Summary

Objective

This report constitutes an updating and summary of the reports **EI från nya anläggningar 2007 (Elforsk 07:50)**, which elaborates on today's electricity generation techniques being implemented in new plants and the associated electricity productions costs, and **Inventering av framtidens produktions-tekniker för el- och värmeproduktion (Elforsk rapport 08:74)**, which reports about continued development of today's commercial techniques and techniques estimated to be of interest in the future.

The objective of the new report series "**El från nya och framtida anläggningar**" is to get an integrated and up to date as well as a comparable picture of the situation 2010 concerning electricity production costs based on commercially available and reliable techniques. Some techniques characterized as new but still in a development phase and therefore less tested with regard to reliability have been included. The scope also involves a forward-looking approach trying to estimate the costs of today's as well as developing techniques in the perspective 2020-2025.

For technical descriptions of electricity generating plants earlier dealt with, reference is made to the above mentioned reports. New techniques that has not been discussed earlier plus necessary complementary additions are included in the present report.

The updating includes and involves also an expanded computer based model (in Excel) for calculation and presentation of the electricity production costs as well as for sensitivity analysis related to essential input factors/quantities and conditions (representing Swedish circumstances).

Techniques

In this first version of "El från nya och framtida anläggningar" 14 new plant types or variants have been added in relation to the previous version of "El från nya anläggningar 2007". Worthwhile mentioning is:

- A small biomass fuel fired CHP rated at 5 MWe
- A CHP 20 MWe burning sorted waste fuels "RDF"
- A CHP 20 MWe for thermal gasification of sorted waste fuels "RDF"
- Condensing plants with CCS (for both coal and natural gas)
- A biomass fired plant with an ORC-process rated at 2 MWe
- A waste heat driven ORC-process rated at 0,5 MWe
- A small hydro power station at 5 MWe
- Solar cells (PV) at 50 kWe
- Thermal gasification of biomass with internal combustion engine rated at 1, 5 and 10 MWe respectively
- A fuel cell (MCFC) for biogas rated at 500 kWe
- A fuel cell (PEFC) for natural gas rated at 50 kWe
- Thermal gasification of biomass with combined cycle CHP rated at 20 and 60 MWe respectively

In addition to the above a number of new versions of formerly described techniques have been included. For the fast developing wind power technology new wind turbines based on increased tower heights, increased wing/rotor diameters and electric power capacities have been introduced along with increased wind park sizes.

A new type of plant that has been added is the "polygeneration" plants based on biomass fuels – "biomass polygeneration". The denomination is used to characterize that production of several different products are integrated in a common process in order to

achieve synergies and maximize the total energy usage. In this first version of "El från nya och framtida anläggningar" two biomass poly generation plants have been introduced and elaborated upon, one for production of vehicle fuel (biomethane/CH4) and another for pellets.

The focus of attention in this version of the report relates to presentation of updated and new data for plants that are assumed be commercial or "semi- commercial" today (perspective 2010). When it comes to the perspective 2020-25 the presentation is reflecting rather the development potential and preliminary assessment of data and costs provided that relevant basic data exists.

Basis for calculations

All relevant conditions for calculation have been updated in relation to the former version of "El från nya och framtida anläggningar". This concerns technical as well as economic conditions.

Fuel prices and taxes

In this report it's not within the scope to evaluate various determining factors such as trends concerning political means of control or development of fuel prices. Calculation of production costs are based on the present fuel prices, taxes and support (systems). This also applies to further developed techniques and plants as well as to plants being ordered and purchased in 10-15 years time.

The calculations have been carried out based on the tax levels specified in the budget proposal 2009/10:41 with additionally proposed reduction for CHP production from January 1, 2011 according to the budget proposal 2010/11:1.

Electricity certificates

The development of the price of electricity certificates has had and has a substantial effect concerning decisions about investments in renewable electricity production. About a year ago the value of the certificates was high, but in recent months the value has dropped. How the value will develop in the next certificate period taking into consideration that several plants will be leaving the system (having reached there maximum affiliation time) plus a possible integration of the Norwegian market is surrounded of uncertainty. The price level used in the present calculations is 280 SEK/MWh, which is based on the average value during the past year.

Operation prerequisites

Prerequisites for operation related to utilization or yearly operation time have been revised in the present edition. Planned utilization time is defined as planned yearly production assuming 100% reliability disregarding deduction for unplanned stops divided with rated output. Net production is achieved by including the set reliability found in the input data sheets of the computational model. For the wind power plants the so called park efficiency, i.e. the fact that single wind turbines are shadowing each other, shall also be specified. New default input data are specified in Chapter 4.4.

