URBAN STRUCTURE AND ENERGY EFFICIENCY

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Abstract

Transforming cities' energy use to address the threats of climate change and resource scarcity is a main challenge in local governance. The EU-FP7 project PLEEC – "Planning for Energy Efficient Cities" – uses an integrative approach to elaborate pathways, considering diverse challenges and requirements, for energy efficient and sustainable urban development.
This paper addresses the challenges of urban energy policy from an urban structure related angle. The relationship of energy and urban structure is investigated by means of a literature review and in-depth knowledge from three case studies of medium-sized Northern European cities.
The study takes stock of the current state of energy in urban development and policy, and reveals current options and constraints of energy efficient urban development.
The case cities go in some ways ahead their national climate and energy policy and aim to establish urban planning as an instrument to regulate and influence the city's transformation process in a sustainable way. At the same time the cities are constantly facing goal conflicts which induce dilemmas in their strategic orientation and planning activities (e.g. regional enlargement and increased commuting vs. compact urban development). We conclude that applying a broader understanding of urban structure than usually encountered in the academic literature turns out as a suitable framework in order to address the challenges of energy efficient urban development.

1 Introduction

In the backcloth of the EU's 2020 climate and energy package ("20-20-20 targets") energy is high on the agenda in current urban development issues. Energy is an important element in various urban visions including being a sustainable and climate-friendly city, being self-sufficient, regenerative (Girardet, 2015) and resilient or also in more general concepts a *Smart City*.

This paper approaches the challenges of urban energy policy from an urban structure related angle. Urban structure is part of the sphere of influence of the municipal planning authorities and can hence be operationalized through urban planning as competence. Municipalities can act within and affect urban structure which enables cities to contribute to the achievement of the 20-20-20 targets.

The chosen cases, Eskilstuna in Sweden, Turku in Finland and Tartu in Estonia, face similar challenges like tendencies of ongoing urban sprawl and regional commuting, strongly related to their position within the regional urban system; as well as partly comparable constraints towards energy efficient urban development. In this sense the cases can to some extend be considered as exemplary for the challenges many medium-sized European cities have to deal with today.

Urban structure is in the academic literature mainly related to *urban form* (morphology, configuration and compilation). This paper suggests a broader approach to urban structure, including *urban administration* (policy, planning and governance) and *urban functioning* (urban system, city-region and flows). This study reveals the interrelations between those three dimensions of urban structure and shows that addressing urban form to increase energy efficiency requires accompanying policies that are likewise addressing urban administration and function as an integrated policy package.

The studied cities go in some ways ahead their national climate and energy policy and aim to establish urban planning as an instrument to regulate and influence the city's transformation process in a sustainable way. At the same time the cities are constantly facing goal conflicts which induce dilemmas and trade-offs in their strategic orientation and planning activities (e.g. regional enlargement and increased commuting vs. compact urban development). Consequently, the paper reveals current options and constraints of energy efficient urban development as well as potential contributions of cities to the achievement of the 20-20-20 targets.

2 Approach and methods

In 2008 the European Union (EU) set up a climate and energy package containing three key objectives for 2020: 20% reduction in EU *greenhouse gas emissions* from 1990 levels, raising the share of EU energy consumption produced from *renewable resources* to 20% and 20% improvement in the EU's *energy efficiency*. Transforming cities' energy use is a main pillar to reach these goals.

The research uses a twofold approach including a literature review on the relationship of energy and urban structure as well as in-depth knowledge from three case studies. The *literature review* examines the state-of-the-art of research on the relationship of energy and urban structure. The review includes conceptual and empirical work published in journal articles, conference papers, books and book chapters, as well as policy-oriented documents from the EU and other organisations. The literature search focused on energy use in urban areas, preferably in a Northern European context, but included further work from e.g. a Northern American and Australian context in case of specific relevance. This paper presents a summary of the outcome of the reviewed literature as baseline for the discussion on urban structure.

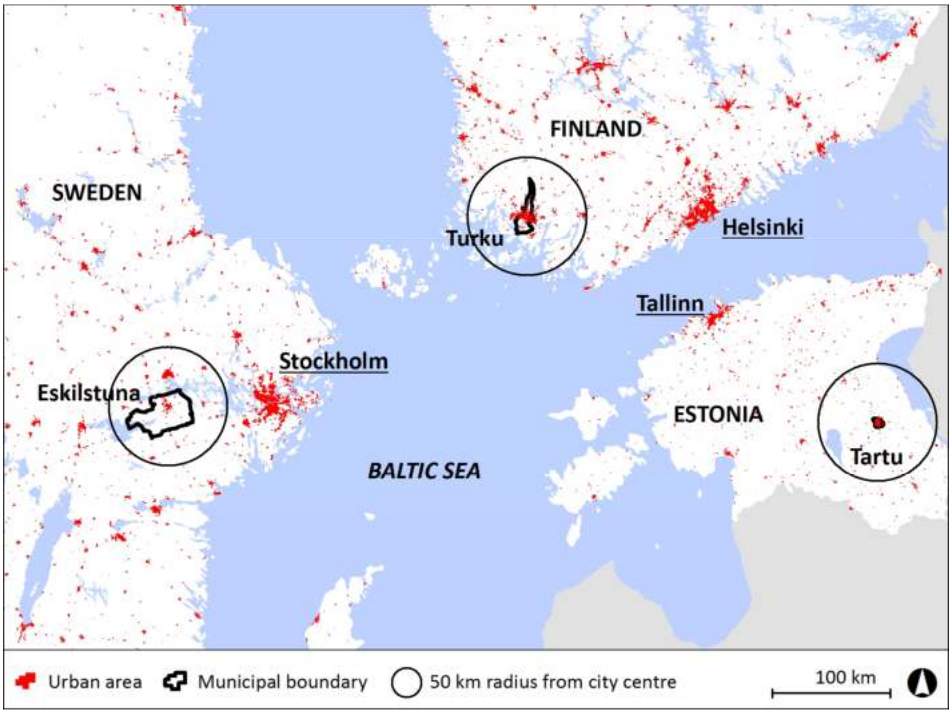


Figure 1. Urban areas in Northern Europe (European Environment Agency (EEA), 2014) and the three case study cities

Three in-depth *case studies* of medium-sized Northern European cities, Eskilstuna in Sweden, Tartu in Estonia and Turku in Finland, form the main part of this study. The case studies were conducted in 2014 as part of the European project PLEEC – "Planning for energy efficient Cities", funded by EU's Seventh Framework Programme (Fertner et al., 2015; Große et al., 2015; Groth et al., 2014).

