Adapting futures scenarios to study UK household energy demand

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Abstract

Greenhouse gas emissions originating from the built environment play a significant role toward climate change. Carefully planning the future of the building sector is key to mitigating these emissions. Addressing this problem using a predictive approach may miss possible futures we cannot anticipate. Using explorative scenarios to perform futures analysis helps widen the range of futures taken into account, which minimises this risk. Tools which use scenarios to help study the resilience of sustainable solutions for UK urban environment are already available. However, they do not facilitate in-depth analysis of future household energy demand. This paper considers how one such tool, 'Designing Resilient Cities' (DRC), could be modified appropriately. It includes: (1) a series of indicators representing factors affecting the energy demand in dwellings, and (2) their characteristics for each scenario to complement the narratives in DRC. As a case study to validate these additions, the resilience of a recommendation to decrease domestic electricity consumption is evaluated.

Keywords

Sustainability, Energy conservation, Environment

List of acronyms

GSG Global Scenarios Group (Tellus Institute)
DRC Designing Resilient Cities (tool to perform futures analysis)
UF Urban Futures (project which developed DRC)
NSP New Sustainability Paradigm (scenario)
PR Policy Reform (scenario)
MF Market Forces (scenario)
FW Fortress World (scenario)

1 Introduction

Although we live in a world where post-truth intoxicates the beliefs of millions of people worldwide, there is scientific consensus on human-made climate change driven by greenhouse gases (Cook *et al.*, 2016). Climate change is one of the Stockholm Resilience Centre's boundaries defining a safe operating space for humanity which we have already violated (Rockström *et al.*, 2009). In order to mitigate this threat, most countries are setting targets to reduce their carbon dioxide emissions. In the case of the UK, in 2008 the Government's Climate Change Bill set a legally binding target of a 80 % reduction in carbon dioxide emissions by 2050 compared to 1990 levels (DEFRA, 2008), and it recognises that the built environment plays a crucial role in achieving this target (Department of Energy and Climate Change, 2009).

Under *business as usual*, energy demand in the global building sector is expected to increase by 50 % by 2050 (IEA, 2013). It has been estimated that to achieve the global goal of limiting the temperature rise to 2 ºC, the building sector has to reduce its carbon dioxide emissions by 77 % compared to the 2013 baseline (IEA, 2013). Carefully planning the future of the built environment —as well as its energy supply technologies and networks— is key in this effort, as we need to ensure resilient and flexible solutions that continue to perform effectively in the future.

The future is, however, uncertain. Solutions which seem very appropriate today may not be useful in a matter of few years if this uncertainty is not taken into account during their design phase. To not do so would mean wasting resources and effort in what would soon become stranded assets. Present research on sustainability faces this problem principally by utilising a predictive approach —*i.e.* based on current and historical trends and predictions. This is perfectly valid, however, it does not account for futures we cannot anticipate (Rogers *et al.*, 2012).

Scenario analysis can help in this regard as it facilitates widening the range of futures considered. So far, scenario analysis has been used mainly to study the consequences of global level interventions, long-term evolution of different systems, and to inform polices (Boyko *et al.*, 2012). However, it is not extensively used to study the performance of specific interventions, or to evaluate the effects that different futures could have on a specific system. In particular, scenario analysis could be used to study the development of domestic energy demand, and the performance of interventions aimed at decreasing it.

In the future scenarios literature, there exist different types of scenarios, tools and methods designed to help perform futures analysis in a wide range of contexts. One tool which is especially suited to study the performance of sustainable interventions in the urban environment is 'Designing Resilient Cities' (DRC) (Lombardi *et al.*, 2012), with their 'Urban Futures Method' (Rogers *et al.*, 2012). This tool was developed by a project called 'Urban Futures' (UF), which published it in 2012 in parallel to a special issue of this same journal. That issue was dedicated to the use of future scenarios to evaluate the resilience of sustainable solutions in the urban environment in UK (Rogers, 2012).

UF used as the basis for their scenarios those developed by the Global Scenarios Group (GSG), a project from the Tellus Institute. These scenarios are integrated —considering major economic, social, cultural, institutional, technological and environmental questions at the same time— and disaggregated by regions and sectors; and they convey this information in various points in the future until the year 2100 (Raskin, Electris and Rosen, 2010). These are explorative scenarios which cover a broad range of possible directions in which the future could unfold, and can be used to formulate 'what if' questions (Rogers *et al.*, 2012). GSG took special care to make the scenarios a logical and plausible evolution from the world today and internally consistent (Gallopin *et al.*, 1997). UF adapted four of these scenarios to UK cities in 2050 and developed DRC to help to evaluate the resilience of sustainable urban interventions (Boyko *et al.*, 2012; Lombardi *et al.*, 2012).

The four scenarios developed by UF are internally-consistent adaptations to the UK urban environment of the following GSG scenarios:

- New Sustainability Paradigm (NSP) – engaged society with a shared vision for sustainability and quality of life,
- Policy Reform (PR) – coordinated action from governments for sustainability and against poverty,
- Market Forces (MF) – reliance on the self-correcting logic of competitive markets,

- Fortress World (FW) – alliances of the powerful to protect their interests, security first; poor majority live outside the fortress (ratio 35:65).

These four scenarios extend to the extremes of plausibility and are sufficiently distinct to cover a wide range of possible futures (Hunt *et al.,* 2012a). The names of the scenarios give a good idea of their characteristics. However, if further description is sought, brief general narratives can be found in the following literature: for the general GSG scenarios see Hunt *et al.* (2012b), for a version representative of OECD countries see Rogers *et al.* (2012), and for the UK urban version developed by UF see Boyko *et al.* (2012) or Lombardi *et al.* (2012).

The 'Urban Futures Method' "aims to broaden the way we think about the form, function, and context of urban development and regeneration by focussing on the likely long-term performance of today's urban design solutions, and their associated vulnerabilities" (Lombardi *et al.*, 2012). This aim partly covers the study of the energy demand of UK's residential sector. However, to do an in-depth analysis of this topic, the tool has to be adapted. Fortunately, the scenarios used in DRC are designed in a way that new indicators and characteristics can be added to them, as well as new scenarios incorporated to the tool (Boyko *et al.*, 2012).

And so, the objective of this paper is to adapt the scenarios from DRC to the study of the energy demand of UK's residential sector. This is done by adding a set of indicators related to household energy demand or its causes, and developing their characteristics for each scenario, which increases the detail of information the scenarios provide in this domain. A short case study is also presented here to demonstrate the use of these additions.

1.1 Future scenarios

One very important characteristic of scenarios is that they do not intend to predict the future. What scenarios do, is to map a *plausibility space* in order to explore or study it (Schwartz, 1991; Foresight Horizon Scanning Centre and Government Office for Science, 2009; Boyko *et al.*, 2012; Rogers *et al.*, 2012). Therefore, scenarios are tools to help thinking about the future in a structured way and based on a set of assumptions which are previously defined.

There exist many types of scenarios with different features depending on the use to which they are put. Some, model possible outcomes and consequences from current actions and may not need any narrative —*e.g.*, the different emissions scenarios that IPCC developed for each of their storylines (IPCC, 2000). The scenarios discussed here, in contrast, are defined by narratives and explore distinct plausible socio-economic futures which could arise from the present.

The use of these kinds of scenarios provides information on the possible evolution of any subject of study in a range of futures. This can be valuable for many purposes. In particular, it can provide information on the performance of any proposed intervention in different futures, thus helping to improve its resilience —*i.e.* its effectiveness in all the scenarios— or, at least, informing of its weaknesses (Boyko *et al.*, 2012; Lombardi *et al.*, 2012; Rogers *et al.*, 2012).

