Towards Energy Efficient Housing – the importance of local energy planning

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ABSTRACT A strategy for local energy planning must be in place in order to transform the local energy system and must comprise all relevant sectors and decision makers, i.e. include the residential sector with its relevant stakeholders. Thus, the housing sector cannot be treated in isolation but should rather be part of an analysis which takes a municipal energy systems perspective. This paper reports from an EU IEE (Intelligent Energy Europe) supported work named PATH-TO-RES which develops a methodology to be used as support tool for local energy planning. The work uses a number of local case studies (Göteborg (SE), Valencia (ES), Dunkerque (FR), Gdansk (PL) and Arnhem and Lochem (NL)) to develop a step-by-step assessment which can evaluate and define Pathways to renewable and efficient energy systems.

A Pathway is a cost efficient way to bridge over from the present energy system to a sustainable system. In short, the proposed methodology starts with a detailed description of the present system (energy infrastructure as well as decision makers and stakeholders) and, based on this, a number of steps are defined with the aim to serve as check points to ensure that one or more Pathways can be formulated which describe how the local energy system can be transformed to comply with goals and targets.

In order to describe the energy systems of the six case studies in a common way, a schematic model called a RES-diagram (RES=Reference Energy System) has been applied, from which the structure (i.e. components, flows and connections) and energy balance of the systems can be determined. In the six municipalities studied considerable variation of population, land area and scale and characteristics of the existing energy systems exist. Differences and similarities between the six systems are highlighted and the paper discusses pre-requisites and conditions for municipal energy planning, based on energy systems of the case study regions.

Key Words

Residential sector, Municipal, Local, Energy planning, Energy efficiency, Buildings

Introduction

Working processes for municipal/local energy planning are carried out in many European countries. If such processes are successful they can be a powerful tool for transforming local energy systems in desired directions (towards; cost efficiency, reduced emissions, enhanced security of supply, etc). According to the IEA guidebook; Annex 33 Advanced Local Energy Planning (ALEP), (Jank, 2000), local energy planning (LEP) has its origin in methods and experiences developed in response to the oil- and energy crisis in 1973. The overall objective of LEP was to influence energy systems towards specific policy driven goals. Experiences indicate that the main focus of LEP's have expanded and changed over time. In the seventies the main areas of focus were reduction of oil consumption and improved efficiencies for energy conversion (e.g. heat and/or power plants). In the eighties, reduction of pollutant emissions had priority. In this decade local sustainability and strategic optimization of the energy system under deregulated market conditions have been identified as the most common areas of focus. Yet it has also been observed that the older areas of focus have not been abandoned and, thus, the general scope of LEP has been broadened since it was initiated (Jank, 2000; Johansson 2001).

Several studies have shown that system boundaries for energy planning have widened over recent decades in certain European countries. Thus, LEP processes have developed from simply being administrated by the municipality, to being a cross functional process including different fields and actors, all of whom have a strong dependence on the local energy situation. Consequently, the need for alignment between individual projects and long-term energy strategies for entire municipally administered areas has been recognised. As a result of this, new LEP methodologies have been developed in recent years that correspond to the requirements of more integrated solutions. LEP has thus veered away from using traditional engineering approach, as technical planning methods are now combined with aspects and methods that have more of a sociologic character (Jank, 2000; Haglund 2006; Butera, 1998)

Notwithstanding the obvious drives towards cost efficiency, reduced emissions, enhanced security of supply in the energy sector there are several reasons why LEP can be considered as a fundamental strategic policy activity, for example (Jank, 2000; Johansson 2001):

- It deals with a long-life infrastructure, which is not well adapted for fast turnover (planning horizons for infrastructure may stretch between 10 to 50 years). Furthermore the effects of changes have long lasting impact.
- Long-term trends and developments in several related parameters from which decisions have to be made are hard to predict e.g. fuel prices, taxes, subsidies, legislations, economic growth and socio-economic changes.
- As previously stated, many different actors are involved, who themselves can have conflicting goals.
- Changes in the energy system may have a large environmental impact.
- Energy planning strongly interacts with other fields of strategic importance e.g. environmental planning, urban planning and/or transport planning.
- The exploitation of local renewable sources like biomass, solar energy, wind, hydro power and waste heat is often expensive and needs stable, long term commitment within a policy framework to justify investments. Energy systems contain many interdependent subsystems, which mean that changes in one subsystem may affect several others. Traditionally, subsystems are often studied and planned separately and then in some cases combined to make an overall plan. Experiences indicate that such an approach often creates suboptimal overall energy systems, since it may neglect important interdependencies between subsystems.

Based on the previously mentioned reasons for strategic planning, Jank (2000) recommends that the planning process is carried out on two levels; one for a comprehensive analysis of the entire local system and a second level for planned or ongoing projects.

