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Benchmarking the energy situation of Danish municipalities. Background Report

Fertner, Christian; Groth, Niels Boje

Publication date:
2015

Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Fertner, C., & Groth, N. B. (2015). *Energy-Smart Cities-DK: Benchmarking the energy situation of Danish municipalities. Background Report*. Centre for Strategic Urban Research. Working paper, No. 23

DEPARTMENT OF GEOSCIENCES AND
NATURAL RESOURCE MANAGEMENT
UNIVERSITY OF COPENHAGEN

Energy-Smart Cities-DK

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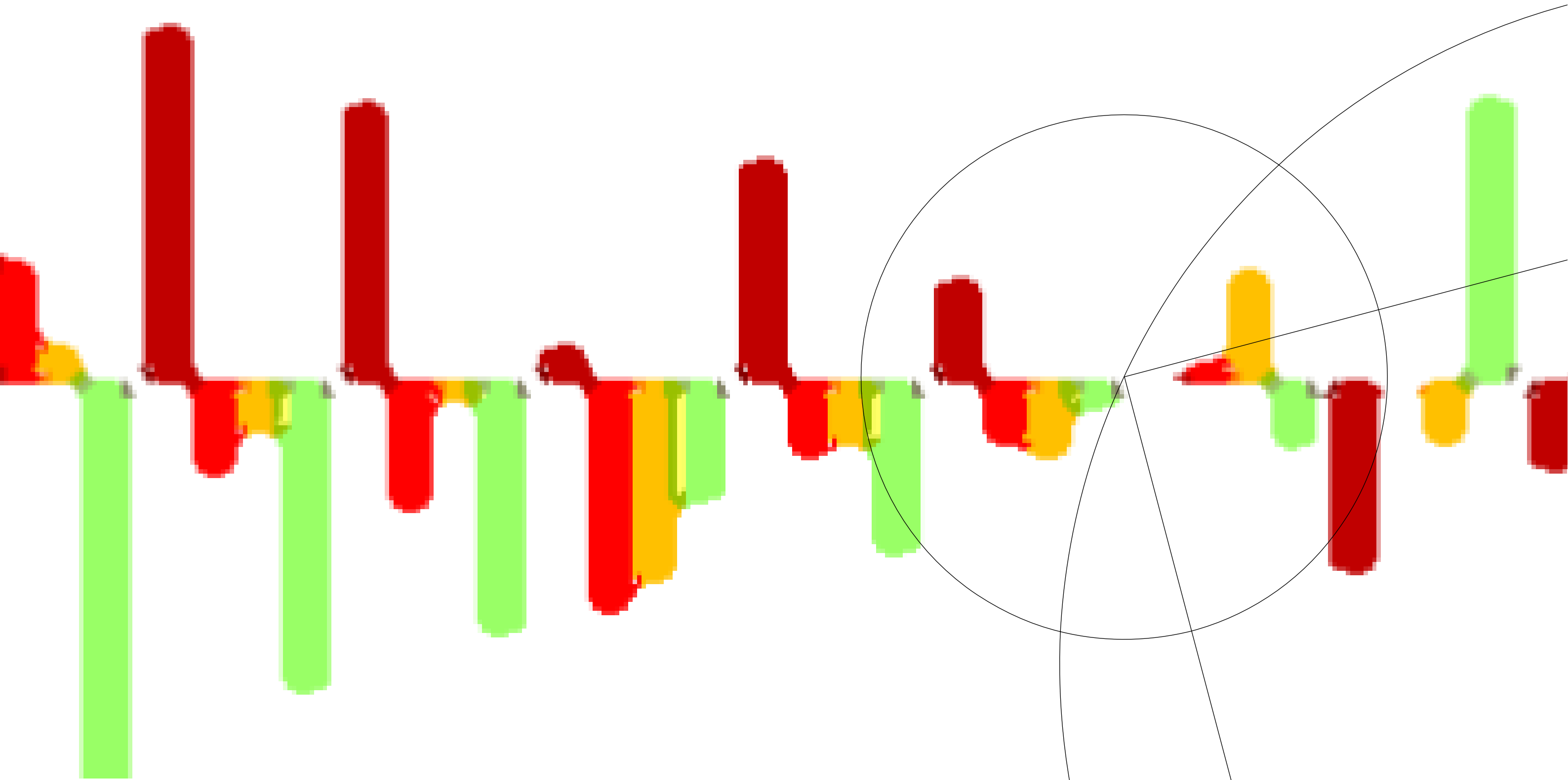
Background Report



Centre for Strategic Urban Research – www.byforskning.dk

Working Paper 23

Christian Fertner & Niels Boje Groth

January 2015

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Energy-Smart Cities-DK: Benchmarking the energy situation of Danish municipalities
Background report

Authors
Christian Fertner (chfe@ign.ku.dk)
Niels Boje Groth (nbg@ign.ku.dk)

Citation
Fertner C. & Groth N.B. (2015) Energy-Smart Cities-DK: Benchmarking the energy situation of Danish municipalities. Background report. Centre for Strategic Urban Research, Working Paper 23, www.byforskning.dk

Publisher
Centre for Strategic Urban Research
University of Copenhagen
Rolighedsvej 23
DK-1958 Frederiksberg C
Tel. +45 353 31500
kahm@ign.ku.dk
www.byforskning.dk

Published
This working paper is available online on www.byforskning.dk

Acknowledgements
This working paper is based on data collected for the project "Energy-Smart Cities-DK" financed by NRGi and their affiliates Kuben Management (www.kubenman.dk). The methodology is based on work done within the EU-FP7 project PLEEC (www.pleecproject.eu), Grant Agreement No. 314704. The paper is published by the Centre for Strategic Urban Research (www.byforskning.dk), a Danish research network supported by Realdania Research (www.realdania.dk).

Contents

1 Dansk resumé

Energi- og ressourceknaphed er ved at blive en af de største udfordringer af vores samfund. Smart city idéen er at arbejde med omstillingen til en mere bæredygtig by og samtidig holde livsstandarden højt ved at bruge eksisterende ressourcer på en 'smarter', dvs. mere effektiv, måde. Viden om energi-situationen i byerne er en vigtig del for at arbejde med det. Med "Energy-Smart Cities-DK" fremlægger vi en benchmarking af alle 98 danske kommuner indenfor energiområdet. Projektet baseres på et indikatorsystem udviklet i EU-FP7 projektet PLEEC og bidrager til NRGi's projekt "Smart city 2014" med input til workshops med interesserede kommuner. Denne baggrundsrapport beskriver metoden og nogle overordnede resultater.

2 Introduction

In this report we present some overall results and the methodology behind the *Energy-Smart Cities-DK* model, a benchmark of the energy situation of Danish municipalities. The analysis was conducted by researchers at the University of Copenhagen, based on work by researchers at the Vienna University of Technology and further partners in the ongoing EU-FP7 project PLEEC (Giffinger, Hemis, Weninger, & Haindlmaier, 2014)[1].