The narrative of the scenarios in DRC comprises a short general narrative and the characteristics of a set of indicators. The general narrative describes briefly and precisely the main aspects of the scenario, and the characteristics of the indicators, its details. The indicators are variables that represent attributes of the system —*e.g.* the size of the population in the scenario— and they can represent any aspect(s) of interest. They have to be accurately defined, with a unit of measurement, and normally their value in a reference scenario or some kind of benchmark. The characteristics of an indicator quantify or qualify, with short statements, its performance under each scenario, normally in relation to the reference (Boyko *et al.*, 2012). For ease of use, the trend in relation to the reference is also portrayed with an arrow. See Figure 1 for a graphical depiction of the composition of a DRC scenario narrative.

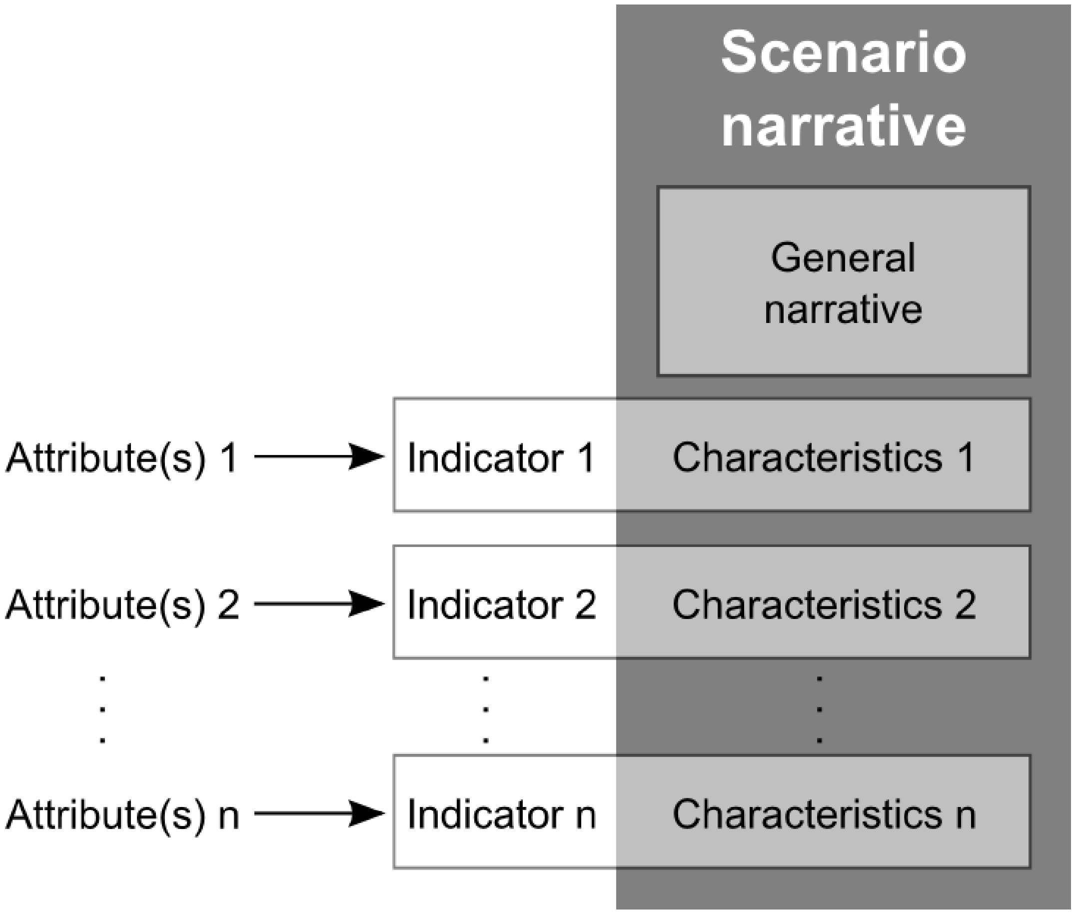

Figure 1. DRC scenario narrative composition. The narrative of each scenario comprises a brief general narrative describing the main aspects of the scenario and the characteristics describing the performance of a set of indicators in the scenario. These indicators are variables representing one or more attributes of the system.

Note that all scenarios are defined by the same set of indicators; the differences in the characteristics of these indicators between the scenarios are what, in conjunction with the general narratives, portray the differences between the scenarios. In order for the scenarios to provide coherent information, it is important that the characteristics of the indicators are internally consistent and that they are based on the relevant literature. Both, GSG and UF have put great effort in doing so (GTI, 2018; Gallopin *et al.*, 1997; Raskin *et al.*, 1998, 2002; Rogers *et al.*, 2012). Otherwise, the characteristics of one indicator could be contradictory with those of another indicator or with the general narrative of the scenario.

1.2 Energy demand in households

Many highly interrelated factors play a role in determining the energy any given building will consume to establish and maintain a comfortable temperature, air quality and light levels (Thomas, 2006).

Larger dwellings tend to use more energy, but still with extensive differences between similar dwellings (Wright, 2008). When trying to understand the key factors which explain the energy consumed in buildings, building factors alone are shown to explain at least 39 % of the variability of energy use in buildings (Sonderegger, 1978; Guerra Santin, Itard and Visscher, 2009; Huebner *et al.*, 2015a). However, Huebner *et al.* (2015a) shows that when taking into account other factors (such as socio-economic factors —which by themselves explain 24 % of variability) in a combined model, they can only explain 44 % of variability.

This leaves more than 50 % of the variability in domestic energy consumption *unexplained* (Huebner *et al.*, 2015b). Indeed, a crucial factor in the energy households consume is the behaviour of the inhabitants of the dwellings (Firth *et al.*, 2008; Perry and Bessant, 2014). Heating (gas) consumption is mainly influenced by occupancy of the property (who, how long...) and temperature management (Fell and King, 2012; Weber *et al.*, 2017), with ventilation behaviour having a major impact too (Weber *et al.*, 2017). Variables influenced by people have the strongest predictive power to explain English household non-heating electricity consumption (Huebner *et al.*, 2016). This consumption is determined mainly by the type and number of electrical appliances, and the use the occupants make of them (Firth *et al.*, 2008; Huebner *et al.*, 2016). However, studies repeatedly show that it is very difficult to change the energy behaviour of a large group of users (Perry and Bessant, 2014).

The energy used for space heating is, by far, the largest slice of the energy used in UK households. Together with water heating —the second largest slice— they accounted for around 80 % of the energy used in UK households in 2011 (Palmer and Cooper, 2013). The energy source used for heating by the vast majority of homes in the UK (more than 80 %) is gas. Most of the non-gas energy used for heating, as well as virtually all the energy used for non-heating related purposes in UK households is electricity. Therefore, these two sources of energy account for almost all the energy used in UK households.

Better building standards and new regulations mandating and promoting them promise to decrease the energy consumed in new buildings. However, there is a large stock of already constructed residences which need to be addressed; it is estimated that two-thirds of the dwellings likely to be in use in UK in 2050 were already constructed in 2005 (Boardman *et al.*, 2005). Therefore, significantly reducing the energy consumption of domestic buildings means the existing stock needs to be refurbished. It is calculated that with only the insulation of lofts and cavity walls, the consumption of fuel for space heating in England could be reduced by between 10 % and 17 % (Hong *et al.*, 2006).

