CHALMERS

# *MODELLING OF BIOENERGY FUTURES – THE CASE OF SWEDEN*

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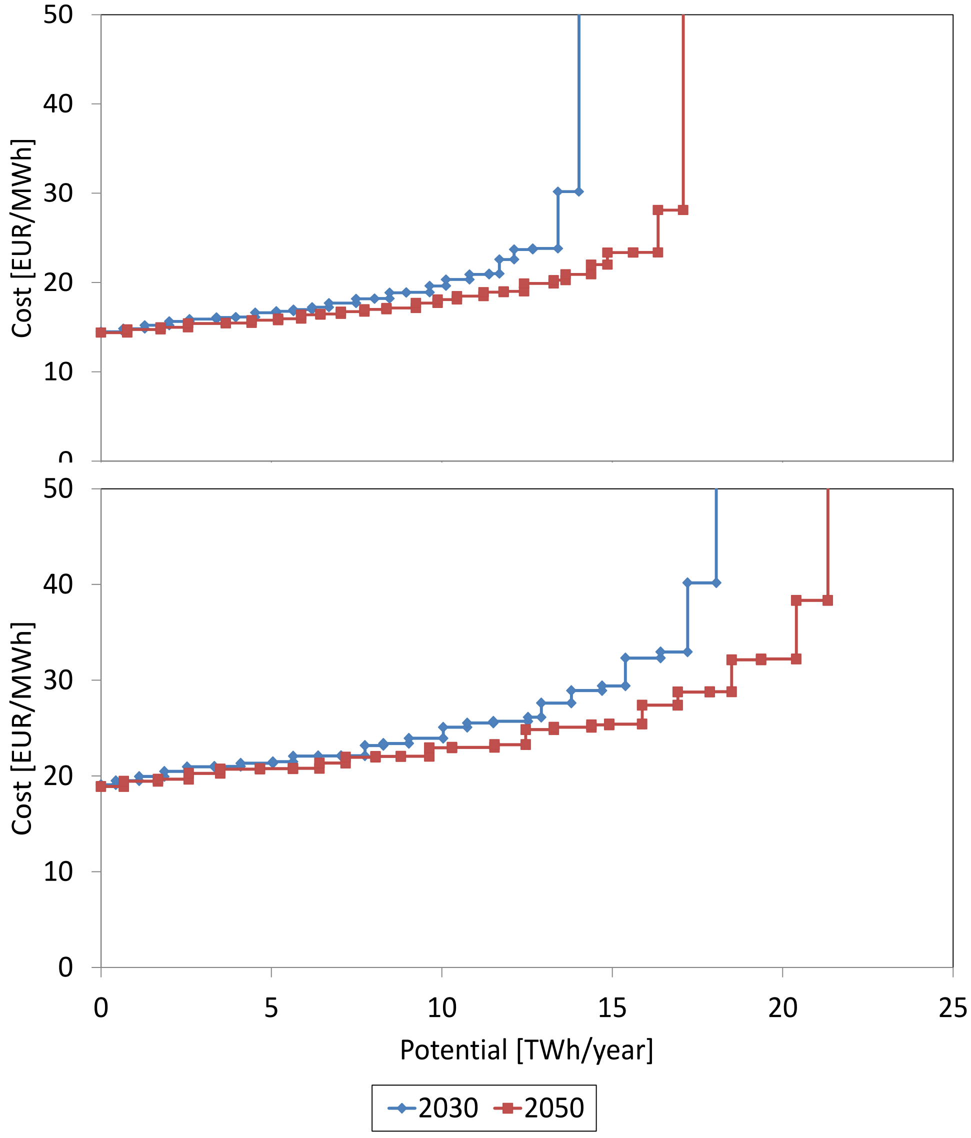
# Part 1

- Potential and supply of biomass
- Competition for biomass between sectors
- (Effects of sector-specific polcy measures in the transport sector)
- ...

# Methods/Tools

- Swedish Forest Inventory (SFI) & HUGIN
  - calculation of potential outcomes of stemwood, logging residues and stumps from harvesting operations
- MARKAL




Supply curve for forest residue tops and branches (top), and forest residue stumps (bottom) for model year 2030 and 2050.

# Part 2 - Background

- Bio combines: several bio-based products and/or integration with district heating or industrial systems
  - ➔High energy efficiency, but implies also increased complexitiy
- Combines often not well represented in national energy system models

# Questions

- *Which bio combines show potential for cost efficiency from an energy system point of view?*

- *Are different types of combines of importance for the future bioenergy use?*

# Metod

- MARKAL_Sverige
- Improved model representation of bio energy technologies, e.g.:
  - Increased number of complex alternatives for transport biofuels.
  - Improved representation of the pulp and paper industry, and of black liquor gasification.
  - Gasification alternatives for transport biofuel production, CHP, and electricity generation.

