Smart cities: the metrics of future internet-based developments and the renewable energies of urban and regional innovation

Mark Deakin[a*], Alasdair Reid[a] and Luca Mora[b]

[a] Edinburgh Napier University, School of Engineering and the Built Environment, Scotland, UK

[b] Edinburgh Napier University, The Business School, Scotland, UK

***** Corresponding author: M.Deakin@napier.ac.uk; Tel.: +44 0131 455 2480

Abstract: This paper studies smart cities as the metrics of future internet-based developments and the renewable energies of urban and regional innovation. It fills a gap that has opened up in the literature currently available on smart cities and around the metrics of future internet-based developments. That gap, which has opened up in studies of smart cities around the metrics of future internet-based developments and that relate to the informatics of the computer science, which underpin digital infrastructures, support data management platforms and set the stage for renewable energies. It achieves this by presenting the findings of a case study on future internet-based developments and accounting for how the informatics of computer science and digital infrastructures of data management platforms set the stage for renewable energies and way this energetic plays out as the renewables of an urban and regional innovation. The case study is drawn from the Hackbridge project in the London Borough of Sutton and serves to demonstrate how accounting for the metrics of future Internet-based developments does matter. Does matter in the sense which the case study serves to demonstrate that merely being able to relate the informatics of computer science to the digital infrastructures of data management platforms is not enough. Not enough because it is only in bottoming out how the informatics of computer science relate to the digital infrastructures of data management platforms as part of a material stock and flow analysis, that it becomes possible to account for the energetic of the renewables and contribution which the installation of them into buildings does to sustain the growth of an urban and regional innovation whose ecological modernisation adapts to climate change.

Keywords: Smart cities; metrics; future internet-based developments; renewable energies; urban and regional innovation, sustainable and inclusive growth, ecological modernization, climate change adaptation

1. Introduction

This paper on smart cities shall account for the metrics of future internet-based developments relating to the renewable energies of urban and regional innovation. Having accounted for the metrics of the future internet-based developments, in terms of the informatics of computer science, digital infrastructures and data management platforms that set the stage for renewable energies, it shall go on to demonstrate how the energetic of these renewables play out as an urban and regional innovation. In particular, how the metrics of such developments, along with the informatics of the computer science they are based, digital infrastructures they stand on and data management platforms they rest, set the stage for the installation of renewable energies in that urban and regional innovation which is known as the Hackbridge Project located in the London Borough of Sutton.

Reflecting on the findings of the case-study analysis, the paper goes on to challenge the status of smart cities as future Internet developments in terms of the informatics of the computer science science they are based, the digital infrastructures they stand on and data management platforms they in turn rest. Not in terms of whether the metrics of future-internet based developments, informatics of computer science, digital infrastructures and data management platforms can account for the stock and flow of the materials associated with the energetic of the renewables, but if the urban and regional innovation this underpins in the city-districts of Hackbridge supports energy efficient-low carbon zones across the London Borough, which are not only smart and sustainable, but that are also inclusive.

2. Literature review

Deakin (2011, 2013, 2014, 2015), Deakin et al. (2012a, 2012b, 2014) and Mora et al. (2017, 2018, 2019a, 2019b, 2019c), review the literature on smart cities and offer a critical synthesis of the developments. This review indicates the types of Ranking Systems that Giffinger (2008) reports on, provides a tool for cities to be smart in marketing the innovative qualities they account for. With this attribute-based account of smart cities standard ranking procedures are modified by pre-fixing the word smart to cities and by going on to account for how they perform against rivals who do not claim such a status. In going on to develop this theme, Schaffers et al. (2011) claim the successful marketing of such innovative qualities does not lie with the physical existence of such attributes, but instead rest on the information and communication (ICTs) that underpin smart cities as developments which support the Future Internet. This is because for Schaffers et al (2011), future Internet developments relate to the broadband of cloud computing and the Internet of Things (IoT) as the ICTs of national innovation systems. Leydesdorff and Deakin (2011) and Deakin and Leydesdorff (2013) suggest that such models of smart cities reflect much of the mode 2 notion of science which the TH model stands in contrast to and distances itself from. For as an scientific exercise in the production of knowledge, the TH model of smart cities instead accounts for the ICTs of national innovation systems in terms of the intellectual capital that underlies the creation of wealth from the broadband, cloud computing and IoT which surface as the metrics of the future Internet developments they in turn offer a measure of.

If we compare what Giffinger (2008) and Schaffers et al. (2011) models of smart cities offer as the metrics of future Internet developments against those the TH offers, the problem these legacy systems encounter quickly become into view. For Giffinger's (2007) model is seen to leave the relationship between smart cities and ICTs unaccounted for and while Schaffers et al (2011) do draw a much clearer link between smart cities and ICTs, especially in terms of the connection they have to future Internet developments, it is Caligilu et al (2011) along with Lazouri and Roscia (2012), who shift the center of gravity. Shift the center of gravity away from the use of ICTs in national innovation systems and towards the intellectual capital that underlies the creation of wealth from the broadband, cloud computing and IoT which surface as the metrics of the future Internet developments regulating the wise management of natural resources. This is achieved by highlighting the role of ICTs as the broadband, cloud computing and IoT of national innovation systems and how the intellectual capital that underlies the creation of wealth which surfaces, play out as the metrics of future Internet developments regulating the wise management of renewable energies as a natural resource.

It is the TH model of smart cities advanced by Hirst et al (2012) that throws further light on the role which ICTs as national systems play in the intellectual capital of wealth creation, by drawing attention to the informatics of the computer science that underpin them and which supports and metrics of future internet-based developments as the wise management of renewable energies Lombardi et al (2012), Deakin and Leydesdorff (2013) and Kuortit (2013) also bring into sharp focus. Lombardi et al. (2012), Deakin and Leydesdorff (2013) and Kuortit (2013) also bring into sharp focus and by honing in on the opportunity the TH model offers smart cities to reach beyond the role of ICTs in national innovations systems. Beyond the role of ICTs in national innovations systems and out towards the intellectual capital of that wealth creation which allow for the metrics of future Internet-based developments to As Deakin (2014, 2015) indicates, account for about 70% of energy consumption and carbon emissions and draw upon this to demonstrate how the wise management of renewables as a natural resource can sustain the growth of as an urban and regional innovation. Can sustain the growth of an urban and regional innovation able to bear down on the emission of greenhouses gases associated with global warming, by way of mass retrofits and through the design and layout of city-districts as energy efficient-low carbon zones.

This in turn suggests that any attempt for the TH model of smart cities to uncover the place which the intellectual capital of smart cities holds in the creation of wealth from the informatics of computer science and as the metrics of future internet-based developments offered up for such purposes, needs to be grounded in the wise management of renewable energies as a natural resource. In that wise management of renewable energies which Kennedy et al. (2007, 2010, 2011) and Bristow and Kennedy (2013) in turn suggest relates this natural resource to a material stock and flow analysis, whose metabolic sustains the growth of an urban and regional innovation able to bear down on the emission of greenhouses gases associated with global warming.