This particular project on benchmarking Danish municipalities is financed by the Danish energy service company *NRGi* and their affiliated company *Kuben Management*, who have an interest in exploring the operationalization of the *smart city*, a term which is widely used in current city development strategies. There are various definitions for that concept – we think the most important characteristic of a smart city is that it can activate and use the resources and capital available in a most efficient way – also in the long run, that means in a sustainable way.

A key issue for smart city development is energy, mainly related to two future urban challenges: Climate change and resource scarcity (Droege, 2011; European Commission, 2010). At this background, the *University of Copenhagen, Department for Geosciences and Natural Resource Management, Section for Landscape Architecture and Planning* is involved in the European project PLEEC, which studies ways for more energy efficient urban planning, focusing on six case cities. To measure the energy situation in these cities, project partners from Vienna developed a benchmarking tool called "Energy-Smart City" (Giffinger et al., 2014). The model forms the basis for the benchmarking approach presented in this report, called "Energy-Smart City-DK".

This report presents the methodology of the benchmarking and some overall results related to a couple of typologies, but no detailed results for particular municipalities.

[1] For further project reports see also www.pleecproject.eu.

3 Why benchmarking the energy situation of cities?

Despite agendas and goals set on national and international level, local authorities are key actors in energy transitions (Lewis, Hogain, & Borghi, 2013). Striving towards energy self-sufficiency, regional energy cycles, energy efficient retrofitting of the built environment as well as the decoupling of urban development and energy use are crucial for a city's future vulnerability and resilience against changes in general energy availability. European initiatives as the *Covenant of Mayors* or *Energy Cities* are closely following this development and support local authorities in their actions including the collection of basic energy data (Cerutti et al., 2013). However, no common model exists, besides a few indicators usually related to greenhouse gas emissions, mainly of CO2. A general benchmarking of states and efforts in regards to energy in all aspects of city development could increase the use of good practice and enforce discussions in lagging cities.

Benchmarking cities has become a very common phenomenon, often taken up by media focusing on the ranking of particular cities. In that respect, benchmarks are mainly used to get attraction (Giffinger, Haindlmaier, & Kramar, 2010) . The actual potential to analyse a city's performance in a particular aspect is seldom used, often because the models are not transparent or the data is not freely available. However, benchmarks can form the basis for further work when results are studied in more detail, with a good understanding of its lacks and limitations. Especially the latter is important, as all models and comparisons are simplifications and aggregations of real world phenomena, using generalisations and compromises to allow quantitative comparative analyses. The outcomes of a benchmark should therefore be used to question and discuss (e.g. is this really like that? Why is it like that?), and not to judge (e.g. this is good/bad). The basis to use a benchmark that way is a clear and transparent methodology and well prepared results.

We try to contribute with this project to (1) the increasing need for evidence-based approaches to handle urban energy transitions, and focus on (2) cities, i.e. the local authorities, who are leading the way for implementation. A benchmark can also contribute to identify good practice and clarify the status of a city's efforts.

Finally we want to emphasize that the path to an energy transition can be very diverse and is very context dependent (Rutherford & Coutard, 2014). A different performance of two cities in a particular indicator or field does not necessarily mean that one city has to change its approach, as the difference can be part of a particular context or development, which might be deeply coupled to other developments in the city, some even desired and planned for.

4 Methodology

4.1 The PLEEC model: Energy-Smart Cities (ESC)

The model used in this project is hierarchically structured, aggregating a range of indicators into domains and further into 6 key fields related to different aspects energy. The indicators are standardized by a *z-transformation*. This method transforms the values of a variable into standardized values with an average 0 and a standard deviation 1. It has the advantages to consider the heterogeneity within groups and maintain its metric information. When aggregated, the indicators are not weighted in particular. However, as some domains have more indicators than others, some indicators account for a higher share of a domain's result (and subsequently the related key field) than others.

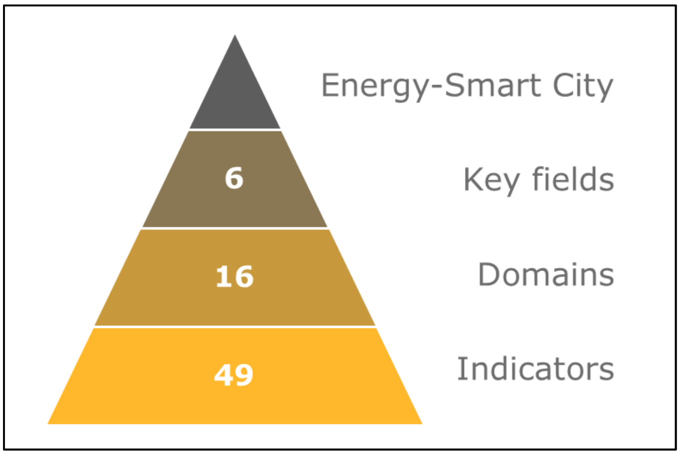

Figure 1: Hierarchical organisation of the Energy-Smart Cities model

This methodology is based on work done in a previous project called "European Smart City ranking" (Giffinger et al., 2007). In that project the focus was not on energy, but on a more general benchmarking of sustainable and competitive development of 70 European medium-sized cities. In the ongoing project PLEEC the methodology was adapted to benchmark and monitor various aspects of energy in cities (Giffinger et al., 2014) and called "Energy-Smart City" (ESC). However, while the *European Smart City ranking* is purely based on freely available data from European databases as the European Urban Audit, the regional database of Eurostat or ESPON, most indicators defined for the new *Energy-Smart City* model are not available from such sources. Only very few energy-related data on regional or local/city level is collected on European scale, and even then often not covering all countries.

In PLEEC, data for the model was only collected for the 6 case cities. In favour of getting as much data as possible, some indicators were differently defined by the cities, which collected the data themselves. Also, not all data is available for all cities and often not for the same years. Despite the very different context the cities are located in, the limitation to 6 cities only makes a benchmark as done in the *European Smart City ranking* not feasible. However, the method was discussed and developed in a joint effort, making it a valuable tool to monitoring progress of the city's efforts in the future.

The conditions to benchmark Danish municipalities are better:

- Several national databases offer energy-related data on municipality level
- Databases cover usually all Danish municipalities
- There are 98 municipalities, allowing for quantitative comparative analysis
- The same national context (political and planning system, national policy and legislation, similar culture, similar climate etc.) applies

4.2 Adaptation to the Danish context: Energy-Smart Cities-DK (ESC-DK)

The original *Energy-Smart City* model was adapted for this project to adjust for the Danish context and the available data situation. To highlight this distinction we call the model *Energy-Smart City-DK.* A few indicators were changed or added and an additional key field called “Energy policy and commitment” with the two domains “Member in international network” and “Member in national network” was added. Furthermore, no data was available for the domains “Renovation” and “Public lightning”, which means that they are virtually not part of the ESC-DK. Figure 2, shows all key fields and domains in the ESC-DK. A full list of indicators can be found in the Annex.

