Identification of potential energy crops

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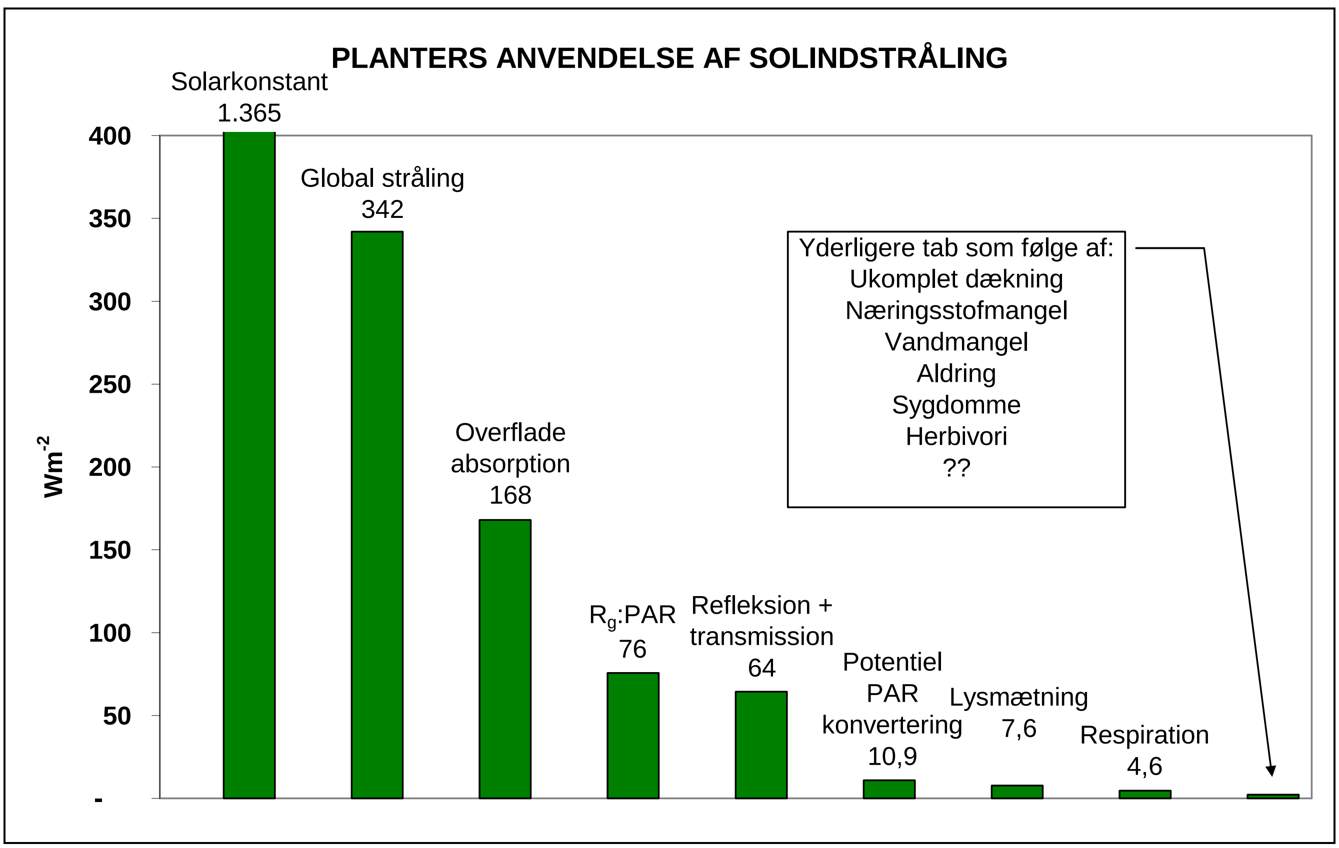
The purpose of the CEESA project is to analyse the potentials and consequences of a transition of the Danish energy consumption from at present based on a mix of fossil and renewable sources to in 2050 to rely on renewable sources only.

Biomass is one of several energy sources (or energy reservoirs as the sun is the energy source) that can be utilised in the energy system. Biomass and other renewable sources are already integrated in Danish energy production, but the renewable sources are very unevenly distributed in the sector. Whereas biomass (and waste) has a relatively high representation in the production of electricity and hot water, it is not present in the transport sector.

Biomass sourced society's need for energy for millennia's with various significance, and under the current "threat" from climate change biomass for energy is again gaining momentum. Production of biomass is not a very efficient use of solar radiation. Only 0.5-2.5 % of the energy content in the incoming solar radiation is converted into chemically bound energy.