Keeping such a material stock and flow analysis firmly in mind, the TH model of smart cities that follows shall account for the place which the intellectual capital of ICTs hold as the broadband, cloud computing and IoT in the creation of wealth and the metrics of future internet-based developments serve to regulate. This shall be presented in terms of the informatics of the computer science whose creation of wealth not only underpins the digital infrastructures which they stand, but that also supports the data management platforms which they rest as the energetic of the renewables that manifests as a metabolic able to sustain the growth of an urban and regional innovation, by way of broadband and through the cloud computing of an IoT. By way of broadband and through the cloud computing of an IoT that is resilient enough for the smart (micro) grids which this lays down for such a sensor-orientated, data-driven processing of information to be energetic. To be energetic in getting the renewables of a mass retrofit to manifest itself as a metabolic able to sustain the growth of an urban and regional innovation which not only champions city-districts as energy efficient-low carbon zones, but offers a number of critical insights into the status of the ecological modernisation this bring about as an adaptation to climate change (Kennedy 2016; Fachinni et al. 2017; Deakin and Reid, 2018).

3. Method

As is normal with the TH model (Leydesdorff 1998, 2000; Leydesdorff and Mayer, 2006; Leydesdorff and Deakin, 2011; Deakin and Leydesdorff, 2013), throwing light on the place of ICTs in in the intellectual capital of smart cities, means drawing attention to the wealth that is created from the informatics of the computer science that underpins the metrics of future internet-based developments and which supports the wise management of renewable energies as a natural resource. In particular, that wise management of natural resources, which is called for by major institutions funding research to underpin renewable energies as a natural resource able to support the growth of such developments as an urban and regional innovation. This draws attention to the policy statements made by the European Commission (EC) as part of the European Investment Bank's (EIB) contribution to the Smart Cities and Communities Programme. That programme funded under HORIZON 2020 and as part of the urban and regional innovation agenda, which supports the ECs Smart, Sustainable and Inclusive Growth Strategy.

Here the outcomes of such research shall be rendered in terms of a material stock and flow analysis, conducted as a joint venture between universities and industry and enterprise developed to generate the intellectual capital of smart cities as the informatics of a computer science it is possible to create wealth from and capture as the metrics of future internet-based developments. As the metrics of future internet-based developments, whose digital infrastructures and data management platforms offer the opportunity for cities to be smart in installing renewable energies into buildings on mass and a part of a retrofit capable of sustaining the growth of this urban and regional innovation. The findings of the case–study shall then be reflected on to distil the critical insights that such a material stock and flow analysis offers into the informatics, energetic and metabolic of the renewable energies invested in the mass retrofits they in turn sustain the growth of as an urban and regional innovation.

4. The metrics of future internet-based developments

The metrics of these future internet-based developments are drawn from the TH model of smart cities advanced by Hirst et al (2012), Lombardi et al. (2012) Lombardi and Giordano (2012) and Kourtit et al. (2013). This "advanced TH model" serves to do what Caragliu et al (2011) and Lazaroiu and Roscia (2012) ask of such developments i.e. reach beyond the attribution analysis of Smart City Ranking(s) and experiment logic of the Future Internet offered by Giffinger (2008) and Schaffers et al. (2011) respectively. This model manages to reach beyond the logic of such an attribution. It achieves this by allowing those cities that pioneer the future Internet to be smart in underpinning the digital infrastructures of a data management platform that support renewable energies and sustain the growth of this as an urban and regional innovation. The future internet-based developments it places under examination are drawn from the research carried out to capture instances of where cities have been smart in underpinning what Caragliu et al (2011) refers to as "a deep restructuring of the ICT sector": in particular and as Lazaroiu and Roscia (2012) stress, as instances of where cities have been smart in underpinning digital infrastructures and supporting data management platforms able to carry the renewable energy agenda set out for the engineering and construction sectors in Europe's Smart, Sustainable and Inclusive Growth Strategy (http://ec.europa.eu/europe2020/index_en.htm). This in turn serves to draws attention towards the metrics of the digital infrastructures, data management platforms, renewable energies, buildings and transport, whose cloud computing and IoT sustains the growth of these internet-enabled developments as an urban and regional innovation.

In line with what Caragliu et al (2011) and Lazaroiu and Roscia (2012) suggest, it also identifies the principal legacy systems of future internet-based developments: namely the ICT sector and modulation of digital infrastructures into a broadband of wireless technologies and mobile services that underlie the data management platforms and whose capture, storage and processing of information support the renewable energies which are installed in buildings.

According to Hirst et al (2012) the focus of attention on the informatics of computer science in the ICT sector is with the smart growth of the first two modulations (digital infrastructures and data management platforms), whereas with the engineering and construction sectors it is on the energetic of the renewables, where particular weight is placed on the renewable energies of the buildings they sustain as the metabolic of an inclusive growth. This also serves to illustrate the top-level issues that get bottomed out within these legacy systems. With the ICT sector, the drivers of smart growth are the digital infrastructures underpinning high-speed broadband and supporting data management platforms in terms of collection and storage. That data management platform, which bottoms-out in the engineering and construction sectors as the smart grids and meters of renewable energies installed in buildings and which they source as combined heat and power (CHP). They in turn source as the CHP of decentralised energy systems, whose city-districts serve as energy efficient-low carbon zones and whose metabolic is able to sustain the growth of an urban and regional innovation (see Figure 1).

