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The Linkage of Urban and Energy Planning for Sustainable Cities: The Case of Denmark and Germany

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***Abstract*—**The reduction of GHG emissions in buildings is a focus area of national energy policies in Europe, because buildings are responsible for a major share of the final energy consumption. It is at local scale where policies to increase the share of renewable energies and energy efficiency measures get implemented. Municipalities, as local authorities and responsible entity for land-use planning, have a direct influence on urban patterns and energy use, which makes them key actors in the transition towards sustainable cities. Hence, synchronizing urban planning with energy planning offers great potential to increase society's energy-efficiency; this has a high significance to reach GHG-reduction targets. In this paper, the actual linkage of urban planning and energy planning in Denmark and Germany was assessed; substantive barriers preventing their integration and driving factors that lead to successful transitions towards a holistic urban energy planning procedures were identified.

***Keywords*—**Energy planning, urban planning, renewable energies, sustainable cities.

I. Introduction

REQUIREMENTS of climate protection, the dependence on imports of energy resources and rising energy prices demand a structural change in urban planning: About 40% of final energy consumption happens in buildings and with up to 80% of this taking place in urban agglomerations [1], one of the biggest challenges in the coming decades for our society will be to transform cities into sustainable and resource-efficient spatial structures [2]. The increasing implementation of decentral renewable energies requires an inextricably linkage of urban and energy planning, because both are executed at community scale and land-use planning in particular can have a strong influence on building energy consumption [3], [4]. In the alignment of urban planning and energy planning lies great potential to increase society's energy-efficiency, which can contribute to the attainment of GHG-reduction targets.

The use of fossil fuels led to a one-way energy infrastructure, with central energy production and a convenient but not very energy-efficient transport to the place of energy demand; historically energy production and energy demand were spatially decoupled. As a result, energy isn't addressed by land-use planning. However, the development of sustainable cities is coherent with the use of renewable energy sources. The majority of these have the attribute of being accessed at the Earth's surface, thus requiring more space, being dependent on natural conditions, thus decentral, and the produced energy is more difficult to transport. Hence, the access to renewable energies is in conflict with other land-uses, or "space equals energy" [5], while energy sources and energy sinks should at the same time be spatially close.

Exploring the correlation of renewable energies and space demands is not new, like the mapping of wind energy or solar power potential in several studies showed. But the mentioned dilemma of spatial concurrence and the need to integrate energy production into cities to decrease the distance between source and sink was only sufficiently approached in a few studies. The majority of studies focus on the general possibility to develop self-sufficient urban energy system models based on a technology mix for energy supply and a decrease energy demand, just to continue scaling the found solutions from building and community scale up to national or global scale [4]. The focus is only on the system, but not on the implementation. Only a few consider the implementation process of these models, such as [2], [6], [7]. The latter identify the importance of local implementation of energy strategies, name barriers and successful energy planning procedures, and claim that the integration of these planning procedures into urban planning fosters the implementation of decentral renewable energy solutions.

Still, integrated urban energy planning is currently rather the exception than the norm. It is widely accepted that integrating energy as a matter into urban planning can contribute to a higher energy-efficiency, but in practice integration is rarely happening to a sufficient extent. The key question is 'how to ascertain the consideration of energy in urban planning processes to facilitate an integrated development of energy sustainable spatial structures?' To approach an answer, this paper assesses the linkage of the urban planning and energy planning systematics in Denmark and Germany. Identified barriers preventing a successful integration of urban planning and energy planning, as well as drivers that enable bypassing these barriers in the formal planning systematics, are described in the paper.

The study analyzed data from Denmark and Germany: general literature on urban & energy planning, legislative documents and information on the administrative structure was evaluated. In a second stage urban development projects from six municipalities (Table I) were assessed to enhance the data from the document analysis with an in-depth case study analysis. The projects were assessed using a combination of

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qualitative research methods; mainly document study, interviews with key actors and observations. The constant cross-case comparison between the projects, based on grounded theory, allowed the identification of patterns in relation to the data from the literature study. A summary of the results is presented in the remainder of this paper.

TABLE I
OVERVIEW ABOUT THE MUNICIPALITIES AND THE STUDIED DEVELOPMENT PROJECTS TO ASSESS THE INTEGRATION OF URBAN AND ENERGY PLANNING

#	Municipality	Population	Reference project	Project type
1	Skive / DK	47.000	Energibyen	Cross section
2	Egedal / DK	43.000	Stenløse-Syd	New community
3	København / DK	508.000	Nordhavn	New community
4	Elmshorn / GER	48.000	Krückau-Vormstegen	Urban renewal
5	Heidelberg / GER	155.000	Bahnstadt	New community
6	Hamburg / GER	1.775.000	Wilhelmsburg-Mitte	New community

II. LINKAGE OF URBAN AND ENERGY PLANNING IN DENMARK

A. National Presets

In 2006, the Danish government set the national long-term energy objective to become independent of fossil fuels; in 2050 Denmark's energy demand for buildings and transport should be entirely covered by renewable energies. Already in 2035 Denmark's building heat and electricity demand should be covered solely by renewable energies [8], [9].