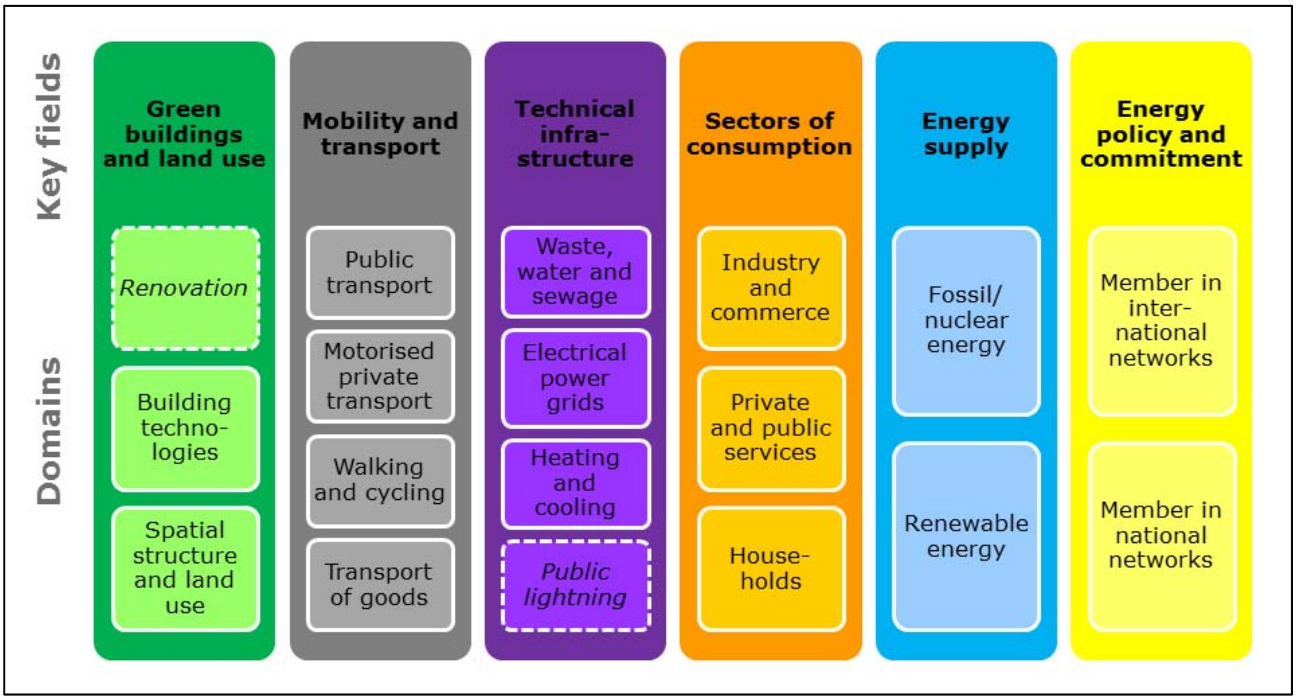

Figure 2: Key fields and Domains in the Energy-Smart City-DK model (adapted from Giffinger, Haindlmaier, & Strohmayer, 2014)

The ESC-DK model with the current data input constitutes as follows:

- 6 key fields
- 18 domains, whereas 16 with data
- 55 indicators, whereas 41 with data

4.3 Data input

The available data covers all 98 Danish municipalities, except data for the two indicators “waste generation” and “recycling of waste”, which are only available for about 60 municipalities (Details in the Annex). All indicators, despite the two on waste which were collected manually, were derived from databases covering all municipalities and thereby providing data which is based on the same methodological background for all municipalities enabling a comparative approach.

Most of the indicators (29) provide data on local (municipal level); some indicators – especially in the key field energy supply – were only available on regional level (nuts 2 or 3, which is equal to *landsdele* and *regioner* in Denmark). The data source and spatial level of each indicator is listed in the Annex.

5 Results

In this report we do not discuss results of particular municipalities, but focus on patterns of energy across different types of municipalities. We apply two typologies:

- Municipalities categorized in 3 groups by Eurostat's urban-rural typology
- Municipalities categorized in 4 groups related to the Danish planning regions

As the data material is very extensive, further analysis should be done to improve the understanding of data quality and potential relationships. The latter could be connected to socio-economic and socio-demographic criteria, economic and industrial structure or geographic features and natural resources. We also present selected indicators to illustrate spatial patterns across Denmark.

However, prior to the analysis using typologies we will conduct some general statistical analysis of the data material. Information regarding the input to the model can be found in the methodology section.

5.1 General statistics

The ESC-model is very comprehensive, including a wide range of different aspects of urban energy. However, this 'inclusiveness' also means a wide variety of different data when operationalised. Besides the fact that the data origins from different databases and on different spatial levels (local/nuts3/nuts2), it is also related to very different contexts – some related to particular geographical patterns, other much more related to particular political decisions and policies. Figure 3 shows the distribution of the 6 aggregated key field-variables. In the Annex, boxplots for all domains can be found.

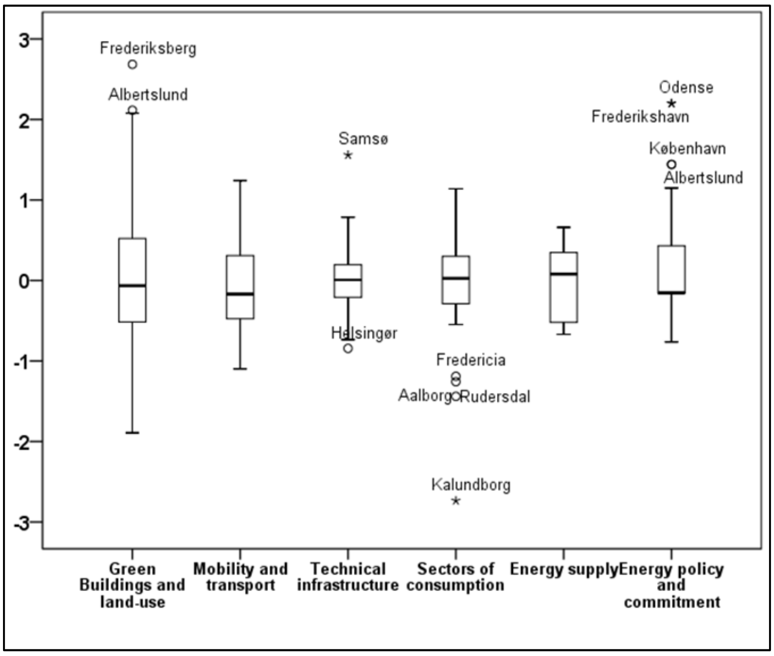

Figure 3: Boxplot[2] showing the distribution of the 6 key field-variables

Boxplots can be used to identify outliers and thereby to check the quality of the data and the choice of the variables. For example in Figure 3 the key field "sectors of consumption" shows the municipality of Kalundborg as a strong outlier. This is caused by energy intensive industry in Kalundborg, mirrored in the indicator on *Energy use in the industry per GDP* – the same accounts for Frederica and Aalborg. Rudersdal has a strong goods transport sectors, accounting for high *CO2 emissions in goods transport* and *Energy consumption in the services per GDP*. Both, the energy intensive industry and the cluster of transportation services are negatively accounted for in the ESC, however, they might be important for the municipalities' economy and its general development. The ESC measures energy performance – other factors as social or economic development do not necessarily correlated with that.