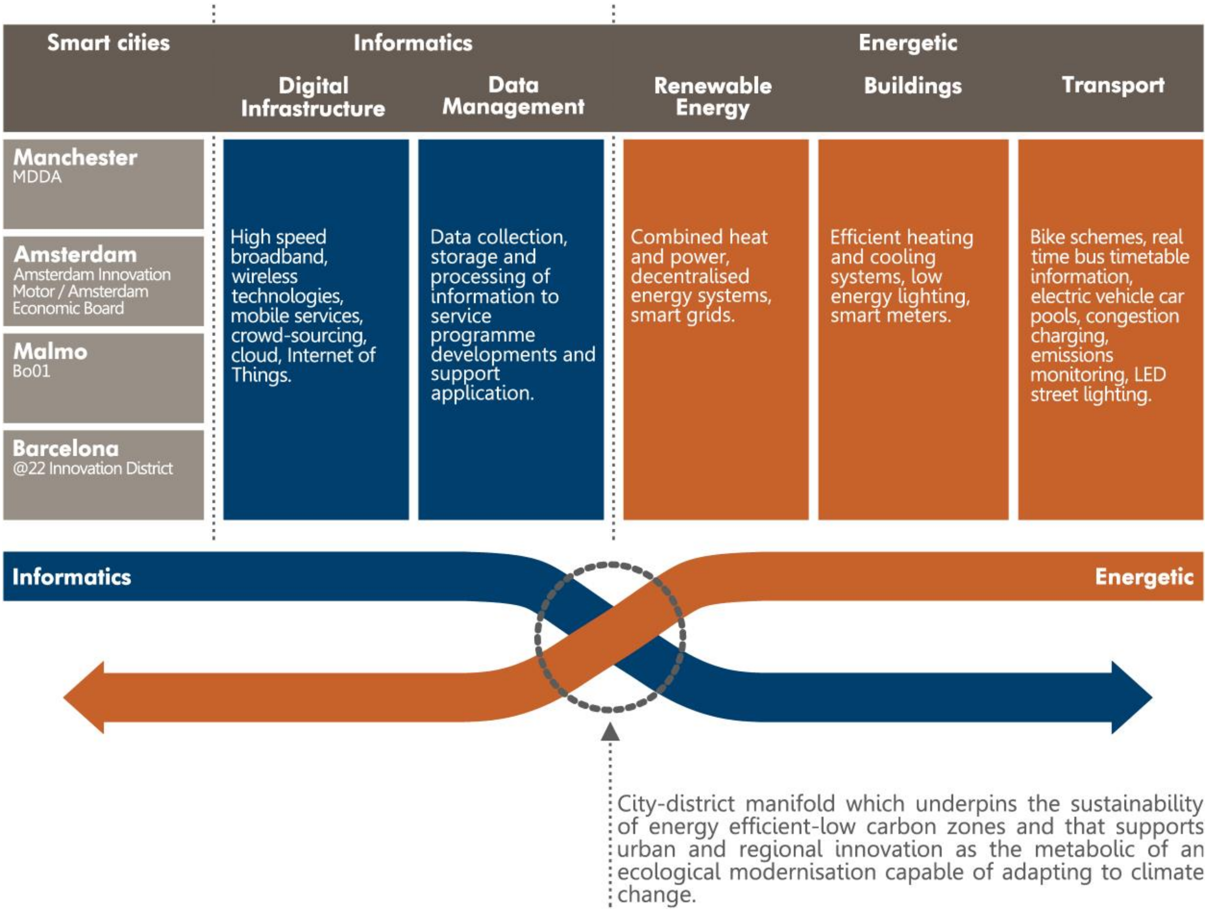

Figure 1. A principle component-based analysis of smart cities as the metrics of future internet-based developments. Source: Adapted from Hirst et al. (2012)[1].

5. The renewable energies of an urban and regional innovation

Drawing on the lessons learnt about smart cities as future internet-based developments by pathfinders such as: Manchester, Amsterdam, Malmo and Barcelona, this knowledge is presented in Figure 1 as the informatics and energetic of those digital infrastructures, data management platforms, renewable energies and buildings, which make up the city-districts as energy efficient-low carbon zones and metabolic that sustain the growth of them as an urban and regional innovation (Hirst et al. 2012; Deakin, 2014, 2015). This modulation of the urban and regional innovation also serves to highlight the novelty of Hackbridge in London as a case study in smart cities as the metrics of future internet-based developments. Not so much in relation to either the digital infrastructures or data management platforms, but rather with respect to the renewable energies installed into the fabric of buildings and found in city-districts whose energy efficient efficient-low carbon zones sustain the growth of them.

6. The case study

[1] Notes: (1) Informatics is the study of the behaviour and structure of any system that generates, stores, processes information and which then presents such information for use. It takes into consideration the interaction between the system and the user, as well as the interfaces, which structure them and behaviours that result; (2) Energetics relates to the exchange of energy within a given activity, how this operates and works; (3) Metabolic is the study of how material is produced, exchanged and rate a given set of resources is either consumed, depleted, or exhausted.

The material stock and flow analysis adopted for this case study in smart cities as future internet-based developments is interdisciplinary in nature (cutting across computing science in the ICT sector and as applied in the engineering and construction of them) and falls within the scoping of boundaries 1, 2 and 3, reported on by Kennedy et al. (2007, 2010 and 2011). Scope 1 captures the boundaries of the developments, whereas scope 2 and 3 account for the out-of-boundary impacts of the renewable energies, related to the upstream production of the materials consumed by the ICTs, engineering and construction of buildings within city-districts and whose energy efficient-low carbon zone sustain the growth of such an urban and regional innovation.

Set within this material stock and flow analysis, the case study augments the morphological model provided by Ratti et al. (2005). That model which is also expanded on by Salat (2009) and which Bourdic and Salat (2012) and Bourdic et al. (2012) . That expanded model, which Kourtit et al. (2014), Deakin (2014), Deakin et al. (2014) and Deakin and Reid (2018), also go on to highlight the significance of this for smart cities as the metrics of an Internet-based development. In this instance, as the metrics of an Internet-based development that is turnkey in the sense which the hardware the infrastructures this assembles, serves to configure the intellectual capital of an operating system (OS) whose platform of software manages to:

- apply the informatics of the computer science underlying the Digital Elevation Model (DEM) as infrastructures that support the Lighting and Thermal Method (LTM) of this data management platform and which augment these internet-based developments into a set of metric, not only able to account the geometry of the material consumed within the landscape, but as a context-specific computation of the stocks and flows also linked to the physics of this emergent space and connected to the application of ICTs by the engineering and construction sectors into renewable energies. In particular, by the engineering and construction sectors into the renewable energies of the buildings such a sensor-driven system of data capture, processing and storage render information about;
- integrate renewable energies into the materiality of the physical spaces that underpins the sensory systems embedded into the intelligence of this landscape and fabric of the energetic which supports the wealth created from the ICT, engineering and construction sectors' instillation of them into buildings;
- highlight the challenges which the crowd sourced data, hosted on the cloud and as the emergent spaces of an IoT poses, especially in terms of what such ICTs capture data about, process and store information on such developments and this in turn means for civil society. In particular, what challenges the metrics of these developments pose for civil society as renewable energies that holdout the prospect of them as a metabolic able to sustain the growth of an urban and regional innovation which communities can participate in. More specifically, communities can participate in the development of as a future Internet whose renewable energies are able to sustain an inclusive growth of such an urban and regional innovation as the ecological modernisation of city-districts which champion energy efficient-low carbon zones capable of adapting to climate change.

Transport is left out of this material stock and flow analysis. This is because Hackbridge developed the infrastructure for a light rail-transit system over a decade ago and the benefits of this traffic management scheme are already in place. In that sense, which already enter into any baseline calculation of energy consumption and carbon emission per household and therefore should not be double counted as either a saving or reduction.

7. The informatics, energetic and metabolic of the case study

The metrics of the future internet-based development captured by the case study are threefold. The first relates to the informatics of computer science in the digital infrastructures and data management platforms. The second to the energetic of the renewables in the ICTs of the engineering and construction sectors and the third to the metabolic of that growth which the cloud computing of this IoT manages to sustain as an urban and regional innovation.