Heat credit entry

Heat being produced in CHP's has to be given a value which is deducted from the other cost entries. It has a significant impact on the finally calculated net electricity production cost. The lower the electric efficiency is the higher is the share of produced heat and as a consequence the importance of the heat credit entry.

There is no general model which can be claimed be correct in every situation and application. The heat credit entry has to be decided upon for each specific district heating system. The starting point for the valuation and the calculation usually is that the heat credit is set based on the best alternative available to produce the heat required. In order to get a clear comparison, similar to earlier versions of the report, a general model based on default input data, which can be altered in the attached calculation model, is used.

However, a partly new model for the specific credit calculations has been introduced. For all CHP's the value is calculated based on the use and the price of biomass fuel as well as associated costs for fixed and variable operation and maintenance (O&M) costs proportioned to the heat production. For large plants the basis for the calculation is a biomass fired heat only plant equipped with a flue gas condenser with similar total heat production. When it comes to the small scale plants included in the study the credit entry is based on biomass pellet fired heat only plants. For both large and small scale plants a fixed credit entry corresponding to the investment of a heat only plant can be made if required, which can be motivated should new capacity be needed in the system.

Product credit entry

For the biomass polygeneration plants other main products as well as possible byproducts need to be assigned a value. The produced heat (for district heating) from the integrated CHP unit is credited according to the above. For the polygeneration plants being introduced in this study, the additionally generated products, biomethan/CH4 and pellets respectively, shall also be credited.

The valuation of the products is based on the same principle being applied when crediting generated heat, i.e. the value shall reflect a production cost representing the value/price in a point where it is left for distribution.

Technical and economic data.

Technical as well as economic input data have been updated concerning all techniques. Technical data and performance characteristics are given in Table 5. For each and every plant specific data, such as specific investment (over night cost), interest payments during construction, operation and maintenance (O&M) costs plus important technical parameters such as electricity efficiency (net) and the alfa-value (electricity to heat ratio), are given in the input data sheets.

Calculation model

The computer based calculation model, which is available on the website Elforsk <u>http://www.elforsk.se</u>, calculates the electricity cost for specified plant options based on the annuity method with the specified (default), but changeable, the input data. Calculation results are presented in tables and graphs. The user specifies for each case the plant options to be included in the calculation.

A distinction has been made in commercial technologies (with guarantees) and in new "semi-commercial" techniques (limiting guarantees), both groups available in 2010 on the one hand, and future technologies that are considered commercial, first from 2020 to 2025, on the other hand. Techniques belonging to each period are selected actively by the user in the model input sheet after specified time period.

The model data comprises input data for all plant options in a for each plant-specific input data sheet. All these data can be changed by the user.

Other public input and conditions can also be easily changed by the user. These are, for example, fuel prices, rate of interest, equivalent full load operation time (duration time), taxes, heat credit entry, product credit entry (polygeneration), subsidies, etc., see Chapter 6.

Results

The presentation has been divided into the following subgroups.

- Fossil condensing plants, nuclear, wind and hydro
- Large-scale CHP
- Small-scale technology (Distributed Generation)

For the presentation and a rational management of different techniques, abbreviations are used in the calculation model. Describing text for each abbreviation is presented in the tables in Chapter 2.

The summary results are presented for commercial and new semi-commercial technologies 2010. Corresponding results for the further developed and emerging techniques are presented in Chapter 7.

Fossil condensing plants, nuclear, wind and hydro

For the first subgroup results are presented with the variation of interest rate, 6% (default) and 10%, and with and without taxes and subsidies (green certificates, grants). Neither heating nor product credit entries are to be considered for these techniques.

Below electricity generation cost are presented for fossil condensing plants, nuclear, wind and water, without taxes and subsidies, at 6 and 10% interest rate:



Baskondens, kärnkraft, vind och vatten 2010 \underline{utan} skatt och bidrag vid 6 och 10 % rta

Below electricity generation costs are presented for fossil condensing plants, nuclear, wind and hydro with taxes and subsidies, at 6 and 10% interest rate:



Baskondens, kärnkraft, vind och vatten 2010 med skatt och bidrag vid 6 och 10 % rta

CHP and Polygeneration

The second subgroup is presented at 6% real interest rate with taxes and grants with "variable" credit entry (generally regarded as minimum credit) and with heat credit entry for both variable and fixed costs (full credit), the latter including capital corresponding to a heat only plant including flue gas condenser for wet fuels with the same total heat production capacity as the current CHP.