The chosen cases are suitable for the intended investigation because they are both contrasting and similar. They are all medium-sized European cities (see Table 1), functioning as regional centres and striving to increase their energy efficiency. However, they face divergent urban dynamics and development challenges and act in different planning systems.

The investigation of the case studies is based on interviews with civil servants and stakeholders in urban development and energy planning, site surveys, scientific publications, planning and policy documents, maps and statistical data. The interviewees were asked about their perception of framing conditions and national energy regulation, the evolution of spatial planning, current transport planning as well as national and local energy policy and the role of regional planning.

The aim of the study is to investigate the relationship of urban structure and energy and examine urban structure as a suitable framework to address questions of urban energy efficiency. Subsequently, current options and constraints of energy efficient urban development and therefore potential contributions of cities to the achievement of the 20-20-20 targets will be elaborated.

3 The relationship of urban structure and energy

Since more than three decades researchers investigate the relationship between urban structure and energy use in cities. The approaches range from urban form related angles to approaches including for example socio-economic factors. Based on a comprehensive academic literature review on the relation of urban structure and energy use this paper provides a summary of main findings.

The reviewed literature proofs a relationship between urban structure and energy use. Næss and Jensen (2004, p. 37) summarize that "urban structure makes up a set of incentives facilitating some kinds of travel behaviour and discouraging other types of travel behaviour"; thus, the structural conditions have relevant potential to influence people's travel behaviour (Næss, 2006). Dense and concentrated cities are considered as contributing to reduce travel activities by car (Næss et al., 1996). Still, it is difficult to clearly verify this relationship between urban structure and travel behaviour; some approaches even consider it as 'weak' or 'uncertain', also due to the importance of socio-economic factors and people's attitudes (Næss and Jensen, 2004). Stead and Marshall (2001) identify effects of land use and socio-economic factors on travel patterns; consequently, policies aiming on influencing travel patterns have to assume "a set of interactions between land use, socio-economic characteristics and travel patterns" (Stead et al., 2000, p. 185), since land use characteristics explain only some of the variation in travel patterns. This relationship between the *parameters* or *structural variables* of urban structure and the final *energy implications* can be simplified as a causality chain (Figure 2), as comparably applied e.g. by Næss (2012, 2006), Næss and Jensen (2002) and Owens (1986):

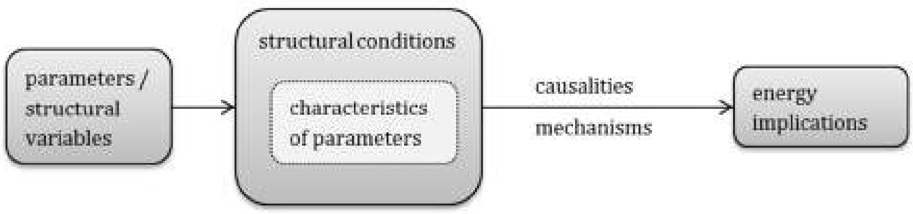
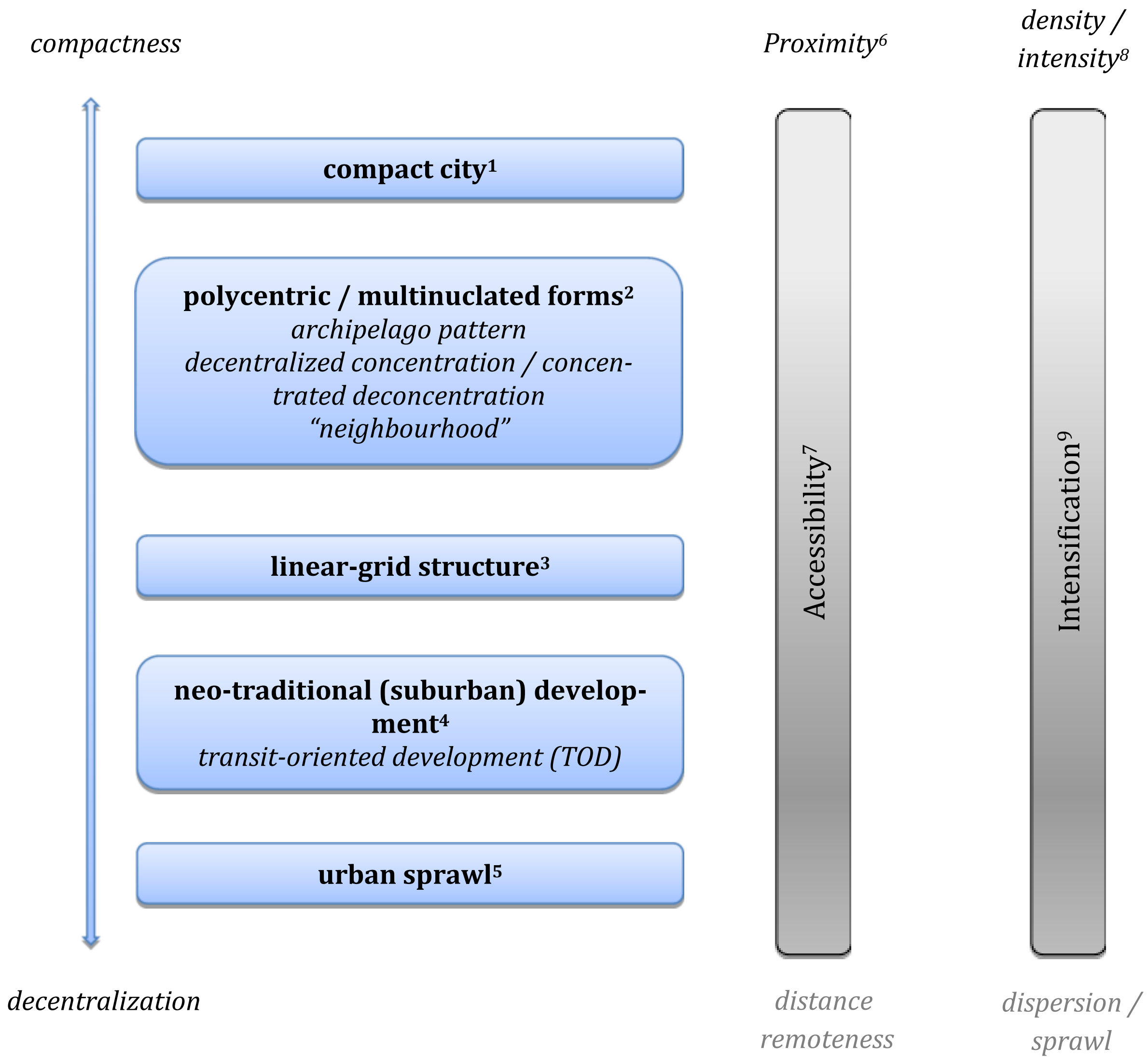


