Final report

Nordic Energy Perspectives

Kompas – improving the description of the demand side in the NEP models

Berit Tennbakk and Miriam Munnich, Econ Pöyry AS

Arve Halseth and Monica Havskjold, Xrgia AS

August, 2008-08-08

Preface

Nordic Energy Perspectives (NEP) is an interdisciplinary Nordic energy research project with the overall goal of demonstrating means for stronger and sustainable growth and development in the Nordic countries.

NEP analyses the national and international political goals, directives, and policy instruments within the energy area, as well as their influence on the Nordic energy markets and energy systems and the infrastructures and institutional structures. NEP aims at clarifying to decision makers the consequences of political and strategic decisions for politicians, energy actors and the public. The project is to promote a constructive dialogue among researchers, politicians, authorities and actors on the energy markets.

For further information about the project, please visit: www.nordicenergyperspectives.org. These series of intermediate reports are the initial reporting from the second phase of the project. The following synthesis, intermediate and final reports are now presented:

Synthesis report, May 2008:

1. First NEP2 synthesis report *(Responsible: Peter Fritz, Håkan Sköldberg, Bo Rydén)*

Intermediate reports, May 2008:

2. Nordic perspectives on the EU goals of 20% CO2 reduction, 20% renewable, 20% energy efficiency by 2020 – first results from the NEP models *(Responsible: Thomas Unger and the NEP model group)*
3. Perspectives on renewable energy and energy with low CO2 emissions, with special focus on biomass*. (Responsible: Tiina Koljonen and Thomas Unger)*
4. Perspectives on renewable energy in the Nordic countries – results from the MARKAL-model runs for EUs 20% goals. *(Responsible: Håkan Sköldberg, Thomas Unger and Bo Rydén)*
   Also including: Perspectives on district heating in Sweden – preliminary results from model runs for EU's 20% goals.
5. Widened view of energy efficiency and resource management – the potential in the whole energy system. *(Responsible: Anders Göransson and Bo Rydén)*

Final report, June 2008:

6. Kompas – improving the description of the demand side in the NEP models. *(Responsible: Monica Havskjold and Berit Tennbakk)*

The KOMPAS project is financed by The Research Council of Norway (RENERGI-program), The Norwegian Water Resources and Energy Directorate (NVE) and Statnett.

Oslo, August 2008

The NEP Research Group

Content

1 Motivation

One major factor in the development of a sustainable energy system in the European countries is the future demand for energy services. In order to identify policy measures for increased energy efficiency and to create models applicable for forecasting the demand on short and long term, it is crucial to understand the driving forces shaping future demand development, be it volatile and increasing energy prices, technology development, economic growth, or changes in industry structures, lifestyle and housing patterns.

Assumptions about energy demand response are fundamental in policy assessments, as policy targets are related to demand development. Energy price forecasts are sensitive to demand side response, but still almost all studies and energy models focus on the supply side. When prices are soaring, as the oil price has been the last months, substitution and reduced energy demand is a rational response. Diversification of the energy system, both to increase security of supply and to enable end users to substitute one energy carrier with another, is a major policy goal. Even so, the focus of attention in a majority of all published studies is on electricity.

In the Nordic Energy Perspectives project (NEP) eight energy models are applied to analyse Nordic energy sector issues relevant for public and private companies and governmental bodies. How should these models be applied to optimise their relevance? The KOMPAS project focuses on two issues documented in two separate reports, both available for downloading at www.nordicenergyperspectives.org: a literature study of energy demand analyses [1], and a comparative analysis of the demand side representation in 7 of the NEP models [2].

2 Summary of literature on electricity demand in the Nordic countries

When analyzing developments in energy markets and the impact of policy measures, the modelling of energy demand is crucial for the results and policy recommendations. For example, Gonzalez and Hernandez (2006) [3], in an analysis of the effects of three environmental policy measures – demand side management, economic support for renewable energy, and $CO2$ reduction measures – conclude that the answer highly depends on how demand responds to price changes. At the same time, it is clear that developments in energy demand and responses to policy measures depend on structural factors. Such structural factors are also studied in the literature and to varying extents captured in different energy market models.