Table 1 outlines the material components of this urban and regional innovation in terms of what the informatics of the energetic related to the renewables of buildings contributes to the levels of energy savings and rate of carbon reduction. This suggests that with an average of 6.7 tons of CO_2 emission per annum attributed to each property within the city-district, the informatics of the mass retrofit offers an energetic which produces a:

- 3-ton reduction in CO_2 emission, sourced from the performance related assessment associated with stage 1. With 2.76 tons of the reduction coming from energy savings related to the building fabric and 0.24 tones to the instillation of renewables in the city-district;
- further 1.7-ton reduction in CO_2 emission under stage 2, generated from the bio-gas CHP installed to supplement this renewable energy with solar and wind power and potential these renewables have to underpin the sustainability of the city-district as energy efficient-low carbon zones.
- 78% overall reduction in CO_2 emissions that is climate neutral in the sense which the energy efficient-low carbon zones have no adverse impact on the environment;
- position whereby 33% of this 78% reduction in CO_2 emission is attributable to the instillation of renewables, with a relatively small proportion of this coming by way of the buildings and the majority through the CHP, solar and wind power servicing the heating and cooling systems.

		Savings CO_2 tons	Savings CO_2 %
Stage 1 Performance related assessment	Secondary glazing; Solid wall insulation (internal/external); Under floor insulation; Heat exchange ventilation; Cavity wall insulation; Double/triple glazing; Boiler replacement	2.76	45
	Solar water heating; Photovoltaic panels	0.24	5
	Total	3	50
Stage 2 Underpinning the sustainability of energy efficient low-carbon zones	District energy network	-	-
	Bio-gas CHP (biomass/arboricultural)	1	16
	Solar energy (poly-voltaic)	0.35	6
	Wind power (turbines)	0.35	6
	Total	1.7	28
Stage 3 Supporting smart (micro) grids	ESCO (Energy Services Company); Peak load management; Dynamic pricing	-	5

Table 1. Staging of the mass retrofit.
Source: Adapted from London Borough of Sutton and Bioregional (2008 and 2012).

The micro-grids, peak load management and dynamic pricing business model of cloud computing developed for the IoT, also has the potential to leverage further CO_2 emission reductions from the sustainable growth of this urban and regional innovation. In this instance, an extra 5%, but as part of stage 3 the city-district does not yet have the ESCO in place. While pivotal to the city-district, they are left out of the savings and reductions reported on in Tables 2-7 and Figures 2-3, due to the experimental status of them as components of this energy efficient-low carbon zone.

Table 2 serves to baseline the sustainability of the inclusive growth strategy adopted for the mass retrofit. This is achieved by relating the levels of energy consumption and rates of CO_2 emissions i.e. metabolic of this urban and regional innovation within the city-district to the types of tenure in the residential property sector. When analysed as Lower Super Output Areas (LSOA), these figures capture the data needed to calculate the energy savings and information also required to measure the CO_2 emission reductions for each of the options it is possible to select as instruments of the mass retrofit (Tables 3 and 4).

	LSOA 1	LSOA 2	LSOA 3	LSOA 4	LSOA 5	Total
Total Energy Consumption (kWh p.a.)	6,733,319	14,644,009	5,576,413	13,140,448	8,079,019	48,173,208
Total CO_2 Emissions (Tons p.a.)	1,904	4,685	1,657	4,002	2,176	14,425
Households	295	741	321	601	318	2,276
Energy Consumption / Mean Household	22,825	19,762	17,372	21,864	25,406	21,116
CO_2 Emissions / Mean Household	6.4	6.3	5.1	6.6	6.8	6.34
Owner occupied	150	571	250	427	235	1,633
Social rented	107	89	31	84	53	364
Private rented	38	81	40	90	30	279

Table 2. Area-based energy consumption and CO_2 emissions.
Source: Deakin et al. (2014) and Deakin and Reid (2018)

	LSOA 1	LSOA 2	LSOA 3	LSOA 4	LSOA 5
Current Energy Consumption (kWh p.a.)	6,733,319	14,644,009	5,576,413	13,140,048	8,079,019
Retrofit(s)					
1. Thermal	1,357,437	2,952,232	1,124,205	2,649,114	1,628,730
2. Thermal-plus	2,413,222	5,248,413	1,998,586	4,709,537	2,895,521
Maximum Energy Savings	3,770,659	8,200,645	3,122,791	7,358,651	4,524,251

Table 3. Energy savings across all LSOAs
Source: Deakin et al. (2014) and Deakin and Reid (2018)

	LSOA 1	LSOA 2	LSOA 3	LSOA 4	LSOA 5
Current CO_2 Emissions (Tons p.a.)	1,904	4,685	1,657	4,002	2,176
Retrofit(s)					
1. Thermal	379	932	330	796	432
2. Thermal-plus	592	1,457	516	1,245	677
Maximum CO_2 Savings	981	2,389	8,456	2,041	1,109

Table 4. CO_2 emission reductions across all LSOAs
Source: Deakin et al. (2014) and Deakin and Reid (2018).

As Tables 3 and 4 indicate, the savings and reduction within the city-district are marked. They show the thermal option generates approximately 25% energy savings. With the thermal-plus (heat and power) option, indicating savings as high as 65%. Together they show the thermal option to reduce the rate of CO_2 emission by 25% and the thermal-plus option as much as 50%. As regards the reductions per household, the thermal and thermal-plus retrofit options have the potential to both save energy and reduce the emission of CO_2 from 6 to 4.5 and 3 tons per household respectively. Table 5 shows the contribution of renewables to these savings and reductions. These are segmented into the building fabric, CHP, solar and wind power that underpin the city-district and which support this energy efficient-low carbon zone as the urban and regional innovation of a smart, sustainable and inclusive growth.

As can be seen, they indicate the depth of saving and breath of reductions by LSOA and serve to highlight the vertical integration of renewables into city-districts as energy efficient-low carbon zones.

	Current Energy Consumption (Tons p.a.)	Stage 1		Stage 2
		with thermal	with thermal-plus and solar	with CHP, solar and wind
LSOA 1	6,733,319	5,375,882	3,786,552	1,223,938
LSOA 2	14,644,009	11,691,777	8,365,189	2,828,262
LSOA 3	5,576,413	4,452,208	3,075,599	936,389
LSOA 4	13,140,448	10,491,334	7,111,752	2,032,851
LSOA 5	8,079,019	6,450,289	4,647,639	1,602,078

Table 5. The contribution of renewables to energy consumption

As aggregates the figures for the buildings tend to under-represent the technical challenges the sustainable growth of this urban and regional innovation poses. For in order to compute what renewables contribute to the building fabric, it is necessary to augment the DEM model with a calculation of the renewables the installation of photovoltaics onto the roofs of residential properties generates. This is calculated to be 4,162,147 kWH of energy and a figure able to reduce the current CO_2 emissions not by 5% as indicated in Table 1, but 8.5%. The renewables from CHP, solar and wind power are calculated as 15,392,605 kWH and a 28% reduction in $C0_2$ emissions. Together this gives a reduction in $C0_2$ emissions of 0.4 and 1.7, or 2.1 tons and not 33 but 37%.

	Current CO_2 Emissions (kVh p.a.)	Stage 1		Stage 2
		with thermal	with thermal-plus and solar	with CHP, solar and wind
LSOA 1	1,904	1,525	1,158	464
LSOA 2	4,684	3,752	2,888	1,193
LSOA 3	1,657	1,327	991	382
LSOA 4	4,002	3,206	2,354	874
LSOA 5	2,176	1,743	1,349	564

Table 6. Contribution of renewables to CO_2 emissions (tons p.a.).