Nevertheless, the transition from central, fossil fuel based energy systems towards decentral energy systems, mainly based on CHP technology to feed district heating and in smaller amounts of wind power and biogas, has already begun in the 1970s. After the oil price-shock Danish politics induced several policies to decrease the dependence on energy exports, which lead to long-term energy plans at national level [10]. The influence of this energy policy change can be seen in an already decentralized energy system, mostly based on CHP and wind power (Fig. 1).

In 2009, approximately 60 percent of all Danish households are heated with district heat from district-heating plants and CHP. 41 percent of the primary energy for district heating is provided by biomass [12]. Renewable energies have a share of about 50 percent in total domestic electricity supply, whereof approximately two thirds come from wind power [13].

Since the Danish Municipal Reform in 2007, the state is divided into three administrative layers: the national level, five regions and 98 municipalities. Actually, the regions play except for some minor fields just an informal role [14], [15]. Hence, the national and municipal levels are decisive for energy planning and urban planning. Municipalities are in particular the most important administrative level. After § 82 of the Constitution of Denmark, municipalities have the right "[…] to manage their own affairs independently, under State supervision […]" [16]. That leads to the municipalities being the decision makers influencing spatial distribution of land-use actively and on a related note energy use passively.

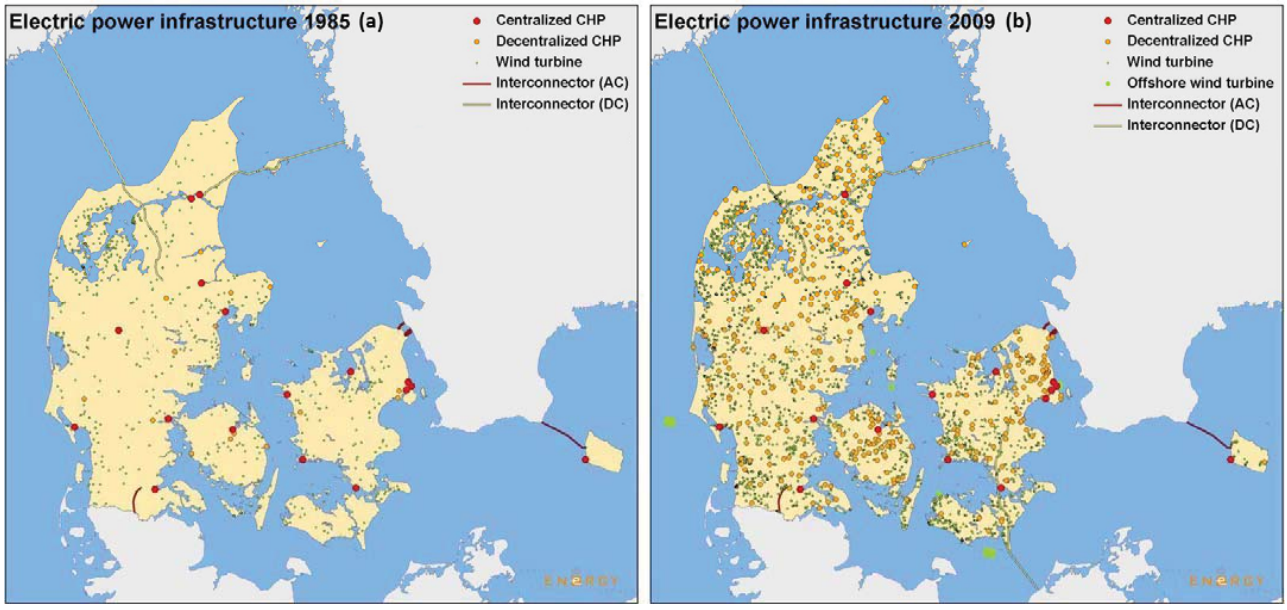

Fig. 1 Decentralization of electric power infrastructure in DK from 1985 (a) until 2009 (b). CHP shown only, if above 0,5 MW [11]

Similar to other EU countries, the electricity (EL) and natural gas market in Denmark was liberalized after the EU directives 96/92/EG and 98/30/EG. While the transmission grid for EL and natural gas is owned by a partly state-owned company and five regional grid operators, plants, local gas and district heating grids are normally owned by regional utilities and municipality works. The majority of local utilities are public cooperation's, owned by the people or municipalities hold the major share. This causes the obligation for utilities not to make a surplus. The companies are in some way always costumer controlled, thus profit is returned to the costumers via lower energy prices.

B. The Urban Planning Process in Denmark

A direct influence by urban planning on energy use patterns is just given on municipal level. Nevertheless, superior administrative levels influence the decisions of urban planning. In Denmark, the *ministry of business and growth* is developing a roadmap for national spatial development and focus areas for municipal urban planning. Matters controlled by the ministry are e.g. the capital region, coastal areas or offshore wind energy. Furthermore, the ministry can intervene into municipal urban planning if matters of national interest are not respected. A spatially sharp plan document with binding stipulations for land-use exists neither on the national nor on the informal regional level [17].

