Sustainable use of energy carriers in the Kattegat/Skagerrak-region – a regional case study

Jan Kjärstad
Dept of Energy and Environment, Chalmers University of Technology, Göteborg, Sweden
e–mail: kjan@chalmers.se

Sóley Emilsdóttir[1], Erika Mata[1], Anne Marie Fatnes[2], Filip Johnsson[1]
[1]Dept of Energy and Environment, Chalmers University of Technology, Göteborg, Sweden.
[2]Tel-Tek Research Institute, Porsgrunn, Norway.

ABSTRACT

This paper reports on a recently initiated interregional project on sustainable use of energy carriers in the Kattegat/Skagerrak-region (KASK) in Norway and Sweden. The work analyses and models large-scale integration of renewable power, the potential of process integration and energy efficiency improvements in key industries in the region and identifies cost efficient solutions for an energy efficient building stock. Energy and emission statistics along with energy and climate plans are used to investigate how well the current "path" with regard to energy use and GHG emissions fits within the corresponding plans for the region. The statistics is also used to define a Reference Energy System (RES) for the region which gives a structured mapping of the energy system of the region, comprising supply, conversion and end-use of the different energy carriers/sources in the region. Based on the analysis the aim of the project is to propose one or more pathways in the short, medium and long term towards a sustainable energy system in the region. The initial work shows that final energy use for parts of the region has actually increased by 25% since 1990 while GHG emissions have declined only marginally, by 3%. Furthermore, although most municipalities in the region have targets or at least visions on significant reductions both with regard to energy use and GHG emissions they lack a clear description (pathway) of how to reach these targets (visions). This clearly indicates that thorough analysis of the energy system in the region could provide valuable insights to decision makers and stakeholders on requirements and challenges for transforming the energy system to reach the visions.

Keywords: Interregional, sustainable, energy carrier, KASK-region

INTRODUCTION

The Kattegat/Skagerrak (KASK) region comprises 124 municipalities in the south of Norway, 55 municipalities in northwest Sweden and north Jutland in Denmark although the Danish part is not included in this project. Combined, the Norwegian and Swedish KASK-region covers an area of nearly 90,000 km2, has a population of 4.1 million people and a gross regional product of € 187 billion. In total the Norwegian and Swedish KASK-region emit around 24 Million tons of greenhouse gases (Mt GHG) per year. The project complements a previous study which analyzed the potential for CCS (Carbon Capture and Storage) in the same region [1]. The overarching aim of the project reported in this paper is to investigate how efficient use of energy and large-scale integration of renewable energy can contribute to an economically sound and sustainable development of the region. The project focuses on the stationary energy system (power, heat and industry) but a simplified analysis of the transport sector is included. The project develops a roadmap in the short (2020), medium (2030) and long term (2050) describing how the region can meet targets both for reduced energy use and lower GHG emissions on EU, national- and regional levels connecting short term strategies to long-term visions. There are several studies on Local Energy Planning (LEP) and on the various methodologies used to analyse local energy systems [2, 3, 4]. The aim of this paper is to describe the methodology applied in this project and to exemplify with some first results related to the trends and scenarios of future energy use in the region. The methodology follows from a previous work [5].

METHODOLOGY

The roadmap into the future is studied by means of a simulating exercise using a reference energy system (RES) to describe the energy system of the region. Thus, the RES is defined for the current energy system and a roadmap in the short, medium and long term is derived using the RES system to assess a realistic pace in the transformation of the different systems represented by the RES.

The RES is based on a database which contains the majority of the electricity and heat producers and consumers and CO2 emission sources in the region. The RES quantifies primary energy use by energy carrier, transformation losses and final energy use by sector. Figure 1 exemplifies the RES of the Swedish part of the KASK region.

