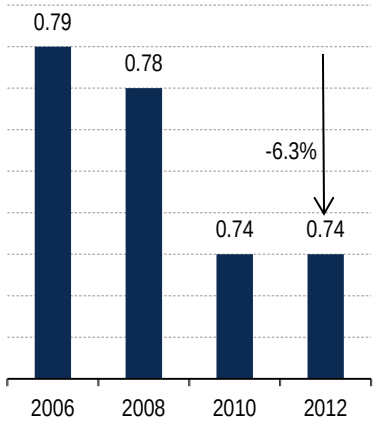
The average number of cars per 1,000 inhabitants is booming in EMs: Beijing +111% and Delhi +88% from 1995-2012 (source: UITP)

Chart 112: Annual vehicle miles of travel per capita in United States



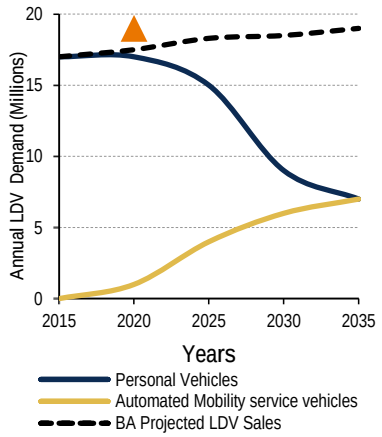
Source: Center for Automotive Research

Chart 113: In the US, vehicle ownership rates per person are declining



Source: McKinsey, Sivak et al

Chart 114: Projected light duty vehicle demand (mn)



Source: Rocky Mountain Institute

Public transport, walking and biking on the rise again: EM cities leading the way

There is a clear global trend to create incentives that make public-transit, walking, biking and shared-transportation options more available and attractive (source: McKinsey).

Case study of "Hyperloop" which we believe could revolutionise public transport between Smart Cities worldwide as the "broadband for transportation" travelling at up to 1,223-1,287 kph (760-800mph):

- **Uses a custom electric motor to accelerate and decelerate a levitated pod through a low-pressure tube**. The vehicle will glide silently for miles with no turbulence.
- **The motor was tested in May 2016, and the full system will be tested in 2017**. It is developing routes in five countries, and the goal is to be moving cargo by 2020E and passengers by 2021E.
- **The first hyperloop system will go from Dubai to Abu Dhabi in 12 minutes** vs. 1h30-2h by car
- **Passengers may ultimately be able to access Hyperloop via an Uber-like App** (source: company, press sources).

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Exhibit 174: This is what Future Mobility could like in a hyperloop future

Source: LS London with support of Transport for London and London Transport Museum

Public transport: a major driver for urban economic growth and jobs

Public transport in particular is a driver for economic growth in many cities with the market estimated at US$61bn and employing nearly 400,000 people worldwide. It also propels urban community growth and revitalisation with the US figures very positive in this regard:

- **Every US$1 invested in public transportation generates approximately US$4 in economic returns**.
- **Every US$1bn invested in public transportation supports and creates more than 50,000 jobs**.
- **Every US$10mn in capital investment in public transportation yields US$30mn in increased business sales**.
- **A two-person household can save, on average, more than US$9,394 a year by downsizing to one car**.
- **Home values perform 42% better on average if they are located near public transportation with high-frequency service**.
- **Public transportation's overall effects save the US4.2bn gallons of gasoline annually** (source: APTA).

1.2-3.9% pa growth in public transport: 2025E goal of doubling market share

After a period of erosion, public transport – including buses, trolleys, light rail, subways/metros, commuter trains, streetcars, cable cars etc – is on a growing trend again, particularly in EMs, where urban sprawl tends to be slowing. Public transport growth is the strongest where efforts to increase its supply are matched by policies that manage private vehicle demand and increase urban density (source: UITP). The International Association of Public Transport (UITP) is aiming to double the market share of public transport worldwide by 2025E (vs 2005 levels). Public transport stakeholders are working hard to improve the attractiveness, capacity and efficiency of mobility systems despite growing limitations of public financing.

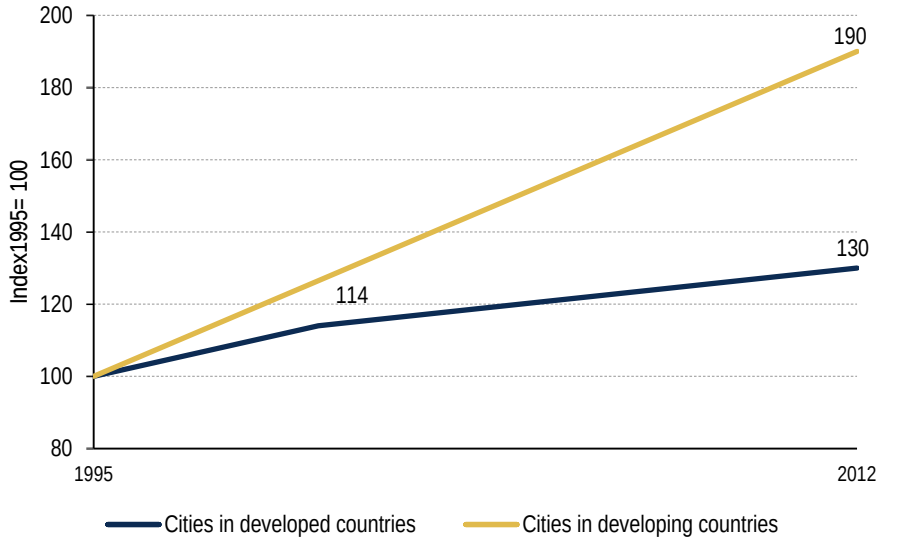
Public transport is growing significantly around the world, by 30% in DM cities and 90% in EM cities from 1995-2012: Beijing +367%, Geneva +49%, Oslo +38%, London +37%, Hong Kong +36%, Paris +28% (source: UITP).

Since 1995, US public transit ridership is +39% (vs +21% population growth and +25% vehicle miles travelled). In 2015, Americans took 10.6bn trips on public transport, and usage is the highest in 50Y (source: APTA).

Top 10 US cities for public transport usage: NYC-Newark (229.8 trips per capita), San Fran-Oakland (131.5), Washington DC (99.8), Athens-Clarke County (99.5), Boston (94.4), Honolulu (88.4), Champaign (87.4), State College (85.0), Chicago (74.7), Philadelphia (87.8) (source: FTA, ACS).

Chart 115: Public transport supply (vehicle x km)

Average evolution of public transport supply between 1995-2012 in 21 cities in DMs and 4 cities in EMs



Source: UITP 2015

- **In DM cities**, the total supply of public transport, expressed in vehicle x km, increased by an average of 2.3% pa between 1995 and 2001 and by 1.2% pa since.

- **In EM cities**, supply grew by an estimated 3.9% pa from 1995 to 2012. On average, the supply of public transport per urban resident has been stable since 2001, at just over 100 vehicle x kilometres per inhabitant in cities within EMs.
- **Beijing, Geneva, Madrid, Oslo and London increased supply at a higher rate than the population increase** over 2001-12 (source: UITP).