Photovoltaic solar panels exhibit far higher efficiencies as do solar panels for heat production (I think). When biomass is favourable it is because of its abundance, wide spread distribution, potentially low demands for technology in energy conversion, and very importantly its multi functionality. Areas with biomass production can at the same time serve functions as wild life habitat, ground water protection, carbon sequestration and recreation.

A complete transition of energy consumption based on fossil fuels to renewable fuels in all sectors of the Danish economy requires a range of different technologies and thus a range of different biomass derived components.

The demand side

Ultimately the energy sector has to support society's demand for:

- Light
- Heating
- Cooling
- Motion

Currently these demands are primarily supported with electricity for light, heating and cooling; Hot water for heating; and gasoline, diesel, LPG, JP1 and electricity for motion (Energistat 2006).

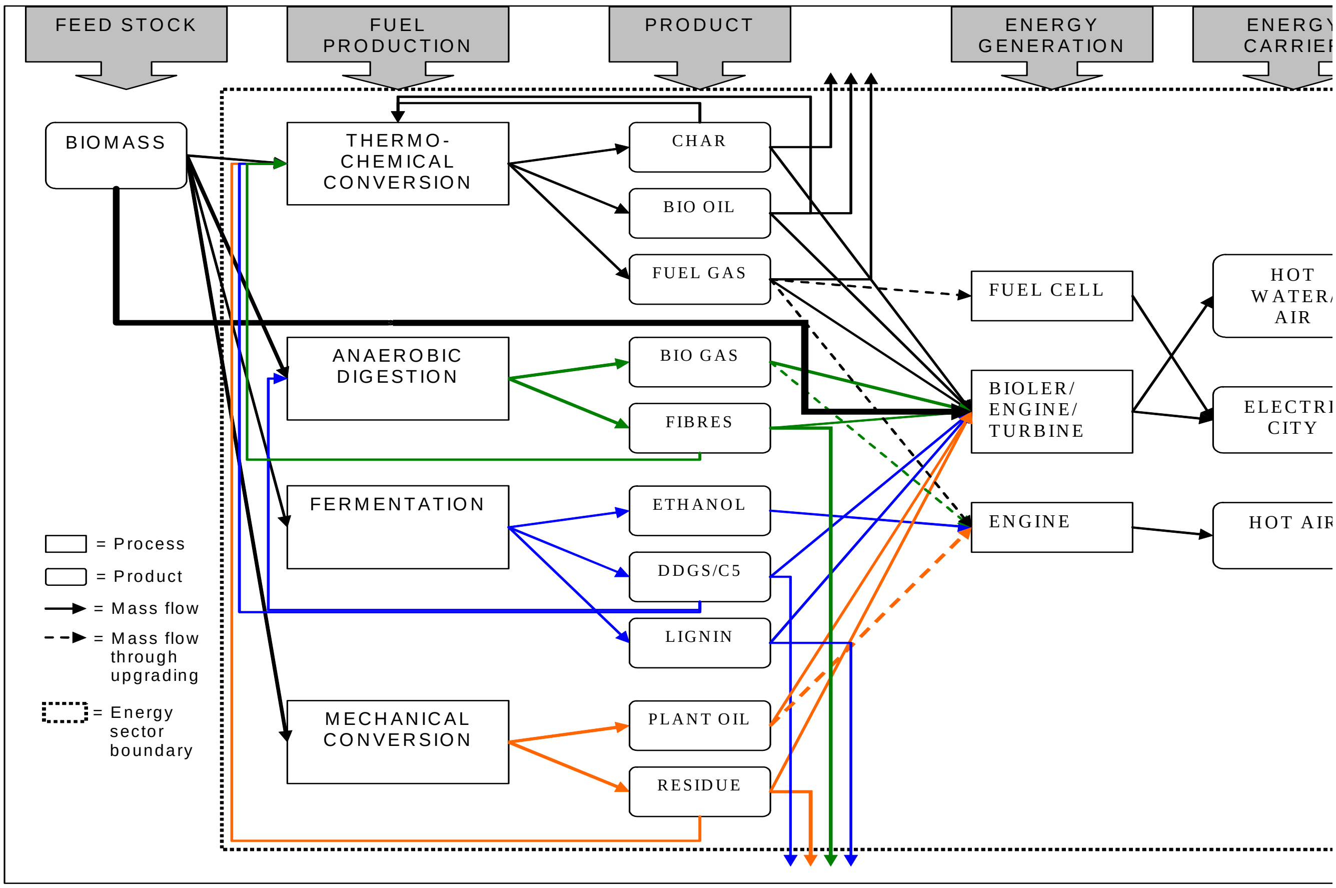
Although biomass is not present in the so-called transport sector a wealth of fixed short distance motion (pumps, fans, valves, conveyer belts, elevators etc.) is driven by electricity and as such partly supported by biomass. There are not really technological constraints against increasing biomass support for this subgroup. Free medium distance motion (fork lifters, small trucks, carts etc.) is not supported by biomass at the same level, whereas free long distance motion (cars, trucks, trains, plains etc.) is almost entirely dependent on fossil fuels. Several technologies are underway that potentially enable renewable sources to support free medium and long distance motion e.g. better batteries for grid fed electricity cars, hydrogen storage and combustion, fuel cells with or without onboard reforming.