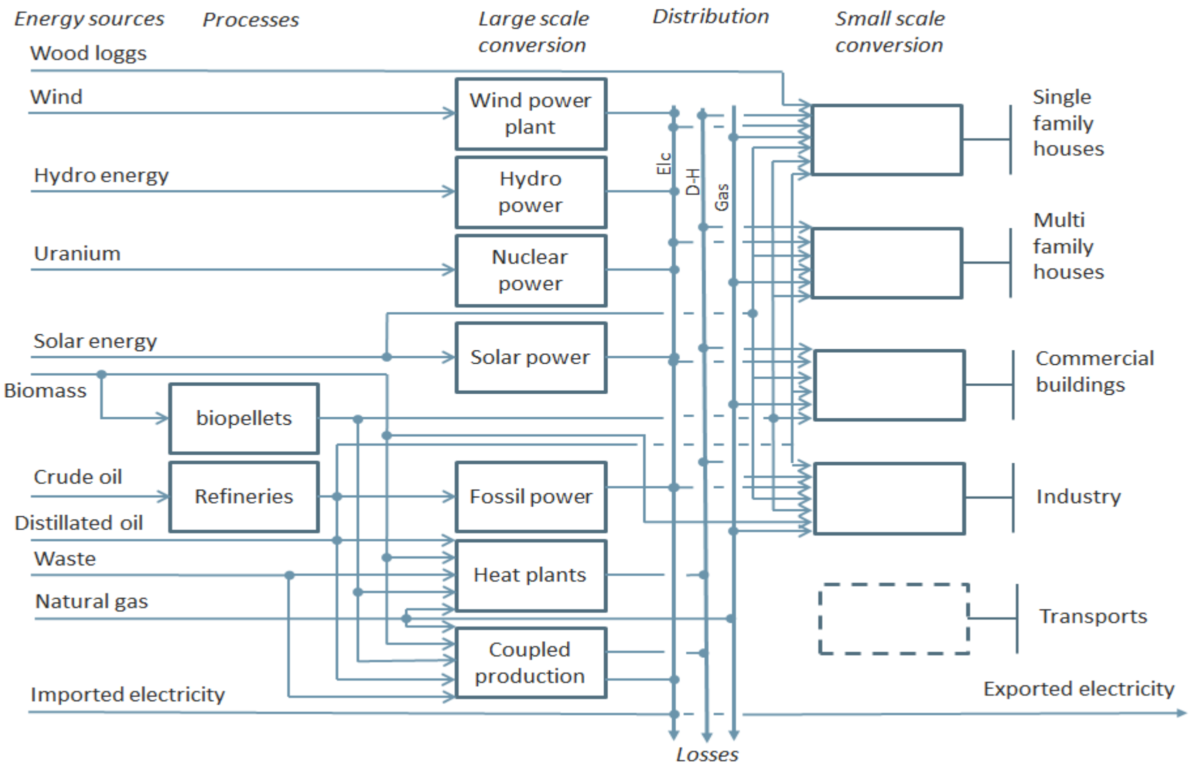


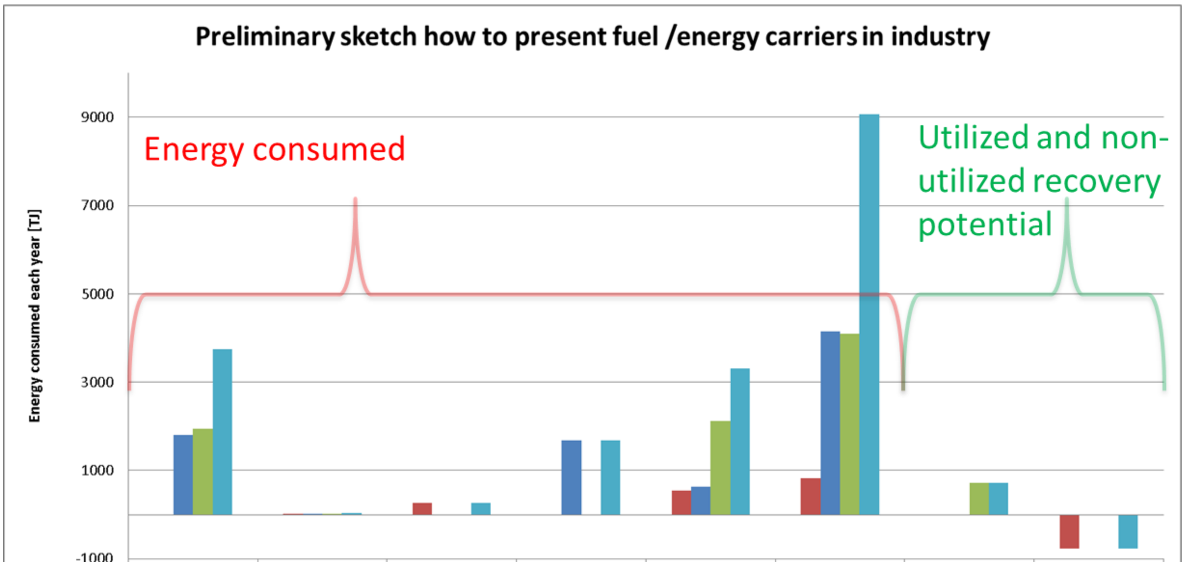
Figure 1: Example of the structure of the Reference Energy System (RES) for the Swedish part of the KASK-region.