This paper reports from an ongoing EU IEE (Intelligent Energy Europe) supported work named PATH-TO-RES (IEE, PATH2RES, 2008) which develops a methodology to be used as a support tool for local energy planning. The work uses a number of local case studies (Göteborg (SE), Valencia (ES), Dunkerque (FR), Gdansk (PL) and Arnhem and Lochem (NL)) to develop a step-by-step assessment which can evaluate and define *Pathways* to renewable and efficient energy systems. A Pathway is thus defined as a cost efficient way to bridge over from the present energy system to a sustainable system. In short, the proposed methodology starts with a detailed description of the present system (energy infrastructure as well as decision makers and stakeholders) and, based on this, a number of steps are defined with the aim to serve as check points to ensure that one or more Pathways can be formulated which describe how the local energy system can be transformed to comply with goals and targets.

Currently most municipalities within the EU have strategies or are developing strategies that aim to fulfil long term international goals such as those contained in the EU Climate change and energy package. These are generally referred to as the "EU202020 goal" (European Commission: EU action against climate change, 2010). There are also several municipalities, mainly within the EU, that have signed up to the Covenant of Mayors and thereby committed their municipalities and cities to go further than the EU202020 goals (European Commission: Covenant of Mayors, 2010). Obviously there are differences in level of skill and experience with energy planning in municipalities across Europe. Related to this, the EU Commission have called for relevant supporting structures for municipalities that need guidance with developing plans and strategies for fulfilling commitments such as the Covenant of Mayors. Thus, there are planning methodologies developed within different EU programmes such as the aforementioned IEE programme. In one ongoing IEE project called PEPESEC[1] (IEE, PEPESEC, 2008), which investigates and compares energy planning processes throughout Europe, it is concluded that although these processes obviously differ from each other, there are several aspects which are general, and rather obvious, such as gaining political support, assessing the current energy system and setting targets. It is also concluded that any methodology chosen will work as long as there is continued commitment to its achievement. Obviously, the engagement of key actors in the planning process is central to its fulfilment.

There are also several guidebooks for local energy planning available for practitioners. Besides the aforementioned IEA guidebook (ALEP) some relevant examples are: Community planning – An introduction to the Comprehensive plan (Kelly, 2010) and Urban Energy Handbook –Good local practice (OECD, Alexandre et al. (editors), 1995). These books describe structured working processes for energy planning as well as practical examples of the implementation of different case studies. There are also several papers written within the scientific community that relate to LEP. Two areas can be identified from papers examined that are relevant to this work. The first evaluates previous or recent energy plans and strategies in municipalities or regions while the second evaluates or proposes energy planning methodologies for the local community. Under the former theme some important issues can be identified. Access to data on municipal energy systems differs across European countries. A study of 12 municipal energy plans in Sweden shows that all of these plans have obtained data on their incumbent energy system and provided a more or less detailed description of their current energy situation (Stenlund Nilsson, Mårtensson, 2002). At the other end of the spectrum, a study over the situation in the UK indicates that access to data for the present energy situation, i.e. supply and consumption of natural gas and electricity, is a major issue in several municipalities (Fleming, Webber 2003). Another important issue is the possibility local authorities have to influence the municipal energy system. Bulkeley and Kern (2006) have made a study of three German municipalities and three British municipalities which indicate that during the last decade's municipalities have successively lost much of the influence they once had over local energy systems. One important reason for this is that several parts of the energy infrastructure previously owned by the municipalities themselves, such as district heating networks, CHP plants[2] and heat only boilers have been sold to the private sector. In an example from the methodologies area, Cormio et al. (2002) propose a linear programming optimisation approach that aims to reduce environmental impact and economical costs for local energy

[1] PEPSEC=Partnership Energy Planning as a tool for realising European Sustainable Energy Communities
[2] CHP = Combined Heat and Power

systems. The model begins from a detailed system description and includes components in the local energy system such as power and heat generation and end use sectors. Another valuable example is a paper from Terrados et al. (2009) which propose a methodology that has more emphasis on strategic decision making processes rather than technical issues. The model combines SWOT analysis (Strengths, Weaknesses, Opportunities and Threats), MCDA analysis (Multiple Criteria Decision Analysis) and Delphi techniques into one methodology that is performed in seven different steps in order to identify the most optimal strategies for increasing the share of renewable energy sources in the local energy system.