In the literature surveyed there is an overweight of econometric studies estimating price and income elasticities. There is also an overweight of studies focusing on household energy demand, and the majority of studies focus on long-term effects. In the Nordic literature most of the studies are Norwegian, and only a small number of studies compare demand characteristics in different countries. The analysis may therefore be perceived as biased, but it is our impression that the selection is representative of the existing literature.

From a methodological standpoint we may distinguish between Top Down and Bottom Up approaches in econometric studies, where Top Down studies are based on macro or aggregated data and Bottom up on micro data. In praxis the difference is not clear-cut: Top Down studies are often disaggregated to some extent (e.g. different sectors and industry branches) and Bottom Up data are typically aggregated to some extent (household types, etc.). Bottom Up studies make it possible to explain changes in behaviour at a micro level, and thus yield information about where the largest potentials for change may be found (e.g. for energy efficiency). Top Down studies are better at capturing the sum of trends and factors affecting demand, including rebound effects. Generally, Top Down models tend to yield higher predictions for future energy demand than Bottom Up models. Berkhout et.al. (2004) [4], in an ex-post study of the effects of changes in the energy taxation in the Netherlands, shows for example that a detailed Bottom Up analysis fails to capture all effects, whereas a Top Down analysis has a much higher explanatory power.

The economic literature on price and income elasticities is quite comprehensive and largely based on Top Down approaches. There are never-the-less substantial differences in methodology, data and results in different studies. Despite this almost all studies yield estimates which are significant and have plausible parameter values. Hence, the literature clearly shows that demand does respond to changes in income and prices. Unfortunately however, the literature is not decisive on which parameter values to adopt in models used to predict future demand. It is fundamentally difficult to measure the isolated effect of a price change. A recommendation is to – as far as possible – use parameter values from studies that correspond to the specification and data set of the market model employed. To "shop around" for parameter values from different econometric studies will yield systematic errors in the predictions.

Espey and Espey (2004) [5] have carried out a Meta analysis based on 36 international studies containing an array of short and long term price and income elasticities. The analysis reveals that long term price elasticity estimates vary between -2.25 and -0.04. The differences can however to some extent be explained by systematic differences between the studies. More specifically the Meta analysis shows that:

- The variation in long term elasticity estimates is smaller than in short term estimates
- Long term elasticities are generally larger than short term elasticities
- If the stock of electric appliances is included in the analysis, higher elasticities are estimated, i.e. models which do not model changes in appliances directly should apply higher price elasticities than models which represent changes in electric appliances directly
- When prices on substitutes are not included, lower estimates are generally derived, probably because energy prices are correlated
- Estimates based on time series yield higher elasticities than cross sectional data analyses
- Finally, monthly data yield higher estimates than annual data

Estimates of income elasticities vary less, but these also depend on whether stocks of electrical appliances are included or not. When stock data are omitted, the effect of income changes on the stock of electric appliances is not captured. A final important result is that income elasticities seem to be decreasing over time. This implies that estimates based on newer data should be preferred to older estimates, but also that predictions will systematically be too high if income elasticities are not adjusted in predictions for future demand.

When it comes to differences between the Nordic countries, there are only a handful of studies to look at. A Nordic Meta analysis by Bye et.al. (2004) [6] concludes that the hypothesis that price and income elasticities are equal in the Nordic countries, can not be discarded. The need for further analysis is however emphasized.

A general conclusion from the survey is that price and income effects cannot be disregarded. However, micro modelling and combinations of different policy measures also impacts demand response to price changes. An interesting (sociology) study of the effect of energy taxation in the Nordic countries has been carried out by Prasad (2008) [7]. The result that demand response to CO_2 taxes seems to have been greater in Denmark, is explained by structural factors, associated with both market characteristics and policy measures. On the one hand the supply of substitutes has been good and the response greater because coal demand was high initially. In addition substitution to gas and renewables was facilitated by differentiating taxes and earmarking of tax revenues for support to renewable energy. In parallel with taxation, a system of voluntary agreements on energy efficiency efforts in manufacturing was implemented. The high price elasticity is thus explained by both market and policy related factors.