Some recommendations to decrease household electricity demand arising from one of the biggest measurement campaigns ever made, in Sweden, are to limit the power consumption of appliances on standby to 0.5 W, encourage cutting the electrical supply of the appliances instead of leaving them in standby mode, and accelerating stricter consumption norms to make class A appliances become the standard (Zimmermann, 2009).

A futures analysis of the factors affecting the energy demand in households would identify a range of distinct plausible paths this demand could take in the future, thus reducing the uncertainty faced when designing interventions, plans or regulations affecting it.

2 Developing domestic energy demand indicators

This section describes the methods used to define the indicators that needed to be developed to study the energy demand of the domestic sector in the context of the tool 'Designing Resilient Cities' (DRC) (Lombardi *et al.*, 2012), as well as how their characteristics for the four future scenarios were developed.

The system attributes that the indicators developed here represent are the main factors affecting the energy demand of households. These factors can be found, for example, in Bhattacharjee and Reichard (2011), Huebner *et al.* (2015a), Jones and Lomas, (2015), Jones, Fuertes and Lomas (2015). These sources were used to rank factors in order of importance. Factors which overlapped significantly with each other and with those from DRC were synthesized to a single indicator (*e.g.* the factors 'number of rooms', 'number of bedrooms' and 'number of floors' were blended into 'total floor area'); sets of factors conveying redundant or overlapping information were grouped to form a smaller number of indicators when this did not imply significant loss of information (*e.g.* three factors grouped to create two indicators); and factors with smaller or no clear impact in the energy demand of households, or without reliable information to characterise an indicator, were discarded (*e.g.* the infancy of domestic energy storage technologies would have made the analysis of their future evolution very uncertain). Then a justification and/or definition was written for each indicator along with the question the indicator answers.

Before developing the characteristics of an indicator, the current value of the indicator was found, and the factors on which the indicator depends were listed. Then, the characteristics of the indicators which give information about these factors (both, from DRC and from the list of indicators developed for this analysis) were put together. If needed, missing information about any of the factors was added from the literature related to the GSG (GSG, Tellus Institute), as well as the characteristics of other related indicators and/or context information extracted from the general narrative of the scenarios. See the indicators and other information used to derive the characteristics of each new indicator in Table 1. With this information the narrative for the characteristics of the new indicators was derived for each scenario, and their general trend in relation to the baseline symbolized by an arrow. Figure 2 depicts an analogy between the process to derive the characteristics of a new indicator for one scenario and a sum. As many indicators depend on each other, iterations of the whole process helped improve the final result. Generally, for clarity, a short review of the information put together for each scenario was written (see Table A1 - 'Review and context' in Appendix). In case of isolated discrepancies between the characteristics of the indicators used to derive new indicators and the general narrative of the scenarios, the general narrative has been used. Find a brief justification on the choice of indicators in the Supplementary information S1.

Table 1. Indicators and other information used to derive each of the new indicator's characteristics. References: E[R] report (Greenpeace, 2015), General narratives from DRC (Lombardi *et al.*, 2012), General GSG narratives (D. V. L. L. Hunt, Lombardi, Atkinson, Barber, *et al.*, 2012), Technical document (Electris *et al.*, 2009), Table generator tool (Tellus Institute, no date).

Indicator	Indicators from 'Designing resilient cities'	Indicators developed in this work	Other factors and sources
Adoption of domestic (or community) micro-generation	• Public service spending • Energy efficiency of building and urban morphology	• Energy prices (domestic) • Attitudes to energy efficiency and sustainability	• Information in the E[R] report • General narratives from DRC
Attitudes to energy efficiency and sustainability	• Attitudes to consumerism • Civic activism	--	• General GSG narratives
Average dwelling (usable) floor area	• Average household size • Housing affordability • Urban dwelling density • Settlement pattern (city scale) • Settlement pattern (neighbourhood scale) • Need for affordable housing	• Type of building	• General narratives from DRC.
Average number and frequency of use of electric appliances	• Average household size • Attitudes to consumerism • Income inequality	• Attitudes to energy efficiency and sustainability	• Information in the Technical document
Dwelling area per occupant	• Average household size • Household overcrowding	• Average dwelling (usable) floor area	--
Energy poverty	• Energy efficiency of building and urban morphology • Income • Income inequality • Public service spending • Community cohesion	• Energy prices (domestic) • Adoption of domestic (or community) microgeneration	--
Energy prices (domestic)	--	--	• Information in the E[R] report • Information in the Technical document • Table generation tool
Type of building	• Adaptability of buildings and supporting infrastructure to new use • Settlement pattern (city scale) • Settlement pattern (neighbourhood scale) • Urban dwelling density • Total amount of green space • Urbanization • Land use • Planning policy • Planning adherence	--	• General narratives from DRC

Use of electric space (and water) heating	--	• Adoption of domestic (or community) microgeneration • Attitudes to energy efficiency and sustainability • Energy prices (domestic)	• Information in E[R] • Information in the Technical document

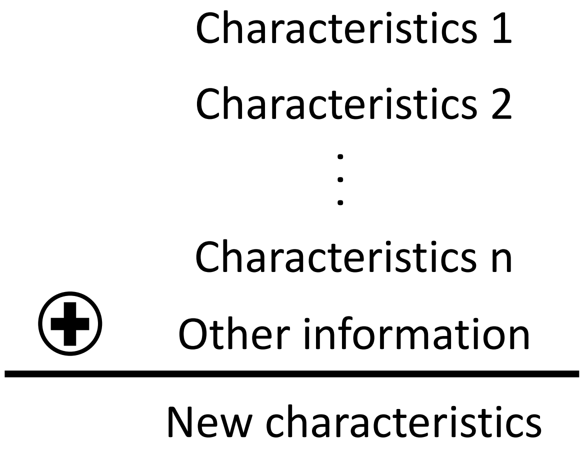

Figure 2. Analogy between the derivation of the characteristics of a new indicator for one scenario and a sum: the added information given by the characteristics of the relevant indicators and other relevant information ‘logically produces’ the characteristics of the new indicator as a result.

2.1 Indicator 'Energy prices (domestic)'

The previous method was not used to develop the indicator 'Energy prices (domestic)', as there are many factors which influence these prices and most of these factors are not related to the indicators from DRC. Based on the fact that the GSG used previous versions of the Energy [R]evolution report (Greenpeace/EREC, 2007, 2008) to develop the energy-related information of their scenarios, the basis to develop the characteristics of this indicator was the information about future energy prices from the latest Energy [R]evolution report (Greenpeace, 2015). See Appendix A7 for details.

3 Results

The results of this work are presented here in table form (Table 2). The table shows the indicators developed, their metrics and baselines. Next to them, for each scenario it shows their global tendency in relation to the baseline (by means of an arrow) and their characteristics. The scenarios are: New Sustainability Paradigm (NSP), Policy Reform (PR), Market Forces (MF), and Fortress World (FW).

Part of the results which give context to this table can be found in the Appendix. There, the following information is provided for each indicator: a justification or definition, the question it answers, an extended version of the baseline*, and a short description of its context for each scenario (Table A1 - Review and context)*. It is recommended to have the Appendix at hand when using the results table.

(* not available for all indicators)

Table 2. Indicators table: characteristics of each of the new indicators for each scenario.