From the aforementioned books and papers it is concluded that there are several methodologies available for local energy planning. In fact the large number of methodologies available can lead to an inordinate amount of time being expended in choosing between methodologies. Two valuable conclusions can be drawn from the review of the scientific papers. First, for several municipalities in countries across the EU, access to basic items such as data on incumbent energy systems and the lack of involvement of local key actors and stakeholders are obstacles to the development of sustainable energy strategies. Second, the methodologies available are believed to provide valuable support for municipalities and regions provided that they have already established working processes for energy planning and access to skilful practitioners. In other cases, there is a risk that these methodologies may be too advanced for municipalities with little previous experience of energy planning. When the PATH-TO-RES project was initiated it was not envisaged to be possible to find one "standardized" methodology that can be applied to any municipality, since all local energy systems are quite unique. Furthermore the idea was not to replace existing methodologies. Instead it was thought to be more appropriate to develop a step by step checklist at a more general level, which can be of use to any municipality and in some cases can also complement other methodologies.

The aim of this paper is to discuss advantages and impacts of energy planning in the context of municipal energy systems with some references to the residential sector. Discussions are based on experiences from the PATH-TO-RES project including the six case studies and the methodology developed. The point of departure is the present energy system and thus emphasis is put on existing conditions in the six cases studied and how they allow for energy planning.

Methodology

As mentioned in the introduction the aim with the PATH-TO-RES project is to develop a support tool for local energy planning (IEE, 2008, PATH2RES, 2008). The basic hypothesis of the work is that seven steps must be analyzed and assessed in order to formulate a roadmap for transforming local energy systems to sustainable systems. The steps are partly carried out in an iterative way (i.e. not in consecutive sequence). The seven steps are:

1. Project initiation [1]
2. Establish a detailed description of the present system
3. Assess local, EU and global goals
4. Identify and assess key technologies which can bridge to a future sustainable system
5. Identify key actors in the region (to ensure correct decisions and competitive markets)
6. Formulate and analyse pathways towards a more sustainable energy system

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[1] The original name of this step was: "Analyze and formulate initial conditions" (Experiences from the case studies indicated that early commitment from key actors and clarification of the purpose is crucial).

7. Establish a roadmap (with respect to technologies, markets, institutions)

The ambition is that the methodology developed should be as user friendly as possible and suit a diverse range of local energy systems with varying size and characteristics. Organisational structures and working processes for energy management differ between municipalities throughout Europe and it is neither intended, nor believed to be possible, to develop a methodology that can replace existing working structures on a general basis. Thus, the methodology is meant to be applied more as a checklist for existing organisational structures.

One important feature of the methodology is the detailed inventory over the present conditions (Steps 1 to 5) with a special emphasis on the description of the present energy system (Step 2). Another important feature is the description of the way of change for the system, i.e. the pathway (Step 6). The previous steps set a foundation for the description of a roadmap for the energy system. Finally, the roadmap which describes a chosen pathway (Step 7) provides an opportunity to integrate short term plans which mainly are action oriented to long term strategies and visions.

In order to describe the present energy system a schematic model called RES-diagram (RES=Reference Energy System) has been used, from which the structure (i.e. components, flows and connections) and energy balance of the systems can be visualised. The following items can be determined and quantified from a RES diagram: Primary energy sources, Energy conversion- and fuel modification units, Distribution networks, Final energy consumers, Energy flows and how they are linked in the system and Energy balances. Figure 1 shows an example of a RES diagram with typical components.

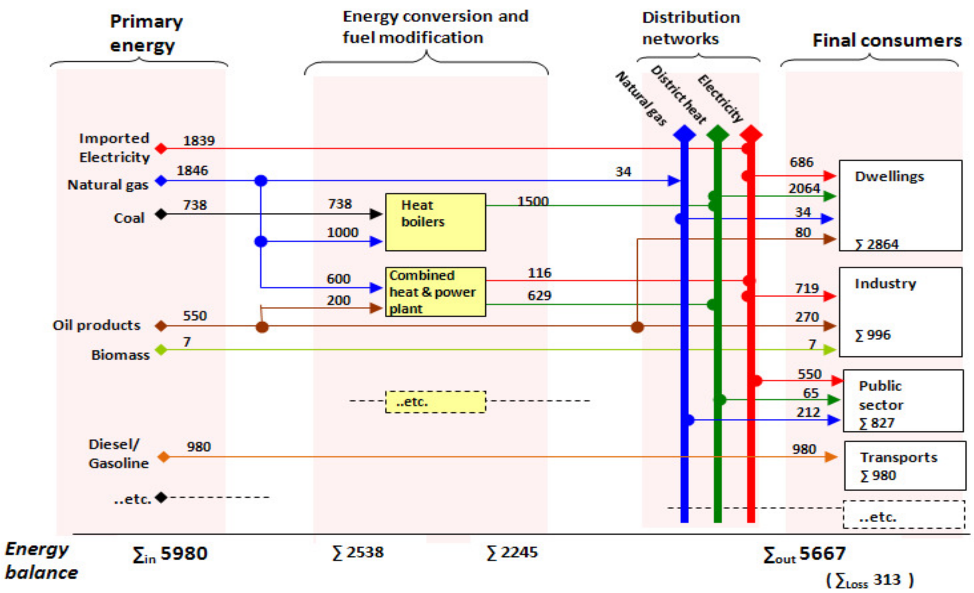


Figure 1: Basic design of a RES-diagram with exemplified structure and data.

