

# Modelling of cost effective energy systems – a regional approach to sustainable energy planning

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## Abstract

Sustainable energy planning should be a priority in local communities for several reasons: it conserves valuable resources, reduces energy related costs and environmental impact and contributes to security of energy supply. Moreover, in order to reduce global green house gas emissions, local measures are required. This paper discusses a regional initiative to sustainable energy planning in five municipalities in the eastern part of Norway.

The planning process is described, focusing on some key measures and activities concerning strategy and energy efficiency. Collaboration between neighbouring communities may give the planning process added value, and synergies can be made by aggregating several local analyses into a regional plan. The outcome of such a regional collaboration is discussed in the paper.

Local energy planning is a process in which one often tries to over-view and analyse a complex energy system, and modelling tools can help facilitate this process. The REAM (Regional Energy Analysing Model) model is designed to analyse local and regional energy systems, supporting the user to identify a cost effective development of the energy system. Important parts of the regional energy system are described: local energy resources, large scale energy conversion, final energy consumption and green house gas emissions. On the basis of the present regional energy system, the REAM model is used to calculate two scenarios for the future development of the energy system, identifying potentials for energy efficiency and renewable energy.

## Introduction

Local energy planning implies analysing the energy system in a municipality in several perspectives; the options for energy conversion, the possibilities for energy efficiency measures and the climatic impacts. A regional approach to energy planning includes several municipalities in the analysis, to identify and create regional synergies and ultimately increase the outcome of the process.

This paper discusses a case of regional collaboration on sustainable energy planning in Sør-Østerdal in Norway. The region consists of five municipalities, and the initiative to perform a regional analysis was raised by the Regional Council in Sør-Østerdal. The initiative resulted in a regional collaboration on energy planning, funded and supervised by the Council. This process is still ongoing.

The framework conditions embracing sustainable energy planning involves targets on international, European and national level. The international targets are defined in the Kyoto Protocol (UN 1998), an addition to the UN Framework Convention on Climate Change (UNCED 1992). The Renewable Energy and Climate Change Package (CEC 2007) defines the targets for the European community, while the Norwegian targets are set in several white papers, treaties and settlements in the parliament. The Norwegian targets are not disaggregated on local level.

In 2008, Enova<sup>1</sup> funded a Norwegian guidebook on “Municipal energy and climate planning” (Enova 2008). The methodology described in the guidebook is partly based on the results from the Intelligent Energy – Europe (IEE) project 3-Nity;

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1. The Norwegian public enterprise for environmentally sound and rational use and production of energy: <http://enova.no>

hence it was suitable to use the guidebook also as a summary of the project results. The guidebook was therefore translated into English under the framework of the Intelligent Energy - Europe (IEE) project 3-Nity<sup>2</sup>.

The objective of this paper is to evaluate the methodology used in the regional energy planning process in Sør-Østerdal, and to discuss benefits and challenges in such a regional collaboration on sustainable energy planning.

## Methodology

The energy planning process which is described in this paper is partly based on the methodology suggested in the aforementioned Norwegian guidebook (Enova 2008). The Enova guidebook treats primarily *municipal* energy planning. There are few examples of regional energy planning initiatives in Norway, and none where modelling tools have been used (Ottosen 2007). The purpose of regional collaboration is to give the planning process added value. The municipalities can have different reasons for engaging in local energy planning, and mutual synergies may be created. A regional collaboration can result in a higher level of competence, and the aggregated plan may give additional outcome which each single local energy plan would not provide. But problems may also occur, due to political differences, conflicts between the stakeholders concerning localization of new development, or lack of leadership and management. Such problems may cause the whole collaboration to fail. Different approaches to regional planning can be used; either 1) aggregating already implemented municipal plans into a regional plan, or 2) first defining a common regional plan, and then specifying municipal contributions in individual, local plans. In this case, the second approach was chosen. When the regional initiative was raised, one of the municipalities had already made a local energy plan. It was partly the experiences from that local process which revealed the need for a regional approach to the matter. The experiences gained so far in Sør-Østerdal are discussed in the paper.

The regional planning process is presented in the paper, describing the general program structure and main focus areas. The main targets and measures are described, followed by a discussion of some key actions focusing on energy efficiency in the heat demand. Due to low electricity prices in Norway, there is a tradition for extensive electrical heating, and replacing electricity with other energy carriers for heating is a major issue. The focus in Sør-Østerdal was therefore primarily on the heat demand, because this can both be subject for efficiency measures, and is energy flexible; meaning that the heat can be supplied from a number of energy carriers. Of course there is also significant electricity saving potential of electricity for appliances, and this will be addressed in the next phase of the project.

A summary of the technical study is presented, describing the present energy system including greenhouse gas emissions in the region. Based on this, two scenarios for the future energy system and greenhouse gas emissions are made with the modelling tool REAM. Finally the most important experiences

gained from the regional collaboration are addressed, and possible improvements of the planning process are discussed.

## THE REAM MODEL

The REAM (Regional Energy Analysing Model) is designed to analyse local and regional energy systems and support the user to identify a cost effective future development. The model handles local energy production and infrastructure as well as final energy consumption and energy efficiency measures. The model can be used to describe in details the energy system in different sectors in a whole or parts of a geographic area. It can also summarise areas into regions. Energy for heating, electricity and cooling may be analysed in the model. The result is a detailed basis for local energy planning in specific areas, municipalities or regions (IFE, Profu 2008). The model is developed on the basis of the experiences from the KRAM-model (Josefsson, 1993).

The starting-point in the calculation is the present situation of different sectors in the energy system in terms of technology, emissions and costs. The description of the technologies in the energy system is divided in *small scale technologies* (individual technologies e.g. oil boilers) and *large scale technologies* (centralized technologies such as district heating). The changes over time is then calculated on a cost-efficient basis (including costs related to investments, fuels costs, taxes and fees, maintenance, ...). All costs are calculated into a total cost for energy, which is then used by the model to rank the technologies in economical terms. This also means that supply technologies are handled in the same way as efficiency measures, which may give an identification of the optimal balance between supply and efficiency. An alternative way to describe the management of the efficiency measures in the model is that they act as “negawatts”, reducing the demand of supply. The time resolution in the model is 24 periods within the year, which can be seen as monthly day and night load levels.

The calculation is made on a broad basis of information, including fuel prices, energy taxes and emission fees, descriptions of present and future technologies (including investment costs and emissions), energy demand in different sectors (both present and future building stock), and finally practical and administrative restrictions for the future development. These data are gathered from local, regional, nation and international sources. As an example, the description of the local technical system is in most cases described on the basis of local sources, while the prices of electricity and oil are gathered from national or international sources. All details concerning the techno-economic data used in this case study will not be given, but some assumptions made in the two scenarios are described.

### System development on a cost effective basis

The development of the technologies (both supply and efficiency technologies) in the demand categories will depend of the total cost of different small scale technologies. More expensive technologies will be replaced with cheaper and more cost-effective technologies. The cost-efficient development is combined with the possibility for the user to specify assumed development, e.g. due to human behaviour.