Urban planning in Danish municipalities has four levels (Fig. 3), with two central plans: The Municipal Plan (MP) sets the overall targets and guidelines for the municipality's development. It contains statements about the main structure, traffic, zoning, density and uses within the municipality. Further, it contains the framework for all local development plans in the municipality, which e.g. includes the arrangement for the heating supply of the area. The MP may not deviate from national or regional directives [18].

The Local Development Plan (LDP) stipulates how a specific part of the municipality may be developed and used. The plan concretizes the political strategy and objectives of the MP. LDPs can contain defaults to reach into a high level of detail, such as building orientation and material, color, the use of renewable energies as mandatory, the building energy standards, green roofs or areas for wind power plants. LDPs are legally binding for property owners. A LDP may not contradict the MP or national planning directives. Nevertheless, the municipality may amend the MP by submitting a proposal for a MP supplement for public comment together with a LDP proposal [18].

There are two ways how project developments in Denmark typically get started: First, via the municipality and second through private initiative. The latter is based on an investor or the landowner coming up with an idea and subsequently with a project suggestion. In bigger projects, exceeding one hectare, the municipality typically demands an architectural or urban design competition that should provide the basic urban design and a proposal for a LDP. In smaller projects urban design competitions are usually expendable. On basis of the urban design proposal the municipality develops in cooperation with the landowner or investor the LDP. The responsibility for land-use planning lies normally in the *administration of technology and environment*, in the *department for city development*. In the case of Copenhagen one unit of the department is responsible for city wide cross-section strategies (e.g. energy strategies are one of these), the other is responsible for urban planning (Fig. 2).

C. The Energy Planning Process in Denmark

While the national energy strategy is set and monitored by the *ministry of energy, utilities and climate*, concrete energy planning is happening likewise to urban planning at the municipality level. Municipalities are required by law to develop a Municipal Heating Plan, which is normally happening in close cooperation with the local utilities. The heating plans identify current and future heating energy demand of buildings and in most cases they also show which heat resources are available in a municipality. The document is legally binding and is integrated into the overall Municipal Plan. Further, it is used as decision-making basis for the heating energy supply of urban developments and LDPs.

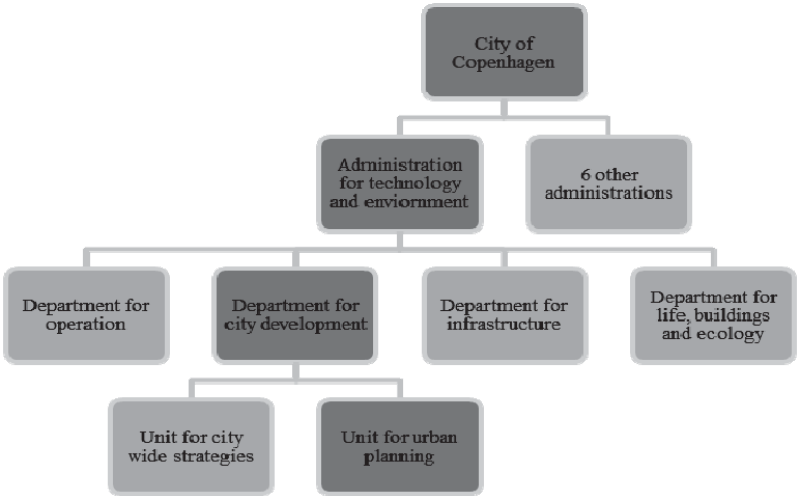

Fig. 2 Location of urban planning (and following land-use planning) within the administration of Copenhagen Municipality [20]

A first generation of municipal heating strategies has A first generation of municipal heating strategies has already been established in the 1980s, followed by a second generation of municipal heating strategies in the 1990s to initiate the transition to more ecofriendly energy sources. Since then heating planning has been stagnant. Electric energy planning has been strongly influenced by the cogeneration of electricity for district heating systems, the shift from oil and coal to

nature gas and biomass, and the extension of wind energy. Thus, electric energy – with the exception of onshore wind power - hasn't been in the focus of municipal energy policy, but is more of a national task [19].

During the process of developing heating strategies an assessment of the most cost-effective options is made. Because of the societal system in Denmark – which is not primarily based on the greatest individual, but more off societal prosperity – the full societal costs for energy projects get calculated. In contrast to cost-benefit analysis of private companies, this secures that mainly projects with the best net-benefit for society get realized. The Danish Energy Agency and the municipalities are monitoring this and intervene in case of societal suboptimal variants and too high prices.

In the last decade, energy planning on a municipal level was mostly project based and has been done by energy utilities. The utilities came up with project proposals (mainly the extension or alteration of district heating systems), whereas the municipality had the responsibility to peruse and approve the proposals. In case of a new LDP the municipality can oblige the utility to develop an adequate heating supply solution for the project that the utility has to fulfill. The project system doesn't necessarily lead to a coherent municipal energy strategy-particularly individual energy solutions or intercommunal energy strategies fell short of expectations, because the existing Municipality Heating Plans were not significantly updated in recent years.