Historical data are used to assess the recent years trends in energy use and GHG emissions to investigate to which extent fulfilling the 2020, 2030 and 2050 targets identified in the work will require disruptive change in the current trends in energy use and GHG emissions. This will give a qualitative measure of the challenge to meet the political visions as formulated by the municipalities in the KASK region. The regional capacity to act when it comes to transformation of the energy system is on the municipality level while the counties may have an indirect capacity to act. Obviously, national and EU targets sets most of the overall targets for the transformation of the regional energy system.

The transport sector is responsible for a large part of GHG emissions in the region accounting for 27% of total GHG emissions in the Swedish part of the KASK-region in 2010. Moreover, transport related emissions in the same region have actually increased since 1990. However, since the transport sector is not one of the priority research areas within the project, proposed pathways for emission reductions in this sector will foremost be based on a synthesis and discussion of previous research.

The energy systems simulation using the RES system gives a first estimate on the possibilities and challenges of transforming the energy system. Three strategically important areas are investigated in more detail with respect to energy use and GHG emissions; Energy efficiency potentials in key industries, large scale introduction of wind power and implementation of energy saving measures in the existing building stock of the region.

Energy efficiency potential key industries: Energy efficiency potentials of key industries in the region are analysed to identify the potential for energy efficiency improvements. First, energy data are collected from the industries, including information about their existing approach to energy savings and sustainable energy use and yielding a RES for each individual plant. Figure 2 illustrates the use of energy carriers in three companies in the Norwegian part of the KASK region.



	TJ Coal	TJ Oil products	TJ Natural Gas	TJ Biomass and waste	TJ Electricity	TJ SUM Company	TJ Residual heat, gas etc. transfered to other consumer as energy source	TJ Residual heat to the surounding environment
Company A	0	10	269	0	551	830	0	-770
Company B	1800	15	0	1690	640	4145	0	
Company C	1950	20	0	0	2124	4094	720	
Sum Fuel	3750	45	269	1690	3315	9069	720	-770

Figure 2: Example of a Reference Energy System (RES) for the industry. Preliminary, not complete

In addition, using methodology available at Chalmers [6] potential abatement technologies available to energy intensive industries will be assessed in view of EU and regional targets, and related to selected scenarios for development of the energy system. One or two focused detail studies will be made using Tel-Tek "Smart Manufacturing methodology" based on multivariate analysis to exemplify the energy saving potential which is believed to be present in many industrial production processes. The method is based among others on data-based latent variable methods for process analysis, monitoring and control. This methodology is described for example in [7, 8] which gives an overview of methods for how to utilize and analyse large process data matrices, including latent variable methods. The project sees it as very important to prepare a basis for industrial production in the region also in the future through developing pathways for more sustainable energy use and improved energy efficiency.

Large scale implementation of wind power. Analysing efficient integration of wind power will require analysis of larger regions and the entire European electricity generation system. This, since electricity is traded on a deregulated marked with countries connected by transmission lines. Thus, the optimal future mix of electricity generation technologies will be decided by the power market, the future price of emission allowances and other instruments such as for instance green certificates. With regard to wind power, investments will need to be balanced between investments in transmission capacity and wind power investments at locations with favourable wind conditions. The project combines bottom-up and top-down analysis to derive a feasible contribution from wind. The top-down analysis utilises Chalmers Electricity Investment (ELIN) model (for a description of the ELIN model see for instance [9]) to analyse cost efficient contribution from wind power under different scenario assumptions with regard to future European energy policy while the bottom-up analysis investigates sites available for wind power in the region and compiles information on plans and goals for wind power within the municipalities in the region. Current work focuses on investigating available sites for wind power utilising GIS (Geographical Information System) to identify land- and sea-based areas that can clearly not be used for wind power.