Indicator	Metric	Baseline	Characteristics			
			UK urban NSP	**UK urban PR**	**UK urban MF**	**UK urban FW** (rich | poor)
Adoption of domestic (or community) micro-generation	% of domestic energy consumption met with micro-generation	1.3 % domestic (2016) and ~0.1 % community (2017)	⇑ Most domestic energy consumption is met with microgeneration, mainly at community level.	⇑ A large percentage of domestic energy consumption is met with on-site or community microgeneration.	⇑ On-site microgeneration increases but the percentage of domestic energy met by it is not very large.	⇑ | ⇓ The overall adoption of microgeneration and the percentage of domestic energy met by it are slightly higher than current.
Attitudes to energy efficiency and sustainability	N/A	some good intentions, less results	⇑ People have the will to be sustainable, the information to be so is widely available, and rules and society favour it. The result is a very sustainable society with people willing and able to be sustainable.	⇑ People's mindset does not change substantially from the current. However, the government puts a lot of effort in sustainable measures to make sustainability the default option. Information is reliable and available, making it easier to act sustainably. The result is a society which is more sustainable than currently (but far less than in NSP), especially the individuals who are engaged.	⇓ Sustainability is far from being a priority for the people, rules do not favour it in any especial way, information is still poor and confusing, and society does not make it easy to be sustainable. There is no big change in society's sustainable attitudes although they worsen, and society makes it as difficult to be sustainable as currently or more. The result is a society which is less sustainable.	⇓ | ⇓ Rich: governments try to keep up with sustainability measures but their priority is security. People, locked up in their enclaves, are not —or do not want to be— aware of the rest of the world. Their attitudes to sustainability are almost inexistent. Poor: although some —especially the youth— grow expectations of fairness and may dream of sustainability, they have many much more urgent issues to deal with.

Average dwelling (usable) floor area	average usable floor area in m^2	mean total usable floor area of 95 m^2 (2013)	⇔ Although people tend to live together in larger households than currently, the average dwelling usable floor area decreases only slightly. This is mainly due to the increased use of flats rather than houses and is exacerbated by the co-housing movement.	⇓ As household size decreases and there is an increase in typically smaller dwellings (flats), the average dwelling floor area decreases notably.	⇓ The average dwelling floor area decreases. The main effect is, however, the polarisation: with a strong increase in dwellings with less than 50 m^2 of internal floor space, and also an increase in those with more than 110 m².	⇑ | ⇓ Rich: the average dwelling floor area for the rich is much higher than the current (110 m² being close to their lower end). Poor: the average dwelling floor area for the poor is much lower than the current. Most of those with dwellings larger than 50 m^2 share their dwelling and many cannot even afford to live in formal developments.
Average number and frequency of use of electric appliances	N/A	almost ubiquitous presence of washing machines, refrigeratio n and media appliances (2011)	⇓ People tend to have and use appliances less than today.	⇑ Appliance use and ownership is similar to current, only slightly higher due to smaller households.	⇑ Dwellings have a larger number of appliances and they are more intensively used than today.	⇑ | ⇓ Overall there are less appliances and are less used because of the large weight of the poor population (35:65).
Dwelling area per occupant	m^2/person	one occupant every 41.3 m^2 (2011-13)	⇓ The dwelling area per occupant decreases considerably out of choice (very homogeneously, there is almost no overcrowding).	⇓ The area per occupant decreases moderately and homogenously, not by personal choice but due to regulations (e.g. favouring flats over houses, which tend to be smaller).	⇑ The average area per occupant increases to some extent. However, the main contributors are middle to higher classes, as for a part of the lower classes it may decrease.	⇑ | ⇓ Rich: increase greatly their area per occupant. Poor: decrease greatly their area per occupant.

Energy poverty	% of population in energy poverty	around 11.0 % (approximately 2.50 million households) (2015)	⇓ Better housing, the almost inexistence of poor people, and government's and society's engagement reduce energy poverty to almost zero.	⇓ The decrease in poor people, better housing and the engagement of the governments contribute to a strong decrease in energy poverty.	⇔ Although inequality increases substantially, the high increase in GDP is able to keep energy poverty similar to current.	⇓ | ⇑ No energy poverty among the rich. Almost all within the poor are energy poor.
Energy prices (domestic)	p (penny sterling)/kWh	Electricity (e): 15.47 p/kWh (2016); Gas (g): 4.31 p/kWh (2016)	e⇑ g⇓ Electricity price will increase similarly to that in MF (17.36p/kWh). The gas price will decrease further than in PR (3.54 p/kWh).	e⇔ g⇓ Electricity price will be very similar to current, 15.25+p/kWh. Gas price will steadily decrease until 3.54 p/kWh.	e⇑ g⇑ Electricity price will increase almost steadily until 17.36++p/kWh. Gas price will steadily increase until 6.21p/kWh.	e⇑ g⇑ Electricity price will increase even further than in MF (17.36+++ p/kWh). Gas price will increase but less than in MF (6.21- p/kWh).
Type of building	% of the building stock compared to baseline	End terrace 10.4 %, mid terrace 18.8 %, semidetached 27.6 %, detached 22.6 %, flat 20.6 % (2013)	Flats: increase. Terraced: similar with tendency to decrease. (Semi-) detached: decrease.	Flats: increase. Terraced: slight increase. (Semi-) detached: decrease (especially semi-detached, as people who can afford it prefer to pay more (detached) for increased privacy).	Flats: increase. Terraced: moderate decrease. (Semi-) detached: increase.	Rich: Flats: strong decrease. Terraced: slight increase. (Semi-) detached: strong increase. Poor: Flats: stay the same percentage. Terraced: decrease. (Semi-) detached: strong decrease. Appearance of large informal developments with shacks and tent-like dwellings.

Use of electric space (and water) heating	% of households using electric heating	8.5 % (2.2m households) (2015)	⇑ There is a moderate increase in use of electric space heating.	⇑ There is an important growth in the use of electric space heating, mainly incentivised by the government. Probably the increase is slightly smaller in electric water heating as technologies as solar thermal are normally not used for space heating.	⇑ There is a slow increase in the use of electric space and water heating systems.	⇑ | ⇓ The general trend is a slight decrease in the use of electric space and water heating systems. However, it increases within the rich.

A table similar to this one with all the indicators from 'Designing resilient cities' can be found here (http://designingresilientcities.co.uk/downloads/Indicators-2.xls.zip)

4 Case study

To demonstrate the utility of the indicators and characteristics developed in this work, DRC is used with the additions presented here to evaluate the resilience of one of the recommendations of the Swedish measurement campaign mentioned in the introduction (Zimmermann, 2009): the implementation of a ban to appliances with standby power above 0.5 W.

The UF methodology consists of 4 steps: 1) identify a solution-benefit pair, 2) identify the necessary conditions, 3) determine the performance of necessary conditions in each scenario, and 4) determine the resilience of the pair in the future. With this information one can decide whether to implement the solution or not. For more details about the UF methodology see Lombardi *et al.*, (2012) or Rogers *et al.*, (2012).

The benefit of the solution chosen is to decrease the electricity consumed in households. Therefore, the solution-benefit pair is: 'implementation of a ban on appliances with standby power above 0.5 W'-'decrease the electricity consumed in households'.

The identified necessary conditions for this solution-benefit pair to work are:

1. Appliances must be used
2. Users must use standby mode
3. Governments must be able to enforce the ban
4. Policy must be maintained despite changes in government

Table 3 shows the summary of the futures analysis for the necessary conditions above. The characteristics of 'Average number and frequency of use of electric appliances' directly determine the performance of condition 1. To determine the performance of condition 2, the characteristics of several indicators are needed, with 'Attitudes to energy efficiency and sustainability' and 'Energy price (domestic)' being central. For the other two necessary conditions, the existing DRC covers their analysis. Therefore, without the additions presented in this paper, a user choosing to evaluate the resilience of such a benefit-solution pair would need to infer *ad hoc* the information used to evaluate conditions 1 and 2. This means that such evaluation would have probably been done without some of the relevant information, and this would likely cause the result to be less consistent.