Case study of Hanoi (Vietnam)'s first bus rapid transit (BRT) system launched on 31 December 2016:

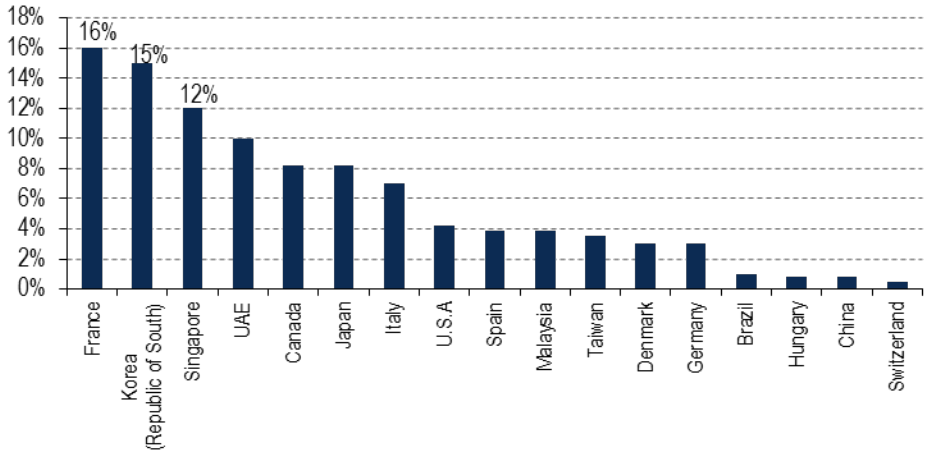
- **On 5 October 2016, Hanoi had the worst air pollution among major cities across the world**.
- **BRT route with prioritised traffic lights and lanes covers 14.7km** from Kim Ma station in Ba Dinh District to Yen Nghia station in Ha Dong District. The BRT system is scheduled to operate 17 hours per day, from 5am to 10pm, with a bus departing every 5, 10 and 15 minutes.
- **It is hoped the BRT will take some of the 5mn motorbikes and scooters off the roads** and reduce congestion and pollution in the city.
- **US$53.6mn development** funded by loans from the World Bank (source: government of Vietnam, press sources).

Automation of metro lines: positive for safety, reliability & capacity

We are seeing a rise in fully automated metro lines, which offer increased safety, unrivalled reliability and the capacity to respond flexibly to surges in demand. For operators, automation has the potential to be a lever of change to develop new organisational models, enriching job profiles and allowing more efficient maintenance and operation. Building on these strengths, metro operating companies are able to offer better service to their customers and respond efficiently to their increasingly changing mobility needs, raising the attractiveness of public transport and ultimately contributing to improving the quality of life in our cities (source: UITP).

As of July 2016, there were 55 fully automated metro lines in 37 cities around the world, operating in total 803km, a 14.2% increase in km over 2014 figures. The projection is that by 2025 there will be more than 2,300km of automated metro lines in operation (source: UITP)

Exhibit 175: Percentage of km of fully automated metro lines per country

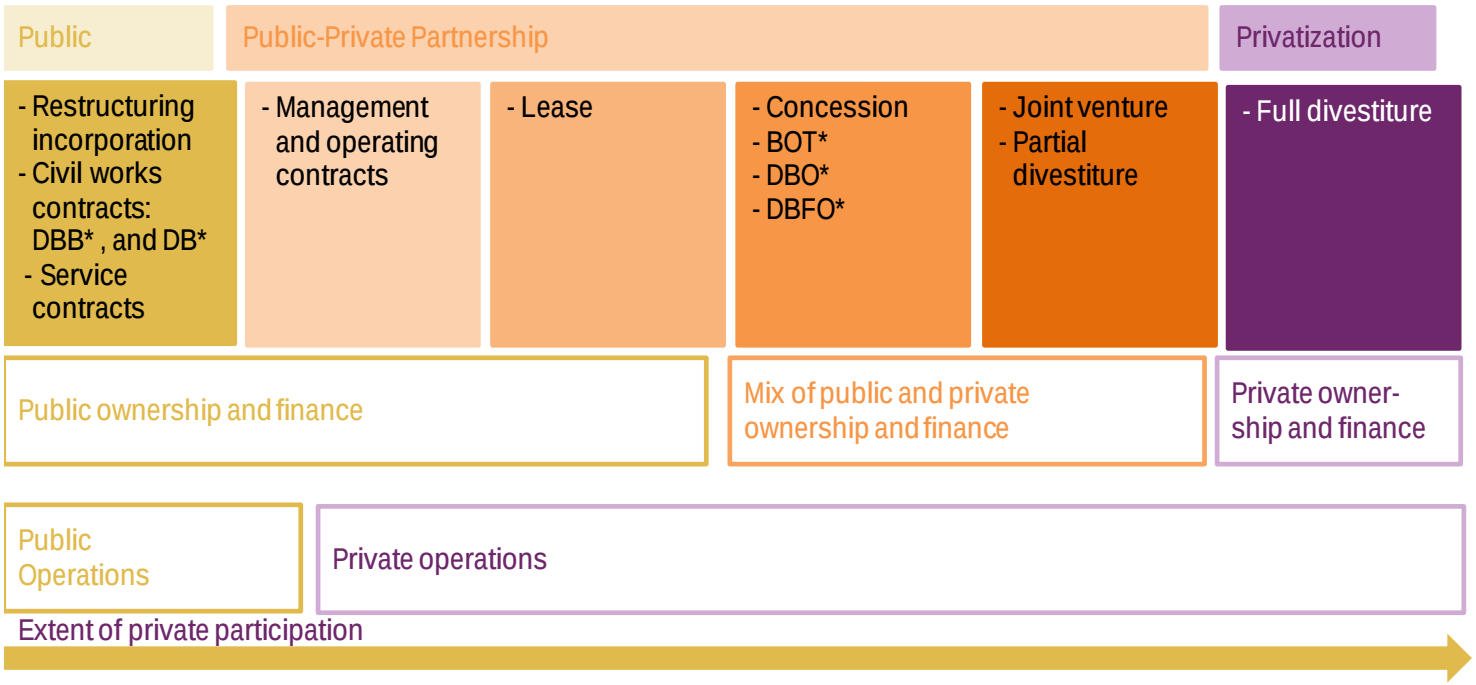


Source: UITP 2016

New models of public transport funding: fares to financing

Devising the right funding mix for public transport is a critical priority for cities to ensure its financial viability. Fare revenues do not always evolve in line with costs of production and the public debt crisis is putting increasing pressure on public resources. This means transport authorities and operators need to assess opportunities to derive additional financing and revenues including from: fares becoming more sophisticated; development of commercial revenues; aggregation of third-party services; charging from indirect beneficiaries of public transport; the private sector taking the lead through PPPs; and the contribution of direct and indirect beneficiaries (eg, land value capture) (source: Arthur D. Little, UITP).