The residual technologies can be replaced in two ways, both illustrated in Figure 1:

2. 3-nity website: <http://www.ieeprojects.net/treenity.html>

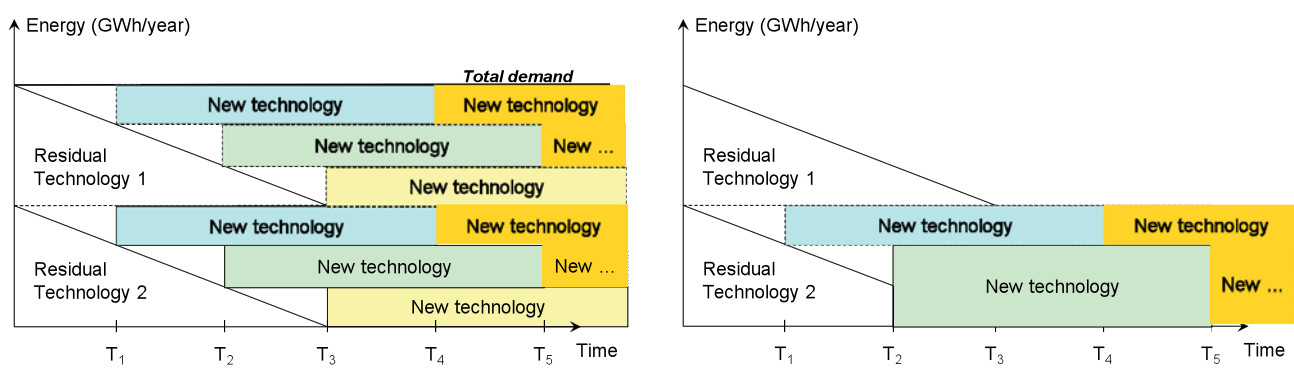


Figure 1 a-b: Illustration of the energy-gap that arises due to the life length and the investments in new technologies. Figure a) represents phasing out situation due to the lifetime and b) when the variable cost is higher than the total cost for a new technology

- phasing out due to end of lifetime
- the variable cost > total cost for a new technology

The description below applies both to supply technologies as well as to efficiency technologies. When a present technology reaches the end of its lifetime (Figure 1a) the residual capacity (presently available capacity) is reduced. In this case the phasing out profile is defined as linear by the user. E.g. the residual capacity of Technology 2 is phased out in 3 periods. In period T<sub>1</sub> the capacity is reduced by 1/3 due to the life length. The arisen energy-“gap” is then filled by the technology with the lowest average cost (including capital cost and other fixed costs). The technology choice in the model is only based on the calculation premises in period T. This is a description of how most energy consumers act when they make a decision concerning energy investments. The phasing out profile depends on the historical investment profile. In many cases the historical development is not known to the modeller, hence the linear phasing out during the estimated lifetime is a common assumption. The other alternative, described in Figure 1b, is when the variable cost of a present technology is higher than the total cost of a new technology. In this case, Technology 2 will already in period T<sub>2</sub> be replaced by the new green marked technology. Also this replacement is made on a cost-effective basis.

As an alternative to the development on a cost-efficient basis, the user can specify an assumed development. With this possibility the user can, via restrictions/constraints of the different changes, analyse the consequences (emissions, costs, energy balances) of a specified development. In a realistic planning situation the modelling is often a combination of these two possibilities (cost efficient basis and assumed development). The restrictions specified by the users could e.g. be a description of the energy user behaviour for energy efficiency measures. The optimal level of efficiency measures is often much higher in an unrestricted cost-efficiency analysis than what will take place in reality, explained by a number of different factors (Björkqvist, 1996). So if the purpose is to specify a realistic development in the model, the user should enter number of restrictions in the use of efficiency measures, as well as supply technologies, based on analysis of human behaviour. The REAM model is developed with support from Intelligent Energy - Europe (IEE), and is already an integrated part of local energy planning processes

in several European municipalities and regions, e.g. in Greece, Slovenia and Portugal<sup>3</sup>.

## The planning process in Sør-Østerdal

The region of Sør-Østerdal is located in the eastern part of Norway, and consists of five municipalities; Elverum, Åmot, Trysil, Stor-Elvdal and Engerdal. The region covers an area of close to 10 000 km<sup>2</sup>, and have about 35 000 inhabitants. At the time this regional approach was started (beginning of 2007), Trysil was the only municipality which had made a local energy plan. The four other municipalities were about to come to a decision on the matter. The initiative to perform a regional analysis was raised by the Regional Council in Sør-Østerdal and this resulted in a regional collaboration on energy planning, funded and supervised by the Council. The main goal is to establish Sør-Østerdal as a leading region in Norway for renewable energy and energy efficiency, focusing initially on local biomass energy for heating, and energy efficiency in municipal buildings.

### ORGANISATIONAL STRUCTURE

Defining targets and measures for the future activities and development is the most important part of a local energy planning process. The targets must be ambitious, but realistic and within reach. The measures must contain detailed, hands-on activities describing a step by step path towards these targets. In this regional approach, the targets and measures are organized in a main program and four sub programs, see Figure 2.

The main program describes strategies, competence and organisational measures on a regional level. The sub-programs are focused on activities and measures on municipal level, in the four focus areas. The four programs reflect the areas on which the stakeholders (the municipalities and the Regional Council) wish to focus. Only some key actions within the main program and sub-program 1 will be addressed in this paper. As described in the introduction, only Trysil had made a local energy plan at the time this analyse is made. However, some of the other municipalities had implemented other tools and activities, which can be of value for the regional planning process. The regional initiative is raised to promote collaboration and create synergies amongst the municipalities. The four sub-programs are initially equipped with some key actions,

3. See 3-nity website: <http://www.ieeprojects.net/treenity.html>

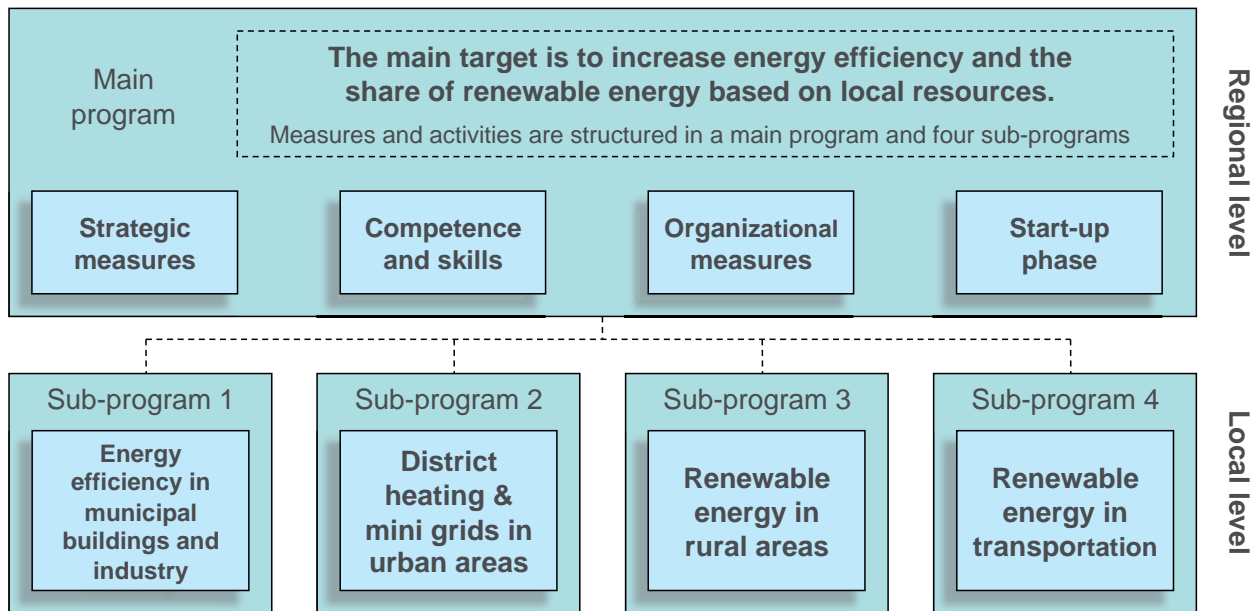


Figure 2: Diagram of the planning process

meant to be further elaborated as all municipalities implement local sustainable energy plans.