Table 3. Summary of the futures analysis of the conditions needed for the pair 'implementation of a ban to appliances with standby power above 0.5 W'-'decrease the electricity consumed in households' (✓, supported in the scenario; ?, questionable if supported in the scenario; ✕, not supported in the scenario).

Condition	Performance			
	NSP	PR	MF	FW (rich|poor)
Appliances must be used	✓	✓	✓	✓ | ✕
Users use standby mode	?	✓	✓	✓ | ✕
Governments must be able to enforce the ban	✓	✓	?	?
Policy is maintained despite changes in government	✓	✓	?	?

The results of the analysis recommend implementing the solution because it delivers benefits in all scenarios. Its weak points are in MF and FW, where pressure from users (MF) and/or from producers (MF and FW) could lead the government to either withdrawal the measure or be lax in its application; and in FW where it is not useful for the poor. However, the application of the measure obliges producers to develop low consuming standby modes which are appealing to users. Only if producers do not manage to do it, or the implementation of these standby modes continues to be expensive for the producers will these benefits be jeopardised. See Table 4 for a synthesis of the results for each scenario.

Table 4. Synthesis of the results of the futures analysis of the solution-benefit pair 'implementation of a ban to appliances with standby power above 0.5 W'-'decrease the electricity consumed in households'.

NSP	PR	MF	FW
The solution delivers its intended benefits. It does so less than in PR because it is less needed: fewer appliances are used and they are often fully stopped instead of left in standby mode.	All conditions perform well. In this scenario, the solution is useful and needed.	This is a very useful and needed solution in this scenario. However, it is possible that it is withdrawn due to market pressures (from users or producers), or not fully enforced.	This is a useful and needed solution for the rich only, as the poor barely use appliances and turn them off when not in use. Although the government is more keen than in MF in securing resources, they may make exceptions when faced with large companies.

5 Discussion

It is important to apply futures analysis to sustainable interventions of all kinds to evaluate their resilience and decrease by design the possibility that assets grow stranded while still operative. Broadening the possible uses of scenario analysis to specific domains, as done in this work, may help in this regard.

This work shows how, indeed, the scenarios from 'Designing Resilient Cities' (DRC) can be complemented and adapted to the specific needs of the user. Figure 3 portrays it graphically: some factors affecting the energy demand in households were not characterised in DRC; they have now been characterised and complement the tool. The scenarios adapted here have a structure —a general narrative plus the characteristics of a set of indicators (Figure 1)— very similar to that of a large body of scenarios developed in the literature. Therefore, this work demonstrates also how such types of scenarios could be adapted to study specific domains of interest outside the original scope of the scenario.

As the case study shows, the generation of the new indicators presented here allows the systematic evaluation of interventions aimed at decreasing the energy consumed in households. This demonstrates the power of future scenarios and their possible extensions to help reveal where alternative thinking may help policy and practice. The specific extension presented here also allows, for example, to explore the evolution of different aspects related to the household energy demand in the different future scenarios, or to project into them current household energy demand data to study their evolution. These properties can be used to inform better regulations or interventions related to the built environment or to plan better, more resilient, energy networks to supply dwellings.

This paper further supports the evidence from the extensive literature regarding future scenarios, in that these are powerful tools to help thinking about the future. In addition, not only does it convey the additional tables of characteristics for each scenario to aid that thinking; it also trains the readers in the process of future thinking and scenario building so that they can form their own arguments. The readers, therefore, are able to use future scenarios and also to develop them further if necessary.

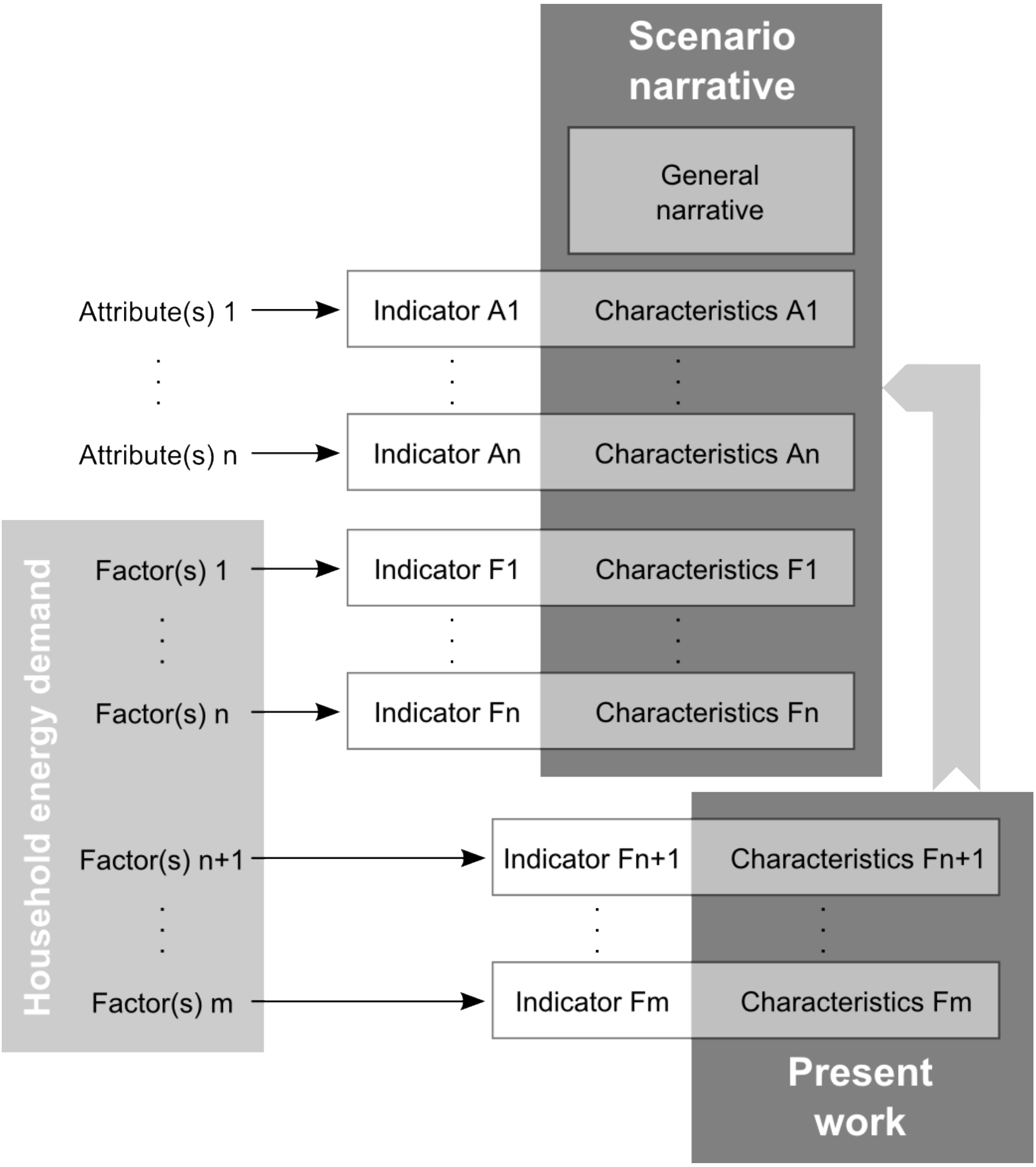

Figure 3. Graphical description of the work done for this paper and how it complements the scenarios from DRC. Some of the attributes represented by the indicators from DRC are factors affecting the energy demand of households. The work done here has defined indicators to represent the missing factors affecting the energy demand of households and characterised them to complement the scenarios from DRC.