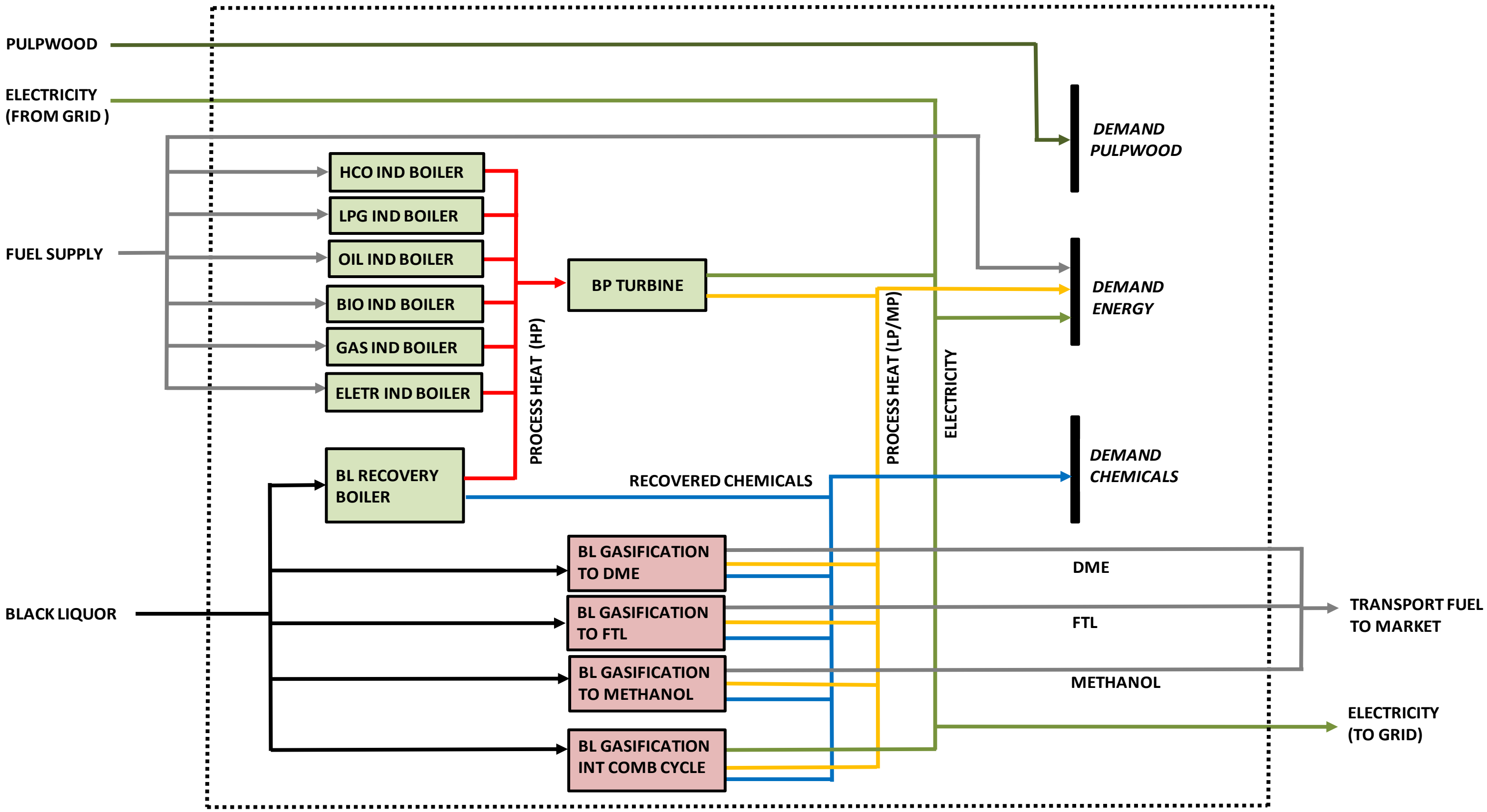
# Alternatives for 2nd generation transport biofuel production in the model

| Table 1. Costs and energy balances for second generation biofuel production technologies in model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Type of fuel production | Type of feedstock | Energy input and output relations | | | | Total Eff. | Inv. cost | O&M cost |
| | | Biomass (In) | Electricity (Net out) | Transport fuel(s) (Out) | Heat (Out) | | (MEUR/MW_in ) | (% of IC); (EUR/MWh f) |
| MeOH (SA) | Wood | 1.0 | -0.01 | 0.51 | | *0.51* | 1.8 | 4.5; 1.5 |
| MeOH (DH) | Wood | 1.0 | -0.02 | 0.51 | 0.12 | *0.61* | 1.8 | 4.5; 1.5 |
| MeOH (BLG) | Black liquor | 1.0 | -0.07 | 0.56 | 0.27 | *0.77* | 1.3 | 4.5; 1.5 |
| DME (SA) | Wood | 1.0 | -0.04 | 0.59 | | *0.57* | 1.7 | 4.5; 1.5 |
| DME (DH) | Wood | 1.0 | -0.05 | 0.59 | 0.11 | *0.67* | 1.7 | 4.5; 1.5 |
| DME (BLG) | Black liquor | 1.0 | -0.07 | 0.57 | 0.26 | *0.76* | 1.3 | 4.5; 1.5 |
| FTD + FTP (SA) | Wood | 1.0 | -0.01 | 0.33 + 0.12 | | *0.44* | 2.2 | 4.5; 1.5 |
| FTD + FTP (DH) | Wood | 1.0 | -0.08 | 0.33 + 0.12 | 0.26 | *0.66* | 2.2 | 4.5; 1.5 |
| FTD + FTP (BLG) | Black liquor | 1.0 | -0.07 | 0.33+0.12 | 0.28 | *0.69* | 1.6 | 4.5; 1.5 |
| SNG (SA) | Wood | 1.0 | 0.06 | 0.70 | | *0.76* | 1.5 | 4.5; 1.5 |
| SNG (DH) | Wood | 1.0 | 0.04 | 0.70 | 0.07 | *0.81* | 1.5 | 4.5; 1.5 |
| EtOH (SA) | Straw | 1.0 | 0.06 | 0.47 | | *0.56* | 1.2 | 4.5; 1.5 |
| EtOH (SA) | Wood | 1.0 | 0.13 | 0.34 | | *0.47* | 2.1 | 4.5; 1.5 |
| EtOH (DH) | Wood | 1.0 | 0.12 | 0.34 | 0.40 | *0.85* | 2.1 | 4.5; 1.5 |
| EtOH + Biogas (SA) | Straw | 1.0 | 0.06 | 0.47 + 0.03 | | *0.56* | 1.2 | 4.5; 1.5 |
| EtOH + Biogas (DH) | Straw | 1.0 | 0.07 | 0.30 + 0.11 | 0.22 | *0.71* | 1.2 | 4.5; 1.5 |
| EtOH + Biogas (DH) | Straw | 1.0 | 0.05 | 0.47 + 0.03 | 0.15 | *0.70* | 1.2 | 4.5; 1.5 |