To counteract the outmoded energy planning only focusing on heating, the Danish Energy Agency set up the program for Strategic Energy Plans (SEP) on regional and municipal level as voluntary addition to the municipalities' sustainability strategy. Nevertheless, it can be expected that the process of these plans will set the standard for the third generation of nationwide Municipal Energy Master Plans. SEPs are typically developed in cooperation between municipalities, the local energy utilities, the regional waste treatment utility, research institutions and consultancy firms steering the process. Electricity grid operators and urban planning departments are not always included in the process. The content related work, addressing the energy systems, has been done by technologists. In some cases, the SEPs are noticeably better aligned with the Municipal Plan and the land-use strategies than the existing energy plans with the alignment of district heating strategies, city extensions and community refurbishments [21].

D. Integration of Urban and Energy Planning in Denmark

The process of developing MPs sets the framework for all future land-use planning. The LDPs set the general targets into legally binding land-use regulations. With a bundle of tools from the Planning Act and Heat Supply Act municipalities can foster the use of energy efficient houses and solutions that are based on collective energy technologies. The LDPs are often developed in cooperation with landowner and under participation of the utilities. This leads to land-use planning and particularly thermal energy planning in Denmark being formally integrated.

To approve local development projects and make sure that the solutions for these are coherent with the municipal strategy, all municipalities in Denmark have heating plans. The majority of municipal heating plans got developed by municipalities and local utilities. The municipalities have, due to special rights and interest in the utilities, a great influence on the decisions in heating supply. Danish heat planning rests on national policies made decades ago to decrease the dependence of fossil fuels. The legal possibilities for municipalities to implement their formerly mandatory and formal municipal heating strategies got continually strengthened in the past. Due to the Danish energy targets, energy is often considered before the development of a LDP and the legally binding land-use planning. This can either be fostered by higher energy standards demanded by the planning department of the municipality (Case 2), a DGNB certification and intensive dialogue between municipality, investor, utility and developer (Case 3), or through a cross-sectional administrational unit to foster renewable energies to strengthen the local economy (Case 1). Still, cooperation between working units within the city administration is not as coherent and well-matched, as it could be and the project based system led to a loss of energy planning knowledge in municipalities.

III. Linkage of Urban and Energy Planning in Germany

A. National Presets

The German government set the national long-term energy objective to increase the overall share of renewable energies up to 60% by 2050. Reduction targets for GHG emissions of at least 40 percent by 2020 and 80 to 95 percent by 2050 (in comparison to 1990) were set in 2010 [22]. The transition of the energy system off nuclear and fossil energy sources towards renewable energies ("Energiewende") is already noticeable: The share of renewable energies at the overall primary energy used in Germany was in 2015 at 12.6 percent [23]; the share of renewables on the electricity consumption is at 32.5 percent. The share in renewable energy production is steadily increasing, with wind power and PV as main drivers [24]. The heating supply of private households is dominated by oil or gas boilers. District heating is at 6 percent and renewable energies at about 10 percent share of the total heating energy consumption – the latter with significant increasing in recent years [25].

Germany is divided into four administrative layers: the national level, 16 states, administrative districts similar to regions and 11.084 municipalities. Federalism is one of the constitutional principles: Topics of national interest are the exclusive responsibility of the federal level, while other matters, such as education or culture, are handled by the states and the federation autonomously. Municipalities are up to a certain size mustered to counties or organized in unions of local authorities, if their size is not sufficient to ensure an adequate performance of administrative obligations. Local affairs are managed entirely by municipalities. The autonomy of municipalities is secured by Section 28 of the basic law with "the guarantee of self-government […]", resulting in legally binding land-use planning being a task for municipalities [26].