There is a lot we do not know about how energy demand is developing, but the literature offers valuable insight into the factors influencing energy demand and how these are captured by different methods. The good news is that the analyses seem to explain a great deal, and there is broad consensus about which factors are the most important. However, the factors explaining energy demand are complex and no single model can be expected to capture it all. In order to capture “the whole picture” it is useful to combine approaches based on both micro and macro data. This applies to demand predictions and to analyses of policy measures as well. In most countries one goal-one measure policies are not the rule. As the Danish example illustrates the effect of a tax change depends not only on the price effect, but on the combination of policy measures and market effects.

3 Choice of Models matters!

There are large variations in forecasts of energy consumption in comparable model studies in general. The explanation for these variations is not quite clear, but the results from the modelling depend profoundly on the choice of model, and the central assumptions. Looking at existing energy models it is obvious that detailed description of energy consumption in most cases is of little or no concern.

Why would it be valuable to have a better description of this in the models? One obvious reason is that energy diversification and energy efficiency are among the top priorities in present energy policies, and model analyses are important for both commercial decisions and policy decisions. If the limitations inherent in the employed model approach are not taken into consideration, the interpretations, and hence policy recommendations and choices, may be incorrect. It is important to study results from model calculations critically. Otherwise results might be misused, since it could be possible to get a preferred result by a “careful” and biased choice of model.

4 Closing the Economist-Engineer trust gap

Major drivers for energy demand in the macro perspective are prosperity and culture, population and technical level. In the micro perspective, energy prices and temperature are the major drivers. Modelling human behaviour, in other words how we respond to changes in these major drivers, is essential in forecasting of energy demand. In addition, technical development is essential – both incremental and radical changes. A good model for energy demand incorporates all drivers for energy consumption and all energy technologies, and it models behaviour appropriately. Deviations from this ideal model result in systematic errors in the predictions for future energy demand.

In general, a Top down approach is used by economists, while engineers seem to prefer a Bottom up-approach. A Top down economist approach emphasises to capture actual behaviour by using econometric techniques to estimate how the energy consumption depends on changes in the underlying drivers, e.g. prices and income. The estimates are normally based on actual observations of the consumers' behaviour, either through using aggregated energy statistics or by conducting surveys of energy demand for individuals. The alternative Bottom up engineer approach will emphasise how a given or exogenous demand for energy may be satisfied by using different technologies or different energy carriers. In engineer models, a wide range of technology options may be modelled explicitly and it is usually assumed that the consumers adapt to order to minimize costs.

Top Down and Bottom Up models have different characteristics. Obviously, the engineer approach gives much better opportunities to simulate how new technologies may change long term energy demand. However, engineer models may be less adequate to forecast the changes in the 'underlying' energy demand. In addition, an assumption that consumers adapt in order to minimise costs may easily overestimate the extent that energy demand is shifted by technological change or changes in energy prices. On the other hand, economic models are basically a mirror of historical behaviour and will have a limited capability to predict new trends in energy demand. Both price and income elasticities may change over time. In addition, there are a number of criteria to be fulfilled for econometric results to be valid.

The two different approaches have hence both strengths and weaknesses – and lately hybrid models incorporating both Top down and Bottom up elements have been developed to be able to incorporate both consumers' actual behaviour and technological change. The hybrid approach is illustrated in Figure 4-1.