Below are electricity generation costs for large-scale cogeneration plants with tax and subsidies at 6% real interest rate, with both variable credit entry and full credit entry respectively:



Kraftvärme storskalig 2010 <u>med</u> skatt och bidrag vid 6 % rta med rörlig resp. full kreditering + produktkreditering (kombinat)

Small-scale techniques

The third and last sub-group, small-scale techniques including "distributed generation" for both power and cogeneration, are presented based on conditions similar to the second subgroup with the difference that the full credit entry is based on a heat only plant or burner for wood pellet fuels. Also in this group there are both commercial and semi-commercial technologies representing 2010 and future technologies and further development of commercial techniques that represent the perspective 2020-25, designated by an alphanumeric combination result of _2.

Below are electricity costs for small-scale technologies with taxes and subsidies at 6% real interest rate, both for variable credit entry and for full credit entry.

Småskalig teknik 2010 med skatt och bidrag vid 6 % rta med rörl resp. full kreditering



Comments

With regard to both performance and cost assessments focus has been on presenting good figures for the plant types that are commercial today. It is of course more difficult to obtain information relating for the perspective 2020-25 and as consequence of this the presented figures for both further development of current technologies and new technologies are much more uncertain. For technologies for which this information is lacking, the same figures as for today's technologies are presented. Hopefully these gaps gradually will be filled in the future planned updates (biannual).

Some observations made on the basis of the calculation results are:

- Selected input conditions and assumptions controls the calculation results
- $\circ~$ For CHP the choice of crediting entry will have a huge impact, particularly true for techniques with a low α value (electricity to heat ratio), ie.;
 - CHP based on waste and RDF
 - Biomass CHP with ORC
 - The electricity production cost for these techniques will be very low relative to other techniques, when high (full) credit entry is used
 - When heating entry is based on a capital-intensive production of district heating – biomass based heat only boiler – the electricity production cost will increase at higher interest rates
 - Electricity production costs for technologies with a low α values and high (full) credit entry will due to this fact result in lower electricity production costs at high (10%) interest rate than at low (6%) interest rate
 - For waste fuel CHP plants the gate fees will also have a very large impact
 - $\circ~$ Especially for techniques with a low α values the reader is recommended to make calculations based on own selected credit entry figures and to choose their own waste gate fees
- Otherwise, the calculation results is considered to be robust considering ranking the techniques

All wind energy options are expected to have lower electricity costs in the 2020-2025 time frame compared to 2010 due to a shift toward more cost-effective wind turbines. Probably, these technologies can be introduced in the market slightly earlier than 2020.

A comparison with the results from the latest version of "El från nya anläggningar 2007" can only be made for the technologies that were presented in that report. A comparison has been made of these techniques and results for a few selected new techniques. This is presented in the following diagram, without taxes and subsidies at 6% real interest rate with the lower variable heating credit entry, which 2007/08 was 180 and 300 SEK/MWh (fixed) for large and small plants respectively and in 2010 232 and 386 SEK/MWh (variable) for the same plants.



Cost information and references which has been available for this update indicate that the investment cost of nuclear power was underestimated in the previous version of the report. This is the main reason why the production cost of nuclear power has increased substantially compared with the 2007 report and now is in the same level as fossil large-scale condensing plants.

The results show a very low electricity production cost for CHP plants for unsorted household and industrial waste, which is associated with a higher heat credit entry, which has a greater impact due to that the electrical efficiency of the current 20 MWe plant is slightly lower than the previous one of 30 MW, ie the alpha-value is slightly lower. Furthermore, operation and maintenance (O&M) costs have been reduced due to the fact that auxiliary power currently is not taxed. Indirectly, this is based on that waste is generally not subject to energy and carbon taxes. When "full" credit is used in the calculations it results in a negative electricity production cost. Since the heat credit entry in the model is based on bio-fuels and is of such importance, it is particularly important that the user of the model selects the right heating credit entry for the actual system. Yet another important factor is the "gate fee", often bringing about a negative fuel price. The gate fees vary regionally today and their development is uncertain. These factors, combined with the fact that the load factor or duration time (default) for waste-based CHP is long (7000h), constitute an advantage for this technology. However, the presented absolute figures should be considered cautiously when compared with other CHP types (duration time 5000h). Direct comparison should rather be avoided. In this case it is recommended that the readers make their own analysis using the model available.

Gas engines have got much higher electricity costs compared to the previous release. This is associated with a significantly higher gas price for small-scale applications. In turn it depends on that the gas price, which is generally higher, also has been given a finer division versus needs (power) and consumption compared with the past. This also affects the smaller gas-fired CHP plant (Combined Cycle).

The production cost of coal based condensing plants has not risen compared to the previous report. This can partly be explained by the fact that price escalation of coal power plants and other internationally purchased fossil fired plant technology have been low compared to continued price escalation of biomass- and waste fired plants. This conclusion can be drawn based on various international indices. Furthermore, the total O&M cost (fixed plus variable cost) was higher in the previous version. A cost base, common and consistent with other fossil fired condensing plants and CCS options, have been used in this update.