Exhibit 176: Spectrum of different public-private partnership models for funding transport in Smart Cities



Source: WEF 2014

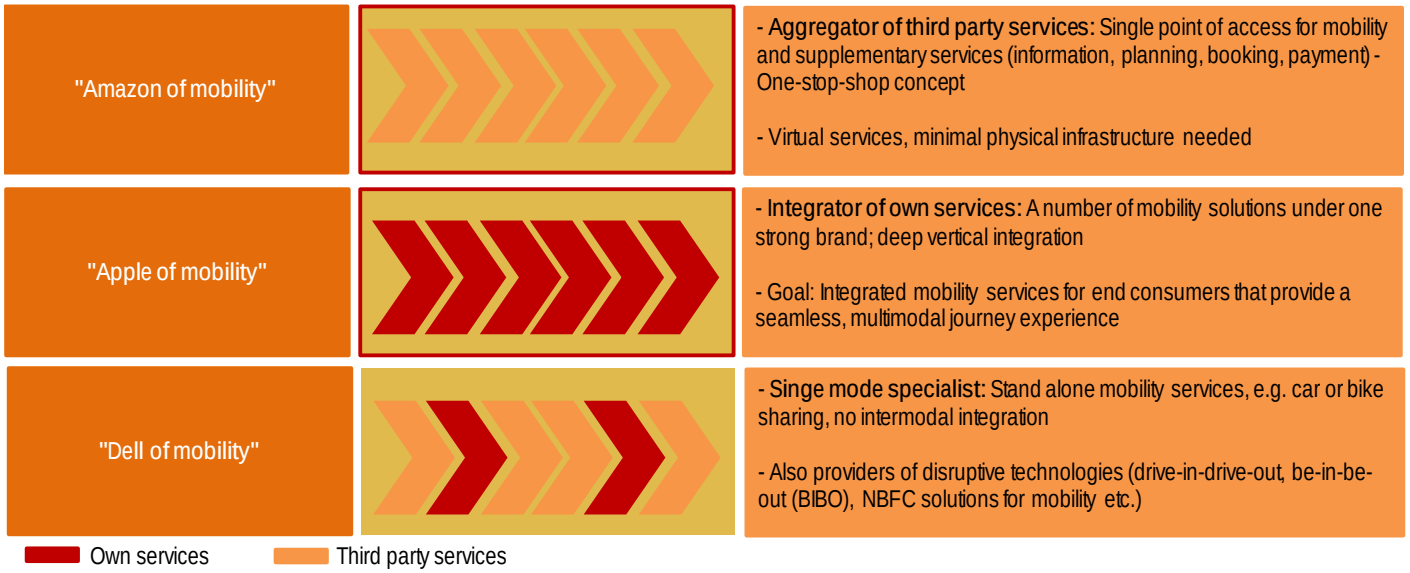
* DBB (design-bid-build), DB (design-build), BOT (build-operate-transfer), DBO (design, build, operate), DBFO (design-build-finance-operate)

Public transport meets new Future Mobility models

Conventional public transport, with its high capacity, is set to remain the transport backbone of cities. However, the sector and city authorities are realising they can up their game by learning lessons from new Future Mobility players. The rise of technology, with the smartphone at the helm, is driving the shift away from urban mobility as a purely physical proposition (source: UITP).

- **Local/regional transport authorities can procure on-demand mobility services**, which, in certain, cases would enable the provision of more-efficient and/or less costly services than currently exist.
- **Mobility as a Service (MaaS), or 'integrated mobility platforms'**, seeks to help travellers to combine and use diverse transport modes as simply as possible.
- **On-demand mobility services offer new business models**. Acting as facilitators rather than direct service providers, such services are designed to be more reactive and flexible – with operators not dependent on fixed routes, infrastructure or fleets (source: UITP).

Exhibit 177: Three long-term sustainable business archetypes for Smart City Future Mobility actors



Source: Arthur D. Little 2016

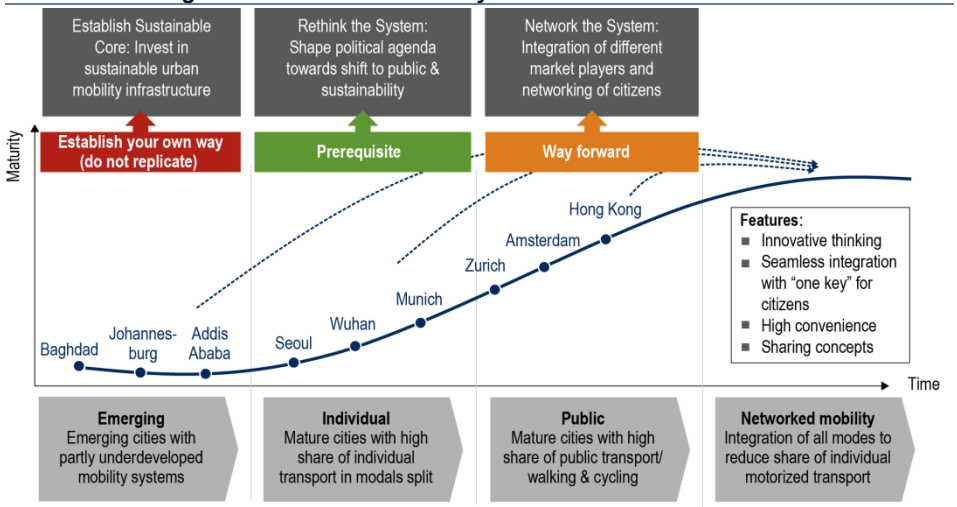
Walking and bicycling: hitting the mainstream again

In addition to the growing use of public transport, many cities are introducing more pedestrian and bicycle zones/paths, restricting access to cars, making the streets more attractive to pedestrians, and closing certain streets on set days (source: McKinsey).

Bike sharing in particular has hit the mainstream and in 2015, more than 850 cities had such programmes, up from 68 in 2007. In 2015, there were more than a million bikes in bike-sharing programmes globally.