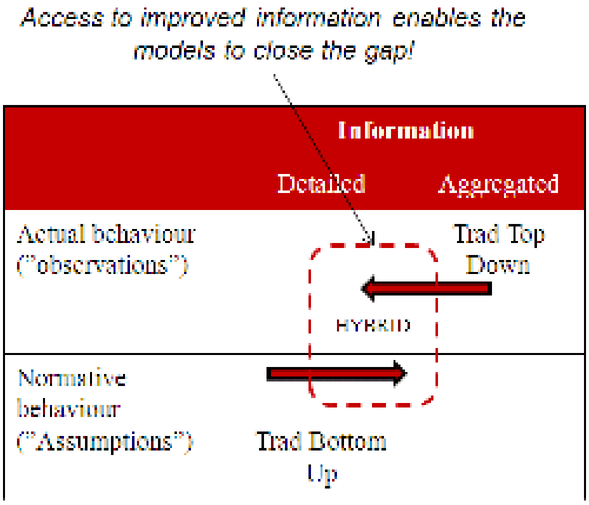
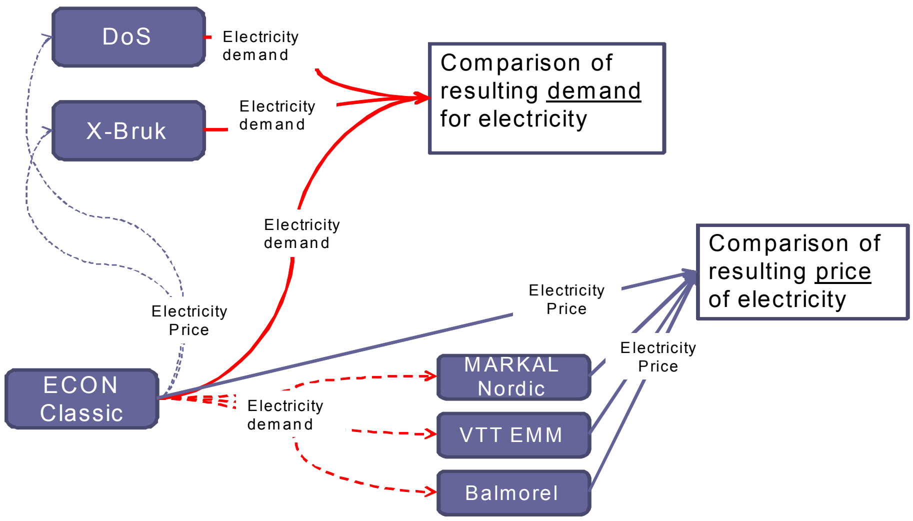


Figure 4-1 Top down vs Bottom up approach

5 A comparative analyses of the NEP models

Seven different models used in the NEP project, all of them used extensively in market and policy studies in the Nordic countries, have been analysed from an energy demand modelling perspective in the KOMPAS project.

In the KOMPAS project, the models were executed in a serial manner, using some of the results from one model as input in the next model.



None of the models studied in KOMPAS calculate the Nordic energy demand endogenously. Only ECON Classic and the DoS model calculate electricity demand, and thus the results of these two models were compared.

At the national level, the Top down model (ECON Classic) seemed to yield higher expected demand than the Bottom up/hybrid model DoS (see Figure 5-1). The largest discrepancy is found in the results for Finland, where ECON Classic predicts 7.5% higher electricity demand in 2025 than DoS. For Denmark, ECON Classic predicts lower demand than DoS, but the difference is small.

NEP models analysed in KOMPAS

Energy system models:

- **MARKAL-Nordic:** Bottom Up, least cost, all technologies
- **Balmorel:** Hybrid, combines Top Down and Bottom Up, electricity and CHP

Electricity market models:

- **ECON Classic**: Top Down, Partial equilibrium model
- **VTT-EMM**: Bottom up model
- **PoMo**: Bottom Up, profit maximising
- **DoS:** Bottom Up/hybrid, Nordic electricity demand

In addition to the NEP models:

- **X-Bruk:** Top down model, Norwegian energy demand (municipality level), developed by Xrgia