6 Conclusions

In order for any intervention not to lose its effectiveness in the future, it is important to make sure it is resilient regardless how the future evolves. Future scenarios are a good tool for helping to designing such resilient interventions. In particular, buildings are responsible for a significant proportion of the greenhouse gas emissions and their average lifespans are very long. It is, therefore, crucial for any intervention in the built environment to deliver its desired effects irrespective of the future which arises. In addition, future scenarios can as well reveal where alternative thinking may help to improve policy for a changing future.

The factors affecting the energy demand in households are complex and interrelated. However, it is possible to curate a set of indicators to take them into account and characterise their evolution in a range of distinct futures.

A set of indicators were characterised to adapt the tool 'Designing Resilient Cities' (DRC) to the study of the energy demand in the residential sector. As shown with the case study, this set of indicators can be successfully used, together with DRC, to evaluate the resilience of interventions aimed at decreasing the energy demand in households. This can be used to improve the design of any kind of intervention in this domain, *i.e.* policy related to housing or interventions aimed at decreasing the energy demand in households.

This paper has demonstrated the methods used to expand existing future scenarios. In doing so, it trains the readers in future thinking, which they can then use in other domains.

As future work, DRC could be extended to other specific domains of the urban environment. It could also be adapted to other urban environments or to take climate change into account.

Appendix

A Derivation of indicators

A1 Adoption of domestic (or community) microgeneration

Definition/Justification: Microgeneration partly avoids the need to demand energy.

Question: What's the percentage of domestic energy consumption met by microgeneration?

Baseline UK: in 2016, consumption of self-produced electricity by the domestic sector was 1356 GWh, which accounts for 1.3 % of all domestic consumption (BEIS, 2012), with a total capacity of 2.55 GW (Ofgem, 2017). Total capacity of community installations was about 0.23 GW (Ofgem, 2017), accounting for ~0.1 % of consumption. In 2010 total installed microgeneration capacity (including commercial and industrial) in UK was almost zero.

Review and context: See Table A1.

A2 Attitudes to energy efficiency and sustainability

Justification/definition: This indicator does not measure intentions but results; therefore, it includes education as well as personal preferences, habits and social trends. Intentions do not always match results; partly due to lack of knowledge, difficulty to change habits (Huebner, Cooper and Jones, 2013; Huebner *et al.*, 2015b), or social environment making it difficult.

Question: What are the general attitudes, knowledge and ease to act in a sustainable way of the population?

Baseline UK (2018): Lack of sustainable alternatives and of simple, coherent and relevant information (The Guardian, 2010; Nuttall and Shankar, 2017). A small proportion of population actively tries to reduce their energy consumption and to be more sustainable in general, but lack of reliable information, difficulty to do what is needed in the current society, consumerism, and social inertia makes it very effort intensive. Therefore, many people tend to pick one 'cause' (*e*. *g*. avoidance of plastics or veganism) and put most of their efforts there, more than to follow an overall 'sustainable life'. Besides, despite good intentions, results are usually very poor due to misinformation, difficulty to change habits and social inertia. And for those who are most knowledgeable, the tension between what they know they should do and what they can actually do can even lead to paralysis (Longo, Shankar and Nuttall, 2017). Saving energy is an idea not promoted beyond it being for saving money (Thøgersen, Curtis and Smith, 2012), therefore it is not high in the sustainability 'causes' list.

A3 Average dwelling (usable) floor area

Justification/definition: Larger dwellings tend to consume more energy (Wright, 2008). Also, together with 'Average household size' it gives information on the average number of occupants per usable area dwellings have, which relates to the amount of energy used in dwellings (see Appendix A5).

Question: How much floor area do dwellings have in comparison to the baseline?
Baseline UK (2013): mean total usable floor area of 95 m^2; 9.4 % have less than 50 m^2 of internal floor space, 24.9 % have at least 110 m^2 of internal floor space (Department for Communities and Local Government, 2015) (Number of dwellings in UK (2013): 23.3 million).
Review and context: See Table A1.

A4 Average number and frequency of use of electric appliances

Justification and/or definition: "Electrical appliances make a very significant contribution to a household's electricity consumption. This impact not only relates to the number of each type of appliance owned, but also to the power demand and frequency of use." (Jones, Fuertes and Lomas, 2015)

Question: How is the use of household appliances in the scenario?
Baseline UK (2011): from Hulme *et al.* (2013):

- Laundry appliances: washing machines in 97 % of households. Median use 4x week at 40 ºC or less. Tumble dryers in 67 % of households. Median use 3x week in winter, few use them in summer.
- Refrigeration appliances: refrigerators in 99 % of households (can be combined with freezer). Freezers in 93 % of households.
- Dishwashers: in 41 % of households. Median use 4x week.
- Cooking appliances: around 38 % of households have electric hobs, around 70 % electric oven, and around 80 % microwave. Use is not determined but the survey 'PERIscope 2017' (Bord Bia, 2018) shows how often people cook food from scratch: Once/few times a day (34 %), Few times a week (31 %), Once a week (11 %), Once/few times a month (7 %), Less often (9 %), Never (9 %)
- Information and communication technologies, and home entertainment: Median number of TVs in homes is 2, the most used one runs 5 to 6 hours per day. No concrete data for other appliances, but different sources show an increase in sells (Euromonitor, 2018), and in appliance energy use (Palmer and Cooper, 2013) in the last years.

Review and context: See Table A1.

A5 Dwelling area per occupant

Justification and/or definition: it relates to the amount of energy used in dwellings: more density of occupants means less space heating per person and more likelihood of sharing consumer items (Bhattacharjee and Reichard, 2011).

Question: What's the average area per occupant in dwellings?

Baseline UK (2011-13): Average household size (2011): 2.3 (Office for National Statistics, 2013) (the indicator in DRC shows 2.4, which is the value from 2001). Average dwelling (usable) floor area (2013) 95 m^2. The result is one occupant every 41.3 m^2.

A6 Energy poverty

Definition: "Fuel poverty in England is measured using the 'Low Income High Costs' indicator, which considers a household to be fuel poor if: 1) they have required fuel costs that are above average (the national median level); 2) were they to spend that amount, they would be left with a residual income below the official poverty line." (BEIS, 2017a)

Question: What is the percentage of population in energy poverty?
Baseline UK (2015): around 11.0 % (approximately 2.50 million households) (BEIS, 2017a). It has been fluctuating less than 2 percentage points since 2003, between more than 10 % and less than 12 %. The average fuel poverty gap in 2015 was £353, which has been slowly decreasing since peaking in 2012 after at least 10 years rising.
Review and context: See Table A1.

A7 Energy prices (domestic)

Justification: The price of the domestic energy can influence the energy demand of households, especially those with low income (BEIS, 2017a). This effect may be amplified if energy prices and energy consumption are made visible and may be used to decrease peak demand —by changing energy pricing depending on the time of the day (Darby, 2006). It is expected that an increase in energy prices would incentivise adoption of on-site generation (Jager, 2006).
A forecast of the future energy prices is outside the scope of this research. However, the relative differences between scenarios and a rough relation to current values is what we can evaluate.