Air traffic

Introducing biomass to support motion vai air traffic offers a certain challenge. Electricity is not in a foreseeable future considered realistic to drive propulsion of air planes. Furthermore low energy density of a fuel may impose restrictions on fuel capacity and thus potential action radius of planes. There are several options for conversion of biomass into suitable fuels for planes. Thermochemical conversion (pyrolysis) produces syngas that can be upgraded to suitable fuels. But also plant oils like rape seed or linseed oil may be refined to suitable fuels. Also compressed biogas must be taken into consideration. Biogas is methane produced from anaerobic digestion of biomass.

Pathways for biomass

4 pathways for biomass through the energy sector have been identified, thermochemical conversion, anaerobic digestion, fermentation and mechanical conversion. All pathways contribute in different ways to society's service demands but only one pathway offer fulfilment of all service demands alone, the thermochemical pathway. When other pathways must be taken into consideration is it because all pathways exhibit different characteristics in conversion efficiency, material recycling and interactions with society outside the energy sector.



Thermochemical conversion pathway

Thermochemical conversion covers conversion of biomass by combustion, gasification and pyrolysis. Combustion is widely applied in generation of heat and electricity in Denmark whereas gasification and pyrolysis only exists in experimental settings.

Favourable traits of biomass to thermochemical conversion are high production rates and high contents of cellulosis and hemicellulosis.

Combustion

Using biomass in heat and power production calls for traits as easy handling, storability, high production rates of dry matter. The heating value of any component is highly correlated to the carbon content of the component. As such biomass crops with high content of lignin, proteins and lipids are favourable although there is a serious trade off on the radiation use efficiency because biomass fractions with high carbon content requires more solar radiation during biosynthesis. High N-content of a component (e.g. proteins) is not desirable as it produces corrosive materials during combustion. Furthermore proteins and lipids are essential to the nutritional value of crops.

Thus crops favourable to combustion has a high dry matter production, perhaps with a high lignin and definitely with low protein and lipid content and low input demands.

Pyrolysis and gasification

Anaerobic digestion pathway

Fermentation pathway

Mechanical conversion pathway

The supply side

The Danish climate is characterised by xx temperature and xx precipitation ranges and this affects the range of crops grown in the region. Even though the purpose of agriculture only to a very limited extend is focused on producing energy a range of the crops grown already may be attractive in the view of producing energy as well.

The purpose of this analysis is to identify the most interesting crops and cropping systems that are able to yield a high satisfaction of the multi facetted demands and expectations to the Danish agricultural land and forests