It should be stated however that the RES-diagram is not the only way to visually describe an energy system, i.e. there are of course other ways to illustrate the above information, such as Sankey diagrams and simple Excel-sheets. No matter what method chosen, it is believed that all of the above mentioned items must be included and the choice of methodology must be consistent throughout the pathway-description.

Besides the physical description of the present energy system it is also necessary to identify and list the actors considered to have the largest influences on the system, for example; political decision makers, representatives from municipal/regional administrations and energy companies involved in the municipality. Furthermore it is crucial to make an inventory of relevant goals and plans that may overlap and/or impact on the local energy system. Together with the physical description, these parameters provide a complete picture of the base conditions that dictate the point of departure of energy planning in the local setting.

Once the conditions for energy planning have been established, pathways for transforming the system can be formulated. Figure 2 has been used within the work in order to describe the pathway concept. In short it has the following key components:

- An appropriate technical description of the energy system (such as the RES diagram) with all its components.
- Time period for which the pathway should cover. The time period is divided into steps (3 steps (short-, medium- and long term) have been applied within this work). The energy system description is then modified for each step.
- Relevant indicators for changes in the system, i.e. the most important energy indicators and indicators for CO2 emissions. (Such indicators can easily be derived from the RES diagram).
- Parameters which define and express the pathway. These parameters are (1) "hard" parameters (such as the components of the RES diagram), (2) "soft" parameters such as goals and visions, present plans and projects and roles of key actors and (3) "Overall reflections" i.e. discussions about how all parameters interact in terms of risks, possibilities, obstacles, etc

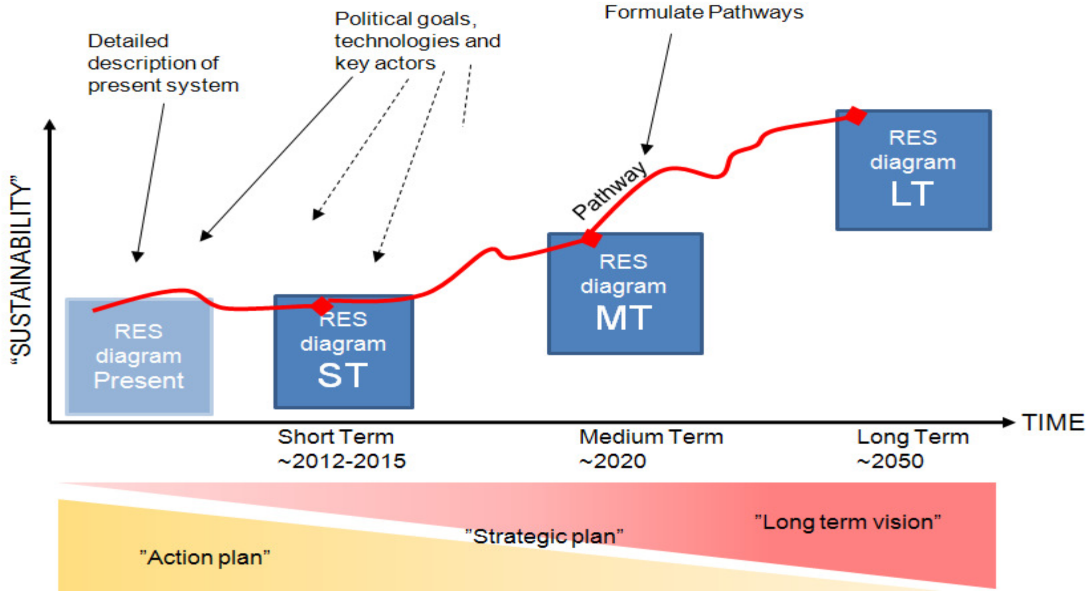


Figure 2 : Basic description of a pathway and how it interacts with plans and strategies for different time horizons.

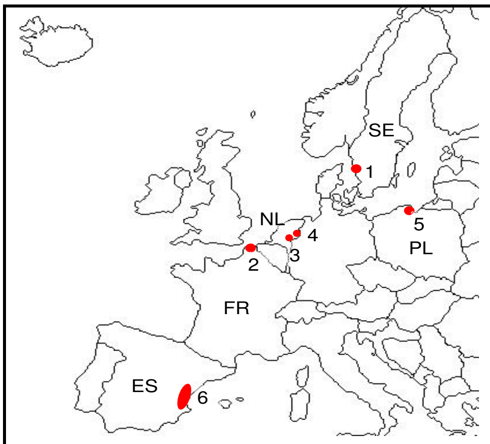
Since the scope of this paper focuses on describing the conditions for local energy planning, the pathway concept is not discussed in detail. Yet, some reflections on the potential transformation of the energy systems in the case studies are given.