[2] A boxplot shows five statistics (minimum, first quartile, median, third quartile, and maximum) and pinpoints outliers.

The ESC measures energy performance – other factors as social or economic development do not necessarily correlated with that.

Another outlier illustrating the weakness of an indicator is Slagelse, about 1 hour by train from Copenhagen and 40 minutes to Odense. Slagelse has the best result in the domain "Public transport" (see Boxplot in the Annex). The domain is comprised of 4 indicators – however, in the ESC-DK only data for one indicator, the transport performance (person-kilometres), is available. This indicator favours municipalities with a high share of public transport but also with relatively long trips, accounting for high person-kilometres. Although a high share of public transport is favourable compared to individual transport, no transport at all or shorter distances would be more favourable in terms of energy use. Data on the actual energy use was unfortunately not available.

5.2 Energy and urban-rural typology

Energy consumption is closely related to the development of urban areas. To get further insights on our data, we use the downscaled urban-rural typology of Eurostat (Fertner, 2012) to categorize all 98 Danish municipalities into *predominantly urban (25), intermediate (28)* and *predominantly rural (45) municipalities* (see Figure 4).

Figure 5 shows the average, standardized values in each key field for a municipality in each of the three categories. Urban municipalities show a much better performance in *Green buildings and land-use* and *in Mobility and transport*, while the patters seems turned around for *Energy supply*. The other three key fields are not the clearly related to the typology.

Figure 6 shows the average performance on the level of domains, showing further relations of energy and urban areas. District heating is clearly more spread in urban areas, while heat pumps (the indicator behind *Electric power grids*) are more spread in rural areas.

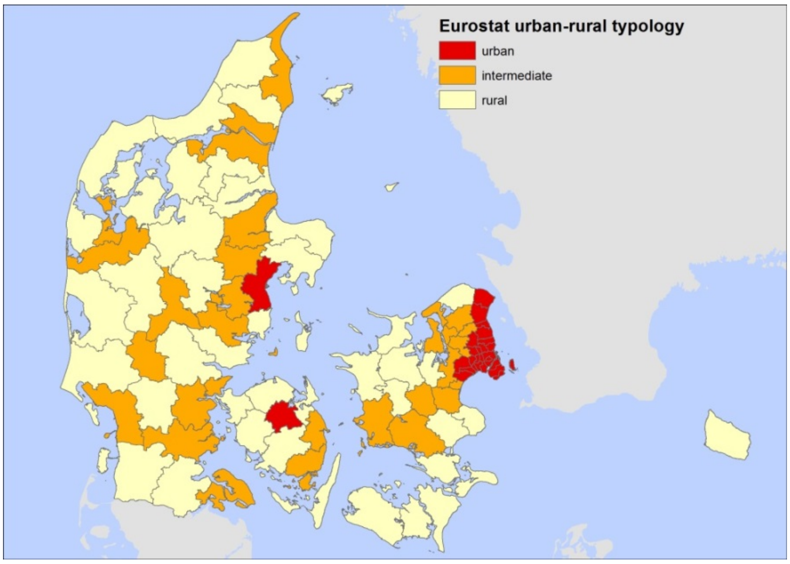

Figure 4: Eurostat's urban-rural typology applied to Danish municipalities

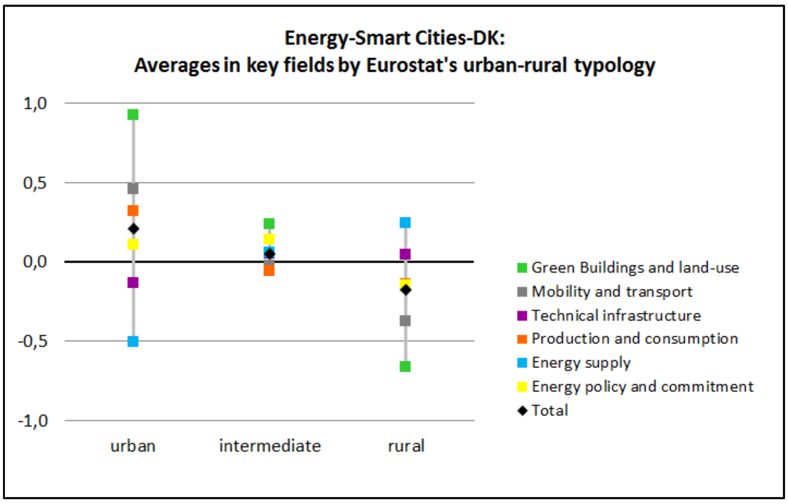

Figure 5: Average performance in 6 key fields by urban-rural typology

Also, urban households use less energy per capita than rural ones which might be connected to the pattern we can see in the key field Mobility and transport.