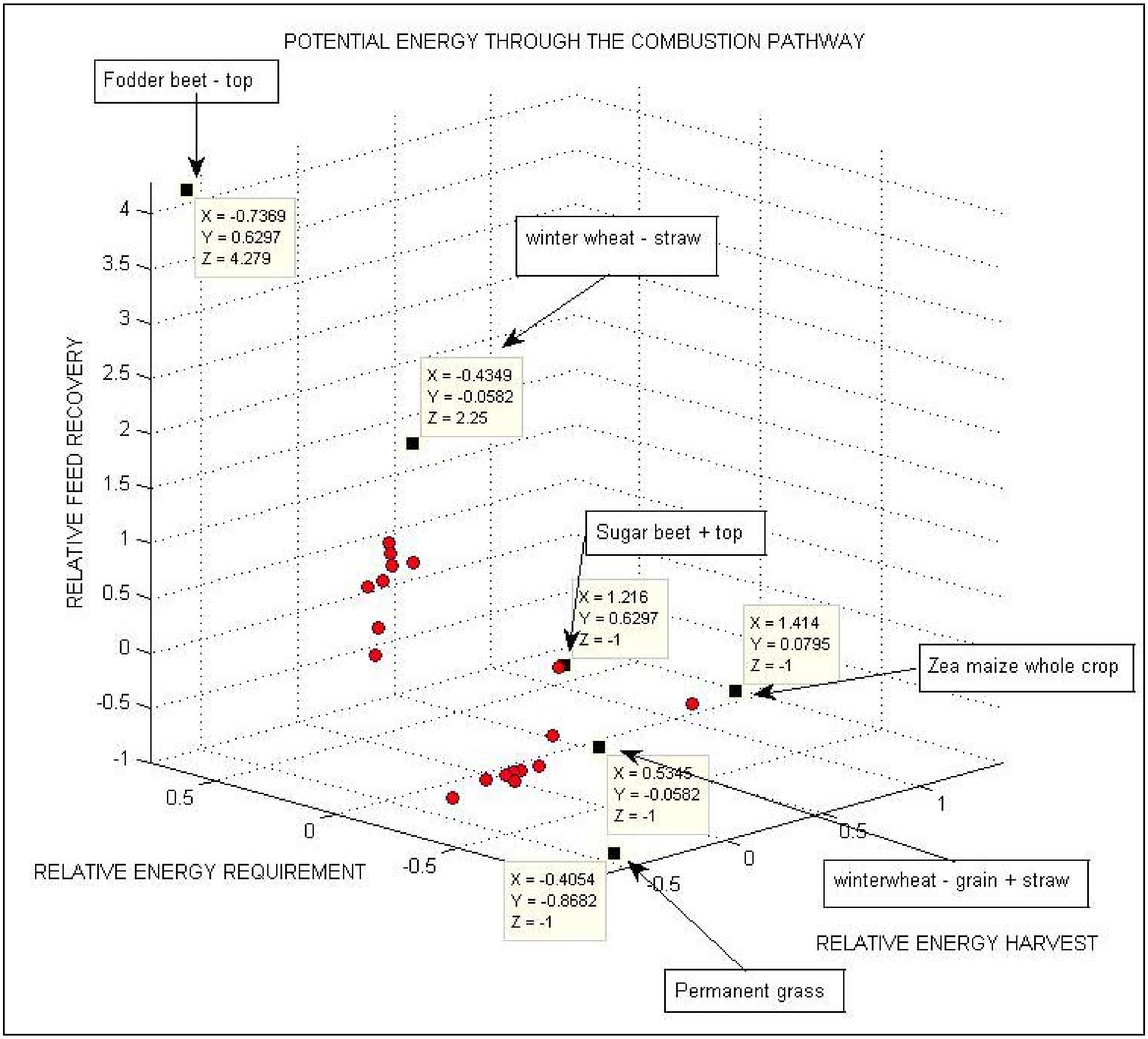
The methodology applied can be either Multi Criteria Analysis (MCA) or a stepwise exclusion algorithm based on a ranking of criteria importance. Economic constraints are not taken into consideration here as the European grant systems may very well change in the future.