#### THE MAIN PROGRAM

As described in the introduction, the regional initiative was raised by the Regional Council in Sør-Østerdal. The first phase of the project is financed by a fund originating from compensation to the region for the repeal of differentiated payroll tax. A project manager is hired, to coordinate the process and support activities on local level. Each municipality has to contribute through man-hours, in addition to some direct funding. Enova may also be of financial support for some activities, as listed in MURE<sup>4</sup>. In a long-term perspective, bigger investments will be required for new facilities and projects, but this will of course not only be a public task. Hence stimulation of local industry and commerce is of great importance.

A number of measures and activities are identified under the framework of the main program, not all are mentioned here. However, a few key activities may be of common interest:

- One of the activities is pre-feasibility study of a “Green economic zone” in the region, suggesting a) expanded conditions for the existing Forest Fund, b) a new regional energy fund financed by a regional electricity fee, c) a regional energy counselling centre, d) a trial arrangement for trading of forest carbon credits, and e) a differentiated income settlement for farmers (Econ Pöyry AS 2008). Such a green zone is possible because the region represents an area and population of sufficient size, exceeding a critical mass with respect to forestry and logging. The study showed that both new funding, and improved incentives within the framework of existing structures, should have a positive impact on the exploitation of biomass energy for heating. Some of

the assumptions concerning costs in the scenario calculations are based on the pre-feasibility study.

- Several activities concerning competence and skills upgrading, as well as self-assessment procedures, are critical for a successful implementation of the plan. One measure is establishing a resource centre on biomass energy and forestry at the University College in Sør-Østerdal. Up-grading courses on renewable energy and energy efficiency for teachers in lower and upper secondary school, and engaging primary schools in the Enova/Intelligent Energy – Europe program “The Rainmakers”<sup>5</sup> can raise awareness and build competence also for the younger generations. To ensure proper follow-up, the Regional Council and the municipalities should identify targets for the internal, organisational development, and perform a self-assessment procedure such as the EFQM (European Foundation for Quality Management) Excellence Model (Gormley et. al 2007). The Excellence Model suggests a self-assessment procedure where the organisation is evaluated through 9 criteria for enablers (leadership, people, policy & strategy, partnership & resources, and processes) and results (people results, customer results, society results, and key performance results).

#### SUB-PROGRAM 1: ENERGY EFFICIENCY IN MUNICIPAL BUILDINGS AND INDUSTRY

All the measures and activities which must be carried out on local level (but still supported by regional collaboration) are organized in the four sub-programs. These sub-programs are meant to facilitate the implementation of activities which will be identified through the local processes of completing the municipal energy plans. Though are several measures already identified, and about to be implemented. Some key actions un-

4. Grants to local heating plants: [http://www.isis-it.com/mure/output2\\_ind.asp?Cod=NOR16](http://www.isis-it.com/mure/output2_ind.asp?Cod=NOR16)

5. The Rainmakers website: <http://www.rainmakers-eu.eu/>.

der the framework of the energy efficiency program may be of common interest:

- A primary focus area should be the municipal buildings, where the municipality itself has the authority, and pays the energy bill. When the regional planning process was initiated, Stor-Elvdal was the only one of the five municipalities which had made a systematic review of the potential for energy savings in the municipal buildings, through energy audits (Aalerud AS 2005). The analysis involved 18 buildings or clusters of buildings, including schools, churches, administrative units, healthcare and social housing. The report suggests insulation actions, ventilation with heat recovery, more efficient heat supply, temperature control with night set back etc., revealing a total energy savings potential of 14% in the buildings<sup>6</sup>. Based on this, a briefer estimate of the savings potential was then performed also in Trysil and Engerdal, comparing the specific energy consumption (kWh/m<sup>2</sup>) with the Enova (2006) standards for energy consumption. This indicated a saving potential of between 14% and 18%. The review and the estimates formed the basis for the assumed saving potentials in the scenario calculations. When the regional initiative was raised, few of the identified energy efficiency measures in Stor-Elvdal were in fact implemented. A first priority is to start implementing the identified measures in Stor-Elvdal, and perform systematic reviews of the energy saving potential in the four remaining municipalities. Expenses may be shared by hiring the same consultant to review the buildings in all four municipalities.
- The local industry is also an initial focus area. Common for the five municipalities is lumber industry, so this branch is suitable for the first further reviews. The lumber industry in the region is closely linked, and some of the units are even under the same ownership. This may facilitate a dialog concerning energy efficiency within the branch. Norwegian studies and benchmarks indicate an average potential for energy savings of about 25%<sup>7</sup>, by comparing best practice with average energy consumption (pay off not yet calculated). This is used as basis for the assumed potential for energy savings in the calculated scenarios. The first, recommended activity is to perform detailed reviews in the local lumber industry, in order to identify the actual potential for energy savings and the pay off, and ultimately implement efficiency measures. The next step is to review the energy efficiency potential in other industry branches in the region.
- Regarding households and private services, an increased use of heat pumps is assumed, contributing to reduce the electricity consumption. Though in most cases this is a profitable investment, conservative behaviours will in many cases prevent owners from investing in new, unknown equipment. A priority activity is to inform both homeowners and owners in private sector of the profitability of such projects, as well as other energy efficiency measures. The multiple Enova

support schemes can be a triggering factor<sup>8</sup>, but this must be communicated. Setting the owners in charge of investment decisions in new buildings is also important, as the history has shown that contractors often tend to choose the alternative with the lowest investment cost (without regard to the pay off).

The most important experiences gained from the Sør-Østerdal collaboration will be addressed towards the end of the paper, a long with suggestions on what could have been done differently in order to increase the outcome of the process.

## Technical study

The technical part of the regional plan contains a mapping of the present energy system. This mapping covers local energy resources, large scale energy conversion and final energy consumption in each of the five municipalities in Sør-Østerdal. The data used will be described. Based on the present status, future scenarios for the stationary energy system are calculated with the modelling tool REAM.