Definition: Average UK domestic energy price (incl. taxes) for a medium customer for a given year.
Question: What are the average energy prices of domestic energy (electricity and gas) for a given year?
Baseline UK (2016): Average for medium consumers, 2016. Electricity price: 15.47 p/kWh (2012: 14.05 p/kWh); Gas: 4.31 p/kWh (2012: 4.46 p/kWh). (BEIS, 2018).

The Global Scenarios Group used Greenpeace's 'Energy [R]evolution' reports (2007, 2008) to help to generate the energy related data in their scenarios. These reports portray a *Reference* scenario (Ref) and an *Energy [R]evolution* scenario (E[R]) which are broadly compatible with *Market Forces* (MF) and *Policy Reform* (PR) respectively. In more recent reports, another scenario is added, *Advanced Energy [R]evolution* scenario (AE[R]). This scenario is, however, not compatible with any of the other scenarios used in DRC. Reproductions of the figures and tables used to characterise this indicator can be found in section S2 of the Supplementary information document. They belong to three sources: 1) the latest Energy [R]evolution report by Greenpeace, (2015) (figure 6.4.6 and table 5.4; the figure shows the development of the electricity generation costs in Ref, E[R] and AE[R] for OECD Europe, and the table shows the projections for fossil fuel and biomass prices for different parts of the world until 2050), 2) the technical document of the GSG's scenarios (by Electris *et al.*, (2009); figure 3-44, which shows the electricity generation shares in 2050 in MF and PR compared to those in 2005), and 3) the table generator tool by Tellus Institute, (2018) (which shows the values for different Western Europe scenarios of selected indicators in different points in the future).

Calculations of final electricity prices in Ref and E[R] (based on information given in Figure 6.4.6 (Greenpeace, 2015), see Figure S2 in the Supplementary information document)

We are interested in the rough evolution of the electricity prices. For that, it is assumed they are proportional to the electricity generation costs and that this proportionality will not change in time. It is also assumed that taxes stay constant. With these assumptions, the relation between the price of UK domestic electricity and the electricity generation costs in 2012 is the same as the relation between the electricity prices and generation costs in 2050 (for the different scenarios). Therefore, a simple rule of three can be used to derive the final electricity prices in Ref and E[R] by measuring the relative increases in electricity generation costs in the figures. This leads to:

Final electricity price in E[R]: 15.25 p/kWh (with a maximum price in 2030 of 18.51 p/kWh)

Final electricity price in Ref: 17.36 p/kWh

Both, the Global Scenarios Group and Greenpeace assume a decrease in the use of nuclear energy in the electricity mix of Europe (their definitions of the area are not exact but similar). UK, however, seems to go in the opposite direction in spite of the increases in electricity costs which this implies (HM Government, 2013; BEIS, 2017b). The narratives of the scenarios suggest this increase will be higher in Ref/MF (17.36++ p/kWh) than E[R]/PR (15.25+ p/kWh).

Calculations of final gas prices in Ref and E[R] (based on information given in Table 5.4 (Greenpeace, 2015) see Figure S3 in the Supplementary information document)

The procedure here is similar than that used with the electricity prices: the price for UK domestic gas in 2012 is defined as proportional to the value for Europe in 2012/2013 shown in the table, and with a rule of three the price for 2050 is obtained.

Final gas price in E[R]: 3.54 p/kWh

Final price in Ref: 6.21 p/kWh

Review and context: See Table A1.

A8 Type of building

Justification: Although it is expected that in OECD member countries approximately 75 % of 2013 building stock will still be standing in 2050 (IEA, 2013) and, that in the case of UK, more than two-thirds of the 2050 housing stock was already built in 2005 (Boardman *et al.*, 2005), the remaining stock will have an impact on both, direct energy consumption (*e. g.* blocks of buildings use less energy than detached houses) (Bhattacharjee and Reichard, 2011; Jones and Lomas, 2015; Jones, Fuertes and Lomas, 2015) and the heat island effect (gardens help mitigate heat island effect, blocks of buildings increase it) (U.S. Environmental Protection Agency, 2008).

Question: What is the composition of the domestic building stock?

Baseline UK (2013): End terrace 10.4 %, mid terrace 18.8 %, semidetached 27.6 %, detached 22.6 %, flat 20.6 % (Department for Communities and Local Government, 2015). For new built: end terrace 10.3

%, mid terrace 12.9 %, semidetached 11.0 %, detached 23.7 %, flat 42.2 % (Department for Communities and Local Government, 2015).

Review and context: See Table A1.

A9 Use of electric space (and water) heating

Justification and/or definition: Heating (space and water) is the largest slice of UK household energy use (80 %) (Palmer and Cooper, 2013), therefore the amount of dwellings using electric heating has a huge impact in the electricity network's load. "In almost all cases, households that use electricity for space heating also use electricity for water heating" and "the vast majority of households that use electric water heating also use electricity for space heating" (Ofgem, 2015), therefore it does not make sense to separate space and water heating in two distinct indicators.

Currently electric heating is not common in the UK and is more expensive than gas heating. However, it is expected to grow by the popularisation of heat pumps, as they are more efficient than other types of electric heating and still are a minority in UK ("typically, heat pumps can produce from 2.5 to 4 times as much useful heat as the amount of high-grade energy input, with variations due to seasonal performance" (Greenpeace, 2015)). The adoption of microgeneration should also push in this direction in the scenarios where decreasing emissions is valued.

Question: What's the percentage of households using electric space (and water) heating?

Review and context: See Table A1.

Table A1 - Review and context. Short description of the context of the new indicators in each scenario.

	Review and context			
	UK urban NSP	**UK urban PR**	**UK urban MF**	**UK urban FW**
Adoption of domestic (or community) microgeneration	Community energy generation units are widely adopted. There are polices encouraging microgeneration, the public has the willingness and the information to adopt it, and total energy demand in households decrease sharply due to better dwellings and better use by occupants.	On-site generation is cheap, electricity is relatively expensive, and government incentivises clean energy and promotes community microgeneration stations. People are not especially inclined to adopt microgeneration, but it is profitable, therefore there is a wide penetration. Buildings are generally better insulated.	On site generation is not too cheap, but high energy prices stimulate the uptake of domestic microgeneration by who can afford it. Buildings still consume a lot of energy, therefore, although on-site microgeneration increases, the percentage of domestic energy met by it is much less than in NSP and PR.	Rich: high energy prices make it favourable for them to install microgeneration devises as in MF. Poor: they cannot afford individual microgeneration devises, but in the cases where communities are in good terms and not too poor, they manage to install community energy generators.
Average dwelling (usable) floor area	There are more people living together, sometimes as co-housing, sometimes with friends, extended family or other families. The dwelling density increases because although flat apartments may be slightly larger than today, they are still smaller than current average terraced and detached houses, and many choose higher quality but smaller homes. However, the amount of very small dwellings decreases due to a decreased interest in living alone and the almost inexistence of poor people.	As current individualistic trends continue, there is a trend toward smaller household sizes (people do not want to share accommodation). It is common to divide large houses in two to accommodate to the market and new built tend to be smaller flats rather than larger houses.	There is a trend towards smaller household sizes as people do not want to share accommodation. At the same time, the affordability of housing decreases, there is more substandard housing. There is a high disparity in urban dwelling density; in high income zones there is a prevalence of houses, while in low income zones there is a prevalence of flats.	Rich live in a similar way to the current (or MF) upper 10 % or 15 %. A large part of the poor who can afford to live in formal developments have to share the dwelling with other families. Most of those who do not share their dwelling do so only because they have been able to divide it or because the dwelling is already very small. There are plenty of informal developments. The trends seen in MF are here exacerbated.
Average number and frequency of use of electric appliances	Larger households and the will of the society make sharing home appliances the norm. More engaged and sustainable society also has the effect reducing the superfluous use and ownership of appliances.	Households tend to be slightly smaller than today therefore appliances are shared by less users. People's search for novelty and status continues mostly unchanged, therefore the ownership and use of appliances increases slightly.	Households are smaller, there is less interest for sustainability and more consumerism (the amount of appliances increases until 2025). Lower earners may not be able to afford all the appliances they would like to have, but this does not counteract the general trend.	Rich: the situation is similar to that of the top 20 % in MF. Poor: they cannot afford much. Most of them have less appliances than they need —if they can afford to own some. Sharing, repairing, reusing, repurposing and recycling appliances is the norm.