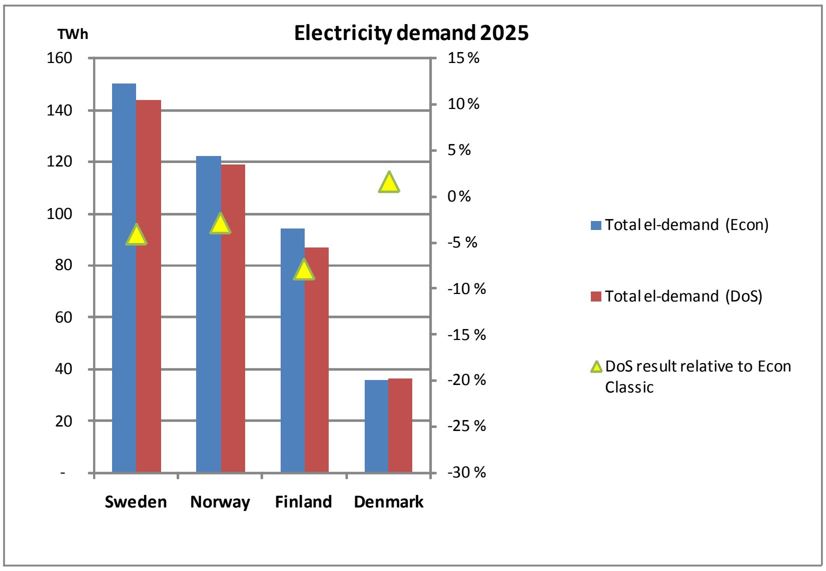


Figure 5-1 Forecasts of electricity demand 2025 (Econ Classic and DoS model)

Splitting the forecasted demand between different end use sectors, the differences appear larger, more than 10 % for some sectors in some countries. For Sweden and Norway, ECON Classic predicts higher energy demand than DoS for both the household and service sector, and for the non energy intensive industry. For Denmark and Finland, the story is opposite. For these countries, ECON Classic predicts lower electricity demand than DoS for households, service and non energy intensive industry. The results are illustrated in Figure 5-2.