### ENERGY RESOURCES AND LARGE SCALE ENERGY CONVERSION

The region of Sør-Østerdal is located in one of the most densely timbered areas in Norway, and common for the five municipalities is that they all have large biomass resources. However, preservation regulations limit the potential logging in some municipalities, particularly in Engerdal. Figure 3 describes the potential according to a sustainable level of logging, but the profitability will likely not justify a realisation of the full potential. Calculations of profitability must be made, comparing consequences of different framework conditions and price levels. The hydro power resources are also substantial in several municipalities. Also the indicated potential for hydro power takes into account preservation regulations, but consists of a number of potential projects, with varying investment costs. All are included here, but as for the biomass potential, detailed studies revealing which projects are profitable must be made. Figure 2 describes both the technical potential for renewable energy resources, and the existing hydro power and district heating<sup>9</sup>, in each municipality. The calculations indicate a technical potential for renewable energy resources in the region of about 2.7 TWh/year. About 50% is forest biomass, and 49% is hydro power. Household waste, farm animal manure and sun collectors make out the small remaining fractions. The columns describing the resources also include existing production, thus the full potential in the municipalities. It is evident that there are large shares of un-exploited renewable energy resources in the region. The largest potential is within biomass energy from forest, but also the hydro power potential is substantial.

The technical potential for energy resources described in Figure 3 has regarded preservation regulations and sustainability measures, but lack of profitability may prevent exploitation of some of the resources. In addition to lack of profitability, a conservative attitude in the forest industry have probably also limited the exploitation of the biomass resources to traditional

6. Required investment 1.3 MNOK (=130.000 Euro), pay off 3.4 years.

7. The Enova Industry Network web-based benchmarking system: <http://industriettverk.enova.no/>. A European web-based benchmarking system which are based on the same methodology can be found in the projects BESS and ExBESS, co-funded by IEE: <http://www.bess-project.info/>

8. Several listed in MURE, e.g. <http://www.isis-it.com/mure/output2.asp?Cod=NOR25>

9. All district heating boilers in this region are supplied by wood chip burners; district heating is in this context synonymous with biomass energy.

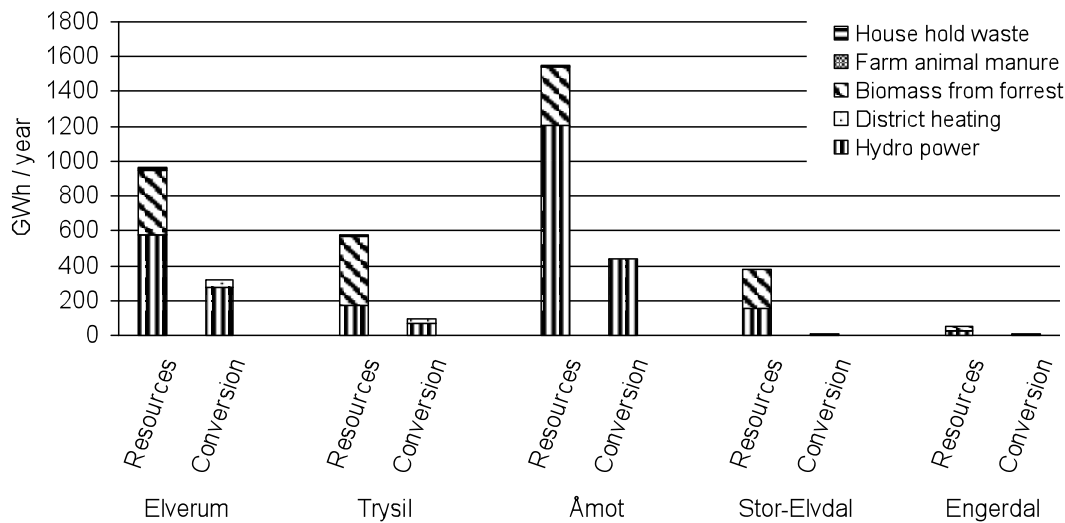


Figure 3: Energy resource and large scale energy conversions in Sør-Østerdal. (Ottosen 2007)

construction purposes. This is closely linked to the Norwegian tradition of electrical heating. However, conversion to more energy flexible supply is a hot topic in Norway, and biomass energy is a part of the solution. An illustration of the potential for biomass energy is therefore relevant. However, the first priority should be to reduce final energy consumption, before investing in new conversion facilities.

Figure 3 shows the potential energy resources on an annual basis. The issue of storage capacity is however relevant, particularly for hydro power. In a normal year in Norway, the reservoirs fill up during the spring flood and the summer, and empty during the winter, until next spring. The highest load is during the winter heating season, and will as such contribute to emptying the reservoirs before the spring flood. In years of heavy fall of rain/snow the reservoirs may run over and thus “loose” energy. Seeing that the majority of the power plants are connected to the distribution grid, the worst consequence is normally that the producer is forced to deliver power to a lower price in a short period, due to low demand. However, this is not a widespread problem. More detailed analysis of reservoir capacities and load curves should be made prior to investment decisions, but this will not be further addressed here. Regarding biomass there are large storage capacities, and seeing that this is also a traded commodity, supply and demand will be regulated by the market.

#### FINAL ENERGY CONSUMPTION

Figures 4 and 5 describe the final energy consumption per capita in Sør-Østerdal, per sector and energy carrier respectively, adjusted for degree days. The figures are based on statistics and measurements (electricity). Statistics Norway provides statistics for final energy consumption on municipal level, both per sector and per energy carrier. The statistics include both purchased energy and estimates for self-produced energy such as log wood. The estimates for log wood are uncertain.

As for most municipalities in Norway without energy intensive industry, transportation and households are the most consuming sectors in Sør-Østerdal, followed by private/public

services and industry. There are however some exceptions. After the closing of a major manufacturing company in Åmot in the 1990s, the energy use in industry in Åmot decreased heavily. A large military base affects the energy use in the service sector in Åmot, which per capita is the largest of the five municipalities. The energy use per capita for transportation in Stor-Elvdal is considerable compared to the rest of the region. This is most likely because of a large share of transit traffic, due to a main road passing through the municipality. The large share of diesel consumption in Stor-Elvdal supports this theory. As expected, the final energy consumption per capita is inversely proportional with the density of the population in the municipalities. The exception is Engerdal, in which there are not much industry, and therefore have lower final energy consumption. From these observations, it is clear that a thorough study of all big consumers and deviations from normal consumptions should be made, in order to identify appropriate targets with respect to energy efficiency. It also shows the limitations of using only a global indicator such as energy consumption per capita. The final energy consumption per capita increased in four of the five municipalities in the period 2000-2006, the biggest contributor being transportation. This is in accordance with national trends. There are only minor differences in the other sectors, except for the aforementioned military base in Åmot, where there has been increased activity. There are also irregular increases in the industry in Stor-Elvdal and Engerdal, for no obvious reasons. A priority is to further study the few, big industrial units in these municipalities, in order to find the reason for the big increases (this might also be a statistical error, further studies will show).