Energy poverty	Better housing insulation, increase in GDP per capita, decrease of income inequality, and increase in public service spending highly reduce the risk of energy poverty. Government helps financing community or on-site microgeneration if needed. The extremely few instances of energy poverty can count on the community to alleviate their problem.	Better housing insulation and increase in GDP per capita decrease energy poverty. The state provides better insulation, domestic energy generation and energy tax discounts if needed. Lower gas prices also help decrease fuel poverty.	Housing insulation is similar to current with no better use of sun. Although GDP increases substantially, also the gap between rich and poor increases, leaving a large portion of society at risk of fuel poverty. The moderate increase of energy prices (in comparison with that of GDP) leave 'only' lowest earners and those living in especially badly insulated dwellings in energy poverty. Government cannot help mitigate it as it has to spend a lot in other issues (such as health).	Obviously there are no energy poor between the rich. The poor, however, are virtually all energy poor — although the definition of energy poverty partially brakes in this case as it is difficult to define "required fuel costs" for those who live in informal developments. Those who live in formal developments struggle with high energy costs and low building standards. Burning (coal, wood…) is the main source of heat.
Energy prices (domestic)	In this scenario the general amount of energy consumed is approximately one third lower than in PR and it is mostly in form of electric energy as well. The share which comes from renewable sources is only slightly higher than in PR. This means that the electricity price will be moderately higher than in PR as prices will lower slower (lower increase with same learning factor implies slower price reduction). Gas demand is around 25 % lower, which will decrease its price even further.	An increase (peaking in 2030 at 18.51+ p/kWh) and posterior decrease of the electricity price are expected. This is due to the introduction of renewable energy sources, which are more expensive at the beginning. However, their price then decreases rapidly due to the high learning factor, especially in PV and CSP. In fact, in 2050 the energy from renewable sources is generally cheaper than that which comes from fossil fuels (Greenpeace, 2015). However, lack of demand reduces gas price.	Increasing prices of fossil fuels (the more depleted they are, the more expensive to obtain more it is), low uptake of renewables (slowing price reduction due to learning factor) and increased use of nuclear power, make electricity prices increase steadily. The increasing prices of fossil fuels also affects gas prices.	In this scenario, the general amount of energy consumed is approximately 10 % lower than in MF and its sources are very similar, with a slight decrease of oil and gas in favour to coal, nuclear and biomass. In this case, biomass is not used to generate electricity; instead it is used by the poor as a source of heat and for cooking. The same is probably true for the increase of coal. The further increase in nuclear share affects the electricity price making it slightly more expensive than in MF. Gas demand is lower than in MF and its price is lower too.

Type of building	There is a decrease in land use, and an increase in urbanization and in the amount of green space. This leads to higher dwelling densities. There are less dwellings built than in other scenarios due to high adaptation of current stock. Current trends increasing the proportion of flats are exacerbated, and there are very few new (semi-) detached houses constructed. Construction of terraced houses stays similar. Green space may be gained where there were old single-family houses with garden, especially (semi-) detached houses. Community feeling drives a decrease in demand of privacy.	The percentage of new built remains similar, with a decrease in detached houses in favour to terraced. This increases dwelling density due to the high percentage of new flats constructed (mainly in city centres) and lower percentage of (semi-) detached houses. However, there is high adaptability of the existing stock, which decreases the amount of new built in relation to other scenarios. Terraced and (semi-) detached houses are still in high demand as people seek privacy.	In highly popular and in lower income neighbourhoods there is a high increase of flats, while in high income neighbourhoods what increases is the presence of new (semi-) detached houses. This scenario presents strong "type of building polarisation". Besides, the replacement levels are high, therefore there are more buildings built than in other scenarios.	There is an overall decrease in dwelling density, but the polarisation between rich and poor is extreme in this scenario. The rich live mainly in detached and semi-detached houses, except by in popular zones, where there is a good provision of high profile flats too. The poor inhabit previously built flats and, in some regions, terraced houses (normally shared between several families). In formal developments new flats are the only new construction. In in-formal developments dwellings are more similar to shacks than to proper buildings.
Use of electric space (and water) heating	Although there is a stronger decrease in greenhouse gases produced by household heating than in PR (and electricity is clean), the uptake of electric space and water heating is lower here. The reason is that there is a much greater increase of district heating and other forms of dwelling heating technologies which use the sun and earth's heat.	Although gas is cheap, as the government is leading a transition to clean energy sources, it incentivises district heating when feasible (often geothermal) and electric heating otherwise. The combination of microgeneration and electric heating is especially appealing for customers. Other heating technologies such as solar thermal also have their role in order to replace gas for heating (mostly water) purposes.	Proportionally, the increase in gas price is much higher than that of the electricity. This will increase the installation of heat pumps in new built and when systems need to be changed. Those who have on-site energy generation will also prefer electric heating.	Rich: similar to MF but probably slightly larger as nuclear energy seem to be preferred than other sources of energy like gas. Poor: they are mostly energy poor, therefore it decreases their use of electric heating. They mostly use biomass or coal for heat.

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Figures and tables caption list:

Figure 1. DRC scenarios narrative composition. The narrative of each scenario comprises a brief general narrative describing the main aspects of the scenario, and the characteristics describing the performance of a set of indicators in the scenario. These indicators are variables representing one or more attributes of the system.

Figure 2. Analogy between the derivation of the characteristics of a new indicator for one scenario and a sum: the added information given by the characteristics of the relevant indicators and other relevant information "logically produces" the characteristics of the new indicator as result.

Figure 3. Graphical description of the work done for this paper and how it complements the scenarios from DRC. Some of the attributes represented by the indicators from DRC are factors affecting the energy demand of households. The work done here has defined indicators to represent the missing factors affecting the energy demand of households and characterised them to complement the scenarios from DRC.

Table 1. Indicators and other information used to derive each of the new indicator's characteristics. References: E[R] report (Greenpeace, 2015), General narratives from DRC (Lombardi et al., 2012), General GSG narratives (Hunt *et al.*, 2012b), Technical document (Electris et al., 2009), Table generator tool (Tellus Institute, 2018).

Table 2. Indicators table: characteristics of each of the new indicators for each scenario.

Table 3. Summary of the futures analysis of the conditions needed for the pair 'implementation of a ban to appliances with standby power above 0.5 W'-'decrease the electricity consumed in households' (✓, supported in the scenario; ?, questionable if supported in the scenario; ×, not supported in the scenario).

Table 4. Synthesis of the results of the futures analysis of the solution-benefit pair 'implementation of a ban to appliances with standby power above 0.5 W'-'decrease the electricity consumed in households'.

Table A1 - Review and context. Short description of the context of each of the new indicators for each scenario.