Energy savings measures in the building stock. The techno-economic potentials of implementing different Energy Saving Measures (ESMs) in the building stock (BS) in the region are assessed with a bottom-up modelling methodology. An existing database of about 1600 representative buildings for the Swedish residential and non-residential BS is used from which a corresponding representative BS in the Swedish part of the KASK-region is derived. The representative BS description of the Norwegian part of the KASK-region will be derived in a similar way following an already developed methodology for definition of archetype buildings. The analysis gives maximum technical potentials for energy saving and CO2 emission reductions. In addition, cost-effectiveness (€/kWh saved) and total cost-effective energy saving potential (TWh) are calculated for the pathways investigated in this work. For example, for each building type, different ESMs are applied yielding a result similar to Figure 3, i.e. the unit costs per maximum potential technical energy savings for each ESM in the BS studied.

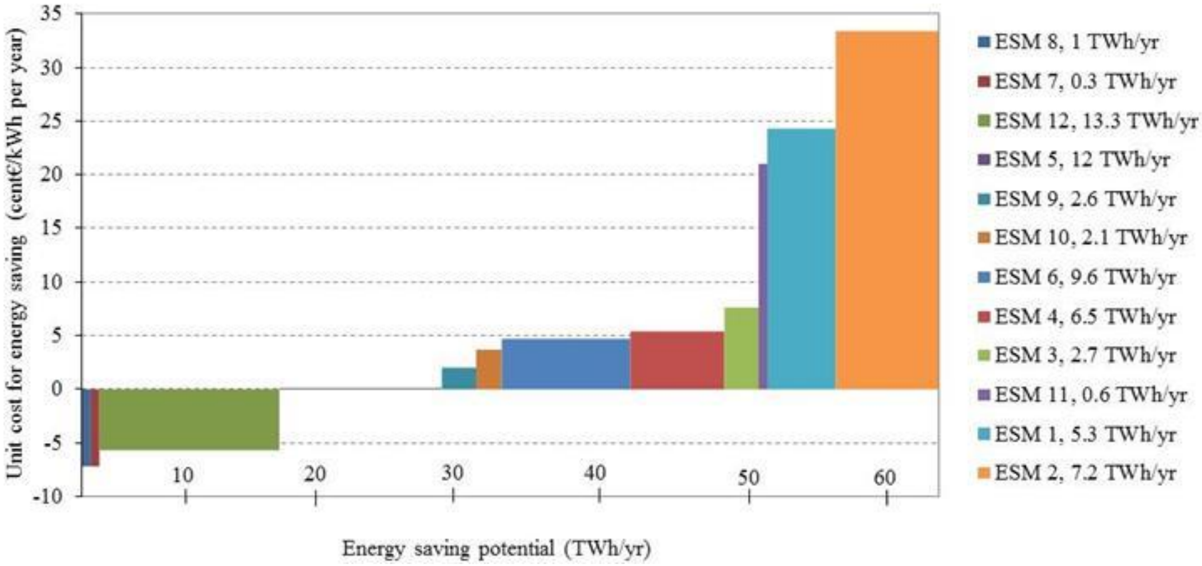


Figure 3: Unit cost per energy saving as obtained for 12 Energy Savings Measurements (ESMs) for the Swedish residential BS. SFD is "Single Family Dwellings" while "MFD" refers to "Multi Family Dwellings".

The analysis of energy use in the building sector is linked to the modelling of the electricity sector (see ELIN model above) to investigate how the ESMs influence the electricity use and the associated CO2-emissions in the region.

Finally, combining the results from the compilation of energy and emission statistics and corresponding goals for the future with the above mentioned analysis of the three strategically important areas mentioned above, the project will suggest pathways to reach regional goals for energy efficiency, share of renewables and GHG emission reductions in the short-, medium- and long-term as illustrated in Figure 4.

