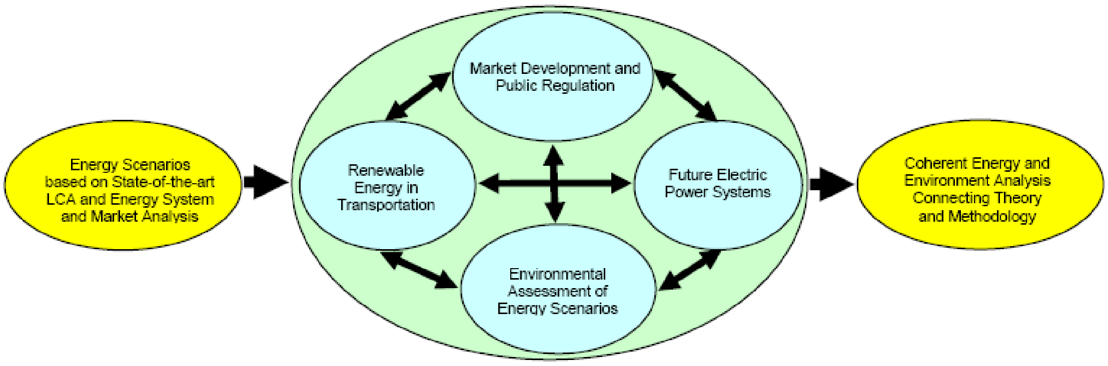
CEESA

Coherent Energy and Environmental System Analysis

Status for the scenario framework WP1 to the Consortium meeting 2nd – 4th June 2008 at Gl. Avernæs castle



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Introduction

This paper shortly gives a status for the work carried out in the work package on the scenario framework WP1, outlining some of the main issues to be presented and discussed at the 3rd consortium meeting, 2-4 June 2008 at Gl. Avernæs Castle.

The work in WP1 has focused on the following:

1. As decided on the last consortium meeting in 2007 the framework conditions for the other work packages are given by three over all scenarios on how to achieve a 100% renewable energy system in the future: 1) A biomass dominated scenario with low demand, 2) A wind dominated scenario with low demand and 3) A combined biomass and wind scenario with high demand. A short summary of the three scenarios is given below.

2. As a result of a closer coordination of the work between WP1 and the other WPs two thematic meetings were organised:
   - Boundary conditions for the power industry were discussed at a meeting at Aalborg University, especially focusing on differences and similarities between the LCA-analyses and the energy system approach
   - A work shop was organised at Risø to discuss a common approach for scenarios for "rest of the World", because the three scenarios mentioned above mainly focus on Denmark. Presentations included the future EU system, the need for LCA data in relation to biomass and energy and, finally, the future potentials for biomass resources (PP-presentations available on request). It was decided to form a specific working task on LCA data needs.

3. As background for the discussion at this consortium meeting a short description of the role and needs of LCA in relation to the energy system is given below.

100% Renewable Energy Scenario Framework for the CEESA project

This paper shortly summarises the scenario framework for the future work within the CEESA project.

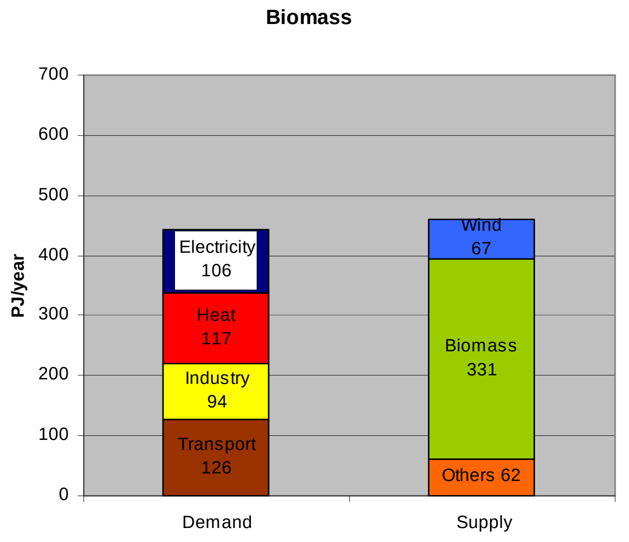
The main scenarios

At the former consortium meeting the following three alternatives were decided as a starting point for the CEESA project:
- ***Biomass scenario***. Based on the IDA 100% RES low demand, mostly biomass.
- ***Wind scenario.*** Based on the IDA 100% RES low demand, mostly wind
- ***High demand.*** Based on the 2004 energy demand, both wind and biomass.

The three 100% renewable energy systems have been analysed by use of the computer model EnergyPLAN. The model is an hour by hour simulation model with an emphasis on balancing electricity and heat supply and demands. The modelling comprises complete energy systems including the transportation sector. Inputs include energy demands and renewable resources. For relevant demands such as electricity and district heating and relevant sources such as wind power and solar thermal, the inputs are distributed into hour by hour values using actual distribution from historical demands and productions. Figure 1below shows details on the energy mix and utilisation of resources in each of the scenarios. Keep in mind that in all scenarios emissions of CO_2 are zero.