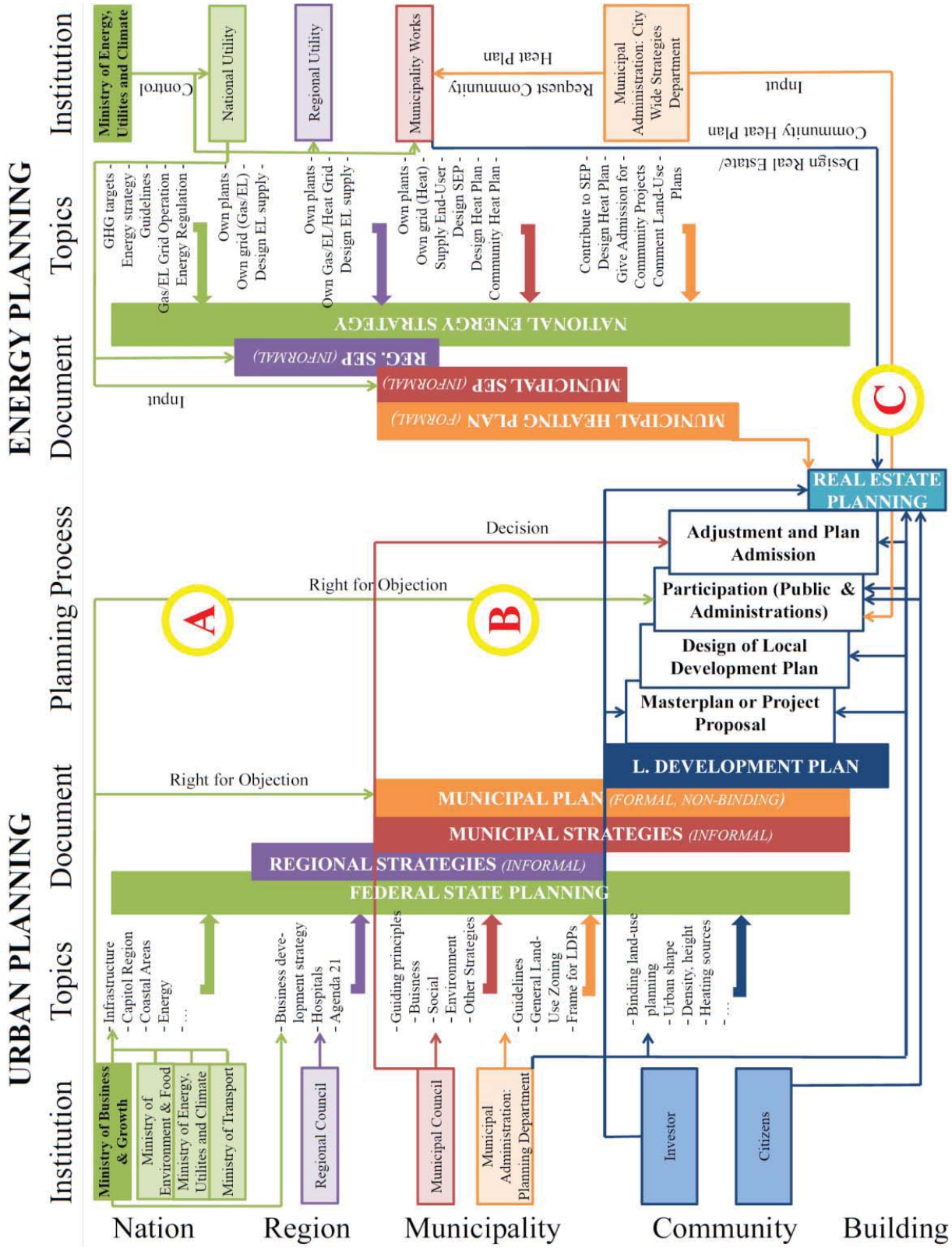

Fig. 3 Comparison of formal urban planning and energy planning process in Denmark with focus on land-use planning process and areas of linkage (A-C)