It should be pointed out that an important part of the work is to collect statistics of energy use and GHG emissions as well as to establish a database of existing and planned large stationary energy consumers/producers and large emission sources. At this point in time in the project (June 2013), most of the work is still related to data gathering and, thus, the results given in this paper focuses on a first analysis drawn from the data gathered so far.

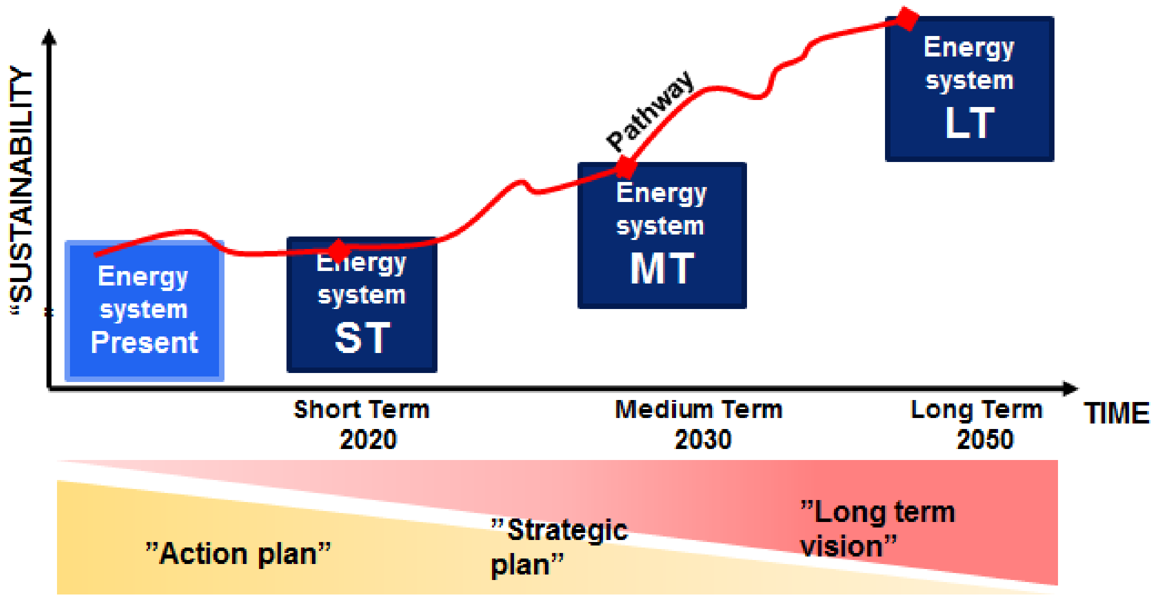


Figure 4. Visualisation of the objectives of WP3, i.e. how to transform the present energy system over time towards a more sustainable system in the future.

Thus, the aim is to present relevant Reference Energy Systems for each of the years 2020, 2030 and 2050 in order to reach the visions of a sustainable energy system in the region by 2050 and hence, also to propose intermediate targets thereby suggesting pathways. The results will be compared with the targets and goals set up by the municipalities in the region and an evaluation of to what extent there is a need for a disruptive change in the development trends will be identified. Thus, this will show to what extent there is a need for additional strong policies on the regional level.

RESULTS AND DISCUSSIONS

From the database of emission sources it can be concluded that a large part of the emissions in the region is concentrated to a few, large stationary sources, mainly industry (as opposed to power plants). For instance, six plants in the region (3 in Norway and 3 in Sweden) emit some 5 Mt CO2 annually, accounting for more than 20% of total GHG emissions in the region. Additionally, a pulp and paper plant in the Swedish region emits another 1 Mt bio-based CO2 annually. There are several options available to reduce emissions from the stationary sources. In the short and medium term process integration and raising energy efficiency appears to be the most obvious solution but getting close to zero emissions in the longer term will require a complete switch to either renewables as a feedstock or application of Carbon Capture and Storage (CCS) [6]. The use of biomass as a feedstock to produce fuel in refineries or as a raw material for the chemical industry has however clear limitations as it will require large amounts of biomass and is likely to compete with other use of biomass. CCS has the potential to significantly reduce CO2 emissions in the region, albeit at a relatively high cost, at least compared to cost for emitting CO2 which currently (May 2013) fluctuates around € 3-4 per ton. A previous study on CCS from the most emission intensive sources in the region estimated cost between € 54 and 86 per ton for the whole CCS chain , (capture, compression, transport and storage) [1]. On the other hand, the price of emission allowances is likely to rise in the future as the number of emission allowances will decrease while at the same time the cost of capture should go down once the first large-scale demo-plants have been running for some years. Based on discussions with the industries in the region it is concluded that they are all focused on improving their energy efficiency and sustainability. We also find that they have very different approach and focus depending on where they have most pressure from present and foreseen future regulations and the most to gain.