From Figure 4, it is evident that electricity is a dominant energy carrier in all municipalities. Throughout the 20<sup>th</sup> century Norway has had near unlimited access of cheap, renewable hydro power, which has led to a tradition of extensive electrical heating. Due to this, electricity supplies between 69% and 86% of the stationary energy consumption in four of the five municipalities. But Norway is no longer self-supported with renewable, electrical power, and in dry years there is now a

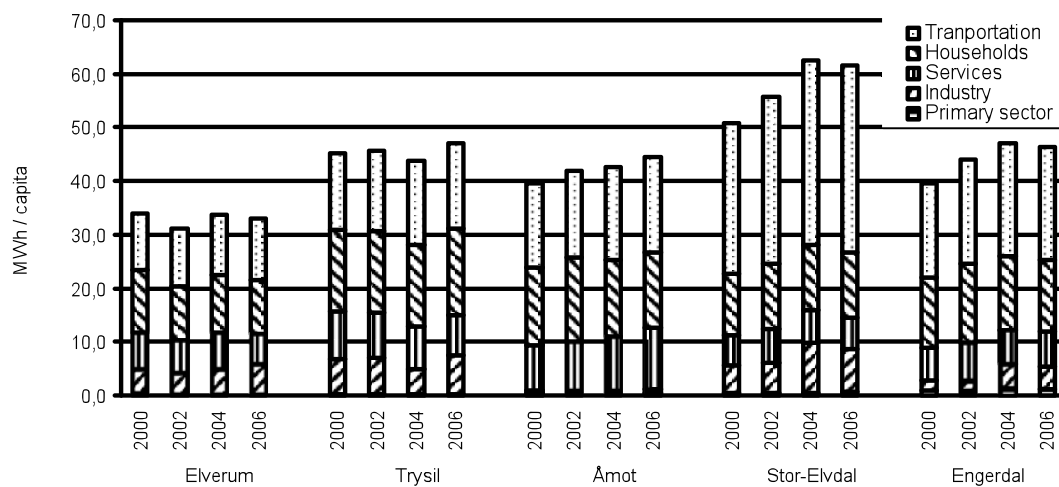


Figure 4: Final energy consumption per capita and per sector in Sør-Østerdal. (Eidsiva Nett AS 2008)

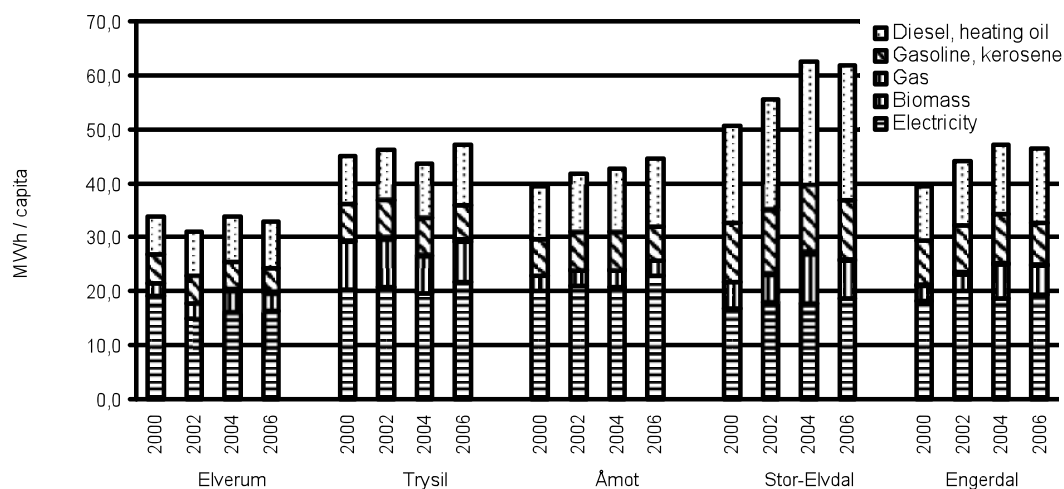


Figure 5: Final energy consumption per capita and per energy carrier in Sør-Østerdal. (Eidsiva Nett AS 2008)

net import of power to Norway. Reducing electricity for heating is important, to release the high quality electricity (100% exergy) to other purposes. Along with energy efficiency, this is a priority in this planning process. Lindberg and Vessia (2008) showed that the marginal electricity consumption (i.e. the use of one additional kWh) in Norway implies a share of imported power, hence also GHG emissions. Despite this, and because of a domestic, on-shore power production which is almost solely based on renewable energy resources<sup>10</sup>, the official emission statistics do not calculate GHG emissions from on-shore electricity use in Norway.

On the basis of the description of energy resources, large scale conversion and final energy consumption, a reference energy system or an energy flow chart should be made, describing the whole energy system in the municipality or region in a

systematic way. This is not included here, as all data is already described in the previous figures.

#### GREENHOUSE GAS EMISSIONS

Figure 6 describes the greenhouse gas (GHG) emissions per capita in the region in the period 1991-2006, from mobile and stationary energy consumption and non-combustion processes<sup>11</sup>. In accordance with the final energy consumption, the emissions per capita are increasing by decreased population density. The exception again is Stor-Elvdal, with a large share of emissions from transit traffic described in the previous chapter. The GHG emissions per capita are increasing in all five municipalities, due to increased energy consumption in transportation. This is a national trend, and should be a focus area with respect to energy efficiency and conversion to renewable fuel. Both non combustion emissions (mainly from agricultural processes and landfill gas) and emissions from stationary

10. Two on-shore gas power plants have recently been built (on Kårstø and Melkøya), so the domestic, on-shore power production is no longer 100 % renewable. The off-shore oil platforms have gas power production.

11. Norwegian Pollution Control Authority website: [http://sft.no/artikkel\\_\\_\\_40919.aspx](http://sft.no/artikkel___40919.aspx)

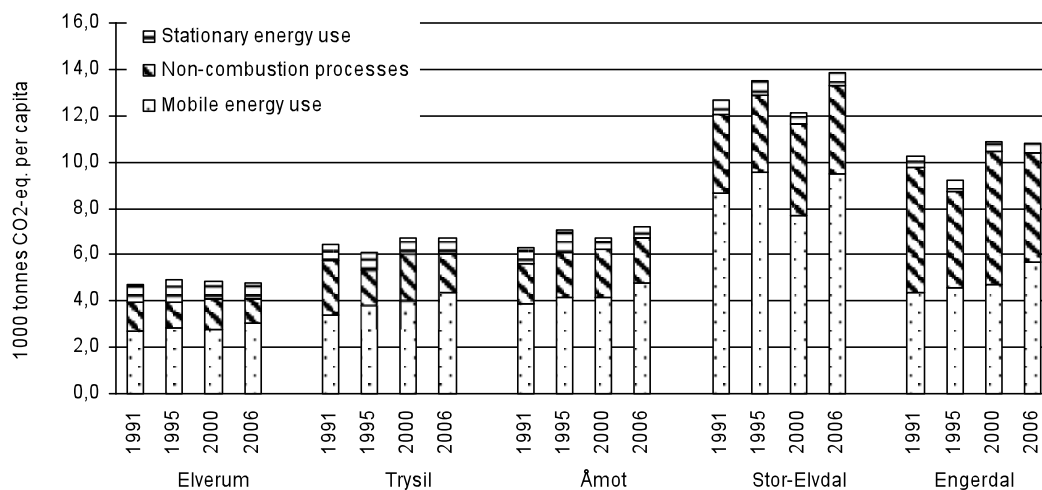


Figure 6: Greenhouse gas emissions in Sør-Østerdal (NPCA 2008)

combustion are either stabilised or decreasing. The decrease of non combustion emissions is most likely due to a combination of less agricultural activity, increased costs for inorganic fertilizer, and in some cases also more environmental routines for fertilizing. There is potential for further reductions through such fertilizing routines, and also manure handling. The emissions from stationary combustion are decreasing in four of five municipalities, and this is expected to continue in a slow pace. The exception is Elverum, the only municipality where there are polluting industry worth mentioning. The reason for the decrease is likely a combination of better energy efficiency through improved building standards, and replacement of old oil burners with heat pumps, pellet burners or district heating in households and private/public services. Although this is expected to continue, focus should be on speeding up the pace. Mature technologies in this segment are available, and zero emissions from stationary energy consumption should be a target<sup>12</sup> by introducing energy efficiency measures and renewable energy. In Elverum, more thorough analysis should be made with respect to reducing the GHG emissions from the polluting industry.