# Pulp and paper industry

- *Chemical pulp*

  (pulp & paper industry sector divided into 6 parts)

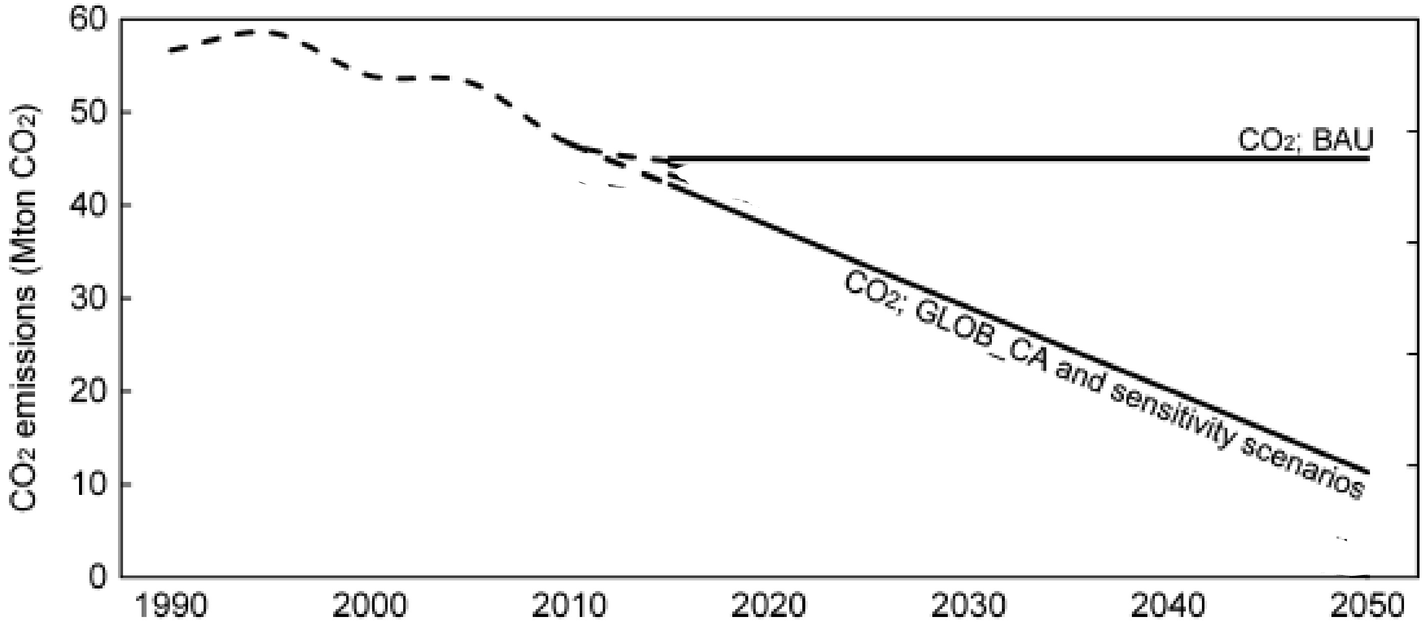


# Modeled cases

- BAU:
  - $CO_2$ +- 0  until 2050
  - No advanced bio technologies available
- GC-scenarier
  - GC = **G**lobal **C**limate action, $CO_2$ -80% until 2050