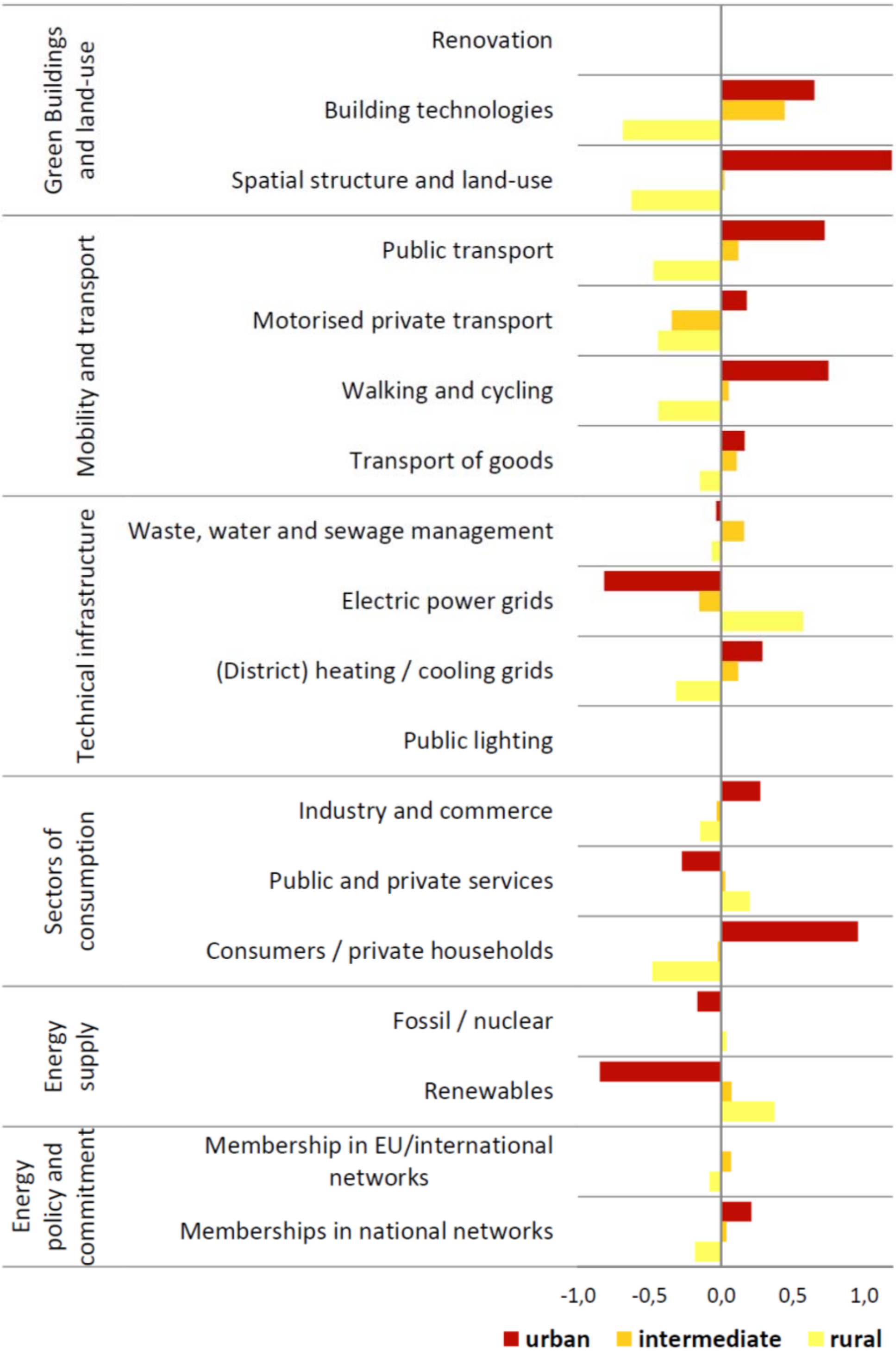

Figure 6: Average performance on the level of domains by urban-rural typology

5.3 Energy and Danish planning regions

The second typology is related to the Danish planning system and was used in Fertner & Groth (2013). It is based on the Danish National planning report (*Landsplanredegørelsen*) from 2006 and the definition of peripheral areas ('yderområder') adopted in a revision of the Danish planning law in 2011. It splits Denmark into 4 regions: the Copenhagen metropolitan area, the East Jutland metropolitan area, intermediate areas with medium-sized towns and peripheral areas.

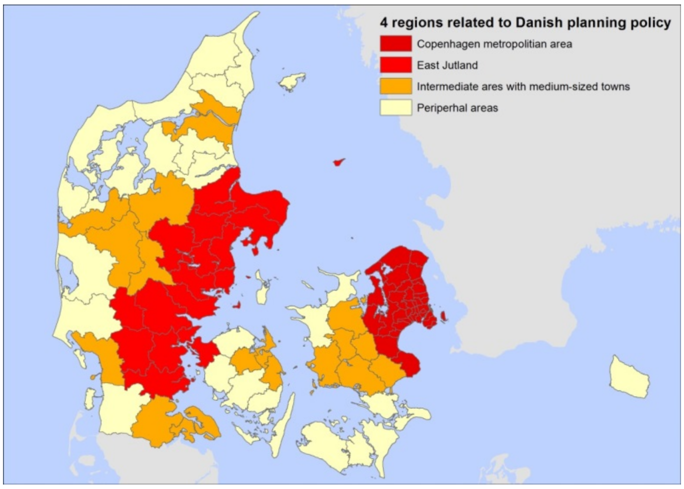

Figure 7: Municipalities grouped in 4 regions related to Danish planning policy

Compared to the pervious typology, this one delineates bigger and partially connected regions. However, the results as seen in Figure 8 are not very much different. Interesting is though the very different profile of an average municipality in the Copenhagen metropolitan area compared to one in East Jutland conurbation – the two major urban regions of Denmark. The polycentric and less densely populated urban region in East Jutland is more depended on car transport but provides relatively more renewable energy, probably due to its size and inclusion of rural areas.

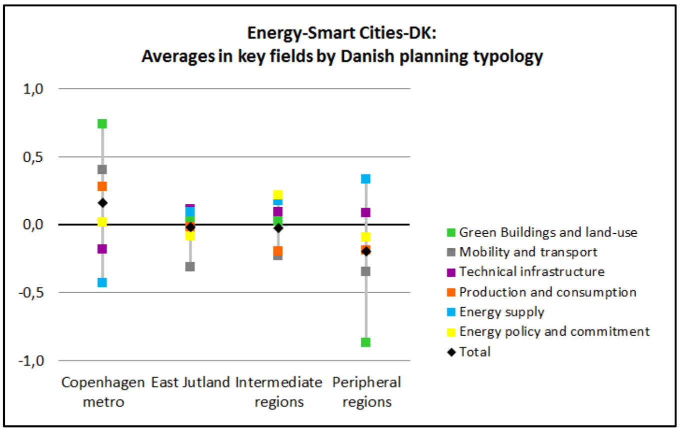

Figure 8: Average performance of a municipality in the four regions

5.4 Other correlations

We did not conduct any in-depth analysis regarding energy and socio-economic development. Despite a general urban-rural divide in energy matters, socio-economics might explain further variations. A quick test with the unemployment rate did not elucidate any pattern. However, income (and income inequality), household structure, age, profession and education could be connected to some results of the benchmark. Also climate variables (January temperature, sun hours) might play a role, e.g. for the connection to district heating. However, the climate is not that different across Denmark.

5.5 Performance in selected indicators

As the aggregated key fields and domains only give a very general picture of the energy situation, a closer look at selected indicators is worthwhile. As far as possible we also included the six PLEEC case cities as references.

Looking for example at the average annual energy demand in households (Indicator PC.06, see Annex) we can see considerable differences, where households in the municipality with the highest average use double the energy than in those with the lowest average. All six PLEEC cities are in the lower end of energy demand in households. However, one has to consider that the PLEEC cities typically only cover the core municipality of the urban area they form. We have no data on their surrounding municipalities.