Figure 2. Causality chain between parameters of urban structure and energy implications

The *characteristics of the different parameters* (e.g. density, land use mix, settlement pattern) form *structural conditions* (e.g. accessibility, mix of facilities and services), which can be understood as “qualities” of a specific urban structure. Specific *structural conditions* induce then specific *causalities* or *mechanisms* that induce certain *energy implications*, e.g. a certain outcome of travel behaviour (modal split, journey frequency, travel distance etc.). The literature indicates that not only urban form parameters determine the relationship between the structural conditions and their energy implications, but a wider set of parameters needs to be included in order to sufficiently explain this relationship.

The identified causalities between urban structure (structural conditions) and energy use in cities are “translated” into concepts of urban structure which are supposed to facilitate efficient energy use. These theoretical concepts presented in the literature, that describe the relationship between urban form and energy use, range between the ‘compact city’ concept as summarizing term for towns and cities which “stress the merits of urban containment” (Breheny, 1995, p. 82) and ‘decentralization’ as referring “to all forms of population and industrial growth taking place away from existing urban centres” (Breheny, 1995, p. 87).

Figure 3 provides an overview of the different concepts of urban structure in the range between compactness and decentralization:



[1] Breheny, 1995; Christensen and Jensen-Butler, 1982; OECD, 2012; Owens, 1986; Rickaby and Steadman, 1992; Westerink et al., 2013
[2] Anderson et al., 1996; Breheny, 1995; Owens, 1986
[3] Owens, 1986
[4] Breheny, 1995; Calthorpe, 1993; Gordon and Richardson, 1997; Handy, 1992
[5] Breheny, 1995; European Environment Agency (EEA), 2006
[6] Anderson et al., 1996; Westerink et al., 2013
[7, 8] Westerink et al., 2013
[9] Jenks, 2000; Williams et al., 1996

Figure 3. Conceptualization of urban structure

Comparing the presented approaches it appears that compact urban structures and concentrated development at least facilitate and favour an efficient use of energy at the city level. In this sense, polycentric spatial structures (decentralized concentration) appear to provide an answer to the trade-offs arising from the pure compact city concept, since they are capable to diminish the disadvantages of a single compact city (e.g. too high densities) while keeping its advantages. Also they provide an alternative spatial principle for regions where compact city development is hardly feasible (e.g. sparsely populated regions).

The reasons for the divergence between (compact city) theory and planning practice are by Williams (1999) accounted also to policy implementation (process), as she questions the power of the (local) planning system to ensure intensification and also to manage its consequences. Complementary to this, Owens and Rickaby (1992, p. 251) consider "the absence of a supportive national policy framework" as one of the reasons that the "intellectual recognition of the links between settlement patterns, energy use and the environment has not yet been translated into real practical significance". Van Stigt et al. (2013) illustrate that the range of local options is determined by sectoral regulations from higher tiers of government when adopting the concept of environmental policy integration.

Furthermore we can conclude from the literature that changes in urban form can facilitate or affect, but not in itself constitute energy savings. Rickaby and Steadman (1992) found out that differences in urban form between different compact city models do not have significant implications on energy use; only competitive public transport systems and accompanying policies could induce reductions in energy use. Also Næss (2006) recognizes the necessity to complement transport reducing urban planning policies and measures with accompanying instruments in order to achieve significant changes. Mutually, public transport needs to be accompanied by land use and transport planning policies restricting car use and orienting development to transit nodes (Anderson et al., 1996).

In the backcloth of the main findings from the reviewed literature the relationship of urban structure and energy is further examined by using and applied approach, the investigation of three cases of medium-sized cities in Northern Europe.

4 Energy planning in three European cities

The investigated case cities contribute in different ways to the achievement of the "20-20-20 targets" [1] of the EU's climate and energy package. The cities' various efforts, current options and constraints towards increasing their energy efficiency will be discussed.

The following chapters are based on the results of the case studies that were conducted as part of the European project PLEEC (Fertner et al., 2015; Große et al., 2015; Groth et al., 2014).