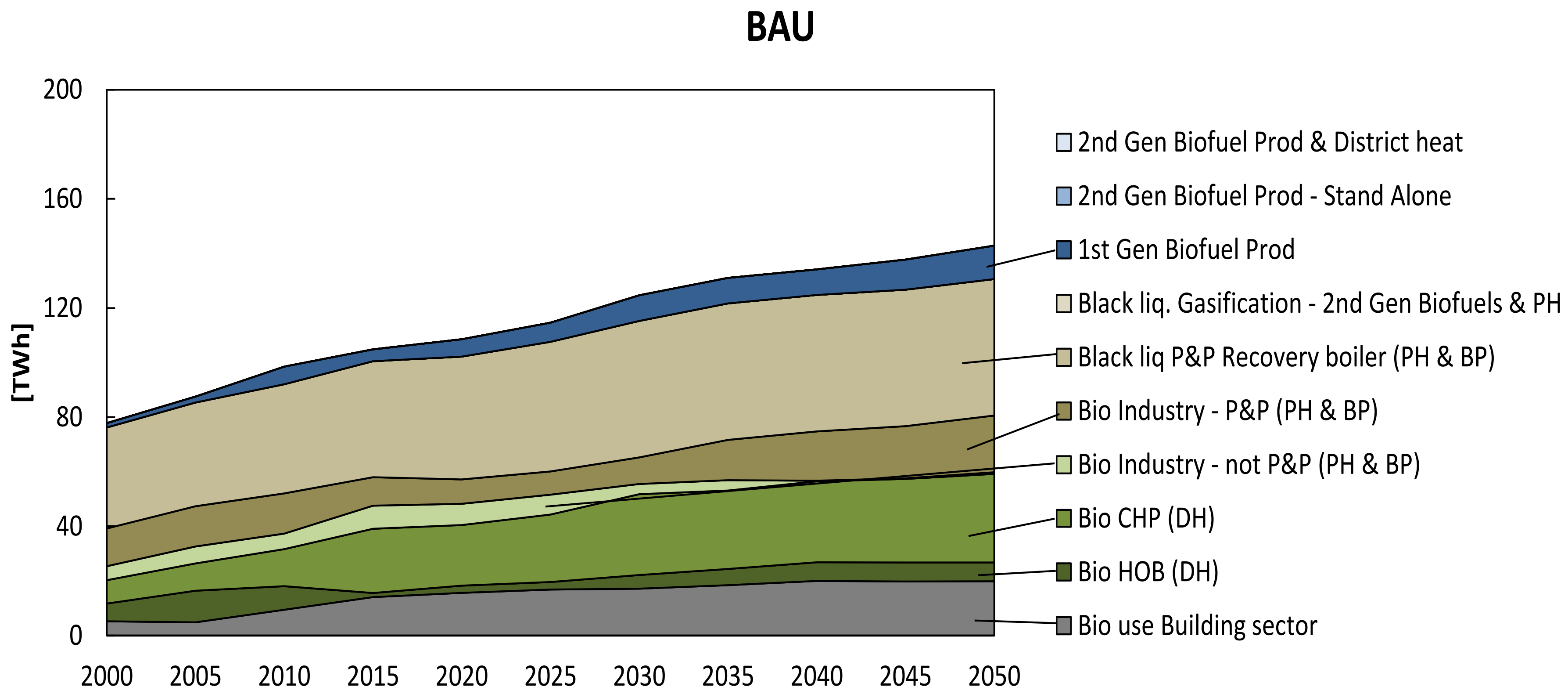
  Available bio combines:
  - GC_SA = only Stand Alone
  - GC_DH= stand alone + bio combines with heat integration DH-sector
  - GC_ALL= stand alone + heat integration + black liquor gasification in pulp & paper industry