In Sweden, all municipalities are obliged by law to have an energy plan. Often, the energy plan is integrated with a climate plan. Yet, there is no requirement on specific targets to be included in such plans. The assessment made so far on the energy and climate plans show that these differ significantly between the municipalities with respect to their ambition and to what extent there is active work with implementing the plans.

The bottom-up analysis of wind power and other renewables have revealed that 48 out of the 55 municipalities in the Swedish part of the KASK-region have a wind plan allocating dedicated areas for wind power within the municipality. The bottom-up analysis also show that there has been a boost in announced new-builds since the Norway and Sweden in 2012 decided to share a green certificate system targeting to raise the contribution of renewable power by 26.4 TWh between 2012 and 2020 corresponding to 10% of total electricity production in the two countries. For instance in the Swedish part of the KASK-region some 900 MW wind power was installed at end 2012, accounting for one fourth of total wind power in Sweden and generating almost 2 TWh. Figure 5 shows development of wind power generation in Västra Götaland county in Sweden since 2000 as well as the region’s plans for the future. Västra Götaland County constitutes by far the largest part of the Swedish KASK-region.

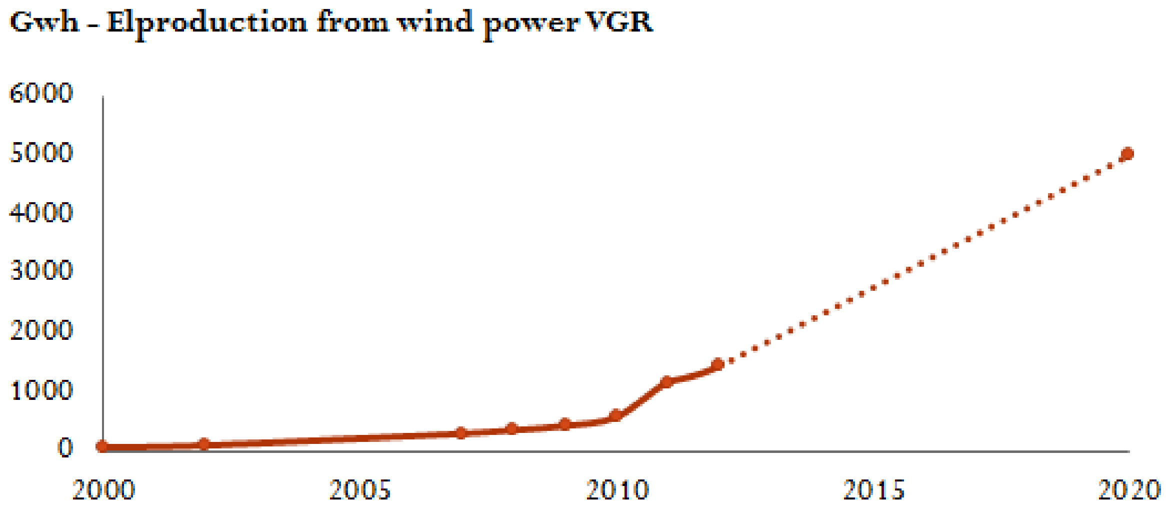
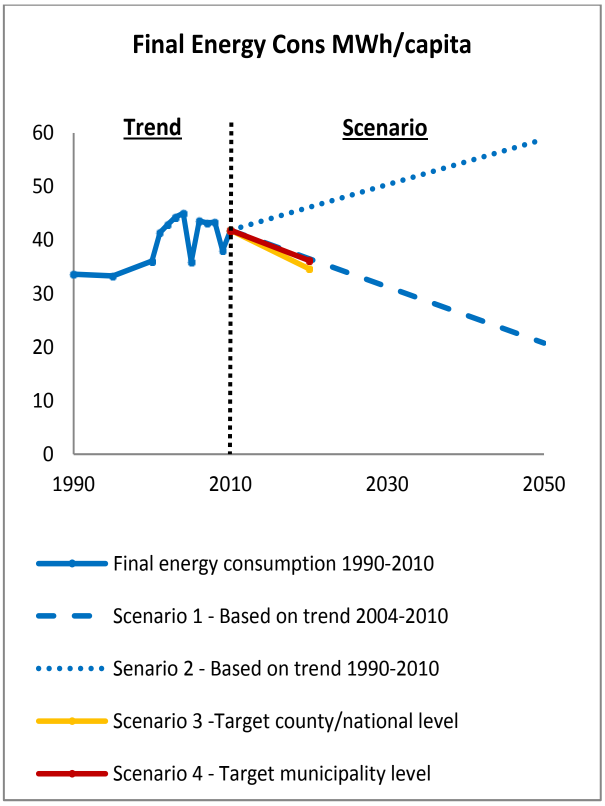