Figures 2 and 3 show the distribution of these savings and reductions across the five LSOAs within the stock of residential buildings. Here the energy savings and carbon reductions are compared to those calculated for the two proposed retrofit options. Note the thermal plus package covering the building fabric includes the installation of solar panels and goes on to show the additional savings and reductions generated from the CHP, solar and wind power components.

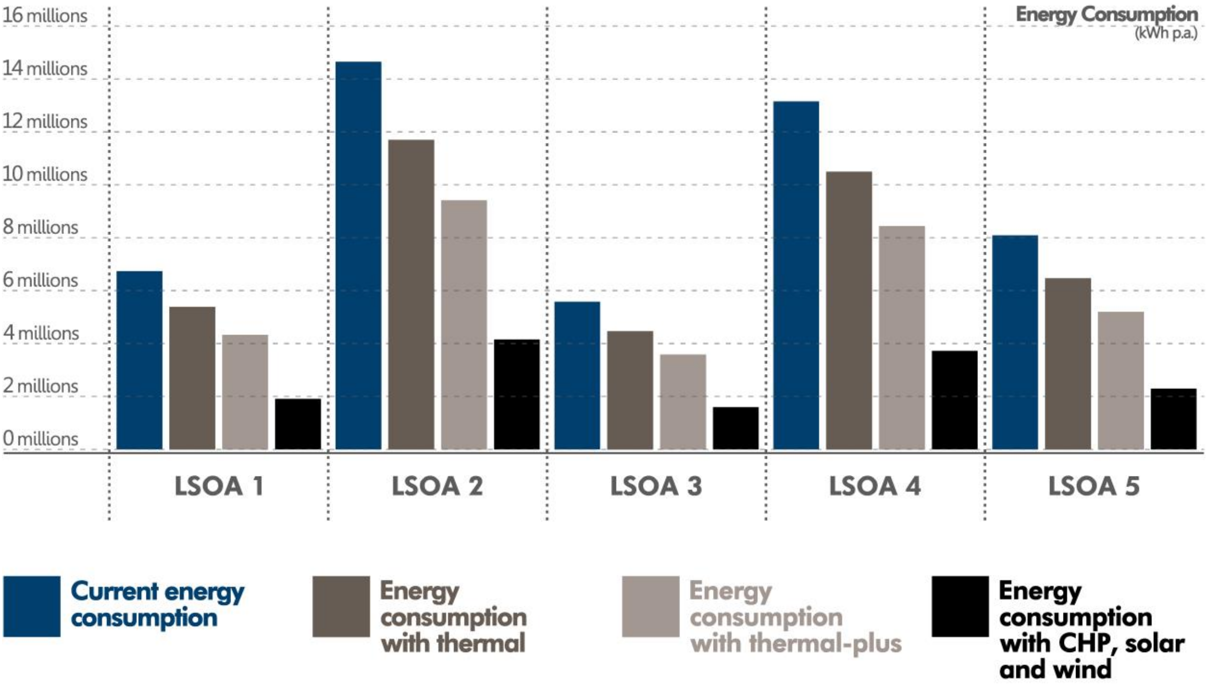

Figure 2. Graphic representation of renewables to energy consumption.

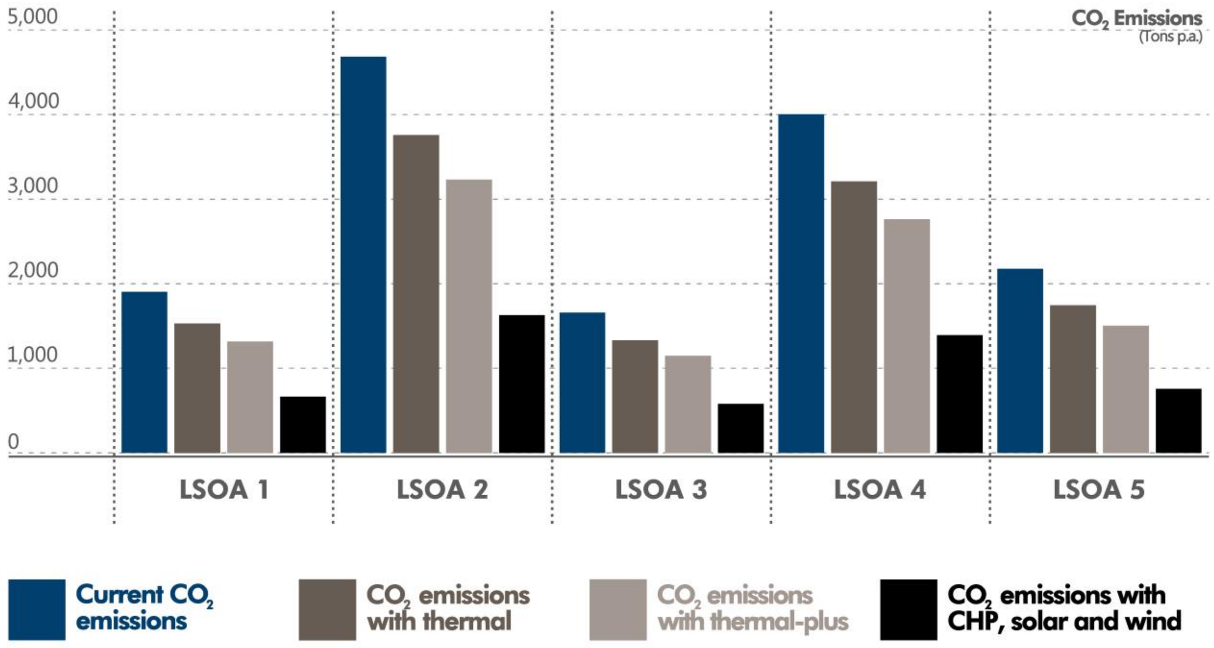

Figure 3. Graphic representation of renewables contribution to CO_2 emissions.

This suggests that if the buildings of city-districts, as energy efficient-low carbon zones, are to be climate neutral, then it is necessary for the mass retrofits promoted by smart cities to not only stand as future internet-based developments, but rest on the renewables of a CHP operating within a distributed energy system. These Internet-based developments in turn needing to be underpinned with the digital infrastructures of a smart grid supporting efficient heating and cooling applications, whose platform of data management can meter levels of consumption and rates of emission from the city-district by way of experiments in cloud computing and through the use of an IoT in this energy efficient-low carbon zone.

Table 7 links energy consumption to CO_2 emissions and connects the metabolic of this energy efficient-low carbon zone to the structure of tenure in the housing market. Using data drawn from LSOA's 1 and 5, these figures measure the consumption and emissions in the least prosperous and most affluent areas of the housing market within Hackbridge. LSOA 1 is ranked amongst the 21% least prosperous areas. LSOA 5 falls within the 30% most prosperous areas in England. It shows the social-rented sector to be concentrated in Area 1. Whereas it also shows that it is the owner-occupied and private-rented sectors which dominate Area 5. This indicates it is the social-rented sector that consume least energy and which emit the lowest amounts of CO_2 when compared to other types of housing (owner-occupied or private rented) in the structure of tenure.