# CO2 limitation

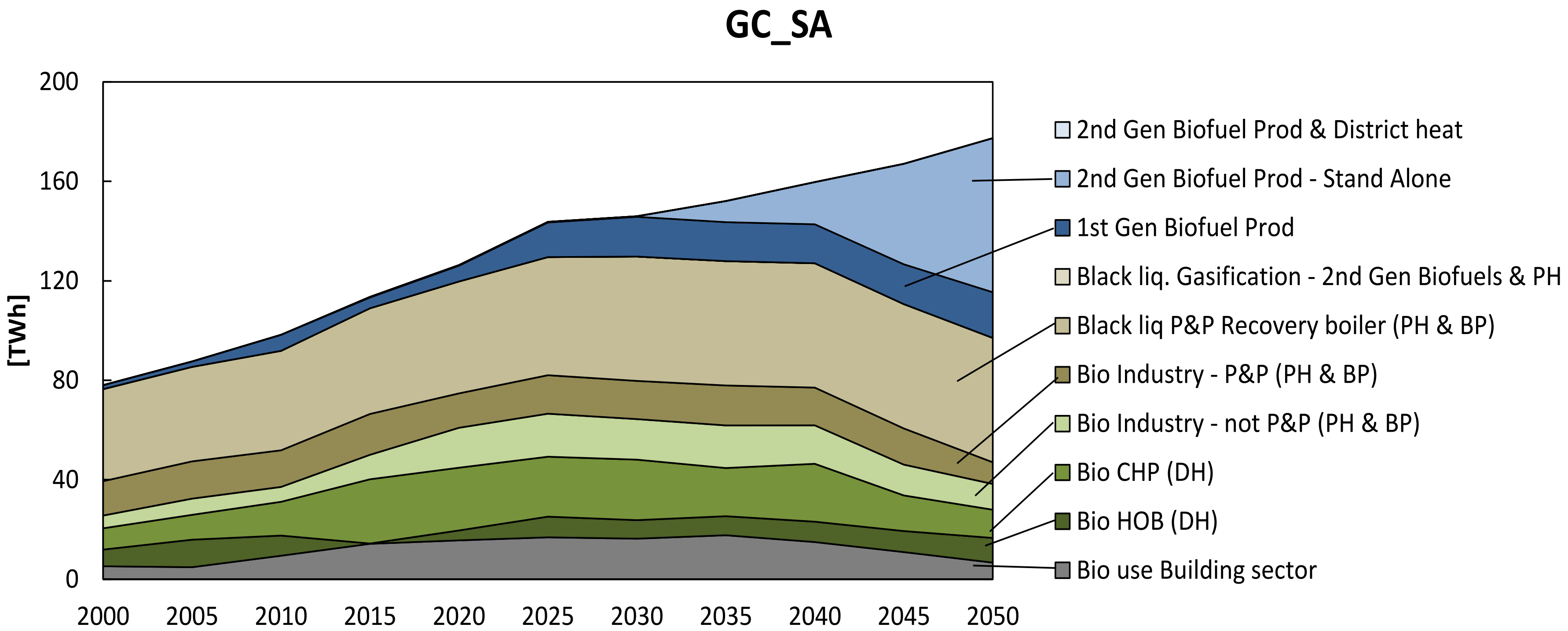


# Results

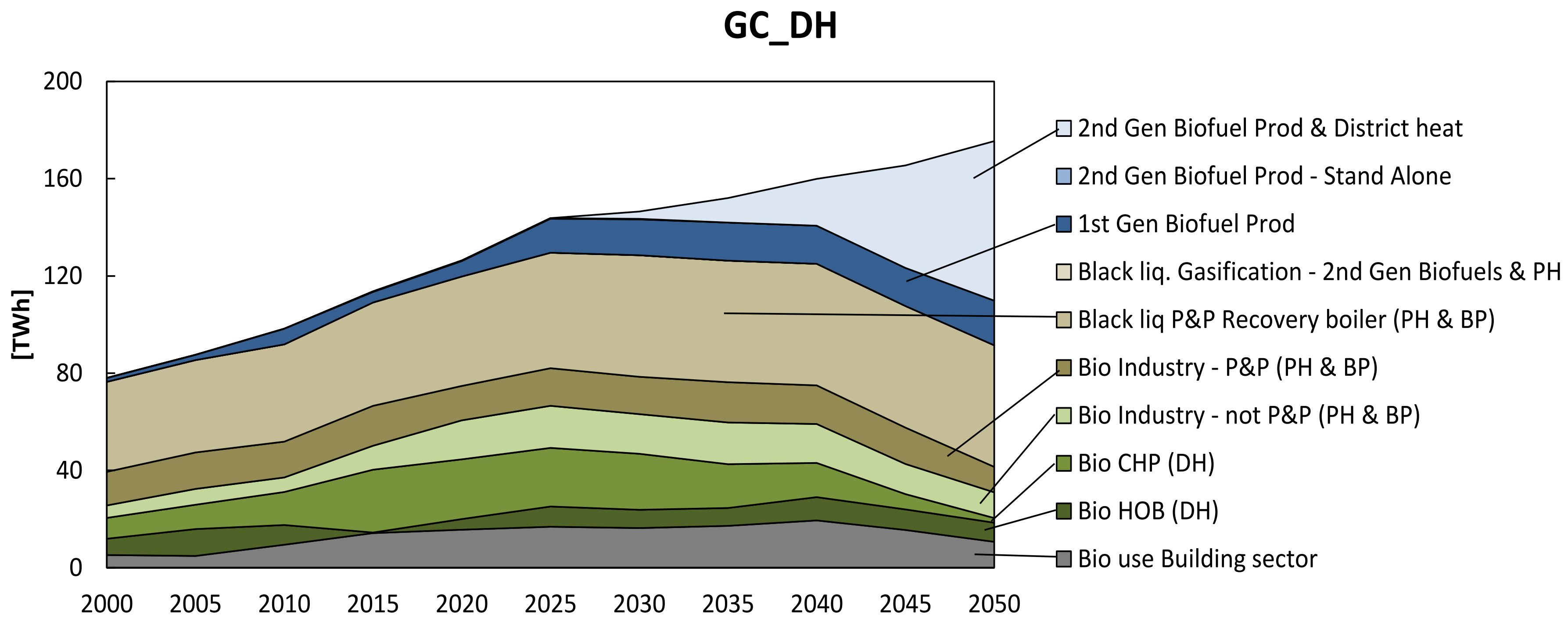
# Bio energy use (exkl. MSW and peat) for BAU