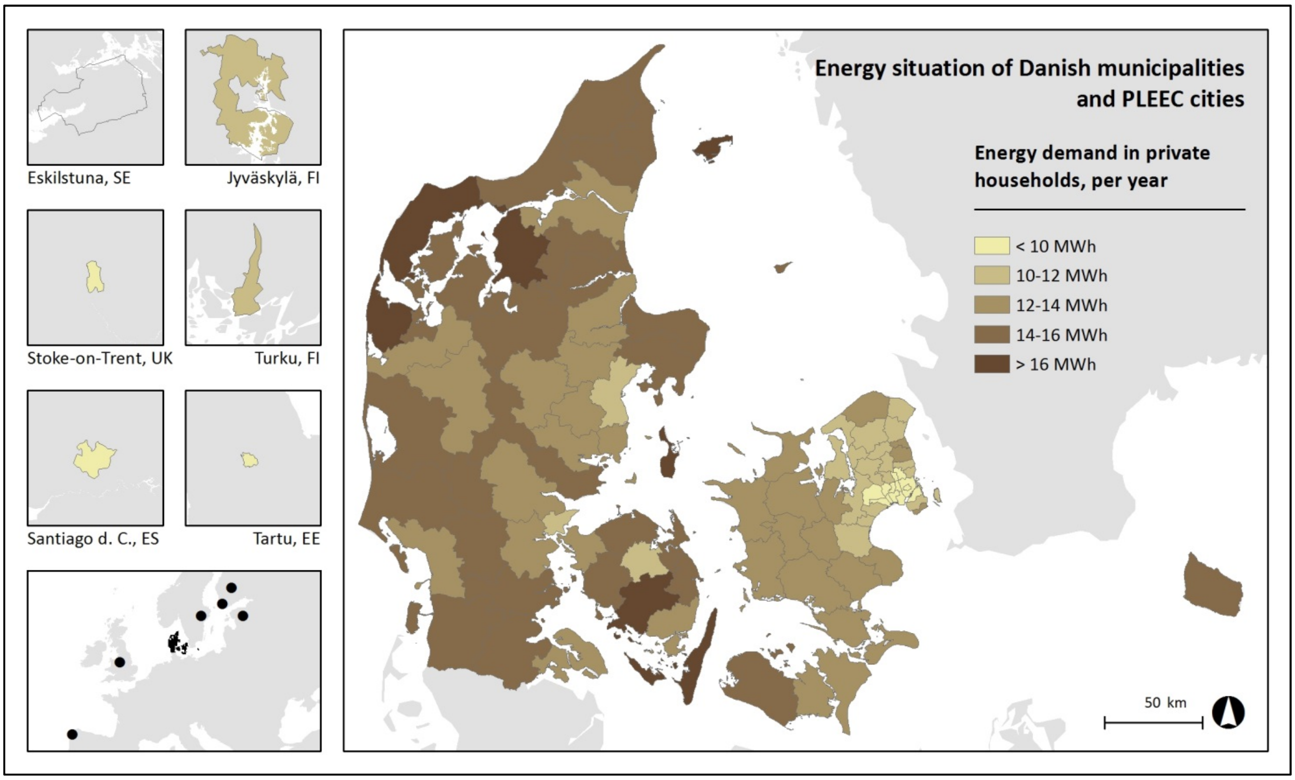

Figure 9: Energy demand in private households in Danish municipalities and PLEEC cities

The focus on selected indicators can sharpen the picture of certain patterns in energy demand and supply, avoiding the aggregation of sometimes opposing indicators (e.g. the share of district heating and the share of heat pumps). Also patterns to other factors can be identified. E.g. the share of energy-efficient dwellings (those with an Energy Label C or better) is highest in the areas with high economic and population growth, which mirrors the high investment in renovation and new construction in these areas compared to less dynamic areas.

6 Limitations and perspectives

As every model, also the ESC-DK is simplifying reality. A selection of indicators are aggregated to benchmark the performance in particular key fields related to energy – case specific contexts and developments can only be marginally accounted for. The model should therefore be used as a screening tool to base further analysis on. Also, the current model only illustrates the status at a specific point in time. Any progress or development is not mirrored. However, that might be possible in future analysis, because most data used in this report is available for several years. A benchmark evaluating on the one hand the status of energy use and on the other hand the progress of getting more efficient, more sustainable, is feasible and would be an important contribution.

The ESC-DK is the first operationalization of the Energy-Smart City model developed in PLEEC. Although key fields, domains and indicators were elaborated with the input and in discussion of many individuals, no validation work has been done yet. With the results of the Danish adaptation we also contribute to a further refinement. Some indicators, as discussed also above, might be problematic and not helpful, others might be missing. Also, the theoretical conceptualisation behind the choice of indicators needs further work and analysis so results can be interpreted easier.

For the workshops with interested municipalities we stated the following questions:

- Are the key fields/domains/indicators appropriate to use for benchmarking and monitoring? Any wrong, useless, missing?
- What typologies or other variables could reveal patterns of energy use and efficiency?
- How could the results be used for planning/policy making?

By January 2015 the results of this model have been discussed in four municipalities with interested planners and officials. Some comments reflected weaknesses of the model, including the weak illustration of the political dimension, the missing illustration of synergies between domains and the difficulty to compare between different municipalities. The latter is also a question of who municipalities compare themselves with – who is the benchmark. For example the City of Copenhagen rather compares itself with other capitals or big cities (Stockholm, Amsterdam) than with other cities or municipalities in Denmark. However, the comparison within Denmark has the advantage of comparing at a similar policy and cultural background.

The results of these discussions will also be brought further in the PLEEC project, were one of the major outcomes will be a general conceptualisation and model of Energy-Smart Cities, related to different contexts.