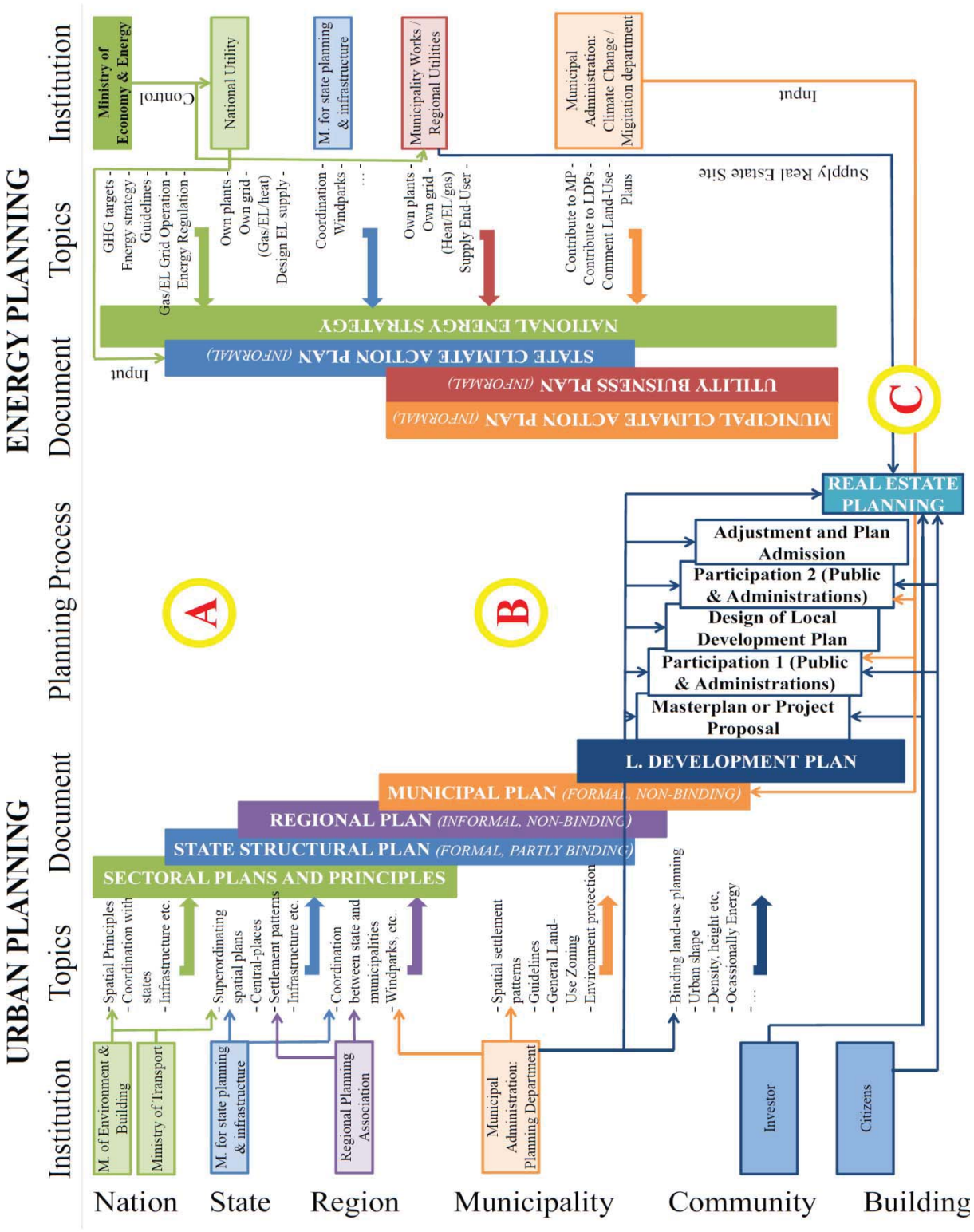

Fig. 4 Comparison of formal urban planning and energy planning process in Germany with focus on land-use planning process and areas of linkage (A-C)

The electricity (EL) and natural gas market was liberalized after the EU directives 96/92/EG and 98/30/EG. While the transmission grid for EL and natural gas is owned by four private regional grid operators, smaller plants, local gas and district heating grids are normally owned by regional utilities or municipality works. Privatizations of state-owned utilities around the year 2000 lead to local energy planning through private companies with and accumulation of economic power at fewer and bigger energy utilities. Still, large energy companies hold only a low share of the renewables market. In the last decade a trend of remunicipalisation of infrastructures and utilities is noticeable. Thus, municipalities partly regain the control over the local energy infrastructure.

B. The Urban Planning Process in Germany

The Spatial Planning system in Germany is distinguished by a high coherence between different administrative layers. The principle of countervailing influence is the cause: Directives from higher administrative levels have to be considered – likewise stipulations from lower administrative levels are relevant for superordinating spatial plans. The *Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)* is setting principles for spatial development and national infrastructures, while all states are responsible for function allocation to urban areas ("central places") and steering settlement patterns within their boundaries. Besides the municipal level, an influence by Spatial Planning on energy use patterns is given via Regional Plans with stipulations for wind power sites. The aim is to reserve areas for wind power to avoid other uses, hence, it is neither actively influencing energy usage nor in the urban context. Still plan documents from state planning and partly regional planning are binding for municipalities, thus, the stipulations have to be considered in MPs and following LDPs, which makes them indirectly binding for land-use [27].

Similar to Denmark, urban planning on municipal level is divided into the MP and LDP. The MP consolidates all regional and municipal spatial plans. It contains statements about the main infrastructure, zoning, density and uses within the municipality. Energy is, except for energy supply facilities, supply lines and areas reserved for renewable energies, not a part of the MP. Thus, the municipality can only ensure energy infrastructure coming from LDPs or other plans; via the MP they have no influence on type and arrangement of energy systems. In contradiction, the LDP stipulates how a specific part of the municipality may be developed and used. LDPs are legally binding and more detailed about uses, building shape and heights than the MP. Energy relevant stipulations are possible after the Federal Building Code, e.g. a ban of air polluting heating supply (§9) or the determination of infrastructure [27]. Other possibilities arise from special plans, local bylaws or urban development contracts allowing an enforcement of a compulsory connection to district heating, the use of solar power or higher energy standards than required by the German building code [28].

LDPs get developed on the basis of a function plan, which is either developed by the municipality or an investor. Basis for this informal plan are in bigger projects urban design competitions; for smaller developments these are redundant. On basis of function plan the planning department within the municipality administration develops the LDP in cooperation with other public bodies including energy suppliers and under consultation of the public. In some big brownfield development or urban renewal projects public development agencies (Case 5&6) often overtake tasks from the municipalities and combine aspects of urban planning with social or energy relevant aspects within one working unit.

