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The impact of future energy demand on renewable energy production – Case of Norway

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ABSTRACT

Projections of energy demand are an important part of analyses of policies to promote conservation, efficiency, technology implementation and renewable energy production. The development of energy demand is a key driver of the future energy system. This paper presents long-term projections of the Norwegian energy demand as a two-step methodology of first using activities and intensities to calculate a demand of energy services, and secondly use this as input to the energy system model TIMES-Norway to optimize the Norwegian energy system. Long-term energy demand projections are uncertain and the purpose of this paper is to illustrate the impact of different projections on the energy system. The results of the analyses show that decreased energy demand results in a higher renewable fraction compared to an increased demand, and the renewable energy production increases with increased energy demand. The most profitable solution to cover increased demand is to increase the use of bio energy and to implement energy efficiency measures. To increase the wind power production, an increased renewable target or higher electricity export prices have to be fulfilled, in combination with more electricity export.

1. Introduction

The future share of renewables is a goal in many policies. Since this is correlated to the future energy demand that is uncertain, the impact of different developments is of high interest. Projections of energy demand are central in analyses and policies to promote conservation, efficiency, technology implementation and renewable energy production. The development of energy demand is a key driver of the future energy system. Many forecasts are based on projections of GDP (gross domestic product) and population [1,2], sometimes including price elasticity of energy-service demand although this is very difficult to estimate [3]. A more detailed projection is presented here, and as in the case of [4] analysis of historical energy use is vital. The focus of this paper is the effect of future energy demand on the energy system, particularly on renewable energy, and it presents projections of both energy service demands and energy consumption up to 2050. The effect of changes in energy service demand as well as in final energy demand is studied, which according to [3], is unusual.

Studies have shown that the predictive approach used here to answer the question "what will happen if?", is less suitable for the analysis of long-term developments since they perform poorly due to the difficulties in addressing structural changes [5]. Even so, it is regarded as appropriate to the purpose of illustrating the impact of energy service demand projections on future renewable energy production and scenario analyses are commonly used to outline possible paths to future low carbon energy systems. Most energy system studies focus on supply-side technologies and pay less attention to end-use energy efficiency technologies (implying a decline in energy use per GDP) according to [5]. They have found that the development of new renewable energy sources is limited by energy efficiency due to the diffusion of more efficient demand-side management in scenarios with low growth in energy consumption. This is found in different studies with different projections of energy demand. In this paper, it is illustrated how this important input to energy system analyses influence the impact of renewable energy production and how important it is in order to reach goals on the share of renewable energy.

The Norwegian energy system has a high share of renewable energy, since the electricity production mainly is based on hydropower. The hydropower production is dependent on the annual

Abbreviations: ETP, energy technology perspectives; GDP, gross domestic product; GCM, green certificates market; IEA, International Energy Agency; RES, renewable energy sources; SEC, specific energy consumption; TIMES, The Integrated Markal Efom System; VA, value added.

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precipitation which fluctuates with stochastic behaviour. The average hydropower production was 123.9 TWh in 2011 based on the normalisation method described in Ref. [6]. As of late 2011, the total installed wind capacity in Norway was 525 MW, corresponding to an electricity production of around 1.3 TWh. The total electricity production from thermal power plants was 4.8 TWh in 2011 [7].

Norwegian final energy use in 2011 was 213 TWh and 105 TWh was electricity [8]. Norway has a cold climate with an annual energy use in the household and commercial sectors of approximately 80 TWh, where roughly half of this is used for space heating. Traditionally, electricity has been relatively inexpensive and is therefore widely used for space heating. The electricity share of total energy use in households has varied between 72% and 79% for the last 20 years. The temperature corrected electricity consumption has been higher than the normalized renewable electricity production in the period 2004–2011, but due to more precipitation than normal, some gas power and in average a warmer climate than normal, Norway has been a net exporter of electricity in five of these eight years [9].