Characteristics for the case studies

The characteristics of the six case study locations differ considerably. In Table 1, basic facts from each are presented. The data in

Table **1** have been collected mainly from surveys filled in by case study representatives. (The data for population and energy figures refer to years between 2004 and 2007). Both area and population vary considerably across the case studies. Arnhem is by far the smallest case study, since it is limited to a block of flats (population 262) and Valencia is by far the largest (population >4.8 millions). Furthermore, the administrative levels of each are different. In most case studies the municipality is the administrative level considered. However, as indicated above, in the case of Arnhem the study is focused on a specific home owner association whereas in Valencia it includes an autonomous region divided into provinces that each contains hundreds of municipalities. Consequently, organisational structures and decision making frameworks differ considerably across the case studies.

Table 1: Basic characteristics of the six case studies



	CASE STUDY
1.	**The municipality of Göteborg. (SE)** (*Extensions of district heating network into two neighbour municipalities are included in the study.)*
2.	**CUD- Greater Dunkirk Urban District Council (FR)** (*Groups together 18 municipal areas (Extension from Grand fort Philippe to Bray-Dunes.))*
3.	**The home owner association of De Stoere Houtman in Arnhem. (NL)** (*The association currently includes 138 apartments and a total number of 262 inhabitants.)*
4.	**The municipality of Lochem (NL)**
5.	**The municipality of Gdansk (PL)**
6.	**The region of Valencia (ES)** *(Including provinces of Valencia, Alicante and Castellón).*

BASIC DATA	**Göteborg**	**Dunkerque**	**Arnhem**	**Lochem**	**Gdansk**	**Valencia**
Population	490 000	263 200	262	32 840	460 000	4 874 800
Approximate area [km²]	451	255	N/A	216	262	10 563
Population density [/km²]	1086	1032	N/A	152	1756	461
Primary energy supply [MWh/year]	$13.8 \cdot 10^6$	$7.7 \cdot 10^6$	$3.1 \cdot 10^3$	$0.68 \cdot 10^6$	$9.1 \cdot 10^6$	$149 \cdot 10^6$
Final Energy Consumption (FEC) [MWh/year]	$13.4 \cdot 10^6$	$6.0 \cdot 10^6$	$3.1 \cdot 10^3$	$0.68 \cdot 10^6$	$6.6 \cdot 10^6$	$117 \cdot 10^6$
FEC /capita [MWh/year]	27	23	12	21	15	24
FEC/capita *(national level)* [MWh/year]	45	33	46	46	19	28
FEC in the housing sector [MWh/year]	$3.6 \cdot 10^6$	$1.8 \cdot 10^6$	$2.0 \cdot 10^3$	$0.25 \cdot 10^6$	$2.8 \cdot 10^6$	$13.1 \cdot 10^6$
FEC in the housing sector [% of total FEC]	27 %	30 %	65 %	37 %	42 %	11 %
FEC in the housing sector/capita [MWh/year]	7	7	8	8	6	3

Based on survey information gathered, RES-diagrams which describe the present energy systems (see previous chapter on methodology) have been constructed. In Table 2, some of the most important characteristics of the six energy systems are summarized.

Table 2: Summary of characteristics of the energy systems of the six case studies.

Gothenburg, Dunkerque, Gdansk	Arnhem, Lochem	Valencia
• Coastal cities including big industries, harbour and refineries. • Strongly influenced by national/international industrial and energy resources. • District heating networks important and comprehensive. • Refineries (import/export of oil) and electricity generation (export in Dunkerque).	• Small municipalities, located in non-coastal areas. • Dwellings and buildings dominating sectors of energy consumption. • Little or no energy production within the municipal border. • Strongly dependent on import of electricity and natural gas. • Limited/no district heating.	• Coastal region including hundreds of small municipalities • Large industries, harbour and refineries (import/export of oil) in the area. • By far the biggest geographic area and population. • Extensive electricity production and use within the border. Only small export of electricity. • No district heating network. • Service sector and tourism important and increasing rapidly.

Although the energy systems obviously have unique features across all case studies, they also have some things in common. Overall, dependency on fossil fuels is high and total shares of renewable sources are still relatively small. Oil product use for non transport uses differ between cases, although for transport it is in all regions by far the largest energy carrier. Networks for natural gas and electricity are vital for distribution in all cases. Due to the diverse geographical locations (as seen in

Table **1**), the temperature and weather conditions for the case studies are obviously different. Consequently the conditions for the energy systems are different from this point of view, in particular concerning demand of heating and cooling in residential and non-residential buildings. As can be seen in

Table **1** the energy demand per capita in the housing sector in Valencia is by far the lowest of all case studies, due to the low heating demand resulting from the Mediterranean climate in the region. In all other case studies the energy demand in the housing sector accounts for at least 25% of the total energy demand.