The total greenhouse gas emissions from the region have increased by 3% since 1991. If the region is to accomplish GHG emission reductions relatively corresponding to the Norwegian Kyoto commitments, reductions by 2 percentage points have to be made within 2012<sup>13</sup>. In order to accomplish the more ambitious targets in the Norwegian Parliament *Climate Settlement*<sup>14</sup>, reductions by 23 percentage points have to be made within 2020. The *Climate Settlement* raises the level of ambition substantially compared to the Kyoto targets, and requires immediate action. Elimination of emissions from stationary combustion, substantial reductions of the emissions from transportation as well as certain reductions of non-combustion processes, is necessary to fulfil the commitments.

12. This assuming that there are no GHG emissions from electricity consumption, in accordance with national statistics as explained above.

13. Emissions statistics on local level is only available for a few, selected years (91-95-00-06), this is assuming that 91-level is equal to 90-level.

14. The *Climate Settlement* is a broad settlement including six of the seven parties in the parliament.

#### SCENARIOS FOR THE STATIONARY ENERGY USE

In this analysis, the REAM model is used to calculate two scenarios for the future development of the regional stationary energy system, based on data for the present status and expected development in heat demand and fuel costs. It was chosen to test the newly developed REAM model in this analysis, even though the model handles only the stationary energy system, and not mobile energy consumption. Measures and activities on transportation are still equally addressed in the planning process, as illustrated in Figure 2. The testing of this modelling tool in the Sør-Østerdal case has provided valuable experiences which hopefully will raise the quality of other scenario calculations further, e.g. how efficiency measures are handled. This is elaborated further below. The Reference Scenario describes a business-as-usual scenario, assuming the same trends as in the past are kept more or less unchanged. The Green Development Scenario describes a possible, but realistic development, provided that an initiative is raised to promote biomass energy and energy efficiency in the region. All techno-economic data used in the model are not described, but some key assumptions made in the two scenarios are referred in Table 1. The assumptions are both related to cost development and human behaviour. Although the assumed development of costs, prices and energy demand has a high degree of uncertainty, the value of the scenarios is to compare the consequences of different price levels and framework conditions, not predicting exactly the cost development or behaviour.

Figure 7 shows the results of the calculations, comparing the heat demand in the final year in the two scenarios with the initial heat demand in 2007. The heat demand in 2027 according to the Reference Scenario resembles today's situation, though with some changes. The overall heat demand is increasing, so is the share of electric heating. The use of heat pumps are increasing both in households, services and industrial processes, replacing about half of the share of fossil fuels, and some wood heating in households. The increased use of heat pumps will of course reduce the electricity supply; meaning that the total heat supply in fact will be reduced more than what is immediately evident from the figure (the electricity consumption in heat pumps are only about 1/3 of the produced heat shown in the figure, due to the COP).



**Table 1: Assumptions made in the two scenarios**

The Reference Scenario	The Green Development Scenario
No specific energy efficiency measures are introduced (except for a slowly increasing use of heat pumps replacing electric heaters, referred to in separate assumption).	Energy efficiency measures are introduced in municipal buildings and certain industrial units, in accordance with analysed potential described in the previous chapter.
Increased supply of district heating only due to expansions in existing district heating grids.	Additional increase in supply of district heating also through realisation of plans for new district heating centrals and grids.
General price development of 2 % increase p.a. for all energy carriers.	The price development of refined biomass such as pellets and briquettes, as well as district heating, is limited to 1 % p.a. due to local policies (e.g. the Green economic zone). The development for the other energy carriers remains 2 % p.a.
The investment costs of the technologies are in accordance with today's recommended prices.	The investment costs for refined biomass burners such as pellet burners and briquette burners are reduced by 10 %. No adjustments in the investment costs for the other technologies.
The past trend of a slowly decreasing use of technologies based on fossil fuels (oil, gas and kerosene) is assumed to continue.	The future development of technologies based on fossil fuels is solely a result of cost effectiveness, without regard to past trends.
The past trend of a slowly increasing use of heat pumps is assumed to continue.	Information about the potentials of energy savings and thus costs is assumed to affect the public behaviour, causing a more rapid pace of investments in energy efficient heat pumps

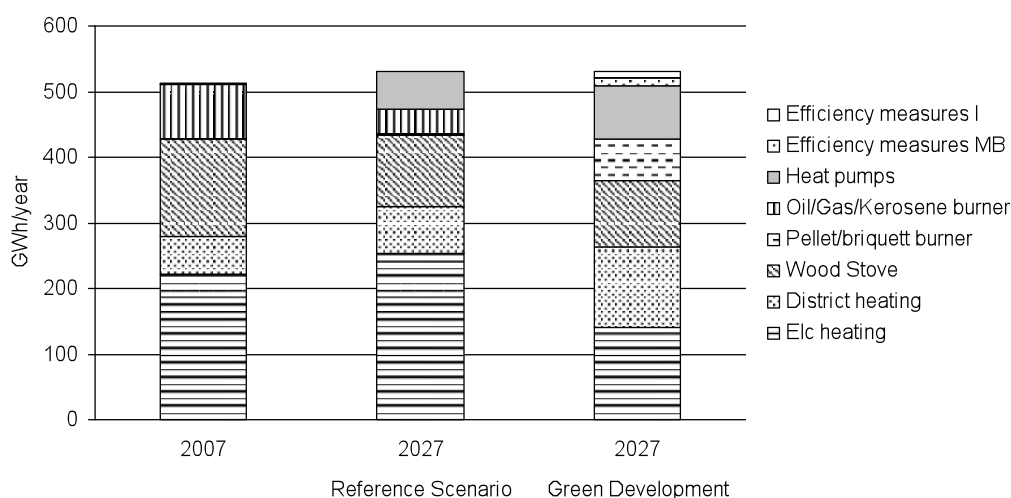


Figure 7: Heat demand in Sør-Østerdal, today and in 2027 according to the two scenarios

In The Green Development scenario, there are substantial changes in the heat demand compared to 2007 and the Reference Scenario. Due to the energy efficiency measures, the predicted growth in energy use in the region will turn down (the boxes representing efficiency measures are not-used energy). If the potential for energy efficiency in industry and municipal buildings is realized (elaborated in the description of the planning process), the total energy demand in the region will decrease slightly towards 2027. Of course the savings potential is limited when only efficiency measures in municipal buildings and industry are included. Efficiency measures in households and private services should also be included (in addition to heat pumps), to show the full energy savings potential in the region. Several municipalities have learned from this, and included more efficiency measures in their individual, local plans, and in new REAM calculations. The fossil fuel technologies are all phased out during the assumed life length of 15 years; electric heating is also heavily reduced. This is being replaced by a doubled share of district heating, assuming that new, profitable projects are being realized. The results of the reduced costs for

pellet/briquette burners and limited price increase of the pellets and briquettes are also evident. The further increased share of heat pumps will cause an additional reduction of the electricity supply.