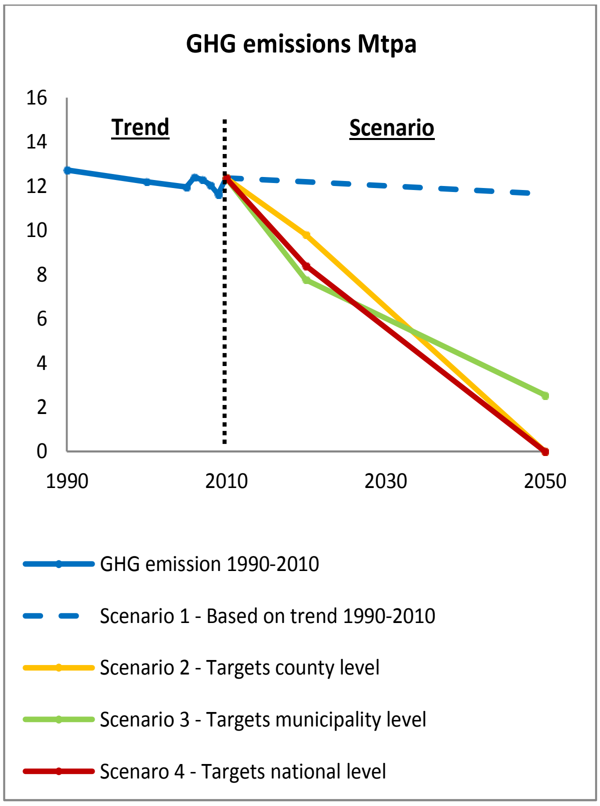
Figure 5: Power generation from wind power in the Västra Götalands Region in the Swedish part of the KASK region.

The Västra Götaland County is targeting a nearly fivefold increase in wind power generation between 2012 and 2020. Further, the bottom-up analysis in combination with the top-down analysis of the European electricity sector to be used as input to the work is expected to reveal 1) whether this is a realistic and relevant goal and 2) what kind of investments into the grid system such an expansion will require. In Norway, the effort to increase renewable energy appears to be more focused on hydro power and although there are a large number of hydro plants under development, relatively few of them will be located in the KASK-region. As mentioned above there is also a concerted effort to increase the share of renewables within the industry in the region, e.g. to use biomass as a feedstock/raw material in a chemical cluster and for production of fuel in two refineries as well as to produce energy in a cement plant [12, 13, 14]. Also, the project GoBiGas (Gothenburg Biomass Gasification Project) which recently was granted almost 60 million Euros in funding from NER300 1st phase (involving sale of 200 million emission allowances) will contribute to increase the use of biomass in the region. The Gobigas project will gasify 130 MW biomass to approximately 100 MW synthetic natural gas, 6 MW electricity and 24 MW heat (the latter two for internal use) [15].