Results and discussion

The work performed in the case studies

Besides the different conditions across the energy systems described, the representatives appointed by the six regions to undertake working activities for work presented have different backgrounds and experiences. Furthermore they have different roles in different types of organisations. These can be, for example, municipal utilities, energy companies, universities and consulting companies. Thus one of the most important aspects with the 7-step methodology is that it must be flexible, not only for different types of energy systems, but also for different organisations and employees that work with such energy planning issues. With this in mind, the different background of case study representatives has been valuable since several common difficulties and uncertainties have been identified and evaluated in the assessment of the methodology.

Description of the present energy systems

The RES-diagram has proven to be usable as a descriptive model for all six of the energy systems studied. The RES-diagram itself is not complicated (in particular when compared to more advanced modelling tools). However, experiences from the work have proved that defining the existing energy system is not trivial. A first and common obstacle, which to some extent was experienced in all of the case studies, was availability of data and statistics in order to construct a RES-diagram. In many cases, relevant data cannot be found in one common source. In such cases time and effort are required to find all of the data necessary. Despite this, experiences from the case studies have shown that most but not all of the data necessary can usually be found. Furthermore, mismatches in data definitions from different sources generally occur. Another common difficulty is the definition of system boundaries. Before the RES-diagram can be constructed, the items for inclusion in the energy balance must be chosen. A logical approach is to include all flows and use of energy that occur within the geographical border of the municipality. However, in several of the case study regions there are items such as power plants (nuclear, other thermal) that produce electricity for the national grid and large oil refineries that export all of their products (diesel, gasoline, etc.) beyond the municipal border. Such units may have minor influence on the energy system of the municipality since the consumption of its products is not within the municipal border. Besides, these plants often produce energy quantities so large that the rest of the municipal energy balance may be negligible in proportion. However, in some cases there are interactions with these type of units, such as that waste heat from refineries can be recovered. Thus, it is not generally obvious that these plants can be neglected. From the issues experienced with access to data and definition of system boundaries, it was confirmed that a systematic approach, such as the RES-diagram in this work, was necessary in order to describe the present energy systems in the six case studies. The following standard categorisation of energy end use sectors can be identified from the case studies (apart from the Arnhem case which only includes residential buildings):

- Residential buildings
- Non residential buildings and services
- Industry
- Transport
- Other sectors, i.e. agriculture, fishing and forestry. (the energy consumption in these sectors are small in comparison to the previous sectors for all of the case studies)

From the RES-diagrams, cross sectorial integrated solutions such as combined heat and power plants (CHP) or recovered industrial heat can easily be identified and analysed. The information in the diagrams also provides a valuable foundation for more detailed analyses supported by modelling tools. Overall, construction of the RES-diagrams was valuable for understanding of the present energy system. Once they were constructed, they provided a useful tool for analysing potential changes that could be made in the energy systems of the case studies.

Assessment of present goals and plans

In general, participants in the case studies experienced little problems in collating inventories of key actors, goals and plans, as compared to creating inventories of data to describe the energy system as discussed above. Yet, in some case studies it was difficult to identify relevant goals and plans relating to sustainability and efficiency for the local energy system. For each case study there are goals on national, EU and international level that are relevant. However, these goals are rather general and it is observed that it can be difficult to directly apply them to the case studies without first considering the local conditions in each case study. From the present goals and plans identified, a varying level of ambition for environmental sustainability and improved energy efficiency in the local setting has been identified. One common problem for short term implementation is that goals are often not quantified and therefore difficult to rely on. In some case studies there were energy plans or strategies which lack specific actions and actors responsible for reaching the goals. In other cases a large number of different goals have been identified in the inventory, although sometimes these goals are not always synchronised and have in several cases been found to be in conflict. One example of such conflicts seen in at least one of the case studies is that there is a goal established that aims to reduce the emission levels from transport, whereas present plans for land use contain projects for expanded road networks which will instead make road transport increase and thus, the emissions from transport will be increased as well. In fact some level of conflict between different goals could be identified in all case studies.

Identification of key technologies

A portfolio of key technologies necessary for transformation of the six respective energy systems has been established. There is obviously a strong connection between the description of the present energy system and assessment of key technologies. Without knowledge of the present energy system, including technologies that already are in place, there is little sense in analysing implementation of new technologies in local communities. It has also been concluded that several of the technologies in the present system, such as distribution networks, plants producing heat and/or electricity should be considered as key technologies also for the future, since they are part of a long-life infrastructure. Thus, they provide a foundation for how the energy system can be transformed.