Type	Age	HA	Average Energy Consumption (kVh p.a.)	Average CO_2 Consumption (Tons p.a.)	Tenure (%) Owner Occupied	Private Rented	Social Rented
I	1990s	1	14,253	5.712	80	12	8
C	1930s	2	20,226	5.841	29	15	56
B	1890-1920	3	33,309	7.616	80	12	8
		Total	67,789	19.06			
		Average	22,596	6.347			

Type	Age	HA	Average Energy Consumption (kVh p.a.)	Average CO_2 Consumption (Tons p.a.)	Tenure (%) Owner Occupied	Private Rented	Social Rented
B	1896-1913	18	37,972	9.358	87	10	3
L	1990s	19	16,956	5.44	87	10	3
F	Late 1930s	20	25,852	6.964	85	3	12
		Total	80,789	21.762			
		Average	26,930	7.254			

Table 7. Energy consumption and CO_2 emissions within the structure of tenure.

8. Reflections and critical insights

The significance of the area-based analysis reported on cannot be underestimated, as the levels of consumption and rates of emission across housing types has proven critical in the development of the mass retrofit. The explanation for this lies in the efficiency ratings of the respective housing types. In particular, with the 75% efficiency rating for the energy consumption and carbon emission within the social rented sector and fact the equivalent figures in both the owner-occupied and private rented sector fall beneath this threshold. In terms of the mass retrofit, these ratings above and below the 75% efficiency rating are significant because they are the threshold levels set for participation in the mass retrofit. Thresholds by which types of housing are either included in, or excluded from the retrofit that is under consideration. Given the social rented sector lies above this threshold, the decision has been taken to exclude it from the mass retrofit and include the owner-occupied and private rented sector, because they fall below it and can benefit from the improvements in energy consumption and CO_2 emission mass retrofits offer without coming up against the technological limits of any such action.

The problem with this decision is that while such a threshold does rank the occupants of the social-rented sector as the most energy efficient, this fails to compensate the occupants of this low carbon zone for being the best-behaved members of the housing market. Instead it does the opposite and not only excludes this sector of the community from the benefits of any such improvements, but the savings and reductions that would otherwise lift them out of fuel poverty.

The real significance of this participation threshold in favour of the owner-occupied sector and private rented tenures, tends to become even more evident when listing the potential benefits the social rented sector is also barred from and not able to access. For while the owner-occupied sector is able to benefit from; (1) lower energy bills and (2) payments for any surplus fed-back into the grid, neither these, nor any increase in the value of the housing can be appropriated by inhabitants of the social-rented sector. How the mass retrofit proposal is planned for and rolled out also tends to reinforce this bias. This is because the plan suggests the thermal and thermal-plus options, should form stage 1, with stage 2 and 3 following on from this.

Such a sequencing of the development, means the benefits of the retrofit are limited. In this instance, limited to the owner-occupied and private rented sectors of the housing market and do not extend into the social sector, which is unable to access them until the completion of stages 2 and 3. This means the contribution that renewables make to the full 78% reduction in carbon emission can be accessed by both the owner-occupied and private rented sectors during stage 1 and 2 of the retrofit, whereas the 28% reduction, which the social rented sector can benefit from, shall not be available until the completion of stage 2.

What the retrofit actions planned for the stage 3 development reveal to be smart about the ESCO, peak-loading management and dynamic pricing still needs to be evaluated. This is also the case for how the cloud computing of the IoT serves to further consolidate the climate neutral status of the city-district. With regards to this matter, all things equal, the extra 28% savings and additional reduction - forecast to be a further 5% - should offer the opportunity for the renewables to further reduce the levels of energy consumption and rates of CO_2 emission.

As the profile that surfaces under stage 1 is seen to over-compensate the middle-to-high-income groups for the energy consumption and CO_2 emission they register, the cross-cutting nature of the digital infrastructures, data management platforms and renewable energies which underpin the sustainability of stage 2 and 3 are significant (Deakin et al. 2014). As together they provide the intelligence needed for the energy savings and CO_2 reductions surfacing from this environmental profile, to cut across the structure of tenure in the housing market and allow the wealth created from the sustainable growth of this urban and regional innovation to be equally accessible. That is to say, be accessible by low, middle and high-income groups alike (Deakin and Reid, 2018).

8. Conclusions

The review of the literature set out in this paper, indicates the types of Ranking Systems and Future Internet development Giffinger (2008) and Schaffers et al. (2011) advance to explain the emergence of smart cities are limited, as the metrics they offer of future internet-based developments, fail to account for either the intellectual capital, or wealth created from the informatics of the computer science that underpins the digital infrastructures and supports the data management platforms of the energetic the renewables stand by. In going on to account for the metrics of these future internet-developments and opportunities they in turn offers cities to be smart, the TH model suggests that it is the reflexivity of the intellectual capital invested to create wealth from the informatics of computer science which is of particular interest. For according to this account of smart cities, intellectual capital is pivotal in cities becoming smart and capitalising on the potential they have to create wealth from the digital infrastructures of data management platforms the energetic of renewables rest on as a natural resource.

In highlighting the potential which the TH model has to break with the legacies of the past and begin casting smart cities as the metrics of future internet-based developments, this account of the intellectual capital invested in such a process of wealth creation, also serves to show how the digital infrastructures underpinning the informatics of the data management platforms and supporting the energetic of the renewables, set the stage for the cloud computing of an IoT, whose stock and flow of materials regulate the engineering and construction sectors' contribution to the metabolic sustaining the growth of this urban and regional innovation as an ecological modernisation. That ecological modernisation which is sufficiently resilient for the smart (micro) grids they lay down within city-districts to underpin the sustainability of energy efficient-low carbon zones which support climate change adaptions able to uphold the transition to a post-carbon economy.

Capturing the outcomes of the literature review in this way, it subsequently becomes possible to counter the claims that are made about smart cities by the likes of de Jong (2015), which suggests there is a tendency for the metrics of future internet-based developments to ignore the environment and focus instead on the economy. That is to say, counter them by bringing the environment centre stage as part of a critical synthesis. Centre stage as part of a critical synthesis which not only centres on the environment, but that positions it within the material whose scientific computation of the stocks and flows into and out of the ICT, engineering and construction sectors, serve to bottom-out the social-demographic structure of renewable energies. Bottom-out the social-demographic structure of renewable energies and get on top of this by capturing what the environment contributes to the sustainable growth of this urban and regional innovation.