Table 1. Key figures of Eskilstuna, Tartu and Turku (Giffinger et al., 2014)

	Eskilstuna	**Turku**	**Tartu**
Inhabitants in the municipality	99,804	180,225	97,847
Inhabitants in the larger urban region	n/a	316,634	150,528
administrative area of the municipality in km^2	1,100	245	39
urban area of the municipality in km^2	51	75	29
population density in inhabitants per km² urban area	1,945	2,403	3,396
Average number of persons per household	2.2	1.9	2.3
Final energy consumption per capita in MWh	26.5	35.3	13.0
share of transport in final energy consumption	16%	9%	20%
Level of motorization - Registered cars per 1,000 inhabitants	450	420	250

[1] 20% reduction in EU *greenhouse gas emissions* from 1990 levels, raising the share of EU energy consumption produced from *renewable resources* to 20% and 20% improvement in the EU's *energy efficiency* until 2020

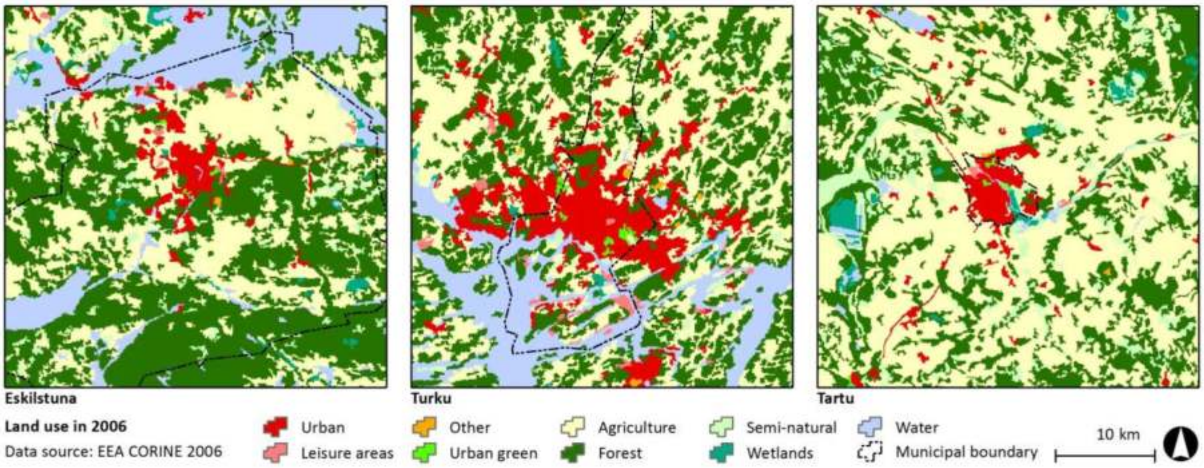


Figure 4. Land use and municipal borders of Eskilstuna, Turku and Tartu 2006

The key figures and the land use maps show the differences between the three cases in terms of their administrative boundaries and the actual urban area. While Eskilstuna municipality includes an area much bigger than the urban area, the urban area of Turku is significantly exceeding its municipal boundary. In Tartu the municipal boundary matches more or less the urban area, although tendencies of exceeding its boundaries are already visible.

Consequently, it is difficult to compare the cities' density or compactness only based on the key figures, they need to be related to the discussed area. Regarding the urban area, Tartu shows the highest population density, whereas Eskilstuna has the lowest density; Turku's density is amounted between Tartu and Eskilstuna, but it has to be considered that Turku urban area is much bigger than the municipal area which might result in a different overall density.

4.1 Eskilstuna

The Swedish municipality Eskilstuna, with almost 100,000 inhabitants (2013)[2] and a size of 1,250 km^2, is located around 100 km west of Stockholm and part of Stockholm's commuter belt. Eskilstuna is situated in the county Södermanland which is part of the Stockholm-Mälar Region, a polycentric region with about 3 million inhabitants. Eskilstuna marks a former major industrial location in Sweden; its population is since the 1970s rather stable between 90,000 and almost 100,000 inhabitants. Deindustrialization in the 1970s caused a pronounced decline in the number of jobs, making the city ripe for urban restructuring.

Comprehensive spatial planning is emphasized as a key instrument of sustainable development in Eskilstuna. Energy efficiency has become an almost omnipresent issue, integrated across sectors and between levels in the municipal organization and as such an issue of general commitment.

Energy and urban development

The biggest consumers of energy are households and transport. But their potentials for reducing the CO_2-emissions vary. With few exemptions transportation depends on fossil fuels, whereas energy consumption in households, mainly serviced by district heating, is composed by a number of energy sources, including an increasing amount of renewables operated by district heating plants as well as by individual house owners' initiatives. Only 25% of the electricity demand is provided by the local

[2] all eurostat (2014)

plants, thus, the main remaining part is imported from the national grid, i.e. produced by energy sources that are beyond the control of the municipality.

Regarding transport, the design of effective incentives to reduce fossil fuels remains the key challenge, also on the national level. Strong structural development trends that have increased transport both internationally and regionally exacerbate such efforts.