As mentioned above an important part of the work is to compile relevant statistics to derive trend lines for energy consumption and GHG emissions. These trend lines are thereafter compared to a compilation of published targets (scenarios) on the same, i.e. energy consumption and GHG emissions. The compilations are done both on a county level and on a municipality level. Based on the database and RES analysis Figure 6 compares trend lines for the period 1990 and 2010 with different scenario lines (based on the trend and on targets both on county level and compiled municipal level) up to 2050 for final energy consumption per capita (Figure 6a) and GHG emissions (Figure 6b) for Västra Götaland County in Sweden.



a)



b)

Figure 6: Final energy consumption per capita (a) and GHG emissions (b) in "Västra Götalands Län" in Sweden between 1990 and 2010 and scenarios based on 1) the trend 1990-2010 and 2004-2010 and 2) officially announced targets compiled both on municipality level and on county level.

As can be seen from Figure 6a, final energy use has actually increased by almost 25% since 1990 while targets for reduced energy use both on municipality and county level extend to 2020 only and are relatively modest, between 16 and 20% reduction in 2020 relative to 2008, i.e. in both cases implying a level of energy use in 2020 above the 1990 level. Targets for GHG emission reductions are substantial (Figure 6b) mostly following the national vision of zero emissions in 2050. Common for most of the targets, both with regard to energy use and GHG emissions and referring to both municipality and county level, is that the targets are mostly visionary without a detailed description (pathways) on how to reach the targets. Thus, these first results indicate that in order to link short term decisions to the long term visions there is a need for strong decisions on policy measures, most likely both on regional and national level.

CONCLUSIONS

This paper presents the overall methodology and first results from a recently initiated interregional project on sustainable use of energy carriers in the Kattegat/Skagerrak-region (KASK) in Norway and Sweden. The first compiling of the energy and emission statistics on municipality and county level and the setting up of the Reference Energy System have provided valuable insights into the state of the current energy system in the region. Comparing these statistics with published targets and breaking it down by sectors yields information on where and when measures need to be taken in order to meet the targets. As this study has shown so far, some municipalities in the region have quantitative targets but most have not and even if they have set targets they lack a clear and concise description on how to reach the targets hence indicating the need for a project like this.

ACKNOWLEDGEMENTS

This work is partly funded by Interreg IVA, Västra Götalandsregionen and TelemarkCounty Council.

REFERENCES

1. ”Carbon Capture and Storage in the Kattegat/Skagerrak region”. Final report February 2012. Can be distributed on request by: www.chalmers.se (contact Jan Kjärstad) or www.tel-tek.no. (contact Dag Björnsen).
2. Jank, R., (editor) 2000. IEA (International Energy Agency). “Advanced Local Energy Planning (ALEP) - a Guidebook”. Annex 33. Klimatschutz- und Energieagentur. Baden-Württemberg GmbH. Karlsruhe.
3. Johansson, B., (editor), 2001. ”Effektiv energiplanering för ett hållbart samhälle” (”Efficient Energy-planning for a Sustainable Society”). Stockholm, Sweden. Formas.
4. Kelly, E.D., 2010. ”Community planning – An introduction to the Comprehensive plan”. Second edition. Island Press. Washington.
5. Johnsson et al., 2010. ”Engineering for a Low Carbon Future – the importance of local energy planning”. The International Congress of Energy and the Environment 2010, Opatija, Croatia, October 18-21, 2010.
6. Rootzén, J., Johnsson, F., 2013. “Exploring the limits for CO2 emission abatement in the EU power and industry sectors—Awaiting a breakthrough”. Energy Policy, 2013, in press.
7. Francois Yacoub et al, , “Robust processes through latent variable modelling and optimization” , AICHE Journal 2010.
8. John F MacGregor et al.; Computer Aided Chemical Engineering, vol 18, 2004, pages 87-98
9. M. Odenberger, T. Unger, F. Johnsson, 2010. ”Pathways for the North European electricity supply”. Energy Policy 37 (5), 1660-1677.

10. Heidelberg Cement, Norcem cement plant, Brevik, Norway: Press release dated May 14, 2013. See www.heidelbergcement.com/no/no/norcem.
11. See www.kemiforetagenistenungsund.se
12. See www.preem.se
13. See www.heidelbergcement.com/no/no/norcem
14. See http://gobigas.goteborgenergi.se/