The case-study analysis which the paper develops, also serves to amplify this message i.e. that environments count, by demonstrating how accounting for what might be best referred to as the geo-metrics of future internet-based developments do matter. Do matter in the sense which the stock and flow analysis tells us that merely being aware about the informatics of the computer science underpinning the digital infrastructures of data management platforms and supporting the energetic of renewables is not enough. Not enough because without knowing whether the wealth created from the informatics of the computer science that underpins the digital infrastructures of the data mangement platforms and which the energetic of the renewables in turn rest, also stand up as environments able to sustain the growth of an urban and regional innovation whose proceeds are shared equally, it is not possible to confirm if the level of energy savings and reduction in the rate of CO_2 emissions associated with the metabolic of this ecological modernisation is just. If the level of energy savings and reduction in the rate of CO_2 emissions that are associated with the metabolic of this ecological modernisation, is just in terms of the climate change adaptation the economics of such a smart, sustainable and inclusive growth strategy relates to.

The paper suggests that in order for the metrics of future internet-based developments to confirm whether-or-not the savings of energy and reduction in CO_2 emission attributed to the renewable energies is fair, it is necessary to: (1) baseline the social-demographic structure which the environenmentally sustainable growth of the urban and regional innovations stand; (2) go on to compile the environmental profile, which the sustainable growth of this urban and regional innovation assembles as the ecological modernisation of a city-district; (3) evaluate whether the energy efficient-low carbon zones such climate change adaptations bring about are neutral and if the metabolic driving this transition to a post-carbon economy is grounded in a smart, sustainable and inclusive growth strategy.

It suggests that only in this way is it possible to know whether the creation of wealth which is associated with the environmentally sustainable growth of this urban and regional innovation, serves as an ecological modernisation able to underpin the sustainability of city-districts and support them as the energy efficient-low carbon zones of climate change adaptations. In this instance, support them as the energy efficient-low carbon zones of a climate change adaptation, that distributes costs and benefits equally across the post-carbon economy of an inclusive growth strategy which is socially just.

What is perhaps most revealing is that in going on to establish this social baseline for the mass retrofit and compile the environmental profile associated with of the sustainable growth of this urban and regional innovation, the demographic structure of the ecological modernisation which emerges is not just. Given cities across Europe, USA, South America, Africa, Asia and China, all now share the ambition to be smart in leveraging the potential renewable energies have for the environment to sustain the transition to a post-carbon economy, the authors suggest these critical insights into the "reflexive instability of the intellectual capital", invested in future internet-based developments are significant. For while the informatics of the computer science underpinning the digital infrastructures of data management platforms and supporting the energetic of renewables may generate the smart and sustainable growth of an ecological modernisation that is climate neutral and an adaptation to change which does not add anything to global warming, the proceeds of what this metabolic contributes to approximately 50% of these savings and reductions are not equally shared.

The evidence presented in this paper would suggest this is because the digital infrastructures, data management platforms and renewable energies which underpin this urban and regional innovation, do not support, either the data capture, storage, or information needed for the cloud computing of any such IoT to assemble an environment that can sustain a mass retrofit as the climate change adaptations of a post-carbon economy whose inclusive growth strategy is socially just. For the digital infrastructures, data management platforms and renewable energies they capture data on, store and process information about as environments able to sustain the growth of this urban and regional innovation, is found to not only be socially divisive, but also so exclusive as to render the metabolic this generates at odds with civil society's expectation of environmental sustainability. In that sense, at odds with the publics' expectation and prospect there is for any environmentally sustainable growth of city-districts as energy efficient-low carbon zone to be socially inclusive. To be socially inclusive in granting those communities undergoing this process of ecological modernisation, equal access to the wealth they create, but which the housing market does not currently legally grant them a right to as adaptations to climate change.

In the interests of smart cities avoiding the potential which the intellectual capital of future internet-based developments have to de-stabilise the environmentally sustainable growth of any such urban and regional innovation, the technical efficiency threshold currently in force has to be removed as a metric that governs the wealth created from the ecological modernisation of climate change adaptation. This means grounding the distribution of wealth created, not in the technical efficiencies of a given tenure, but something else. Not in technicalities, but instead in the socio-demographic structure which the renewable energies of any environmentally sustainable growth stand as an urban and regional innovation and that a just appropriation of the wealth created from any smart, sustainable and inclusive growth strategy in turn rest. In that socio-demographic structure which not only baselines the renewable energies, but which also augments them into an act of wealth creation. Into an act of wealth creation, that relates the environmentally sustainable growth of such an urban and regional innovation to city-districts, which are able to underpin them as energy efficient-low carbon zones and whose climate change adaptation supports the transition to a post-carbon economy as an inclusive growth strategy seen to be socially just.

For it is only in base-lining the social-democratic structure upon which the renewable energies of this environmentally sustainable growth stand as an urban and regional innovation, that it subsequently becomes possible to not only create wealth from any such an ecological modernisation, but as the city-districts of energy efficient-low carbon zones, which the climate neutral adaptations of a post-carbon economy in turn render as an inclusive growth strategy. In turn render as an inclusive growth strategy known to be socially-just it terms of what smart cities represent as the metrics of future internet-based developments and the renewable energies of urban and regional innovation.

References

Bourdic, L. and Salat, S. (2012) Building Energy Models and Assessment Systems at the District and City Scales. Building Research and Information, 40 (4): 518-526.

Bourdic, L., Salat, S. and Nowacki, C. (2012) Assessing Cities: A New System of Cross-Scale Spatial Indicators. Building Research and Information, 40 (5): 592-605.

Brandt, N., Campbell, F, Deakin, M., Johansson, S., Malmström, M., Mulder, K., Pesch, U, Tatarchenko, O. and Årman, L. (2014) Technical Report: European Cities Moving Towards Climate Neutrality Participation, Indicators and Benchmarking, KTH, Stockholm.

Bristow, D.N. and Kennedy, C. (2013) Urban metabolism and the energy stored in cities: Implications for resilience. Journal of Industrial Ecology, 17 (5): 656-667

Caragliu, A., Del Bo, C. and Nijkamp, P. (2011) Smart cities in Europe, Journal of Urban Technology, 18(2): 65-82.

Caragliu, A., Del Bo, C. and Nijkamp, P. (2013) Smart Cities in Europe. In: Deakin, M. (ed) Smart cities: governing, modelling and analysing the transition. Routledge, Oxon.

de Jong, M., Joss, S., Schaven, D., Zhan, C. and Weijnen, M. (2015) Sustainable–smart–resilient–low carbon–eco–knowledge cities; making sense of a multitude of concepts promoting sustainable urbanization. Journal of Cleaner Production, 109: 25-38.

Deakin, M. (2011) The Embedded Intelligence of Smart Cities, International Journal of Intelligent Buildings, 3 (2): 189-187.

Deakin, M. (2014) Smart Cities: the State-of-the-Art and Governance Challenge. Triple Helix, 1 (1): 1-17.

Deakin, M. (2015) Smart Cities and the Internet: from Mode 2 to Triple Helix Accounts of their Evolution. In Vesco, A. ed. Smart Cities Research Handbook: Social, Environmental and Economic Sustainability, IGI Publishing, Hershey.

Deakin, M. (2018) Smart Cities, Metrics and the Future Internet-Based Governance of Urban and Regional Innovations. *S*cienze Regionali, 17 (1): 39-56.

Deakin, M. (ed.) (2013) Smart Cities: Governing, Modelling and Analysing the Transition, Oxford, Routledge.