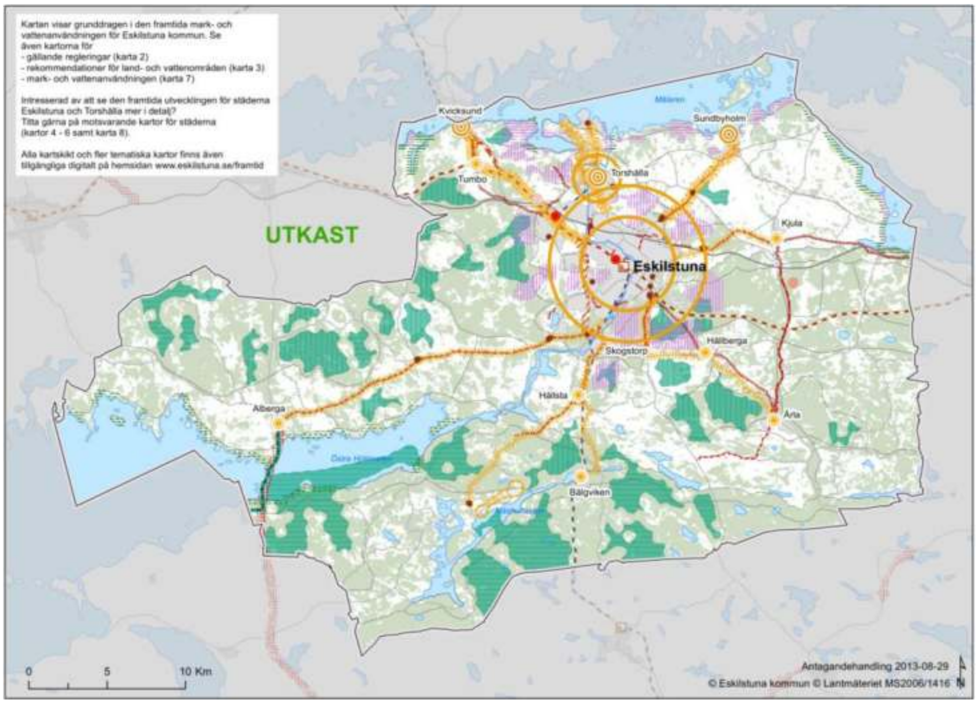


Figure 5. Development concept of Eskilstuna comprehensive plan (Eskilstuna kommun, 2013a)

Urban densification and urban connectivity to transport routes facilitated by public transport are generally acknowledged as the two main principles of energy efficient urban development in Eskilstuna. With the current comprehensive plan (Översiktsplan 2030, Eskilstuna kommun, 2013a) a radical decision was taken by abandoning former settlement planning in the attractive coastal area of the lake Mälaren. Furthermore, future urban development will be concentrated within or close to the existing urban cores as well as in connection with public transport links between these cores (Figure 5). Currently two thirds of the inhabitants live within 3 km of Eskilstuna city centre.

Policy arenas

Energy and climate policy is carried out at *two policy arenas*: The arena of the municipality acting as a concern (‘planning’) and the arena of the municipality acting as a stakeholder of energy initiatives (‘strategy’).

The municipal climate plans and projects are carried out with high level of effectiveness by the Eskilstuna municipal concern (municipal services, energy supply, public enterprises), which is in charge of all decisions concerning municipal planning, services and infrastructure. The climate strategies concerning the entire municipality have much larger potentials for e.g. CO_2-savings, but the development and implementation of such strategies relies upon partnerships to be established between the Eskilstuna municipal concern and e.g. private companies, organizations and the public, all of which operate outside the direct influence of the municipality.

The efficiency of the first is very high, due to an omnipresent 'sustainable thinking'. The total effect of the latter is, however, much larger, due to the size of the arena. For example, the concern's share of CO_2-emission reductions amounts only for 7% of the total reductions in Eskilstuna. The distinction between those two policy arenas is very relevant for the operational preparation of plans, projects and strategies.

First- and second-order policies

In Eskilstuna energy efficiency policies are developed subordinate to the basic drivers of economic development. Regional enlargement and entering Stockholm's labour market offered the municipality a way out of a long economic downturn from the mid-1970s to the late 1990s but is also facilitated by increased commuting. This development of the regional urban system is not questioned by the city authorities; it is taken as point of departure for policies that aim on compensating the effects of commuting; policies to enhance commuting by train rather than car and the development of a dense urban structure in hub-and-spoke patterns adjacent to public transport lines.

Although the municipality has a clear "climate oriented" strategy and a concrete orientation in planning within the municipal concern, two kinds of strategic planning are at play: first, matching trends in the outside world (e.g. 'threats' and 'opportunities') and second, setting up hierarchies of visions (strategy) and goals (plans and projects). In this sense, although the Transport Plan (Eskilstuna kommun, 2012) and the Climate Plan (Eskilstuna kommun, 2013b) contain concrete measures towards sustainable transport, these remain "mild answers to strong trends" as part of the latter strategy. Policies of energy efficiency are of *'second-order'* compared to the economically driven *'first-order'* development of the regional urban system coming along with increased transport.

4.2 Tartu

Tartu is with 98,000 inhabitants (2014) and a municipal area of roughly 40 km² the second largest city in Estonia after Tallinn, located about 180 km southeast of the capital and the centre of southeast Estonia. Tartu has no relevant big industries; the main employers are the municipality (incl. hospital) and the university. Energy related challenges occur from transport and residential (district) heating.

Energy and urban development

The highest share of emissions is allotted to energy production. In terms of energy sources Estonia is highly dependent on imports like oil and gas and the Estonian electricity production is to more than 90% based on Estonian oil shale. Due to Estonia's high dependency on resource imports, national efforts towards higher energy efficiency are rather driven by ambitions to decrease fuel dependency and secure energy supply than merely sustainability objectives.

Although, regional energy production and increasing the share of renewable and local fuels are considered as relevant measures, the above mentioned policy related goal conflicts are also reflected in the planning documents. Those lack concrete energy efficiency measures that affect urban energy policy. Municipal energy planning therefore has to deal with a different commitment to energy efficiency or sustainability than for example in Eskilstuna.

One major problem in Tartu is regional commuting, short distance commuting due to ongoing urban sprawl and far-distance commuting, e.g. to Tallinn. This is also caused by the orientation on the capital Tallinn, providing diverse employment possibilities. Thus, the modal split shows big differences between journeys within Tartu and journeys between Tartu and its surroundings. While the first shows a high share of public transport and walking, the latter includes a high share of car use, especially in work related travelling. A strong driver for this development is also the ongoing catch up with European standards of car ownership, the number of registered cars is constantly increasing in Tartu since 2008 (eurostat, 2014).