C. The Energy Planning Process in Germany

While the national energy strategy is set and monitored by the *BMUB,* respectively working units within such as the *Federal Network Agency*, concrete energy planning is happening at the regional or municipal level. The state coordinates the extension of gas and electricity transmission grid, as suggested by the energy utilities. The states develop Climate Action Plans that set focus areas for GHG emission reduction and the expansion of renewable energies. These are mostly used to allocate subsidies for projects and provide guidelines for municipalities in Energy planning. Municipalities have similar Climate Action Plans that set goals for reductions in GHG emissions and combine these with certain programs, such as energy renovation or the development of wind parks. These plans, normally developed by the working unit of climate protection & adaption within the department for city development in municipal administrations, are included within urban planning documents. But, these plans are on all levels purely informal and in smaller municipalities (e.g. Case 4); only few or just one person is responsible to secure the integration of these matters into urban planning. This leads to energy planning, except for very ambitious municipalities or projects steered by development agencies, being mainly carried out by utilities. It needs a good cooperation between utilities and the municipality to foster the integration of urban and energy planning, which is in a lot of smaller municipalities not given. Thus, the ambition of a local development project in relation to energy is strongly depending on the political climate, the dedication of single members within a municipality's administration and the availability of progressive local energy utilities.

D. Integration of Urban and Energy Planning in Germany

The urban planning is based on a strong coherence between different administrative layers, leading to a firmly and formally well integrated urban planning. Strong regulations allow municipalities to enforce land-use planning to secure sustainable settlement structures. Municipalities have via urban planning a toolset to address energy related issues, for example via LDPs, local bylaws or urban development contracts. But energy gets mostly addressed in Climate Action Plans, thus there is often no stand-alone and proactive energy planning from state or municipal administration. Further, the documents are informal which leads to energy planning mainly being executed by private utilities. The lack of a formal public

energy planning leads to energy being a subordinated matter in urban planning and an insufficient integration of urban planning and energy planning to reach a transition towards sustainable spatial structures.

The toolset and public participation in the LDP development process already allows a strong integration of energy into urban planning, but it is often not used, because of a missing community energy plan as counterpart to the LDP and the informal character of energy targets. In the Cases 5 & 6 energy standards were secured via property acquisition agreements and the municipality in Case 4 refused to use the legal possibilities given by urban planning to integrate energy standards in a development project. The informality of energy planning in Germany causes an under fulfillment of possible synergies between urban and energy planning.

IV. Comparison between Countries and Analysis of the Linkage of Urban and Energy Planning Procedures

A. General Spatial Planning Systems

The wider distribution of spatial planning to four administrative layers leads to a more coherent and more integrated spatial planning in Germany than in Denmark with in fact only two layers. On the other hand is Denmark a lot smaller than Germany, thus two regional planning layers might not be needed. The municipalities in both countries have a remarkably strong position, responsibility, and autonomy compared to other European countries, whereas the autonomy of German municipalities is due to the strong regional planning lower than in Denmark. As a reason, the regional planning in Germany is more formalized, which doesn't necessarily lead to a better regional cooperation than in Denmark – again, because of the size. Virtually, one could compare the structure of the federal states of Germany, without the national level, to the whole of Denmark.

B. Integration of Energy into Urban Planning

The Local Development Plans, as binding land-use planning instruments that actively influence energy usage patterns, are of similar structure in both countries. The LDP in Germany is a legally stronger instrument than in Denmark, which can also be initiated without a current development project, resulting in a longer planning process with a broader participation of administrations and public and often a wider scope. In comparison, Danish municipalities have a wider range of possible energy relevant stipulations in the LDP.

The integration of energy issues into urban planning in Denmark is by tradition more formalized than in Germany, leading to an overall increased awareness for energy as a matter for the weighting of interest within the planning process. Hence, the coherence between urban and at least heating energy planning is on a relatively high level. The active role of the Danish municipalities in heating planning, e.g. with the mandatory heating plans, has a high impact on the integration of energy into urban planning. In contrast, climate protection programs and energy plans are just informal instruments in Germany's spatial planning hierarchy. The differences in the planning procedure can be seen in the higher level of renewable energies used in Denmark and the more ambitious climate targets that many Danish municipalities set.

In Figs. 3 and 4, the main strategies and planning documents from urban planning and energy planning are listed in matching colors according to the administrative level on which they were developed. Distinctly, on all levels are linkages between energy & urban planning. While the linkage on the national and regional level (marked with A) is mainly about including energy issues into spatial plans and setting up the framework for the national energy system, the linkage is very concrete and intensive on the municipal level (B). This linkage is formalized with the municipal heating plans in Denmark, which establishes a strong linkage between urban & Energy Planning. In Germany there is no formally established connection between energy & urban planning on municipality level. As a result, progressive municipalities in Germany are on the same level in proactive integration of energy issues into urban planning as average performing municipalities in Denmark. In the majority of German municipalities energy planning is purely informal and the concrete energy strategies are developed by energy utilities. The linkage on community scale or the level of binding land-use planning via the LDP (C) is similar in both countries. While the LDPs in Denmark are framed by stipulations of the MP, originating from the Municipal Heating Plans, it exists no framework for energy relevant stipulations in Germany. Thus, the general use of energy relevant stipulations in Germany is depending strongly on the type of community and awareness of the municipality. As outcome possible stipulations to foster the use of renewable energies, that are almost as wide as in Denmark, are often not used in German LDPs. It is remarkable that in both countries there exists no counterpart to the LDP on the energy planning side, which results into abstract energy strategies on community scale, if there is no community energy concept prevailing.