Deakin, M. and Leydesdorff, L. (2013) The Triple Helix of Smart Cities: A Neo-evolutionist Perspective, in Deakin, M. (ed.) Smart Cities: Governing, Modelling and Analysing the Transition, Oxford, Routledge.

Deakin, M. and Reid, A. (2017) The embedded intelligence of smart cities: Urban life, citizenship, and community, International Journal of Public Administration in the Digital Age (IJPADA) (4): 62-74.

Deakin, M. and Reid, A. (2018). Smart cities: Under-gridding the sustainability of city-districts as energy efficient-low carbon zones. Journal of Cleaner Production, 173: 39-48.

Deakin, M., Campbell, F. and Reid, A. (2012a) The Mass-retrofitting of an Energy Efficient Low - Carbon Zone: Base-lining the Urban Regeneration Strategy, Vision, Master-plan and Redevelopment Scheme, Energy Policy, 45: 187-200.

Deakin, M., Campbell, F. and Reid, A. (2012b) The Mass-retrofitting of an Energy Efficient Low - Carbon Zone, Energy, 65 (4):197-208.

Deakin, M., Campbell, F., Reid, A. and Orsinger, J. (2014) The Mass-Retrofitting of an Energy Efficient – Low Carbon Zone, New York, Springer.

Fachinni. A., Kennedy, C. and Stewart, I. (2017) The energy metabolism of cities, Applied Energy, 186, 15: 86-95.

Giffinger, R., Kramar, H. and Haindl, G. (2008) The Role of Rankings in Growing City Competition. XI EURA Conference, Milan.

Hirst, P., Hummerstone, E., Webb, S., Karlsson, A. K., Blin, A. S., Duff, M., Jordanou, M. and Deakin, M. (2012). JESSICA for Smart and Sustainable Cities, European Investment Bank, Luxemburg.
Intergovernmental Panel on Climate Change (2015) Climate Change 2014: Mitigation of Climate Change (Vol. 3). Cambridge University Press.
Kennedy, C., Cuddihy, J. and Engel-Yan, J. (2007) The changing metabolism of cities. Journal of Industrial Ecology, 11 (2): .43-59.
Kennedy, C., Steinberger, J., Gasson, B., Hansen, Y., Hillman, T., Havránek, M., Pataki, D., Phdungsilp, A., Ramaswami, A. and Mendez, G.V. (2010) Methodology for inventorying greenhouse gas emissions from global cities. Energy Policy, 38 (9): 4828-4837.
Kennedy, C., Pincet l, S. and Bunje, P. (2011). The study of urban metabolism and its applications to urban planning and design. Environmental Pollution, 159 (8-9):1965-1973.
Kennedy, C. (2016). Industrial ecology and cities. In Taking Stock of Industrial Ecology, Cham: Springer
Komninos, N. (2014) The Age of Intelligent Cities, Oxford: Routledge.
Komninos, N., Pallot, M. and Schaffers, H. (2013) Special Issue on Smart Cities and the Future Internet in Europe. Journal of the Knowledge Economy, 13 (2): 119-134.
Kourtit, K., Deakin, M., Caragliu, A., Del Bo, C., Nijkamp, P., Lombardi, P. and Giordano, S. (2013) An advanced triple helix network framework for smart city performance, In: Deakin, M. (ed.) Smart Cities: Governing, Modelling and Analysing the Transition, Oxford, Routledge.
Lazaroiu, G. and Roscia, M., (2012) Definition methodology for the smart cities model. Energy, 47 (2): 326-332.
Leydesdorff, L. and Etzkowitz, H., 1998. The triple helix as a model for innovation studies. Science and public po*licy*, 25 (3); 195-203.
Leydesdorff, L., 2000. The triple helix: an evolutionary model of innovations, Research policy, 29 (2); 243-255.
Leydesdorff, L. and Meyer, M., 2006. Triple Helix indicators of knowledge-based innovation systems: Introduction to the special issue. Research policy, 35 (10); 1441-1449.
Leydesdorff, L. and Deakin, M. (2011) The Triple Helix of Smart Cities: A Neo-evolutionist Perspective. Journal of Urban Technology, 18 (2): 53-63.
Lombardi, P. and Giordano, S. (2012) Evaluating the European Smart Cities Visions of the Future. International Journal of the Analytic Hierarchy Process, 4 (1): 27-40.
Lombardi, P., Giordano, S., Farouh. H., and Yousef, W. (2012) Modelling the Smart City Performance. Innovation, European Journal of Social Science Research, 25 (2): 137-150.
London Borough of Sutton (2008) Energy Options Appraisal for Domestic Buildings in Hackbridge. Produced by Parity Projects. Available at: http://www.sutton.gov.uk/CHttpHandler.ashx?id=5173&p=0
London Borough of Sutton and Bioregional (2012) Hackbridge – a Zero Carbon Suburb. Available at: http://www.bioregional.com/files/publications/Hackbridge-an-area-based-strategy-for-zero-carbon-buildings-may2012.pdf
Mora, L., and Deakin, M. (2019). Untangling Smart Cities: From Utopian Dreams to Innovation Systems for a Technology-Enabled Urban Sustainability. Amsterdam: Elsevier.
Mora, L., Bolici, R., and Deakin, M. (2017). The First Two Decades of Smart-City Research: A Bibliometric Analysis. Journal of Urban Technology, 24 (1): 3-27.
Mora, L., Deakin, M., & Reid, A. (2019a). Combining Co-Citation Clustering and Text-Based Analysis to Reveal the Main Development Paths of Smart Cities. Technological Forecasting and Social Change, 142, 56-69.

Mora, L., Deakin, M., & Reid, A. (2019b). Strategic Principles for Smart City Development: A Multiple Case Study Analysis of European Best Practices. Technological Forecasting and Social Change, 142, 70-97.

Mora, L., Deakin, M., and Reid, A. (2018). Smart City Development Paths: Insights From the First Two Decades of Research. In A. Bisello, D. Vettorato, P. Laconte, & S. Costa (Eds.), Smart and Sustainable Planning for Cities and Region: Results of SSPCR 2017 (pp. 403-427). Cham: Springer.

Mora, L., Deakin, M., Reid, A., & Angelidou, M. (2019c). How to Overcome the Dichotomous Nature of Smart City Research: Proposed Methodology and Results of a Pilot Study. Journal of Urban Technology, 26 (2): 89-128.

Ratti, C., Baker, N. and Steemers, K. (2005) Energy Consumption and Urban Texture. Energy and Buildings, vol. 37 (7): 726-776.

Salat, S. (2009) Energy Loads, CO_2 Emissions and Building Stocks: Morphologies, Typologies, Energy Systems and Behaviour, Building Research and Information, 37 (5–7): 589-609.

Schaffers, H., Komninos, N., Pallot, M., Trousse, B., Nilsson, M. and Oliveira, A. (2011) Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation, in Domingue, J. et al. (eds.) The Future Internet: Future Internet Assembly 2011 - Achievements and Technological Promises, LNCS.