How to understand the scenarios

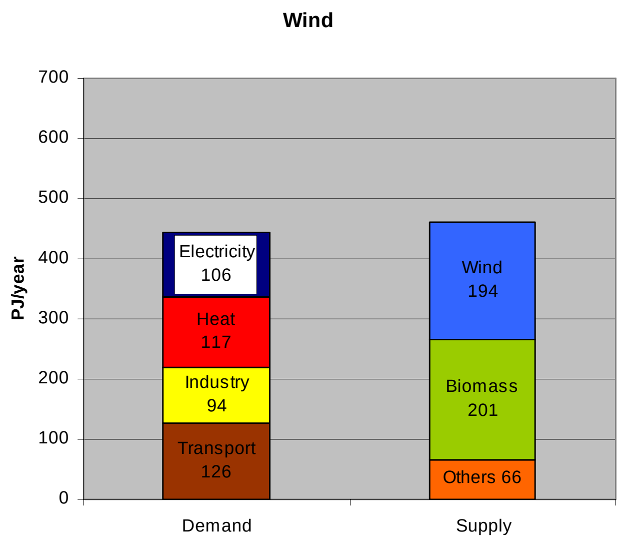
The scenarios are to be used as a first framework for the CEESA project. The scenarios are to be further developed in an on-going process during the period of the project, which among others will include the following work:
- The individual energy systems of each scenario will be better optimised, e.g. the capacities of electrolysers and choice of individual heating etc. This will take place within the WP1.
- LCA analyses of the scenarios will be incorporated. How to do this will call for further developments of theories and methodologies and is a core issue of the CEESA project. Such development will be based on a close collaboration between WP1 and WP4 and further involve the whole consortium.
- The analysis of scenarios will be expanded to include electricity (and eventual biomass fuel) exchange analyses. How to define and model external markets will be discussed between WP1 and WP5.
- The transportation alternatives will be further developed in WP2.
- How to design the best production of biomass resources will be developed in WP2.
- How to develop the electric grid will be discussed between WP1 and WP3. Such discussion may lead to additional scenarios including the distributed versus centralised parameter, which has so far not been included into the scenario framework.



The Biomass Scenario

(Based on the IDA 100% RES 2050 proposal)

- Savings: 30-50% in space heating, electricity and industry compared to BAU 2030
- transportation demands stabilised at 2004 levels
- Efficiencies: More CHP and better power plants based on FC technology and heat pumps.
- 700 MW PV and 500 MW wave power. Solar thermal 15% of heat demand
- 6000 MW wind power

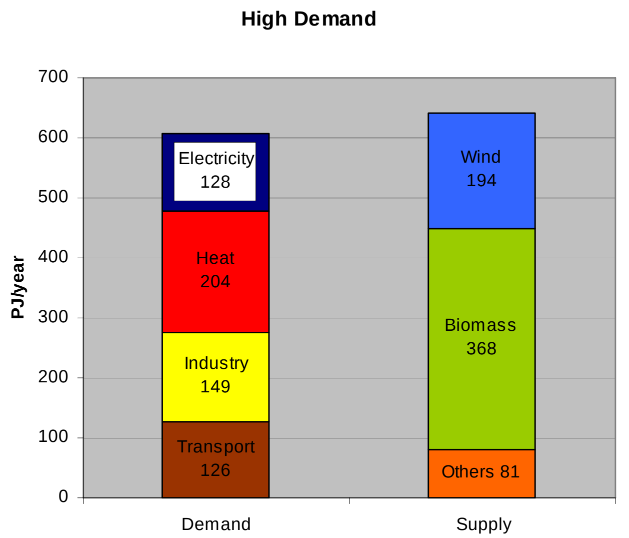


The Wind Scenario

(Based on the IDA 100% RES 2050 proposal)

Same as Biomass Scenario apart from

- 15,000 MW wind power instead of 6,000 MW
- additional 10,000 MW electrolysers and 3000 GWh hydrogen storages.



The High Demand Scenario

Same as Wind Scenario apart from

- 2004 electricity, heating, industry and transportation demands.
- 2,500 additional electrolysers to produce hydrogen for FC micro CHP units for individual heating.

Figure 1: Demand and supply in the three scenarios.

Key Assumptions and Boundary Conditions for Life Cycle Assessment of Bio-energy Technologies

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Any energy system will interact with its surroundings through market mechanisms and other contextual relations, and the nature and scope of markets for electricity, fuels, food and animal feed influence on the outcome of the assessment of the environmental aspects of the system.

The key issues to be addressed are listed in the table below and further elaborated in the subsequent text.