A development concept addressing those challenges is the concept of *"Low-density urbanized space"*, as implemented by the National Spatial Plan (NSP) "Estonia 2030+" (Ministry of the Interior, 2013). It is also transferred into the previous and current Master Plan of Tartu (City of Tartu, 2006). The concept aims to combine the concept of sustainable (compact) urban space with the low-density settlement characteristics in Estonia. By these means polycentric spatial structures (decentralized concentration) provide an alternative spatial principle for regions where compact city development is hardly feasible. Contrary, Tartu is facing ongoing *urban sprawl* and car-dependent commuting, also because planning documents assign new residential areas in the outskirts of the city.

Scope of action

The outlined challenges like regional commuting and urban sprawl require coordinated cross-municipal efforts on the regional level. However, the Estonian planning system allots the main responsibilities for planning activities to the local level, whereas the regional level (county) is rather weak. Estonia has 215 municipalities[3] and the municipal areas are quite narrowly confined. Thus, the local planning competences have a very limited scope of action, tied to the core municipal territory.

This implies a gap of cooperation on the regional level. Therefore, addressing problems that exceed the city scale is hardly feasible, which leads to dispersed urban development in suburban areas and contradicting interests and developments between neighbouring municipalities, since their interests reasonably exceed their municipal borders. In this sense also the Tartu City Transport Development Plan 2012-2020 (Tartu City Government, 2011) is limited to the municipal boundaries. Similarly demands of regional positioning and integrated planning within the functional urban area, as e.g. mentioned in the Development Strategy "Tartu 2030" (Tartu City Government, 2006), can be hardly addressed neither fulfilled. Hence, urban planning is 'locked-in' the framework of the local power relations and limited commitment to sustainability, not favouring efforts for urban energy efficiency.

4.3 Turku

Turku is with a population of about 180,000 inhabitants (2014) in the municipality and 316,000 inhabitants in the larger urban area the centre of the region Southwest Finland. Turku is situated at the southwest coast of Finland, about 150 km west of Helsinki. It is an important university town due to the presence of different universities and about 40,000 students living there.

Since industrialization Turku has also been an important industrial town. Today, after considerable restructuring of the industrial sector, 79% of the jobs in the city of Turku are within services. Besides its economic base, Turku is experiencing a change in the former prevalent urban sprawl, characterizing urban development since the 1950s. The city is densifying and promoting sustainable urban development, though, with several growth centres at a regional scale. Today, approximately one-third of the 150,000 jobs in Turku's urban region are located in the centre of Turku, while the rest are located elsewhere in the urban region.

Compact city and polycentricity in a low density country and on a voluntary cooperative basis

Turku has experienced extensive urban growth since the 1950s. While the municipality of Turku is stagnating since the 1970s, the city region has grown further, resulting in a large urban area and a dispersed settlement structure in the fringe. Thus, Turku is, as many Finnish cities, urbanizing but in parallel undergoing tendencies of urban sprawl, inducing regional and car-dependent commuting as far as

[3] Currently a reform to join local governments (municipalities) up to a minimum amount of inhabitants (e.g. 5,000) is in process.

to Helsinki. This urbanization trend needs to be operationalized as a chance towards more energy efficient urban structures.

The traditional low density settlement structure in Finland marks a key challenge; similar to Estonia, urban settlements are dispersed and long-commuting distances are usual. Furthermore, Finland is characterized by a fragmented municipal structure, especially in urban areas, and extensive municipal self-government competencies. Regional coordination is therefore dependent on voluntary collaboration of municipalities. Consequently, it is – despite ambitious targets in energy efficiency issues – very difficult to address problems crossing municipal borders, whereon – in terms of urban sprawl – the main effort should be directed.

In the beginning of the 1990s Finland underwent an "exceptionally deep" economic depression, which turned out to become a turning point in the Finnish planning. Municipalities started to review their relationship to the private sector and their administration and organization methods in favour of an incremental and project-based planning. This turned out to have a major impact on local land-use planning; "[t]he local plan is not made as a proactive regulative statement to guide future urban development, but rather as a reactive document whose primary function is to provide the judicial legitimation for development decisions made elsewhere" (Mäntysalo, 1999, p. 179).