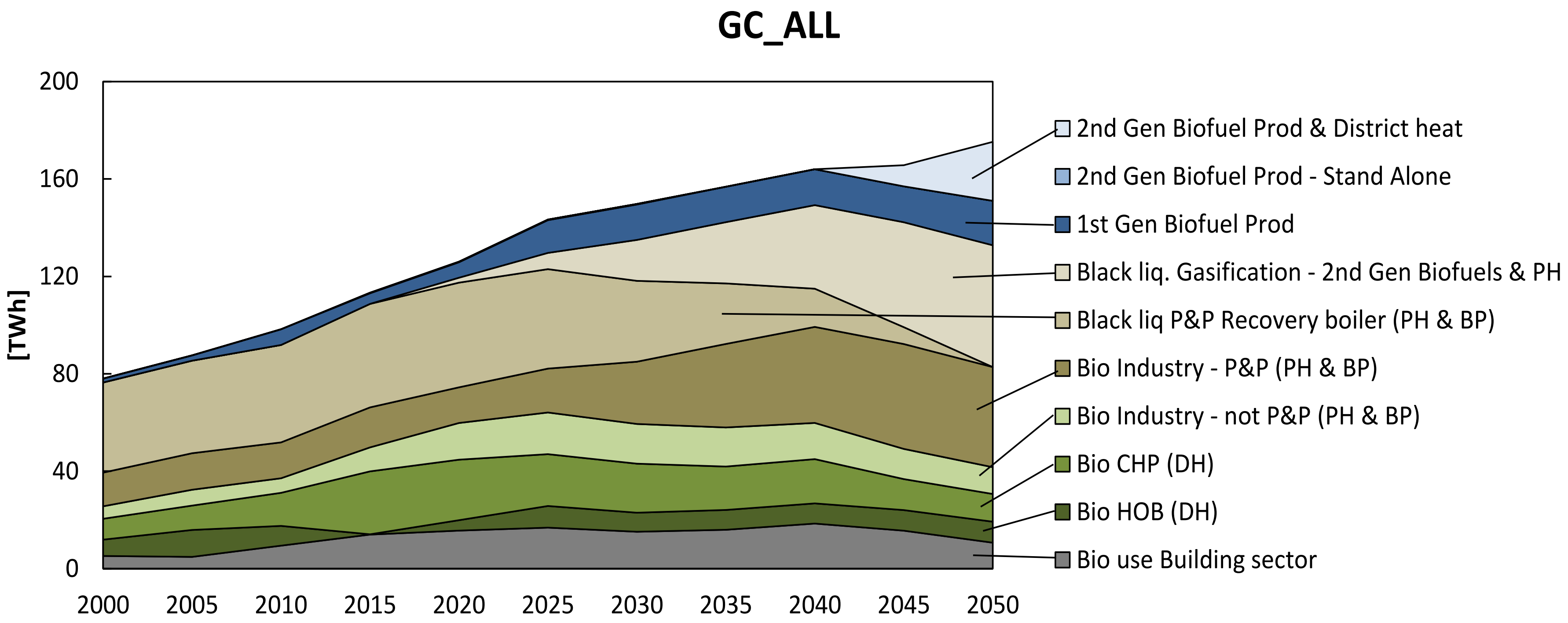
# Bio energy use (exkl. MSW and peat) for GC_SA



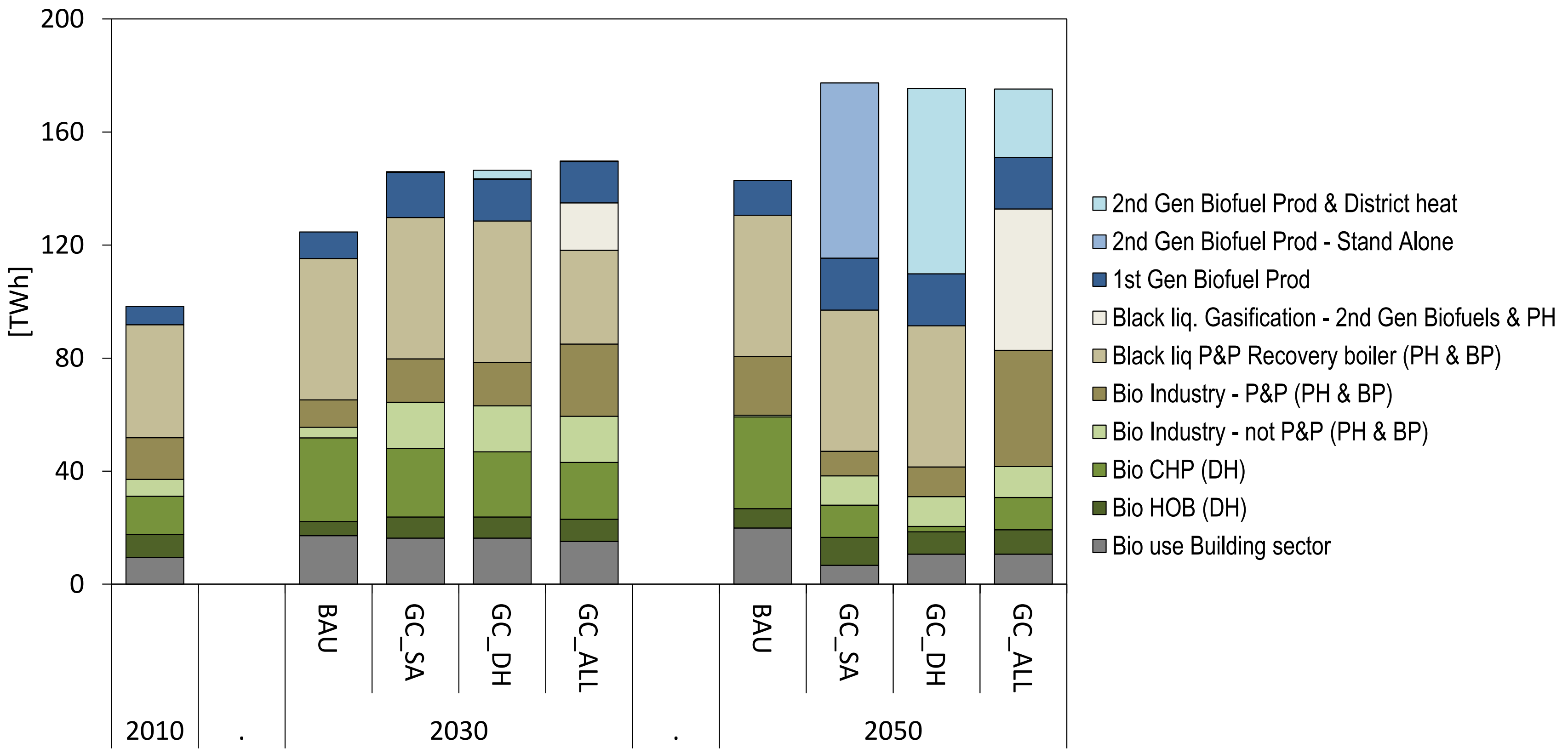
# Bio energy use (exkl. MSW and peat) for GC_DH