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8 Annex

Table 1: List of indicators

Key field	Domain	Ind_id	Original indicator ESC-PLEEC	Indicator ESC-DK	unit	level	+/-	*
Green Buildings and land-use	Renovation	GB.01	Share of annual thermal renovations	not available				
	Building technologies	GB.02	Share of dwellings in low- (zero-) energy buildings	Share of dwellings with Energy label D or worse	%	local	(-)	1
		GB.03	Share of public low- (zero-) energy buildings	not available				
	Spatial structure and land-use	GB.04	Population density	Population density	pers/km2	local	+	2
		GB.04 b	not in original model	Total floor area per person	m2/pers	local	(-)	2
		GB.05	Share of detached houses	Share of detached houses	%	local	(-)	2
Mobility and transport	Public transport	MT.01	Transport performance in public transport	Transport performance in public transport	pkm	local	+	3
		MT.02	Energy demand in public transport	not available				
		MT.03	CO2 emissions in public transport	not available				
		MT.04	Cost of a monthly ticket for public transport	not available				
	Motorised private transport	MT.05	Transport performance in motorised private transport	Transport performance in motorised private transport	pkm	local	(-)	3
		MT.06	Energy demand in motorised private transport	not available				
		MT.07	CO2 emissions in motorised private transport	CO2 emissions in motorised private transport	CO2t/pers	local	(-)	4
		MT.08	Cost of petrol	Cost of petrol	EUR/l	nuts 0	+	5
		MT.09	Parking fee	not available				
		MT.10	Level of motorisation	Level of motorisation	cars/pers	local	(-)	2
	Walking and cycling	MT.11	Transport performance in bicycle transport	Transport performance in bicycle transport	pkm	local	+	3
		MT.12	Transport performance in pedestrian transport	Transport performance in pedestrian transport	pkm	local	+	3
		MT.13	Length of bicycle network per inhabitant	Length of urban bicycle network per inhabitant	m/pers	local	+	6
	Transport of goods	MT.14	Transport performance in transport of goods (freight)	Transport performance in transport of goods (freight)	tkm/GDP	nuts 3	(-)	2
		MT.15	Energy demand in transport of goods (freight)	Fossil energy use in sector "Trade and transport"	MWh/GDP	local	(-)	7
		MT.16	CO2 emissions in transport of goods (freight)	CO2 from fossil energy use "Trade and transport"	CO2t/GDP	local	(-)	7
Technical infrastructure	Waster, water and sewage management	TI.01	Waste generation	Waste generation in households	t/pers	local	(-)	8
		TI.02	Recycling of waste	Recycling of household waste	%	local	(-)	8
		TI.03	Waste collection fee	not available				
	Electric power grids	TI.04	Share of smart-meters	not available				
		TI.04b	not in original model	Share of dwellings with heat pumps	%	local	+	2
	(District) heating / cooling grids	TI.05	Share of district heating	Share of dwellings with district heating	%	local	+	2
	Public lighting	TI.06	Share of energy efficient lamps	not available				

Table 2: List of indicators (cont.)

Key field	Domain	Ind_id	Original indicator ESC-PLEEC	Indicator ESC-DK	unit	level	+/-	*
Sectors of consumption	Industry and commerce	PC.01	Energy demand in industry	Energy demand in industry	MWh/GDP	local	(-)	7
		PC.02	CO2 emissions in industry	CO2 emissions in industry	CO2t/GDP	local	(-)	7
		PC.03	Share of companies with energy management	not available				
	Public and private services	PC.04	Energy demand in service sector	Energy demand in service sector	MWh/GDP	local	(-)	7
		PC.05	CO2 emissions in service sector	CO2 emissions in service sector	CO2t/GDP	local	(-)	7
	Consumers / private households	PC.06	Energy demand in private households	Energy demand in private households	MWh/pers	local	(-)	7
		PC.07	CO2 emissions in private households	CO2 emissions in private households	tons	local	(-)	7
		PC.08	Share of household income spent on petrol	Share of household income spent on petrol	%	nuts2	(-)	2
		PC.09	Share of household income spent on electricity	Share of household income spent on electricity	%	nuts2	(-)	2
Energy supply	Fossil / nuclear	ES.01	Energy supply - solid fuels	Energy supply - solid fuels	MWh/pers	nuts3	(-)	9
		ES.02	Energy supply - gas	Energy supply - gas	MWh/pers	nuts3	(-)	9
		ES.03	Energy supply - crude oil and petroleum products	Energy supply - crude oil and petroleum products	MWh/pers	nuts3	(-)	9
		ES.04	Energy supply - nuclear	Energy supply - nuclear (no nuclear power in Denmark)	MWh/pers	local	(-)	9
		ES.05	Electricity tariff - traditional mix	Electricity tariff - traditional mix	EUR/KWh	east-west	+	9
	Renewables	ES.06	Energy supply - wind	Energy supply - wind	MWh/pers	nuts2	+	7
		ES.07	Energy supply - biomass	Energy supply - biomass	MWh/pers	nuts2	+	7
		ES.08	Energy supply - solar	Energy supply - solar	MWh/pers	local	+	9
		ES.09	Energy supply - hydropower	Energy supply - hydropower	MWh/pers	nuts2	+	7
		ES.10	Energy supply - tide, wave, ocean	not available				
		ES.11	Energy supply - geothermal including heat pump	not available				
		ES.12	Energy supply - waste	Energy supply - waste	MWh/pers	nuts2	+	7
		ES.13	Electricity tariff - renewables mix	not available				
Energy policy and commitment	Membership in international networks	PO.01	not in original model	Membership in Covenant of Mayors	3 stages	local	+	10
		PO.02	not in original model	Membership in Energy cities	y/n	local	+	10
	Memberships in national networks	PO.03	not in original model	Membership in Greencities.dk	y/ass./n	local	+	10
		PO.04	not in original model	Membership in DN Klimakommuner	y/n	local	+	10

*** Data sources:**

1 OIS (Danish Public Information Server, www.ois.dk)
2 DST (Statistiks Denmark Database, www.statbank.dk)
3 DTU TU (Transport survey of the Technical University of Denmark)
4 DTU TU and Key2Green.dk (estimate for CO2 emissions for cars in Denmark)
5 EOF (Energy and Oil forum, www.eof.dk)
6 OSM (OpenStreetMap, www.osm.org)
7 DST/Region Syddanmark (www.detgodeliv.regionsyddanmark.dk/talbank/talbank)
8 Manual collection from municipal waste plans
9 ENS (www.ens.dk)
10 Manual collection from the respective organisation’s website