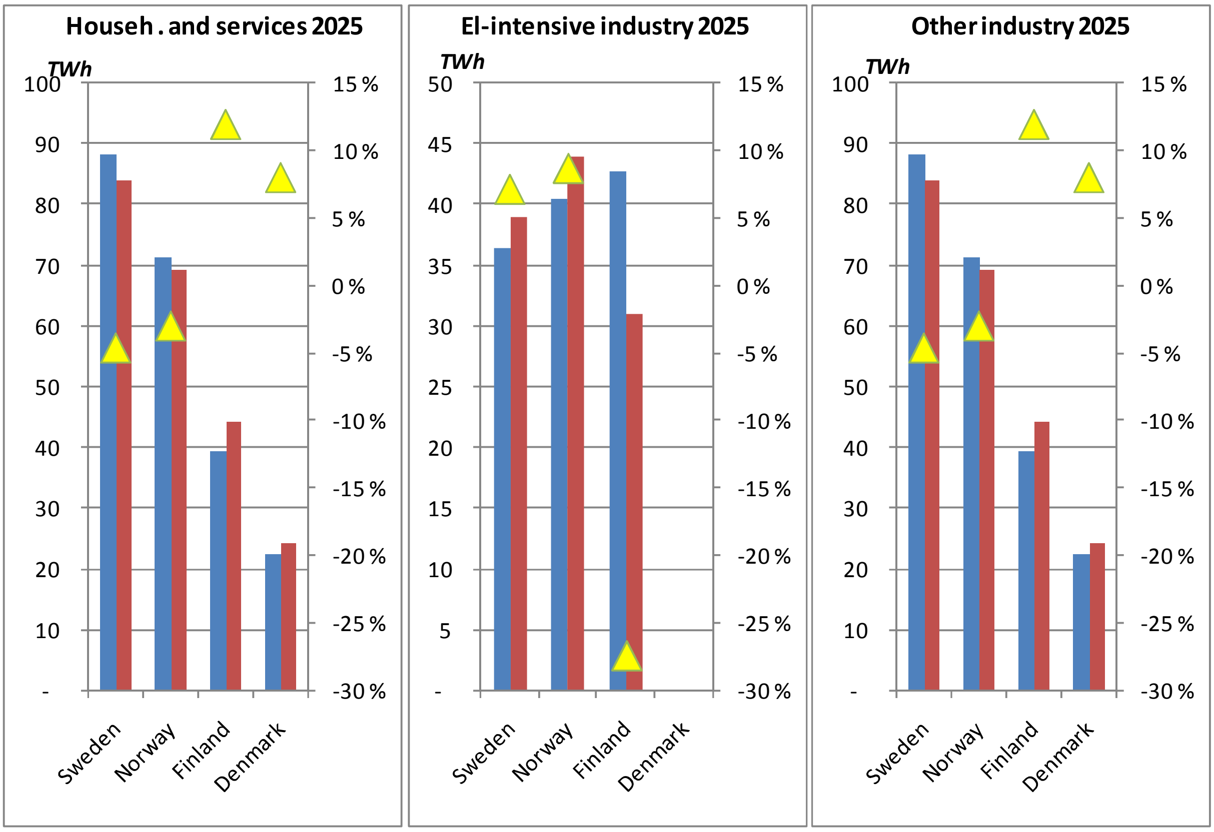


Figure 5-2 Electricity demand forecasts 2025 (Blue/left bar: Econ Classic, Red/right bar: DOS)

The results should not be taken as “right” or “wrong”, but as indications of different approaches reaching deviating conclusions. As policy measures are often applied on a sectoral level, disaggregated analyses should be performed, preferably for the different sectors of the economy. It is necessary to analyse measures with more than one model, to be able to understand the complex mechanisms involved, and to take into account the strengths and limitations of the different models when using the results.

6 How may KOMPAS influence/improve the NEP2 project?

The findings of the KOMPAS project will hopefully influence and improve the NEP2 project in a number of ways.

- KOMPAS offers insights in international demand modelling and in the possibilities to combine different kinds of models to amend limitations of single models.
- KOMPAS results encourage researchers, and users of model results, to take the demand side more actively into consideration in the analysis of results.
- KOMPAS also stimulates improvements in existing models, by exposing the deviating forecasts on a sectoral level, encouraging the researchers to reveal and analyze the mechanisms causing these divergences.
- KOMPAS finally reveals the requirements for new types of models, for example "soft-linking" Top Down and Bottom Up models, and models that endogenously forecast energy demand, not just electricity demand.

Even if the development of hybrid models seems to be a sensible development, our conclusion in the KOMPAS project is that this is not necessarily the best way for the NEP model portfolio. Large hybrid models may result in a "black box" model with a lot of details, giving less instead of improved *understanding* of the mechanisms and drivers. Instead, utilization of both Top Down and Bottom Up models in series and/or parallel, with researchers discussing their results in a forum of economists and engineers, will both close potential trust gaps and result in new insights in the complex mechanisms involved. The NEP project is an excellent arena for such an approach.

7 References

1. **"Efterfrågan på elektricitet i de nordiska länderna – översikt och litteraturgenomgång**",
   Berit Tennbakk and Miriam Munnich, Econ Pöyry (in Swedish)
2. **"KOMPAS - komparativ analyse av forbruksmodelleringen i 8 nordiske energimodeller",**
   Monica Havskjold and Arve Halseth, Xrgia AS (in Norwegian)
3. Gonzalez, P. og Hernandez, F. (2006): How do energy and Environmental policy goals and instruments affect electricity demand? A framework for the analysis. Sustainable Energy Reviews, 11(9) 2006-2031.
4. Berkhout, P. H. G., A. Ferrer-i-Carbonell og J. C. Muskens (2004): The ex post impact of an energy tax on household energy demand. Energy Economics v. 26, 297-317.
5. Espey, J. A. og Espey, M. (2004): Turning on the lights: A Meta-analysis of Residential Electricity Demand Elasticities, Journal of Agricultural and Applied Economics, v. 36(1), 65-81.
6. Bye, T., Wist Langmoen, M. og. Aasness, J. (2004): Pris- og inntektselastisiteter for husholdningenes etterspørsel etter elektrisitet – en metaanalyse for nordiske land. Notat utarbeidet for NVE. Statistisk Sentralbyrå, Norge.
7. Prasad, M. (2008): Taxation as a Regulatory Tool: Lessons from Environmental Taxes in Europe. Department of Sociology, Northwest University.
   http://www.sociology.northwestern.edu/faculty/prasad/Taxation_3_25_08.