The changes in the energy mix described in the Green Development Scenario have a big impact on the emissions from the stationary energy consumption, described in Figure 8. There are three flue gases included in the simulations; CO<sub>2</sub>, NO<sub>x</sub> and sulfur. In the Green development scenario, the CO<sub>2</sub>-emissions are heavily reduced because the fossil fuel technologies are phased out. However, the NO<sub>x</sub>-emissions are increasing due to increased use of biomass energy. There are only minor changes in the sulfur emissions. Be aware of the denomination, which differs between CO<sub>2</sub> (100 tonne) and NO<sub>x</sub> and sulfur (tonne).

Note again that there are many uncertainties in such calculations. Particularly the prognoses for investment costs and fuel prizes are most uncertain. The predicted demand for energy in the region is also uncertain, and may deviate from what is expected today. None the less, both scenarios describe possible future developments.

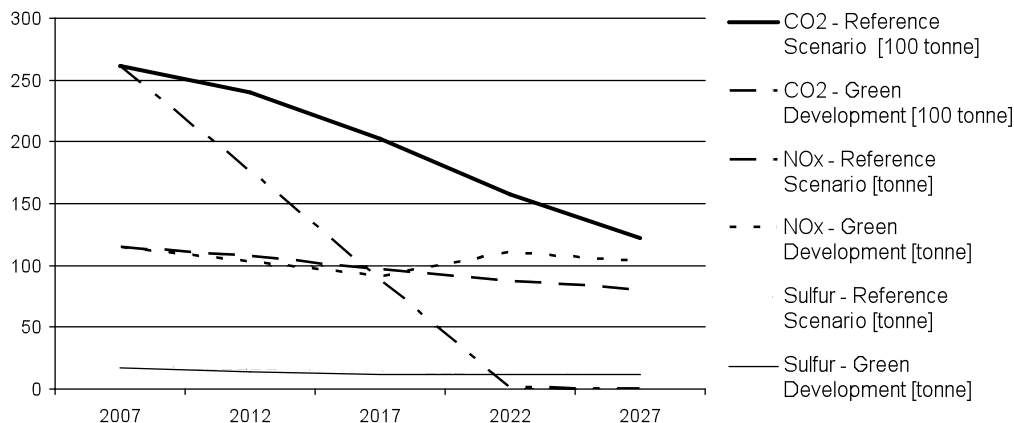


Figure 8: Flue gas emissions in Sør-Østerdal 2007–2027 according to the two scenarios

## Experiences from the regional collaboration

The regional initiative in Sør-Østerdal is a long term commitment, started in the first half of 2007. The process is meant to carry on, without a defined finalization, but with continuous evaluation, cf. the self-evaluation with the EFQM Excellence Model. Although it is at present premature to evaluate the whole process, experiences of both positive and negative characters have already been gained.

The forming of a steering committee and the employment of a project coordinator substantiate a proper follow-up of the regional collaboration. Several initiatives also confirm that the regional collaboration already has had some impact on the level of activity, such as the pre-feasibility study of the “Green economic zone”, which could not have been initiated without the regional collaboration. The common initiative to carry out audits to identify energy saving potentials in all municipal buildings in the five municipalities also proves that the regional collaboration has created synergies. The five municipalities have even agreed to be pilot studies in the SEC-BENCH project, which is co-funded by Intelligent Energy – Europe (IEE)<sup>15</sup>. This project aims to develop a web-based benchmark tool for energy performance in municipal buildings, using a bottom-up approach. Municipal buildings should be a priority in local energy planning, seeing that the municipality can both reduce its own energy expenses, and set an example for the local industry and commerce and the public in the municipality. However, energy efficiency in private industry and commerce as well as in the housing sector should also be in focus. Several municipalities will therefore identify efficiency measures also in these sectors in their individual, local energy- and climate plans. This will not be further elaborated, as the individual planning processes are still ongoing.

Regarding the gathering of data for the technical study and REAM calculations, this has not involved any major difficulties. There are quite reliable statistics for energy consumption and GHG emissions available in Norway, also on local level. The statistics are mostly based on top down-calculations, so there are of course some uncertainties which should not be ignored, e.g. concerning the share of transit traffic in a region. Enova

provides overviews for economic data. The energy suppliers are in most cases helpful with providing data for large scale energy conversion, if it is treated with required sensitivity. However, the implementation of REAM in other European countries has showed that the availability of data on local level is varying, sometimes not existing, and energy suppliers are often reluctant to provide sensitive information. This will complicate such technical studies; a solution may therefore be to focus on bottom-up approaches in selected buildings, as done in SEC-BENCH.

So far there have been no obvious problems due to political differences, but for a region of only five, fairly similar municipalities with respect to geography and demography, this may not be surprising. For regions of fifty or hundred municipalities, this will most likely be a much bigger challenge, and require a more strict and extensive management. Traces of localisation debates can already be detected, in connection with plans for a new combined production and research facility on gasification of wood chips. This is manageable, but gives reason to believe that new debates will arise as new projects come along. A close dialogue and good management should prevent such debates from being too destructive.

So far, the role of the steering committee and the coordinator has not been too dominating. This means that the progress to a large extent has been the responsibility of the municipalities, and guidance and follow-up have been given on request. One example is the progress of the local energy planning processes in the four municipalities besides Trysil, which has been rather slow in some of the municipalities. Seeing that the local plans were meant to elaborate the measures and activities in the aggregated, regional plan, this has yet not been completed. A more active management could have accelerated this process, but on the other hand, this could have been perceived as too intrusive locally. Having a genuine ownership to the planning process is critical for ensuring a proper follow-up, and this must not be jeopardised.

An alternative order could have been to first establish a steering committee and employing a coordinator, but to postpone the forming of a regional plan until all five local sustainable energy plans were implemented. This would have ensured both local ownership, and that the aggregated regional plan addressed all local issues. On the other hand, this approach

15. SEC-BENCH website: <http://www.sec-bench.eu/>

may not have created the optimal regional synergies, and the progress might have been even slower.

### A SEVEN STEP CHECKLIST FOR ACHIEVING A SUSTAINABLE ENERGY SYSTEM

Even if it is still too early to draw conclusions from the project in Sør-Østerdal, it can be fruitful to evaluate the process so far, looking for ways to improve such an initiative. The ongoing project Path-to-RES, funded by Intelligent Energy – Europe (IEE) (Chalmers 2008)<sup>16</sup>, aims to identify pathways to renewable and efficient energy systems. The project suggests a seven step check list for local energy planning, in which the Pathways are the sixth step. The check list, which still has status as a working hypothesis, consists of the following steps:

1. Analyse and formulate initial conditions
2. Establish a detailed description of the present system
3. Assess local, EU and global goals on sustainable development
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
7. Establish pathway (with respect to technologies, markets, institutions)

Looking at the process in Sør-Østerdal, we find that the steps 1, 2, and 3 are carried through. Step 5 is to a certain extent also being followed, by appointing a steering committee and a project coordinator. The progress so far indicates that a more active management could have accelerated the process, but then risking jeopardising the local ownership of the project. By awaiting the implementation of all five local sustainable energy plans before establishing a regional plan, this problem could have been avoided. The REAM calculations have initiated step 6, but a more detailed description of how to realise The Green Development Scenario should be performed. This detailed description is closely connected to step 4, which is neither thoroughly discussed in the initiative in Sør-Østerdal. Ultimately step 7 is to establish the pathway, which is what the region now is in process of doing.