London is building 12 "cycle superhighways" and NYC expects to have 1,800 miles of bike lanes by 2030E (source: McKinsey)

Exhibit 178: Strategic directions on Future Mobility for Smart Cities



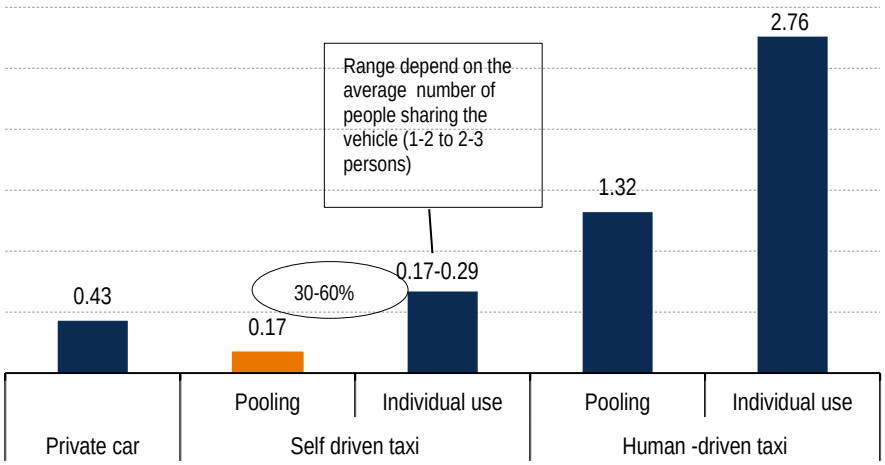
Source: Arthur D. Little

Shared autonomous EVs: the optimal mode of transport for Smart Cities

In the long run, a shared vehicle that replaces its ICE with electric, and replaces its human driver with AI, will be the cheapest, fastest and most flexible form of transport. Today, a fleet of autonomous EVs on the Tesla Network would cost around US$0.42-0.49/mile, including charging, insurance, and maintenance. This is 70-85% cheaper than ride-hailing, up to 50% cheaper than car ownership, and even 35-65% cheaper than car-sharing (source: Chen et al 2016). Many studies show that the long-term cost of a robo-taxi could be as low as US$0.17-0.30/mile as infrastructure, R&D, and other start-up costs fall (source: Chen et al 2016, BCG 2016, KPMG, BNEF/McKinsey, Rock Mountain Institute). This is 40-70% cheaper than ownership, and could even be cost competitive compared with mass transit at a rate of two passengers, but with a 40% lower commute time (source: BCG).

60-80% of the price of an Uber ride is for the driver
US$4,000/car the potential cost savings of EV vs ICE by 2030E
(source: Uber, Rocky Mountain Institute)

Chart 116: Consumer cost of transport in the US ($/mile (1.6km))



Source: BNEF/McKinsey

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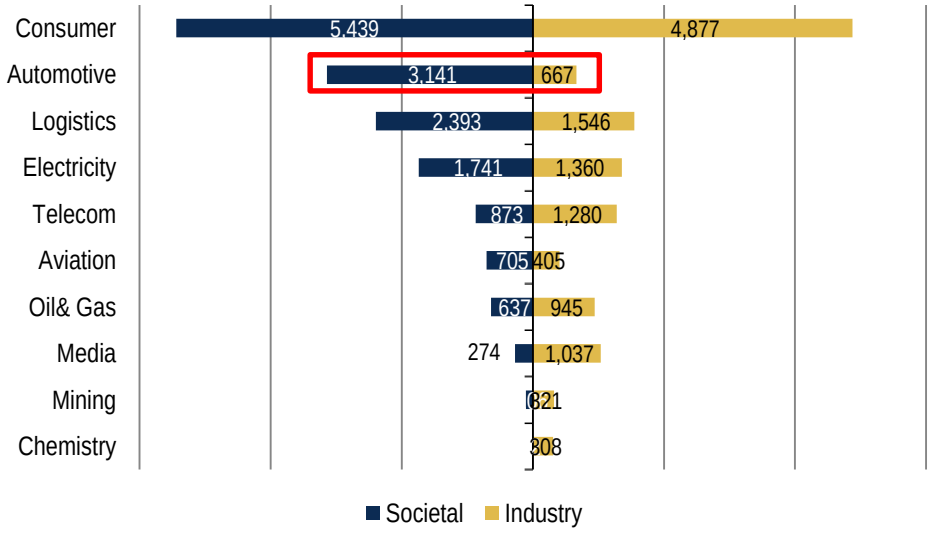
McKinsey believes that autonomous driving alone can create US$200bn-1.9tn of positive impact annually by 2025E (source: McKinsey).

Chart 117: Disruptive Tech: cumulative value 2016-2025 to society and Industry ($ billion)



Source: World Economic Conference 2017, Accenture

Smart Cities & Future Mobility: a seamless on-demand service

Mobility as a utility: It is more likely that road transport becomes a utility, something that can be bought by volume, like gas, electricity and water

The confluence of electric, autonomous, shared, connected cars, and greater use of public transport will give rise to an entirely new transportation paradigm. Similar to other sectors, access will ultimately trump possession, where we believe transportation will become a utility, just like electricity or water. Today, transportation is often centred on the vehicle, which is used for various purposes. We expect this to evolve towards a platform-centric model, where consumers can select the optimal mode of transport based on their needs – commuting, leisure, vacation, shopping, etc. Transport will also be greener, safer, faster, on-demand, and personalised for the user.

Elon Musk's Master Plan, Part Deux for Tesla:

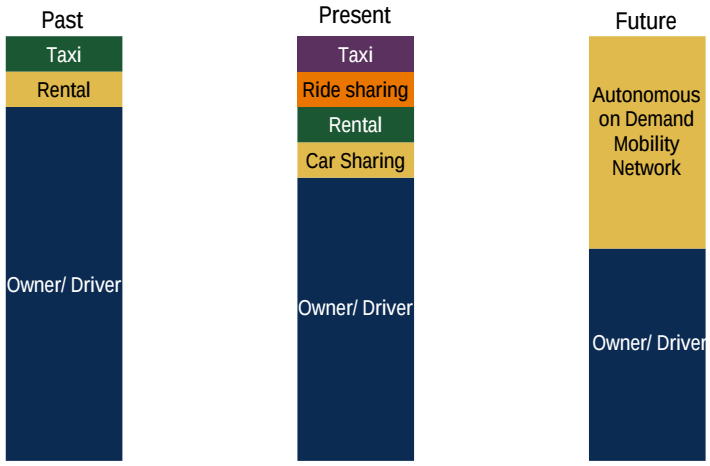
- **Create stunning solar roofs with seamlessly integrated battery storage**.
- **Expand the electric vehicle product line to address all major segments**.
- **Develop a self-driving capability that is 10X safer** than manual via massive fleet learning

- **Enable your car to make money for you** when you aren't using it.

Transforming our world, beyond the car

In terms of city infrastructure, fuelling and parking infrastructure are likely to be consolidated. City streets and parking spaces, which comprise up to 59% of land today, can be taken back and repurposed for other uses. This will also likely give rise to new business opportunities as the car evolves towards a robot on wheels (90% of cars connected by 2020E), and frees up over 50min of time day for the average traveller (source: McKinsey, Hitachi, Telefonica, AAA). Data generated will be analysed by artificial intelligence, leading to dynamic routing for smarter cities. Ultimately this also means that personally owned vehicles will likely decline as a percentage of the total, putting pressures on ancillary sectors such as insurance, repair, oil, fuelling and other services.