Key actors, organisational structures and decision making mechanisms for the energy system

From the inventory surveys and the roadmaps developed in each of the case studies, it is obvious that the basis for making decisions for the different parts of the energy system differ across the case studies. In the case studies where the energy system is mainly characterised by high dependency on imported natural gas and electricity, the supply and distribution of energy through local grids and pipeline networks are owned and operated by actors at the national level, with little influence from the municipality themselves. Consequently, large parts of the energy infrastructure cannot be influenced by direct decisions in these municipalities. Thus, energy related policy may have lower priority in local administrations and utilities in such municipalities, compared to the ones with a more extensive energy system with internal generation in heat and/or power plants that produce district heat and/or electricity for the local grids. In some of these case studies there are energy companies owned by the municipality that operate most of the production units and the distribution networks. Thus, in these cases the municipality can directly influence large parts of the energy infrastructure. On the other hand, in some of the cases most of the energy infrastructure is owned by other actors, such as private companies or national/international energy companies. In these cases bringing changes to the energy infrastructure through decisions by local politicians is a more drawn out process.. Experience from the case studies showed that gathering representatives from all relevant key actors in a municipality takes time, in particular if such parties have not previously interacted. It is usually also more difficult to gather actors from outside the municipal organisation such as industries and private energy companies, unless communication channels are already well established.

Planning and Efficiency in the Residential Sector

In the six regions studied the Residential sector is the largest, or at least one of the largest sectors of energy end use. This emphasises its importance from an overall systems perspective. The sector consists of buildings which are long-life infrastructures, not well adapted for fast replacement. This calls for an integrated planning process to minimize the risk to tenants, but also to the energy system as a whole, of costly lock-in effects. In a European context one can assume that the majority of present buildings will most likely not be replaced in the short or medium term.

For the purposes of energy planning for the residential sector and for a municipality as a whole, the RES diagram can be used to identify and assess the different options for integrated technical solutions from a system perspective i.e. the impacts of energy efficiency and other technical measures in the residential sector and their impacts on other sectors too. For example, the effects on the energy use in the houses can be studied with respect to introduction of small scale conversion units, such as solar panels for water heating, structural changes in domestic heating systems and improved thermal insulation in housing as well as with respect to changes in the energy supply sector and on the overall energy balance of the municipality. It is important to make an integrated analysis of the housing sector and not to analyse the sector in isolation. This is especially important in order to identify possible conflicts between different measures employed in different sectors. An example is the impact of reduced demand for heating in relation to the use of waste heat for heating in district heating system. It may not be wise to prioritize improved thermal integrity in building envelops where they are connected to waste-heat fuelled district heating (assuming that the waste heat can be assumed to be available over a long period of time). Better then to start energy efficiency improvements in buildings not connected to district heating.

In summary, experiences from the case studies show that local energy planning, using a structured methodology such as the one proposed in this work, is required in order to find good policies for transforming the local energy system with respect to environment,, cost efficiency, comfort and affordability for tenants as well as to maximize socio economic factors such as security of supply, quality of life and employment. Thus, the methodology developed in this work can help to illustrate the impact of policies employed and reduce the risk of long term lock in effects.

Conclusions

Experiences from case-study based work on local energy planning are presented. Six case studies around Europe gave valuable insights both with respect to general status of work on energy planning and with respect to the methodology developed in this work. Overall, it can be concluded that in all cases there is a need for a structured and clear planning of the energy system with specific goals with respect to environment and sustainability. In some of the case studies, there are indeed goals and plans available but there is a need to establish clear descriptions of the energy system in its present form and what it should look like in the short, medium and long term. Such a description was not available in any of the six municipalities studied, but was instead produced from the work reported here in form of roadmaps. In addition, in two of the case studies, these roadmaps were officially adopted by the municipality.

From the cases studied it can be concluded that local energy systems in general have a high level of technical complexity. Yet, the organisational complexity is typically also high. Thus, all involved in the case study work conclude that an effective process of local energy planning is crucial for development towards efficient and sustainable energy systems in each of the regions studied, including the residential sector. Overall it is concluded that the methodology proposed should be a valuable supporting tool for municipalities regardless of their planning processes and methods used. There are obviously important connections between the different parts of a local energy system and thus it is crucial that those parts are not treated in isolation. One of the most important parts of local energy systems is the building stock, including the residential sector where the largest proportion of buildings energy consumption takes place.