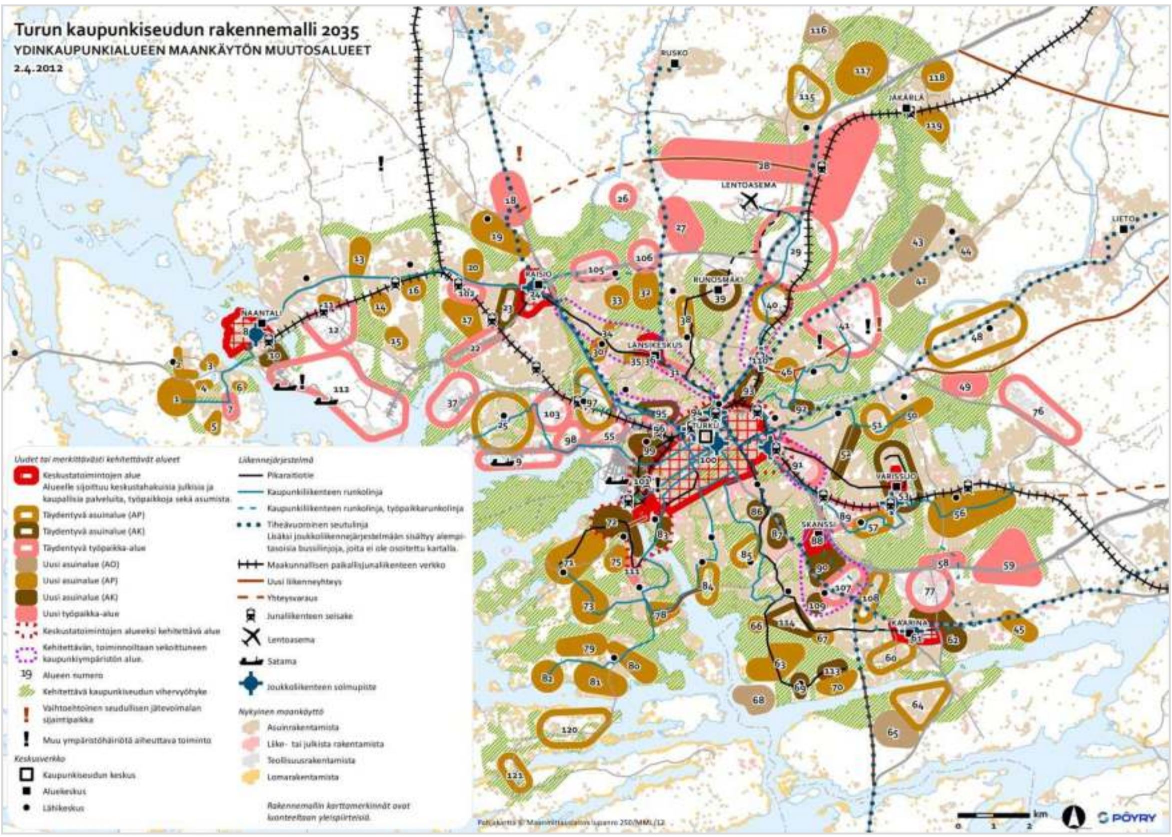


Figure 6. Regional structural model 2035 (City of Turku, 2012)

To coordinate urban development, Turku and 13 neighbouring municipalities have set up the "Regional structural model 2035" (City of Turku, 2012) as a common land use strategy, developed out of the national municipality reform. The Structural model 2035 aims on common objectives for all significant land use activities and focuses on more compact urban development along public transport corridors (Figure 6). It can be considered as a remarkable step towards policy and planning coordination on a regional level.

Current urban development and energy supply

Despite decreasing importance, industry is still an important sector for the city and not least for the wider region. From an energy perspective, industry is though important, e.g. as big customer of the district heating system, which makes district heating in some areas feasible. However, industrial development can also be seen as a hamper for the sustainability goals of the city.

The waste incineration plant in Turku was closed down, also because its old technology did not match with the general goals of an environmentally friendly city development. A sustainable industrial development has therefore also been seen in the light of new, renewable energy sources and how those are distributed.

Skanssi is a new urban development area in the southeast of the city centre of Turku. It is a pilot project for an integrated energy supply and demand system, mainly operating self-sufficiently.
Both, the lasting importance of industry and the development of a new urban area, reflect ongoing growth tendencies of Turku. Hence, Turku is facing the challenge to connect growth policies, by attracting population and industries, and energy efficiency policies.

5 Reconsidering urban structure

Energy consumption corresponds with urban development. Accordingly, principles of urban development, notably urban structure, are supposed as crucial for energy efficiency. This study provides evidence for the need to reconsider the understanding of urban structure when discussing energy efficiency.

The reviewed literature on the relationship of urban structure and energy addresses mainly parameters of *urban form* (morphology), such as settlement pattern and shape, density and land use mix, and their energy implications. Although some contributions add parameters related to *urban functioning* (e.g. communication, transportation system, location in the urban system) or acknowledge the relevance of *socio-economic factors*, the main focus sticks to a spatial perception (urban form) of urban structure; both terms are often used synonymously.

We argue, that the structural conditions, which have certain energy implications, are not only determined by *urban form* (morphology, configuration and compilation) related parameters, but include dimensions related to *urban functioning* (urban system, city-region and flows) and *urban administration* (policy, planning and governance) as well as that considerable interrelations and interdependencies between those dimensions exist. Hence, this paper suggests and applies an extended understanding of urban structure, including a *functional* and *administrative* dimension (Figure 7).

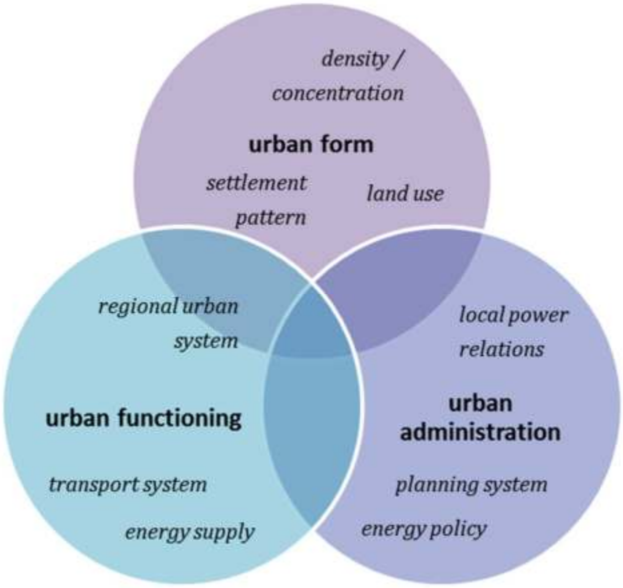


Figure 7. Dimensions of urban structure and exemplifying parameters

Urban functioning describes how the "system city" works; it includes all kinds of urban flows and interactions, like the transportation and energy system, as well as a city's position in the regional urban system. *Urban administration* describes the organization of the "system city" and includes the relevant organizing principles like the planning system, the local power relations and driving policies. We argue that addressing *urban form* to increase a city's energy performance requires considering *urban functioning* and *urban administration* in terms of providing adequate conditions to enable implementation as well as accompanying policies in order to exploit the potential of urban form. Urban functioning and administration inherit also additional potential to improve energy efficiency on a city level.

Urban form – urban administration

All three case studies exemplify how the actual scope of action of a municipality is determined:

- By the allocation of planning competences to the national, regional and local level,
- the territorial scope of a municipality, defined by the municipal boundaries or
- the coverage of a municipal concern, like in Eskilstuna.