Chart 118: Car-based Urban Mobility Reshaping Transportation



Source: IHS 2016

Step-wise function: big, Smart Cities will lead the way

We expect adoption to occur as a step-wise function depending on the population density, income levels, consumer acceptance, and government legislation of the region. Urban settings are likely to be the first adopters of a mobility framework, because they have the scale required for such a platform to thrive. There are around 50 urban areas that may adopt this by 2030E, and they fall into three main categories: (1) clean and shared – high EV uptake and high sharing; (2) private autonomy – high EV and AV uptake but low sharing; and (3) seamless mobility – high EV, AV, and sharing uptake (source: BNEF/McKinsey). Rural areas, especially those low in income, will be the last to adapt.

Table 57: City and transport scenarios by 2030E

Mode of Future Mobility	Clean and Shared	Private Autonomy	Seamless Mobility
Regional Characteristics	Developing, dense metropolitan areas	Developed, suburban sprawl	Dense, developed metropolitan areas
Sample city	Delhi, Mexico City, Mumbai	Los Angeles	London, Chicago, Hong Kong, Singapore
% EVs	42%	34%	60%
% AVs	3%	32%	40%
Passenger miles travelled by 2030 (indexed vs 2015)	186%	125%	130%

Bank of America Merrill Lynch

Table 57: City and transport scenarios by 2030E

Mode of Future Mobility	Clean and Shared	Private Autonomy	Seamless Mobility
Vehicle miles travelled by 2030 (indexed vs 2015)	159%	135%	137%
Vehicle Parc by 2030 (indexed vs 2015)	163%	108%	93%

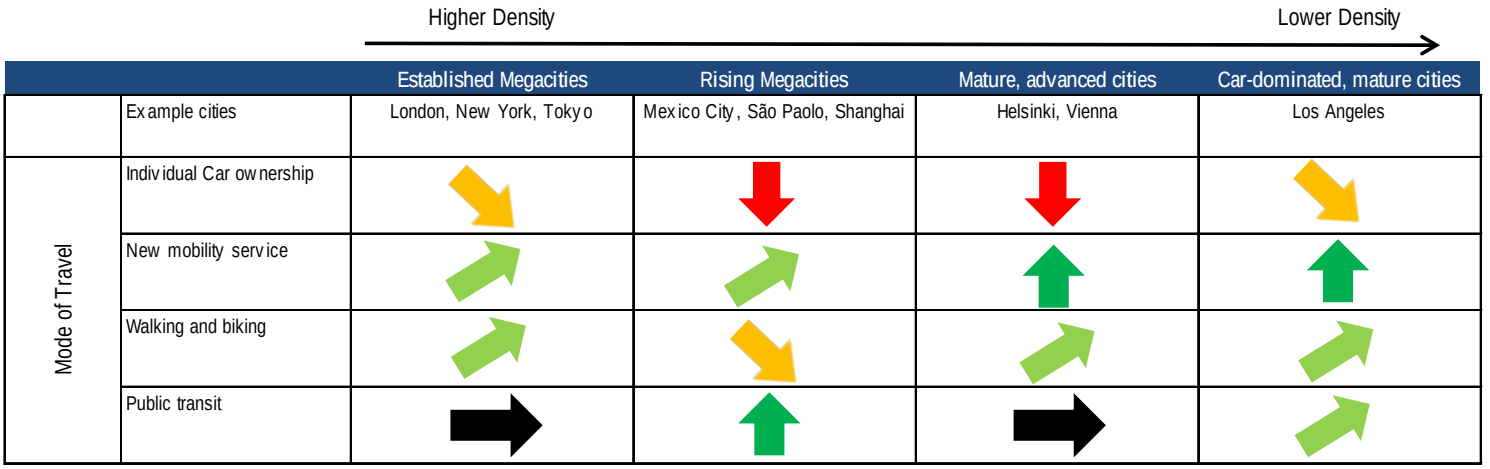
Source: Bloomberg New Energy Finance & McKinsey 2016, BofA Merrill Lynch Global Research

Many cities already mobilising; London, Singapore, Paris, Oslo, Beijing et al

Many cities in both DMs and EMs of varying population densities have already started taking steps. Cities including London, Singapore, Paris, Oslo, Helsinki, Amsterdam, Beijing have begun curbing traffic from personally owned vehicles, either through congestion charges, charges on older, more polluting cars - or full-on traffic restrictions. At the same time, several have started to roll out early versions of a seamless mobility system. We expect many other city-planners to follow the same route as a way to limit congestion and improve air quality.

It will cost £21.50 (US$26.73) to drive a pre-Euro 4 vehicle (pre-2006) in Central London between 7h and 18h Monday to Friday when existing congestion charges and new pollution charges are factored in. In Paris, older, more polluting cars are banned between 8h and 20h on weekdays (source: city governments).

Exhibit 179: How mobility is likely to change, by type of city

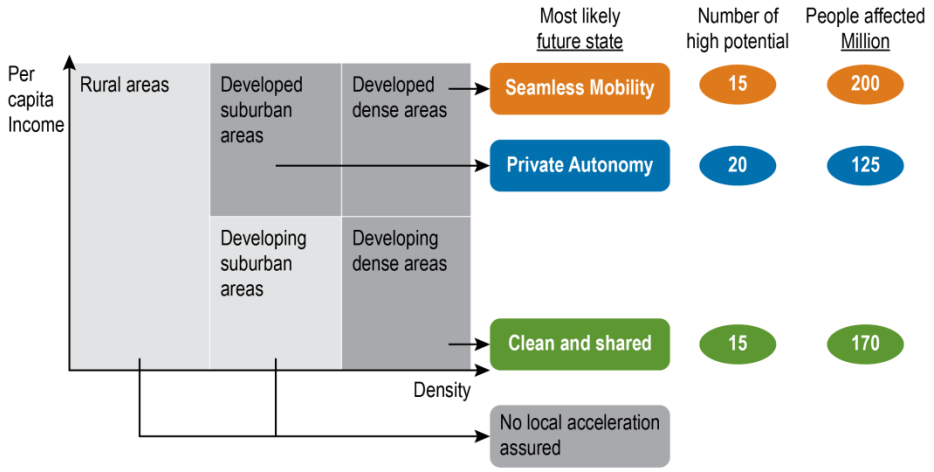


Source: McKinsey 2016

First adopters: 50 cities, 500mn people, US$600bn societal benefits by 2030E

Adoption of future mobility will be a step-wise function, where 50 urban areas with 500mn inhabitants will likely accelerate towards this mode by 2030E. The first movers will be driven by need (congestion, pollution), as well as economic progress, and government effectiveness. High-income, population-dense urban cities will advance the quickest. This will lead to less traffic, cleaner air and safer streets.