A detailed description of the present energy system is one of the most important foundations for energy planning and the experience from this work is that it is a must to provide such description as a starting point for the analysis. This may seem obvious but in more or less all of the case studies, such descriptions were either not readily available or there was lack of fundamental data for an easy establishment of such description. In the latter case, it is important to make assumptions for the parts were data is lacking. In this particular work, a so called Reference Energy System (RES) diagram was found to be an efficient way to structure and describe the energy system, both in its present form and for describing future energy systems for various scenarios. The main issues related to the work with the RES diagrams were found to be data collection and definition of system boundaries.

There are many different actors and decision makers involved in the transformation of local energy systems. Some level of conflicting interests should always be anticipated. The energy system analysis opens the possibility to allow key actors to agree on a common direction for how the system can be transformed, thus reducing the level of probable conflict. The importance of identifying and involving key actors already at an early planning stage in order to have their commitment to the process should thus be pointed out.

There is large potentials for efficiency improvements using commercially available technologies and measures of which many are cost efficient. Thus, a coordinated energy planning procedure with a broad consensus in the municipality should have a high success factor.

For the assessment of goals for the planning process, the experience from this work point to that a) Global goals should be adapted for the local conditions b) Short term goals must be quantitative in order to be possible to implement and c) Long term goals on a more visionary level are important to define the overall direction and principle of the transformation of the energy system. The important thing is that the planning process should result in goals on all three time horizons.

With respect to the residential sector it can be concluded that local energy planning provides a tool which can contribute towards energy efficient housing although from a systems perspective as opposed to planning and transforming the buildings in isolation from the other sectors in the municipality. Of special importance in this respect are interactions between the residential sector and fuels and technologies for heating and cooling (e.g. centralized vs individual heating) and implications on energy efficiency measures. In summary, an integrated planning process can help achieve overall system goals and highlight optimal solutions and trade-offs.

References

Alexandre, A., De Michelis, N., Fleming, Dr. P., (editors), 1995. Urban Energy Handbook – Good local practice. OECD. Head of publications Service, OECD 2, rue André-Pascal, 75775 PARIS CEDEX 16, France.

Bulkeley, H., Kern, K., 2006. Local Government and the Governing of Climate Change in Germany and the UK, Urban Studies, Vol. 43, No. 12, 2237–2259.

Butera, F. M., 1998. Moving towards municipal energy planning - the case of Palermo: The importance of non-technical issues.

Cormio, C., Dicorato, M., Minoia, A., Trovato, M., 2002. A regional energy planning methodology including renewable energy sources and environmental constraints. Dipartimento di Elettrotecnica ed Elettronica, Politecnico di Bari, Via E.Orabona 4, 70125 Bari, Italy.

European Commission: Covenant of Mayors, 2010 [Online]. [Cited 2010-05-07]; Available from: http://www.eumayors.eu/

European Commission: EU action against climate change [Online]. [Cited 2010-05-07]; Available from: http://ec.europa.eu/environment/climat/climate_action.htm

Fleming[1], P.D., Webber[2], P.H., 2003. Local and regional greenhouse gas management. [1]Institute of Energy and Sustainable Development, De Montfort University, Scraptoft Campus, Leicester, UK. [2]Leicester Energy Agency, Leicester Energy Efficiency Centre, 2–4 Market Place South, Leicester, UK.

Haglund, M., 2006. Hur kommunal energiplanering kan vara ett verktyg för arbete med energifrågor - En studie av tre kommuner i Västra Götaland *(How municipal energy planning can work as a tool for questions regarding energy – A study of three municipalities in Västra Götaland)*. University of Linköping.

Intelligent Energy Europe [Online]. [Cited 2010-05-12]; Available from: http://ec.europa.eu/energy/intelligent/

Jank, R., (editor) 2000. IEA (International Energy Agency) annex 33 Advanced Local Energy Planning (ALEP) - a Guidebook. Klimatschutz- und Energieagentur. Baden-Württemberg GmbH. Karlsruhe

Johansson, B., (editor), 2001. Effektiv energiplanering för ett hållbart samhälle *(Efficient Energy-planning for a Sustainable Society)*. Stockholm, Sweden. Formas.

Kelly, E.D., 2010. Community planning – An introduction to the Comprehensive plan, Second edition. Island Press. Washington.

PATH-TO-RES fact-sheet. 2008. Available from: http://www.path2res.eu/

PEPESEC, 2008. About the project Available from: http://www.pepesec.eu/

Stenlund Nilsson, J., Mårtensson, A., 2002. Municipal energy-planning and development of local energy-systems. Environmental Technique and Management, IFM, University of Linköping, Sweden.

Terrados, J., Almonacid, G., Pérez-Higueras, P., 2009. Proposal for a combined methodology for renewable energy planning. Application to a Spanish region. Research Group IDEA, Polytechnics School, University of Jae´n, 23071 Jaén, Spain.

UNECE, 2009. Green Homes – Towards energy-efficient housing in the United Nations Economic Commission for Europe region. UNECE, Geneva.