Experiences from the process in Sør-Østerdal so far indicate that the steps likely should have been performed in an iterative way in order to identify the best solutions and win acceptance among stakeholders and decision makers. Could the planning process and the outcome in Sør-Østerdal have been improved by following the check list for local energy planning iteratively? Following step 4 and 5 in the suggested order might have made the accomplishment of step 6 more easily, ultimately facilitating the establishment of the pathway towards a renewable and efficient energy system. Or could it be that the impact would have been minor? A comparative analysis of two regional projects,

one that has followed the seven step check list and one that has not, may provide answers to these questions.

### Conclusions and discussion

This paper describes a regional approach to sustainable energy planning in the Norwegian region of Sør-Østerdal. The structure of the planning process is described, and some key measures and activities are addressed. A technical study of the energy system is presented, and two scenarios for the future heat demand are modelled.

The regional collaboration is structured in a main program focusing on organisational and strategic measures on regional level, and four sub-programs focusing on specific measures and hands-on activities on local level. One of the sub-programs addresses energy efficiency measures. The priority is energy efficiency in the municipal buildings, where the municipality itself has the authority, and pays the energy bill. By performing energy efficiency measures the municipal administration can both reduce its own energy expenses, and set an example for the local industry and commerce and the public in the municipality. Based on experiences from one of the municipalities, a common initiative is raised to carry out energy audits to identify saving potentials in the municipal buildings in all five municipalities. Also the potential for energy savings in the local lumber industry are addressed; up until today the lumber industry has mainly been included in the planning process as biomass suppliers. A priority must be to also perform specific analysis of the energy savings potential in the industry, as well as in private services and the housing sector.

The technical study revealed a large, unused potential both of biomass energy resources from the forest, and hydro power. Replacing electrical for heating with more flexible heat supply is a focus area in Norway, and seeing that biomass is one, potential energy source in such a flexible system, these results are of value. However, focus should be on reducing the final energy consumption before investing in new energy production. The specific energy use has increased in four of the five municipalities since 2000, and the total greenhouse gas emissions in region have increased by 3% since 1991. In order to fulfil the targets in the Norwegian Parliament *Climate Settlement*, reductions by 23 percentage points have to be made within 2020.

Based on the present energy system, and a number of assumptions concerning cost development and human behaviour, the simulation tool REAM is used to model two scenarios for the future heat demand. The Reference Scenario describes a business-as-usual scenario, assuming the same trends as in the past are kept more or less unchanged. The Green Development Scenario describes a potential development assuming that an initiative is raised to promote energy efficiency and to improve premises for local biomass energy. According to the calculations, a zero-emission stationary energy system can be realized in a 20-year perspective, through efficiency measures and replacement of fossil fuel with biomass energy and heat pumps. However, the results also indicate the need for improved premises in order to realise the potentials.

16. Path-to-RES website: <http://www.path2res.eu/>

## References

- Björkqvist, Olof (1996). Perspectives on demand-side management, Diss. Chalmers tekniska högskola, Göteborg (Doktorsavhandlingar vid Chalmers tekniska högskola, NS; 1212)
- Chalmers University of Technology, 2008, PATH-TO-RES: Work package 2, Deliverable 2.2 Principal Pathways, EIE/07/068/SI2.466697, <http://www.path2res.eu/>
- Econ Pöry AS, 2008, Green economic zone in Sør-Østerdal, Note 2008.027 (Norwegian) [http://www.econ.no/modules/trykksak/project\\_list.asp?mnusel=a185a253a305a](http://www.econ.no/modules/trykksak/project_list.asp?mnusel=a185a253a305a)
- Eidsiva Nett AS, 2008, Local Energy Reviews for the municipalities of Elverum, Trysil, Åmot, Stor-Elvdal and Engerdal (Norwegian), <http://www.eidsivaenergi.no/nett/144-lokale-energiutredninger>
- Commission of the European Communities (CEC), 2007, An Energy Policy For Europe, SEC (2007) 12, [http://ec.europa.eu/energy/energy\\_policy/doc/01\\_energy\\_policy\\_for\\_europe\\_en.pdf](http://ec.europa.eu/energy/energy_policy/doc/01_energy_policy_for_europe_en.pdf)
- Enova (The public enterprise for environmentally sound and rational use and production of energy), 2006, Enova's Building Statistics 2006, (Norwegian): <http://naring.enova.no/sitepageview.aspx?sitePageID=1268>
- Enova (The public enterprise for environmentally sound and rational use and production of energy), 2008, Municipal energy and climate planning – a guidebook to the process <http://www.enova.no/minas27/publicationdetails.aspx?publicationID=366>
- Gormley, B., Lewandowski, J. and Mydske, H.J., 2007, 3nity Work Package 5 Report: Sustainable Excellence, EIE/05/188/SI2.419825, <http://www.ieeprojects.net/treenity.html>
- IFE, Profu, 2008, REAM - Regional Energy Analysing Model, - Guidelines to energy planning and user manual for REAM, EIE/05/188/SI2.419825, <http://www.ieeprojects.net/treenity.html>
- Josefsson, A., Johnsson, J., and Wene, C-O., 1993, Community-Based Regional Energy/Environmental Planning, Nota di Lavoro 78.94, Fondazione Eni Enrico Mattei
- Lindberg, K.B., Vessia, Ø., 2008, Will a lower energy use in Norway reduce the CO2-emissions from European power production?, Quarterly report for the power market, 1. Quarter 2008, NVE 11-2008 (Norwegian), [http://nve.no/modules/module\\_109/publisher\\_view\\_product.asp?iEntityId=11317](http://nve.no/modules/module_109/publisher_view_product.asp?iEntityId=11317)
- Norwegian Ministry of the Environment (ME), 2006-2007, White Paper nr 34 2006-2007: Norwegian Climate Policy (Norwegian), <http://www.regjeringen.no/en/dep/md.html?id=668>
- Norwegian Ministry of Petroleum and Energy (MPE), 1998-1999, White Paper nr 29: About the Energy Politics (Norwegian), <http://www.regjeringen.no/en/dep/oed.html?id=750>
- Ottosen, Endre, 2007, Sustainable Energy Analysis for the Region of Sør-Østerdal – Testing and use of modelling tools. Master Thesis, Norwegian University of Science and Technology (Norwegian), <http://daim.idi.ntnu.no/soek/>
- United Nations Conference on Environment and Development (UNCED), 1992, United Nations Framework Convention on Climate Change, FCCC/INFORMAL/84 GE.05-62220 (E) 200705
- United Nations Framework Convention on Climate Change (UNFCCC), 1998, Kyoto Protocol to the United Nations Framework Convention on Climate Change, [http://unfccc.int/kyoto\\_protocol/items/2830.php](http://unfccc.int/kyoto_protocol/items/2830.php)
- Aalreud AS (2005): Review of the energy savings potential in municipal buildings in the municipality of Stor-Elvdal (Norwegian), <http://www.aalerud.no/>