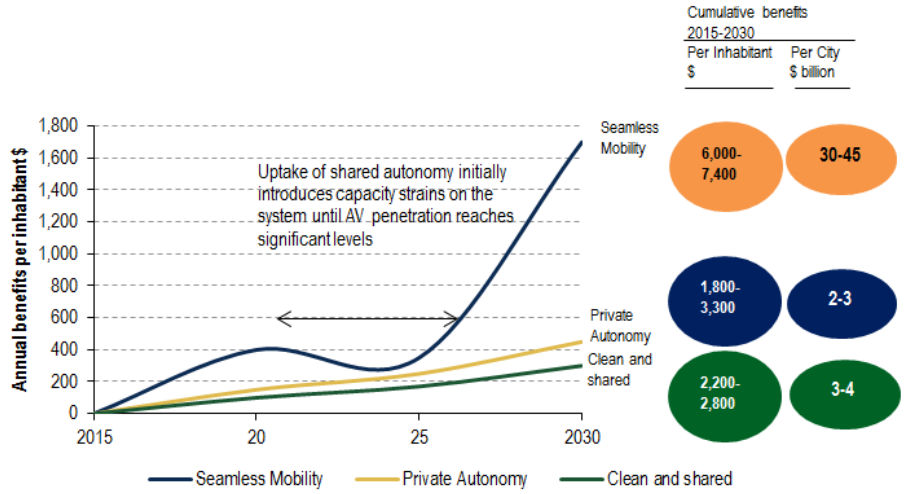
Exhibit 180: Around 50 Large Metropolitan areas have the highest potential to accelerate



Source: BNEF/McKinsey

The projected cumulative societal benefits between 2015 and 2030E is US$600bn. Cities that move towards a seamless mobility framework using electric robo-taxis could generate as much as US$7,400 per person, and boost GDP by 3.9% (source: BNEF/McKinsey 2016).

Exhibit 181: Societal benefits are highest in seamless Mobility



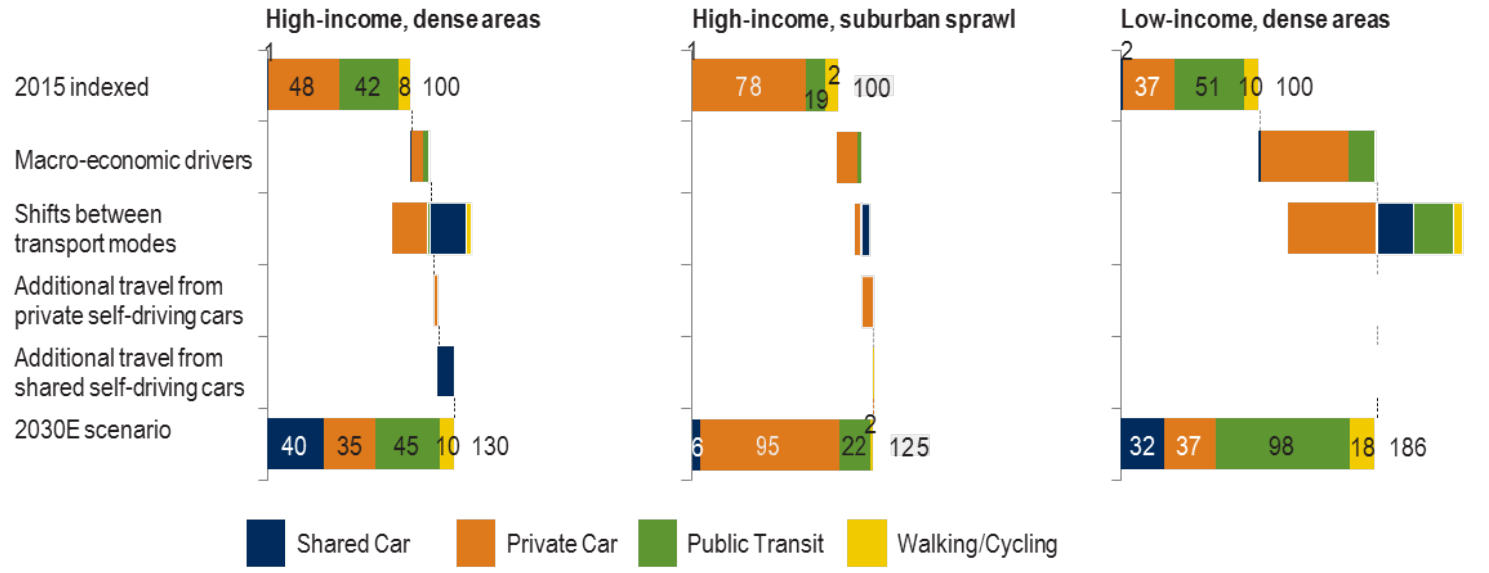
Source: McKinsey

Meeting new demand: distance travelled to rise 25-86%

The average passenger miles travelled is expected to rise given that a shared AV scheme could be 40-70% cheaper than traditional car ownership, and will increase access to transport to a wider population (source: Chen et al 2016, BCG 2016, KPMG, Rock Mountain Institute). Distance travelled in low-income population-dense areas can rise as much as 86% driven by increased robo-taxi utilisation and public transport. Even developed markets are projected to see a rise of 25-30% as the price of transport falls (source: BNEF/McKinsey)

Bank of America Merrill Lynch

Exhibit 182: Passenger miles travelled 2030E scenario for various types of regions

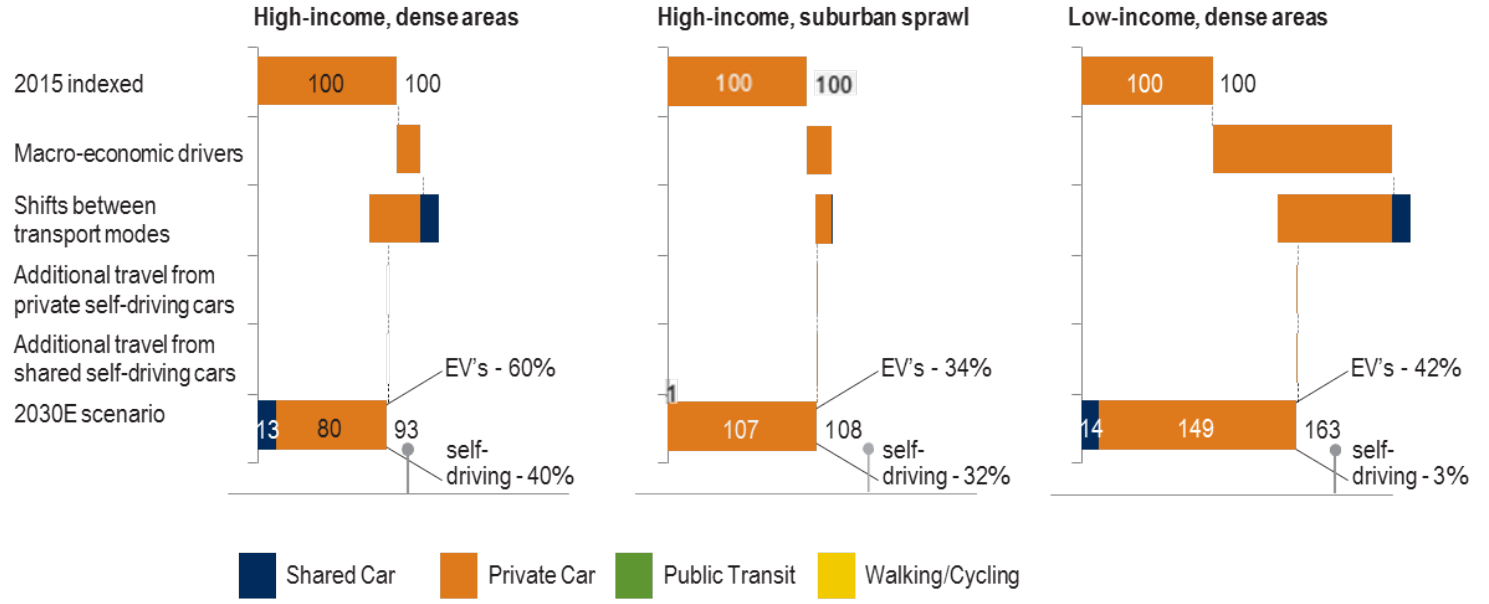


Source: Bloomberg New Energy Finance, McKinsey 2016, BofA Merrill Lynch Global Research