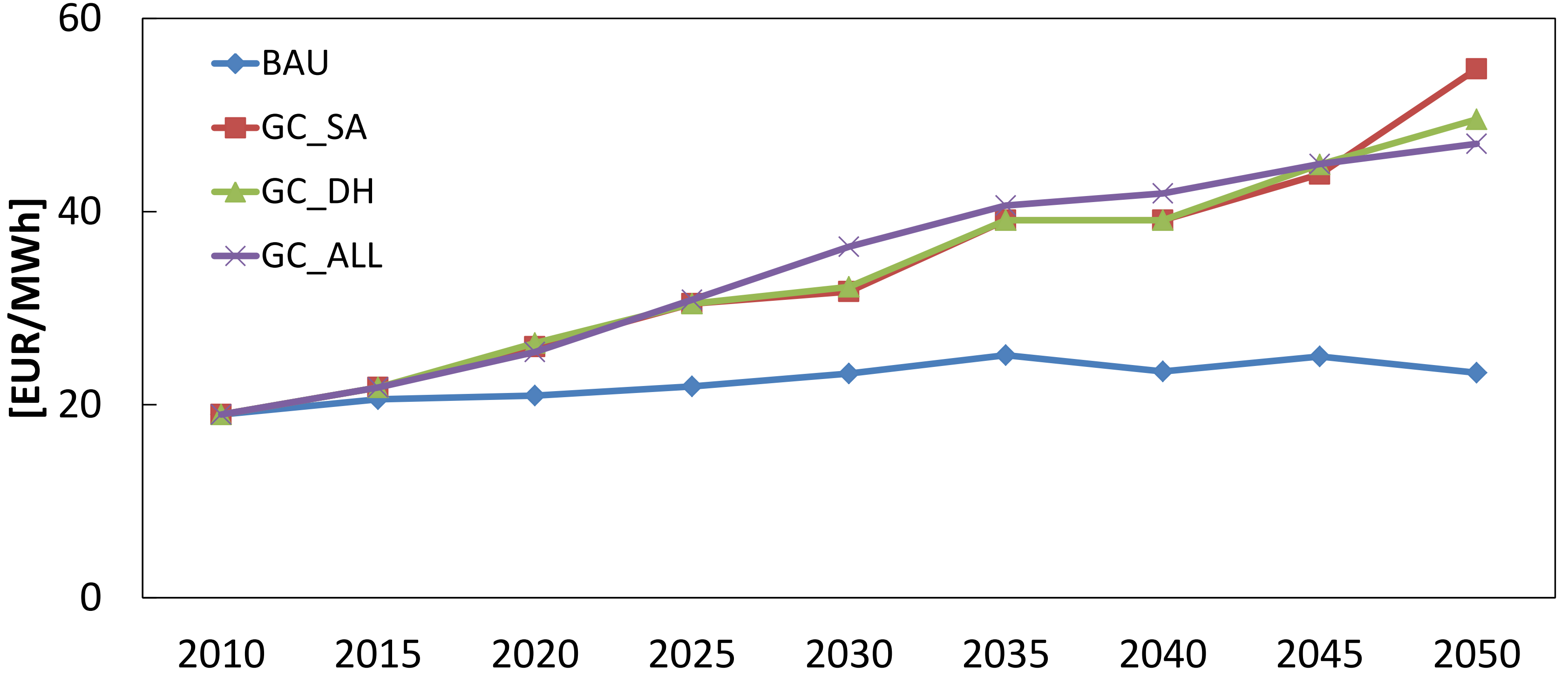
# Bio energy use (exkl. MSW and peat) for GC_ALL