Strong planning competencies at the local level combined with narrowly confined municipal boundaries, like in Estonia and Finland, imply a gap of cooperation on the regional level. Consequently, development challenges that cross municipal borders can only be addressed on voluntary effort between municipalities. But problems of regional and long-distance commuting in all three cases show that questions of energy efficient urban development are not tied to the core city level; they require a wider perspective taking into account the regional urban system ('functional urban area') and questions of regional positioning within that system. Also Jørgensen and Ærø (2007) recognize formal and cooperation based weaknesses on the regional level in the Nordic countries and thus, difficulties in handling problems exceeding municipal borders.

The scope of action for municipal urban planning (municipal planning authority) and options to include energy issues in urban development are framed by the organization of the planning system and the local power relations. The capability of urban planning to influence urban form, e.g. by land use planning, is strongly related to the allocation of planning competencies as well as the interdependencies between the different planning authorities and stakeholders, namely urban administration.

Urban administration – urban functioning

Constraints in addressing energy efficiency in urban development can also originate from contradictions in leading principles in national or local policies as well as the need to react to trends in the outside world.

The case of Tartu illustrates that the actual commitment to sustainability or the driver behind energy efficiency in national and urban policies determines both the content and the total effect of set up objectives and measures – either energy efficiency is a subordinate or a leading principle. This is in line with Jørgensen and Ærø (2007) who attest the state a still strong role in urban policy ('national urban policy'). Solving urban problems on a local level requires backing from the state level; but likewise the state requires strong stakeholders on the local level in order to conceive and implement its urban policy (Uitermark, 2005).

In the case of Eskilstuna it is not a lack of commitment to sustainability but a twofold strategy in urban policies, following first-order economically driven policies and downgrading energy efficiency as a second-order policy. This twofold strategy is partly a reaction to trends from the outside world, but it is also taken for granted and negative effects of those are compensated by second-order 'sustainability' policies.

Both cases provide examples for policy trade-offs that originate from goal conflicts – either due to subordinate commitment to energy efficiency or ambiguities in the development strategy. These conflicts take place in the interplay between urban administration and urban functioning, as how energy efficiency is carried out in first- or second-order policies.

Urban form – urban functioning

The differences between the three cases regarding their municipal area in relation to their actual urban area exemplify the interrelation between urban form and urban functioning. Eskilstuna municipality comprises its urban region whereas Turku and Tartu municipality hardly comprise their urban area. Therefore, Eskilstuna municipal planning can address urban form, as related to the core urban area, and the surrounding regional urban system; Tartu and Turku municipal planning is, however, tied to the core urban area, or even less in Turku.

But, for example the way people travel is not sufficiently explained by the characteristics of urban form, as also the case studies show. Specific characteristics of urban form parameters can facilitate sustainable transport, but urban form alone does not determine specific energy consumption patterns. Travel patterns are for example strongly related to a city's positioning in the regional urban system, as the case of Eskilstuna in regional commuting to Stockholm shows.

Urban form, as related to the urban area of a city, is in some respects overlaid by the regional urban system.

Three dimension of urban structure

The cases reveal limitations and obstacles in urban development towards increasing energy efficiency. Thereby the cases illustrate also the interrelation and interdependency between urban form, functioning and administration and provide evidence that addressing energy efficiency from an urban structure related angle requires a broader understanding of urban structure than limiting it to urban form.

Limiting urban structure to urban form implies also to neglect factors besides urban form, like the traffic flows within the regional urban system (regional commuting) or the organization of public transport, which are crucial for the successful implementation of energy efficiency efforts.

The reviewed literature indicates and the case studies show clearly, that understanding and responding on the relationship of energy and urban structure requires taking e.g. organizing principles like local power relations, the planning system and energy policy as well as the embedment of a city in its regional urban system, the transport and energy system into consideration.

Furthermore changes in urban form are difficult and long-lasting processes. Urban functioning and administration, however, are likely more accessible to induced changes, within the scope of action of municipalities, than urban form.

6 Conclusions

The capacity and options of urban energy planning to influence urban energy efficiency are determined by the interplay between *urban form*, *urban administration* and *urban function*. Although the presented cases are quite different regarding the framing conditions, like the planning system, the economic situation and their positioning in the regional urban system, the constraints towards energy efficient urban development show similarities. Just as well face the cities similar challenges: tendencies of ongoing urban sprawl and regional commuting, strongly related to their position within the regional urban system. The outlined constraints mark as the same time aspects which can be affected in order to increase the capacity of urban energy planning. Addressing energy efficiency from a structure-related angle requires addressing urban form, administration and function as an integrated policy package. The study shows furthermore that applying this broader understanding of urban structure turns out as a suitable framework towards energy efficient urban development.

Urban structure is part of the sphere of influence of the municipal planning authorities and can hence (according to the framing national policy) be operationalized through urban planning as competence. Municipalities can act within and affect the three dimensions of urban structure which enables cities to contribute to the achievement of the 20-20-20 targets – decreasing CO_2-emissions by working on sustainable transport, increasing the share of renewable sources by local energy generation as well as increasing energy efficiency through building refurbishment, combined-heat-power generation and regional product cycles.

Nevertheless, the paper illustrates that addressing urban energy efficiency also requires an understanding of urban planning that is not restricted to municipal planning authorities. Urban planning needs to apply a cross-level and cross-sectoral form of policy integration, which exceeds public (municipal) boundaries and involves actors and stakeholders from outside the established public institutions and hierarchical decision-making chains, in order to enlarge its scope of action and respond to the actual local power relations.

The study shows that, with regard to increasing the use of renewable sources as well as urban resilience and self-sufficiency, the relevance of urban energy production as well as a city's heat energy and electricity consumption requires further discussion. Moreover, the policy trade-offs as a result of goal conflicts which take place in different stages and levels of national and urban governance and determine the policy outcome remarkably need to be further investigated in terms of their causes and how to handle those dilemmas.

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