Total vehicles likely to plateau for high-income areas

While total car ownership is likely to rise in EMs on the back of low absolute levels of penetration and macroeconomic growth, ownership in DMs is projected to flatten or decline by 2030E due to sharing and higher utilisation (source: BNEF/McKinsey).

Exhibit 183: Vehicle Parc 2030E scenario for various types of regions



Source: Bloomberg New Energy Finance, McKinsey 2016, BofA Merrill Lynch Global Research

DMs cities the epitome of future mobility: 60% EV and 40% AV

High-income urban settings in the developed world are likely to be the epitome of a seamless mobility revolution – where the electric robo-taxi revolution takes full hold. In these areas, EVs can account for as much as 60% of all vehicles on the road and AVs for 40% (source: BNEF/McKinsey). This revolution is contingent on a few other changes:

- Introduction of **smart infrastructure** in cities
- Customers rely on a single **integrated software platform** for mobility needs

- Transit is deployed and optimised using **Big Data**
- **Legislative support** for electrification, autonomy, and sharing.

Case study of Uber partnering with Summit, New Jersey in a 2016-2017 pilot project to solve the problem of overcrowded parking lots at its commuter train station:

- **Summit residents with prepaid parking permits are given free Uber rides to and from the train station during weekday commute hours.**
- **Residents without a prepaid permit would pay US$2 per ride** to and from the station, which costs the same as the US$4 daily parking fee. Summit will pay Uber the difference for the cost of these rides.
- **Summit officials estimate 100 parking spaces at the train station will be freed up, which could save the city up to US$5mn** in not building another lot. The benefit for Uber is getting more people to use its service (source: city, Uber, press sources).

Heading towards a "world of zeros" in Smart Cities

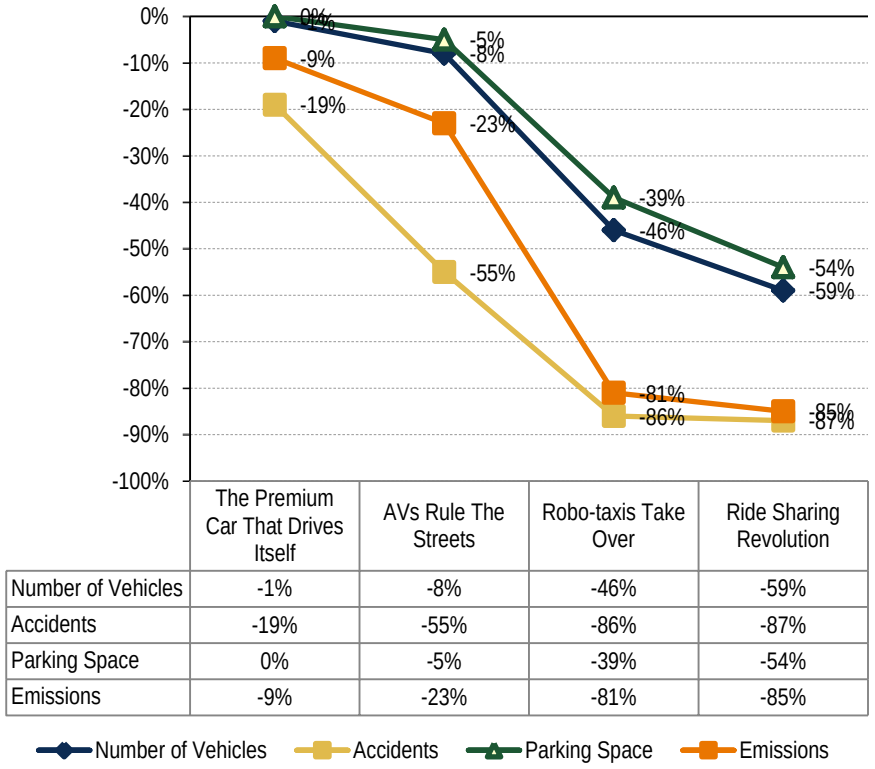
A seamless green robo-taxi mobility system will also drastically change our space. When this scenario is reached, we will be looking at fewer accidents, emissions and cars on the road. This merely assumes self-driving taxis average 2 passengers instead of 1.2 today (source: BCG 2016). Freed-up parking lots and road space will also likely be repurposed for greenery or socialising.

The benefits for Smart Cities of an EV robo-taxi revolution:

- **59%** fewer cars
- **87%** fewer accidents
- **85%** fewer emissions
- **54%** fewer parking spaces

Chart 119: Autonomous driving and mobility services uptake and potential impact on cities

Car demand, Accidents, Parking Space, Emissions to reduce significant



	The Premium Car That Drives Itself	AVs Rule The Streets	Robo-taxis Take Over	Ride Sharing Revolution
Number of Vehicles	-1%	-8%	-46%	-59%
Accidents	-19%	-55%	-86%	-87%
Parking Space	0%	-5%	-39%	-54%
Emissions	-9%	-23%	-81%	-85%

Source: Boston Consulting Group, BofA Merrill Lynch Global Research

Uber Elevated ambitions for a flying car:

- **In 2017, Uber hires a veteran NASA engineer as director of engineering for aviation to work on a flying car** (so-called VTOLs – short for vertical takeoff and landing) - initiative known as Uber Elevate.
- **In an October 2016 white paper, the company laid out a vision for airborne commutes** and identified technical challenges it said it wanted to help the nascent industry solve, like noise pollution, vehicle efficiency and limited battery life.
- **The ride-hailing company envisions people taking conventional Ubers from their homes to nearby "vertiports"** that dot residential neighborhoods. Then they would zoom up into the air and across town to the vertiport closest to their offices (source: Bloomberg 2017, company).