Key issues	Framework condition in general	
	a	b
Scope of trade: Overall geographic scope of the trade on the markets for electricity, fuels, energy crops, food & feed crops	International	National/regional
Correlation: between energy and food/feed sectors	Correlation	No correlation
Fuel marginal on the fuel market	Fossil	Biomass/other non-fossil
Marginal supplies outside Denmark	Fossil	Biomass/other non fossil
Land-use marginal for energy crops	Natural land with high carbon sequestration	Natural land with low carbon sequestration
Land-use marginal for food/feed crop displacement-replacement	Natural land with high carbon sequestration	Natural land with low carbon sequestration

<u>The scope of trade: The geographic scope of the markets for electricity, fuels, energy crops and food/feed crops</u>

We can look at the significance of these market scopes by choosing 2 overall future scenarios at each 'end of the interval': one with very international markets and one with national/regional markets. Looking at the energy scenarios, i.e. the high wind versus high biomass, we will most probably end up by finding the same environmental priority independently of the scope of the trade, but potentially with much higher quantitative differences in case of an international scope (see later sections below for further justification of this statement).

<u>Correlation between the energy and the food/feed sectors</u>

If, in the future we are looking at, we have a significant part of the agricultural area on our planet dedicated to energy crop production – as well as food/feed crop production – there will be a significant correlation between the fuel markets and food/feed markets. Simply because farmers can choose crops for sale at both market categories. The price for crops on the food/feed market will/may, thus, have to follow the price on the energy crop market and vice

versa. In case of significant correlation, changes in demand and supply of energy crops will through market mechanisms and price relations, thus, implicitly also influence demand and supply in the food/feed sectors and thus the environmental aspects of these sectors, which accordingly have to be modelled.
As we are looking at energy scenarios with high versus low biomass including high versus low use of agricultural land for energy crops, there will be differences in the amount of food & feed produced by Danish farmers between the two scenarios. If we do not assume any changes in import export ratios of food/feed between the two scenarios, we implicitly claim that Danish food/feed consumption will vary significantly depending on our choice of energy production scenarios. This, of course, is not a valid assumption, and of course Danish import-export will change with changing Danish food/feed production. An LCA is by convention made to compare scenarios with the same functional outputs on all goods and services produced by the alternative systems, in this case energy, transport, food, feed and more. Because of differences in price relations between scenarios, an assumption of fully equal functional outputs is not the whole truth either, but in any case the large differences between food/feed production from the two scenarios must be dealt with by modelling the reactions from the market when less food/feed is sold from Denmark in the high biomass scenario, i.e. the replacement of supply by other suppliers outside Denmark.

Fuel marginal

Our base assumption is that we do not use any fossil fuels in Denmark in the future we are modelling/designing. The question of the fuel marginal, i.e. whether it is of fossil or biogenic origin, is therefore only relevant for a future in which we assume a significant international trade on the fuel markets. As we do not, in the scenarios we are looking at, consume any fossil fuels in Denmark, the question is, if the biomass-for-energy market is international or not.

In case of an international market for energy biomass, and in case the surrounding world still use fossil fuels, the marginal fuel may be fossil, i.e. we can substitute fossil fuels only to the extent we have alternatives like biomass, meaning that any prioritisation of biomass for one use implies an equivalent use of fossil fuels for another purpose. If the biomass marginal is in fact a fossil fuel, it implies that biomass technologies disappear from the LCA being represented by their fossil marginals. The difference between wind and biomass will then be equal to the difference between wind and fossil.

Marginal supplies outside Denmark

Parts of the systems, we are studying, will be outside Denmark independently of the markets for electricity, fuels, food and feed – as we will in any case import components of the studied technologies. As the energy and material aspects of such marginals are the crucial ones, the most important aspect of this is again judged to be, if they are of a fossil or biogenic origin.

Land-use marginal for energy crops

Assuming that the biomass fuel marginal is biogenic, we must be able to define the area or land use marginal for the energy crops in question. This in turn has to be done in due respect for the market based displacement-replacement responses to changes in crop demands between scenarios, i.e. that the energy crop displaces a food/feed crop that in turn will be replaced fully or partly by other suppliers to the crop markets in question. Such chains displacement-replacement reactions will take place until they rest at final cultivation of new land (marginal land) at the frontier between agriculture and nature or till they are counteracted by changes in agricultural yields driven by the demand change in question. This holds true independently of the geographical scope of the markets, but requires the most complex modelling for international markets.

If the land use marginal fully or partly ends up in environmentally sensitive areas, e.g. nature types with a high carbon binding in soil and vegetation (e.g. primary forest, peat land, wetlands), there will be high implications on global warming from the high biomass scenarios. As the latest articles from Science and Nature suggests, the greenhouse implications of energy crop consumption may in this case be even higher than if the fuel marginal was fossil.

If the land use marginal ends up in other less sensitive nature types, the implications will be less. But even so, biomass consumption is judged to have higher environmental impacts on the traditional LCA impact categories from releases of N, P, N_2O and CH_4 from agricultural production.

Land-use marginal for food/feed crop prduction
Same considerations as above.

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