The EU Renewable Energy Directive sets a target of increasing the share of renewable energy use in the EU from 8.5% in 2005 to 20% by 2020 in order to limit greenhouse gas emissions and to promote cleaner transport [6]. The directive is implemented in Norway with a national target of 67.5% renewables in 2020 (roughly calculated as the renewable energy production plus the direct use of bio energy divided by the total end use of energy). One important measure to achieve this target is the common GCM (Green Certificates Market) that is agreed on by the governments of Sweden and Norway. By 2020, the new market mechanism is expected to annually generate 26.4 TWh electricity.

The paper is structured with a methodology description in chapter 2, the resulting projection of useful energy demand is presented in chapter 3 and the TIMES-Norway model is described in chapter 4. In chapter 5, the base scenario is presented together with assumptions and different scenarios. The results of the analyses are presented in chapter 6, succeeded by discussions and conclusions.

2. Methodology

First, the development in useful energy demand is calculated based on the assumption of no market based changes in energy efficiency, in alternative fuels and no alternative use of technology. These projections are based on assumptions of economic growth, business development, demographics etc. and the development of energy indicators. Time-series analyses are used in this evaluation work. It also includes normative measures such as building regulations. The energy demand is divided into four main sectors; industry, households, service & other and transport. These are further divided into sub-groups and the projection is calculated for each of these (Appendix A).

Secondly, the projections are input to analyses with the energy system model TIMES-Norway [10,11]. Analyses with TIMES-Norway result in market adjustments due to alternatives of fuels, technologies, energy efficiency measures with different assumptions of oil prices etc. Price elasticity between energy carriers and energy efficiency is included in the model, and the scenario approach simulates other demand elasticity. A similar approach was applied to the building sector of Portugal, by first modelling the energy service demand and secondly analysing with TIMES_PT to project detailed end-use demand [12]. A methodology based on energy indicators and a TIMES-model was also used by Ref. [13], but input to TIMES-Norway is based on in depth analysis of the important Norwegian industries instead of a GDP development. A base scenario and four different demand scenarios are analysed to study the impact of future energy demand on the energy system and particularly the renewable energy share. In each analysis, demand of useful energy per demand sector and time step is input to TIMES-Norway and model results are e.g. use of different energy carriers and investments in energy production and end-use technologies.

When projecting energy demand, both the development in the activity, for instance production volumes, and the development of the energy indicators have to be considered. A reduction of the energy indicator may be caused by e.g. more energy efficiency in the sector, technology change or by change in product mix. An increase may in the opposite way indicate a less energy efficient production or changes to products or processes that are more energy consuming. Knowledge of the industries analysed, is necessary to explain the development of energy indicators and estimating the future development in each subsector. The energy consumption is based on the energy balances [8]. Energy use and activity figures are collected in a database, used in the Odyssee-project [14].

The projection method used is a bottom-up approach. The best energy indicator in each subsector is used together with a projection of the activity in order to estimate the future energy demand.

$$E_t = I_0 * \left(1 + \frac{\Delta I}{I_0}\right) * A_0 * \left(1 + \frac{\Delta A}{A_0}\right) \quad (1)$$

where:

E_t = energy demand in year t (GWh)
I_0 = Energy intensity in base year (kWh/household, kWh/m^2, kWh/capita etc.)
ΔI = change in energy intensity
A_0 = activity in base year (number of households, m^2, persons etc.)
ΔA = development in activity

The demand projection is calculated as useful energy (E_{useful}), since the composition of different energy carriers affect the final energy use. The energy demand projection is divided into electricity used for specific electrical use, such as motors, electrical appliances, lighting, and thermal/process energy. Useful energy is calculated with the efficiencies used in the energy balance [8]. The projections are based on the most recent energy balance (in this case 2007), while the base year of the TIMES-Norway model is 2006.

3. Resulting projection of useful energy demand

3.1. Industry

Historical energy use in 14 industrial subsectors, back to 1980, has been analysed together with the development in value added, production index and, in the cases where it has been possible, also the production volumes in tonnes. Different energy indicators are calculated such as energy intensity (E_I), SEC (specific energy consumption) and energy per production index (E_{PI}):

$$E_I = \frac{E_{useful}}{VA} \quad (2)$$

$$SEC = \frac{E_{useful}}{P} \quad (3)$$

$$E_{PI} = \frac{E_{useful}}{PI} \quad (4)$$

where:

E_{useful} = useful energy (GWh)
VA = value added