Criteria

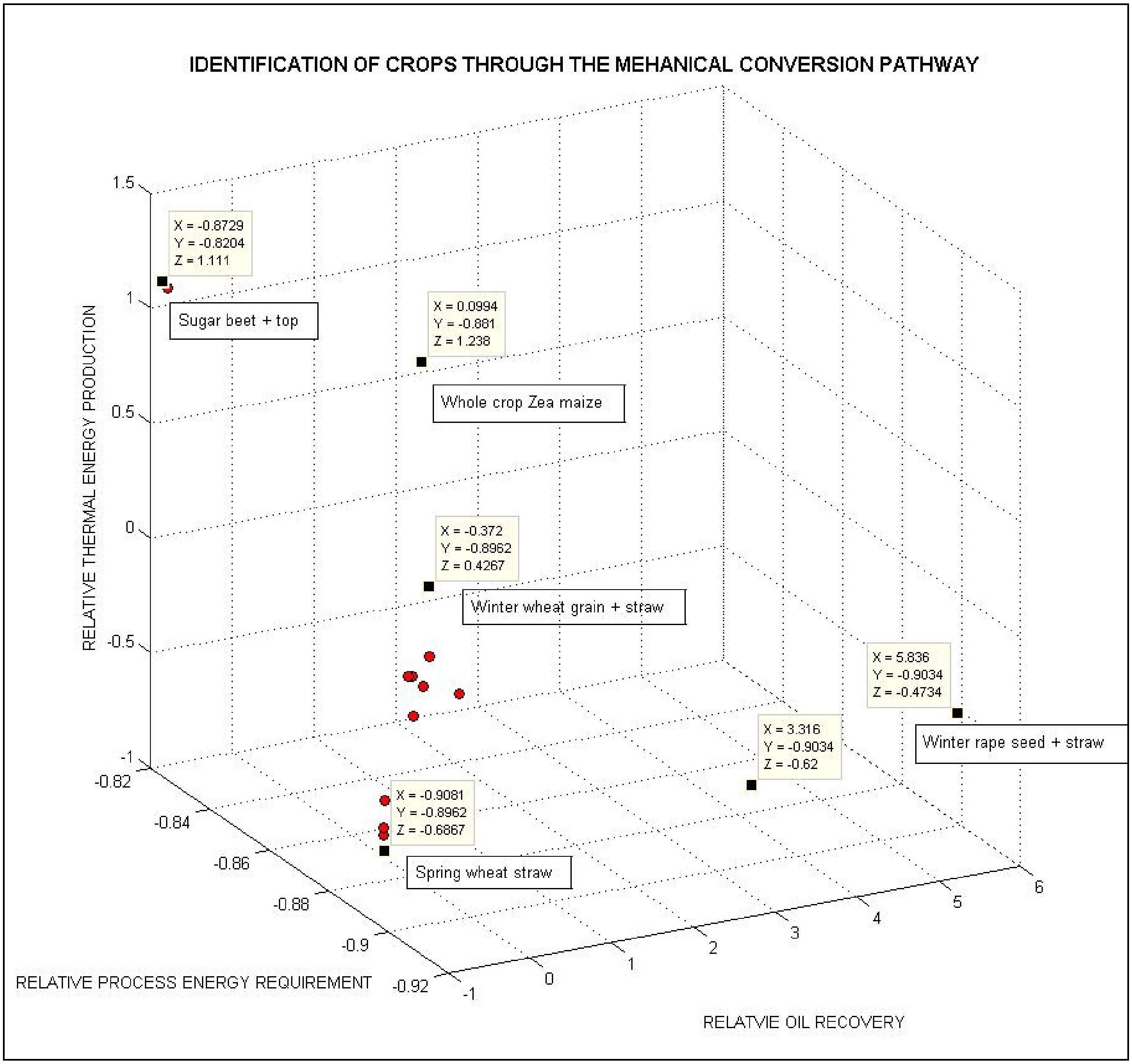
The Danish, as well as most others, lands support a diversified range of expectations from society. Below a list of indicative criteria to include in the identification of desirable energy crops is given.

- Production rate
- Soil type amplitude
- Required input
- Favourable in crop rotation
- Landscape disadvantages
- Conversion technology adaption
- Yield security (year to year variation, disease vulnerability)
- Protein recovery
- Water use efficiency
- Energy gain (Output-Input)
- Conversion energy requirements
- Nutrient leaching potential
- Long-term stability (forestry)
- Certification scheme / legal / (political) restrictions

Below is shown two examples of identification based on 3 criteria (visualisation of more than 3 criteria is difficult)



POTENTIAL ENERGY THROUGH THE COMBUSTION PATHWAY
Fodder beet - top
X = -0.7369
Y = 0.6297
Z = 4.279
winter wheat - straw
X = -0.4349
Y = -0.0582
Z = 2.25
Sugar beet + top
X = 1.216
Y = 0.6297
Z = -1
X = 1.414
Y = 0.0795
Z = -1
Zea maize whole crop
X = 0.5345
Y = -0.0582
Z = -1
X = -0.4054
Y = -0.8682
Z = -1
winterwheat - grain + straw
Permanent grass
RELATIVE FEED RECOVERY
RELATIVE ENERGY REQUIREMENT
RELATIVE ENERGY HARVEST
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1



Transition to new technologies

Currently the transport sector relies on technology that is more than 100 years old, and other energy conversion technologies may be even older. A future energy system based entirely on renewable sources may include a transition to completely new technologies and as a consequence new infrastructures (electricity grid, fuel distribution etc.) must be implemented. Technology leaps can not be expected neither on global nor on national scale, so transition technologies (step stones) or parallel systems may need to be taken into consideration.