Case studies of Grab, NuTonomy & Uber enabling smart cities

Grab Taxi's self-driving cars was the first robo-taxi scheme to launch

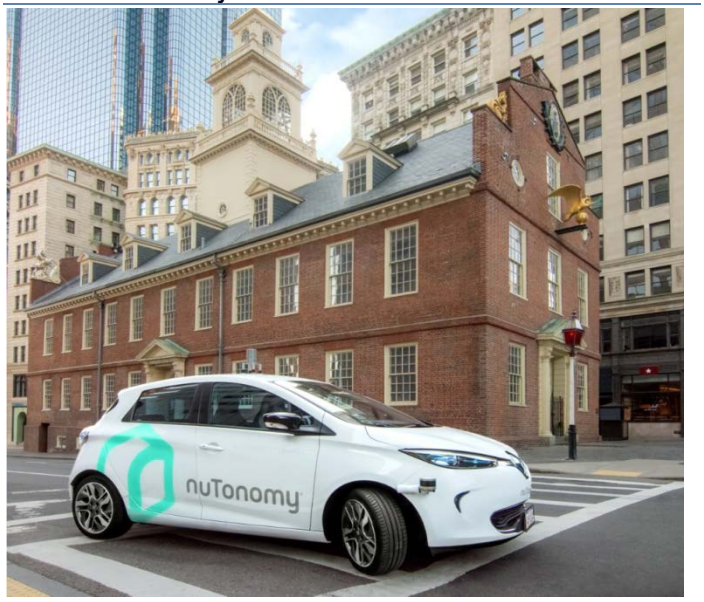
The Southeast Asian ride-hailing company paired up with MIT's spinout start-up NuTonomy, and began publicly testing robo-taxis on Singapore's streets in August 2016.

They expanded to Boston in November 2016. While the JV involves no financial investment from one another, Grab is meant to provide the mapping and traveller platform, while NuTonomy builds the self-driving software. The companies have received financial support and/or partnered with local governments in both cases. In Singapore, the AVs are originally from a 2.5km square business district area called "One North" which the government has designated to test self-driving cars. Grab is aiming to build a driverless commuting network for underserved areas in Singapore, targeting 2018 to bring a commercial product to market. The JV began testing in Raymond L. Flynn Marine Park in the Seaport section of Boston before the end of 2016, but will not be tasked with collecting passengers (source: Grab, IEEE).

Singapore has to be proactive about self-driving cars: "The city-state's 5.6 million people are packed into just over 700 km2, making it the third most densely populated country in the world. Roads in Singapore take up nearly as much land as housing does... Boston has similarly run out of road room. " – Evan Ackerman of IEEE

Boston has America's worst drivers for 2016. The typical driver gets into a collision once every 3.7 years, 167.6% higher than the national average (source: Allstate)

Exhibit 184: NuTonomy in Boston



Source: NuTonomy

Robo-Ubers begin testing on US home turf

Uber began testing robo-taxis in August 2016 in Pittsburgh, and has since attempted to expand to San Francisco. Uber and Volvo joined forces, contributing a combined US$300mn to the project. Volvo made the base vehicle – XC90 – which will have Uber and/or Volvo AV software built on top. The companies' San Francisco experiment was short-lived, when the California Department of Motor Vehicles revoked the registrations of Uber's 16 testing vehicles because the company had failed to acquire an autonomous vehicle permit prior to testing. Uber has since announced it will test robo-taxis in Phoenix early 2017.

The California Department of Motor Vehicles has issued AV permits for the following actors (As of 8 Dec 2016):

- Volkswagen Group of America, Mercedes Benz, Google, Delphi Automotive, Tesla Motors, Bosch, Nissan, GM Cruise LLC, BMW, Honda, Ford, Zoox, Inc., Drive.ai, Inc., Faraday & Future Inc., Baidu USA LLC, Wheego Electric Cars Inc., Valeo North America, Inc., NextEV USA, Inc., Telenav, Inc., NVIDIA Corporation (source: CA DMV)

Exhibit 185: Uber's Volvo XC90 used in San Francisco

Source: Uber

Exhibit 186: Uber's Ford Fusion used in Pittsburgh

Source: Uber

US$1.5tn seamless mobility market by 2030E

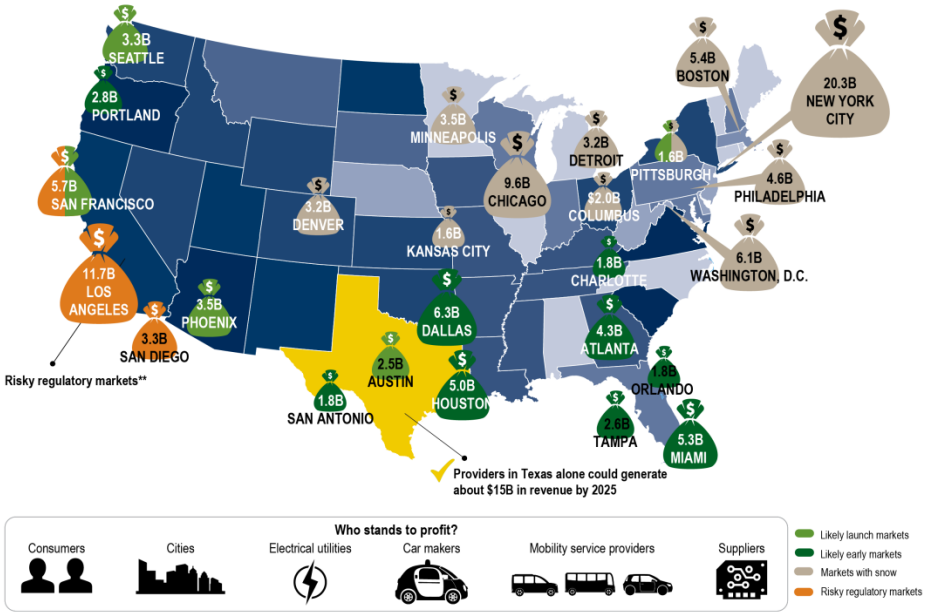
Seamless mobility can rise to become a US$1.5tn global market by 2030E versus US$30bn today. This includes over US$450-750bn in data connectivity, apps, navigation, entertainment, remote services and other tech-based solutions which would be created on the back of future mobility. Recurring revenues are expected to become more dominant vs vehicle sales today (source: McKinsey). While the total size of the transport market will likely expand for the next 5-10Y, this may plateau and decline thereafter as the overall cost of transport becomes cheaper.

US$120bn potential in US by 2025E

In developed regions such as the US, the market opportunity for mobility services could be as high as US$120bn by 2025E. This would benefit mobility service providers, suppliers, select automakers, electric utilities and ultimately the cities and consumers themselves (source: Rocky Mountain Institute).

Exhibit 187: The US$120bn opportunity of automated mobility services in the US by 2020E

Ranking the mobility market of various US cities



Source: Rocky Mountain Institute, BofA Merrill Lynch Global Research

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Neutral	≥ 0%	≤ 30%
Underperform	N/A	≥ 20%

* Ratings dispersions may vary from time to time where BofA Merrill Lynch Research believes it better reflects the investment prospects of stocks in a Coverage Cluster.

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