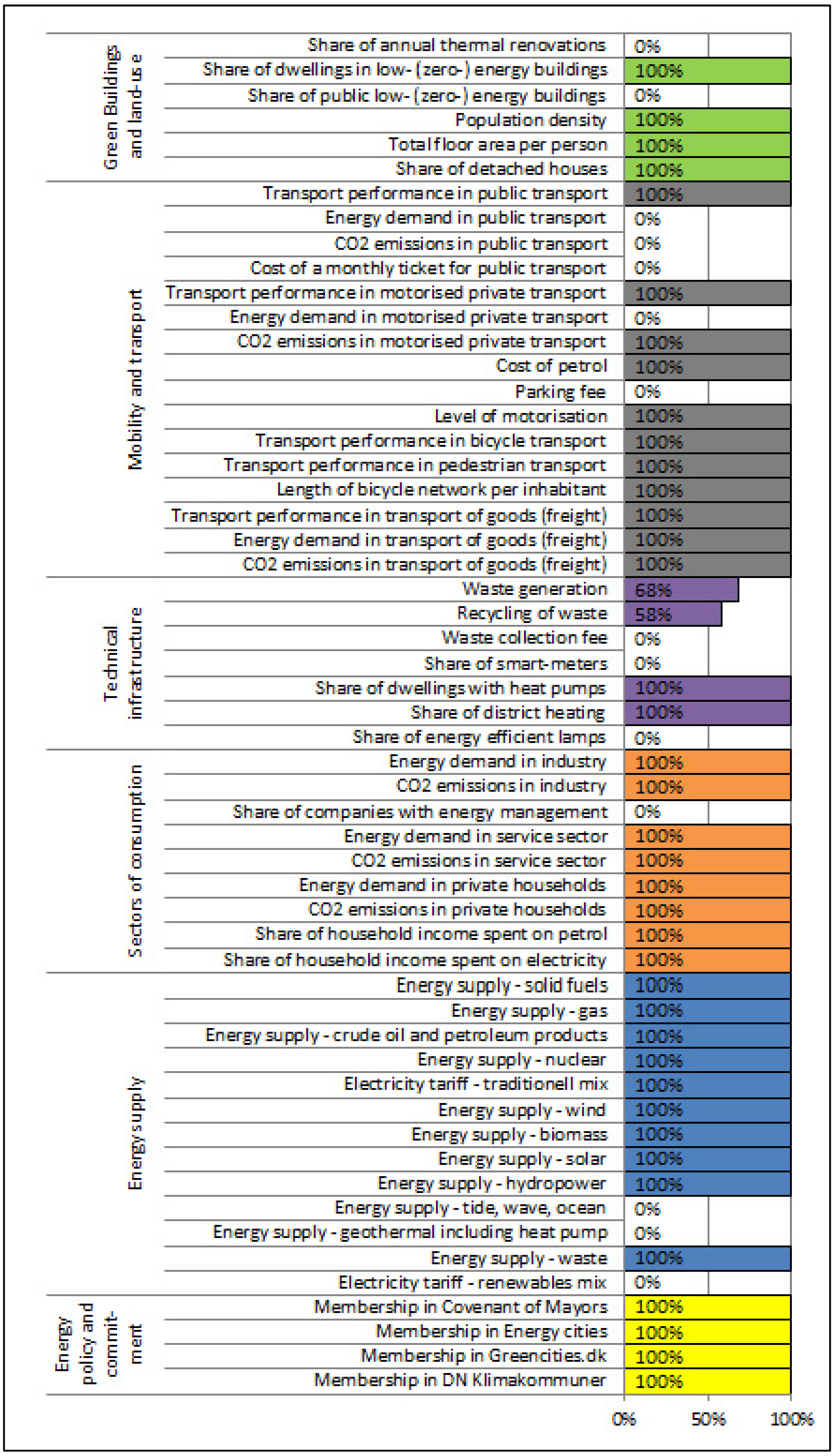

Figure 10: Data coverage in ESC-DK, version May 2014
Percentage of Danish municipalities (n=98) which are covered in each of the 55 indicators.

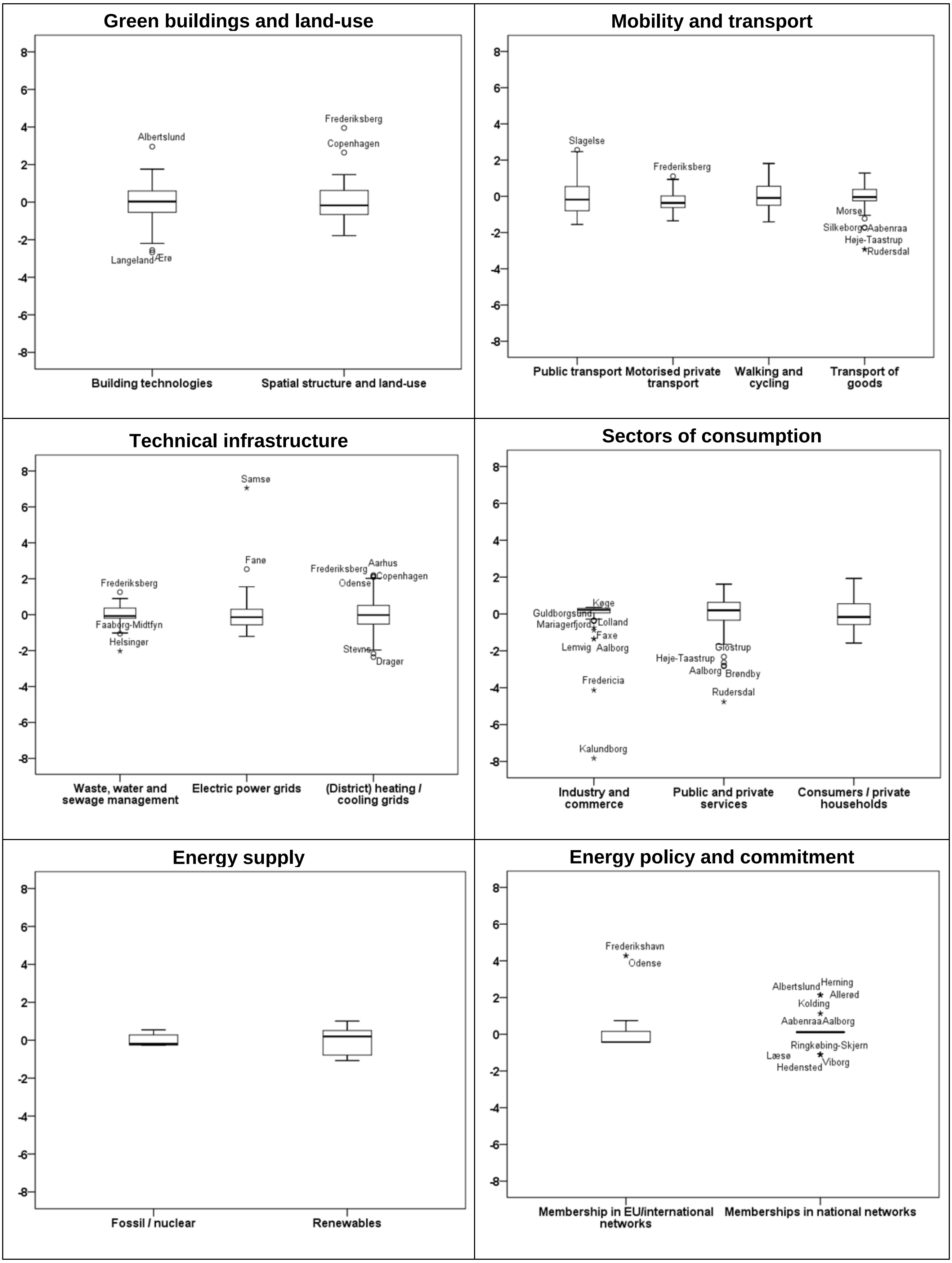

Figure 11: Box-plots per key field