C. Actors in Urban and Energy Planning Processes

Despite the integration of heating planning into urban planning in Denmark, the cooperation between working units within the city administration is not as coherent and well-matched as it could be. Energy planning has to be to some extent technically detailed, which makes the contribution of energy utilities necessary. The project based system in Denmark led to nearly sole takeover of energy planning by utilities, which results into a further depletion of energy planning knowledge in municipalities. This applies even stronger to Germany, where almost no tradition of public energy planning exists.

While utilities in Denmark are still mainly under public control and restricted to work in a societal way, the privatization of public infrastructure in Germany decoupled energy & urban planning even further. The achievement of GHG emission reduction targets is depending strongly on cooperation between municipality and energy utility, which is often at a low level. This is caused by a different understanding in the responsible planning entities: Energy

utilities are responsible for technical concepts; the municipality administrations by contrast develop strategic concepts with a stronger influence on other, more social aspects. The units for climate protection in the municipality administrations in Germany that could introduce technical knowledge to urban planning are often too small, hence, not strong enough to have a greater impact. But to activate municipalities as proactive promoter in the transformation of energy systems, it would need a stronger integration of technical knowledge into urban planning [29].

V. Conclusion

Despite distinct legal and administrative systems, findings showed similarities between the countries: urban & energy planning is typically carried out by separated planning entities, leading to incoherent planning processes, resulting into diametrically opposed problem understandings and working procedures; technology versus sociology. Main barriers are located among the interaction of engineers, with their technical knowledge into the minutest details, and municipalities, with rather generic strategies and lack of technical knowledge or lacking interplay of technical and social factors to develop energy strategies that are suitable for implementation. Hence, municipalities are unable to take a coordinating role, which weakens the integration of energy in urban planning. As a further weak point, energy planning in Germany is completely informal, which weakens the position of energy within the weighting of interest as performed in urban planning.

The underperformed implementation of existing Energy Plans, besides the general problem of several stakeholders with conflicting interests, is partly caused by a too low plan resolution: While in both countries the MP is followed by an LDP responsible for binding land-use planning, public energy planning stops at municipal level. Hence, the LDP is missing an opponent on the side of Energy Planning, which makes Energy Plans to abstract to be implemented in particular development projects and leaves this tasks mainly to energy utilities. Nevertheless, project based urban planning entities showed an increased awareness and implementation rate of energy issues into development projects than sectoral organized administrations. In development projects where energy strategies were beneficially connected to other municipal policies, the linkage of urban & energy planning was successful. As conclusion several points were identified to improve the integration of urban & energy planning and eventually contribute to more energy-sustainable cities. These points are listed below, structured by the responsible administrative level.

A. What Has to Be Done on the National Scale?

The development of SEPs on regional and municipal level should be mandatory in Denmark. The integration of transport, thermal energy and electricity supply – as attempted in available SEPs – into a common energy strategy is overdue and should be available in all Danish municipalities. Further, it should replace the existing heating plans as basis for decisions about the energy supply of new LDPs. A national subsidy program should be initiated to foster such a planning process within all municipalities.

The same applies for Germany, with the significant difference that there hasn't been a mandatory heating planning this far. Thus, similar to the MP Germany's municipalities should have formal Energy Plans or an extension of the MP that addresses the future energy scenario for the municipality, in the same way it is already possible for wind power today. The emphasis of energy planning would require stronger climate change working units in the municipalities' administration, which would also increase the knowledge on energy planning within municipalities. It doesn't necessarily need new administrative structures or planning methods, but a reconcilement and interconnection of Energy & urban planning to reinforce each other and create an added value.

To enable municipalities to take an active role in Energy Planning, both in Denmark and Germany, the national level has to provide tools, how it is to some extend already happening in Denmark [30]. Examples like energy potential maps, such as the Danish Heat Atlas, simple calculation tools as used in Case 2 or a description of energy technologies in terms of urban planning implications would be a great help to municipalities, how some of the investigated cases showed.

B. What Has to Be Done on the Municipal Scale?

An important step from a SEP to the implementation is translating energy strategies to community scale. Hence, for every community development – new developments and urban renewal projects – community energy concepts should be developed to integrate the required measures into formal urban planning before the LDP gets developed. The cases (in particular Case 2, 3, 5, and 6), where this was performed, showed a better integration of energy issues into the Master Plan, following LDP and in the finished community.

Additionally, a closer cooperation between planning entities, public and private, is needed. A result could be periodic update meetings between utilities and municipal administrations or a mandatory inclusion of energy utilities in the first steps of community developments.

The latter could eventually lead to a merging of technical and social factors in energy strategies and urban planning, which is desperately needed in Germany and Denmark: The implementation rate and quality of energy strategies is strongly depending on who is responsible for energy planning – the more technical energy utilities or the more strategic orientated municipality administration. If it is possible to merge technical knowledge and energy strategies with municipal development strategies, thus, to generate co-benefits for other municipal policies, a crucial barrier for the integration of energy into urban planning can be bypassed.

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