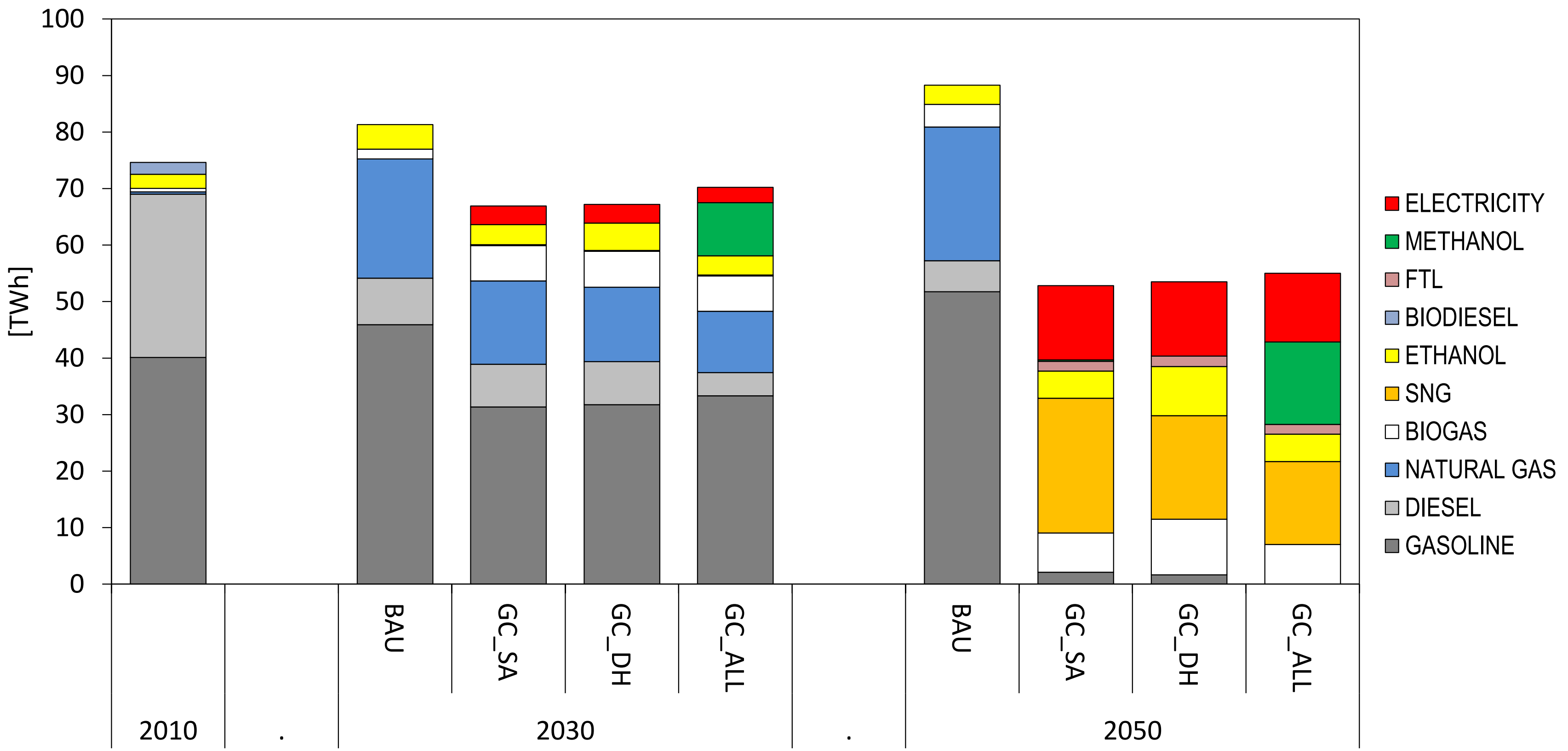
# Bio energy use (exkl. MSW and peat) at different availability of bio combines



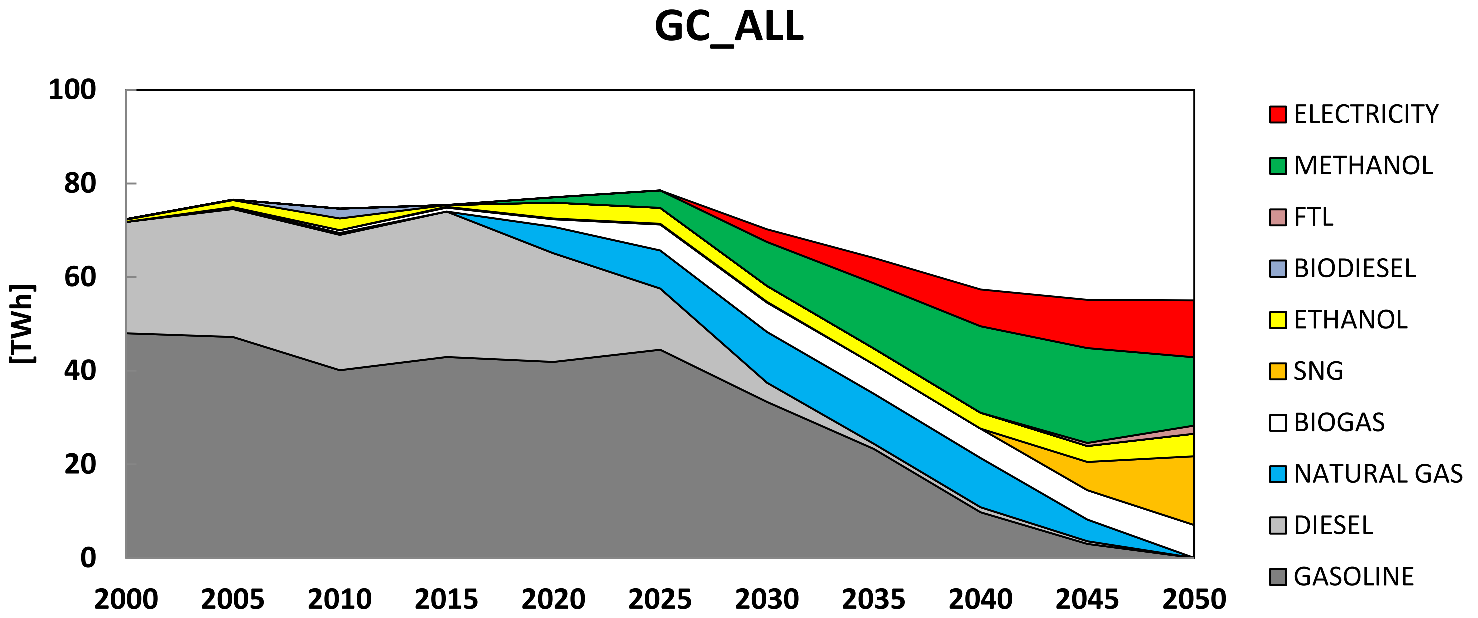
# Price biomass



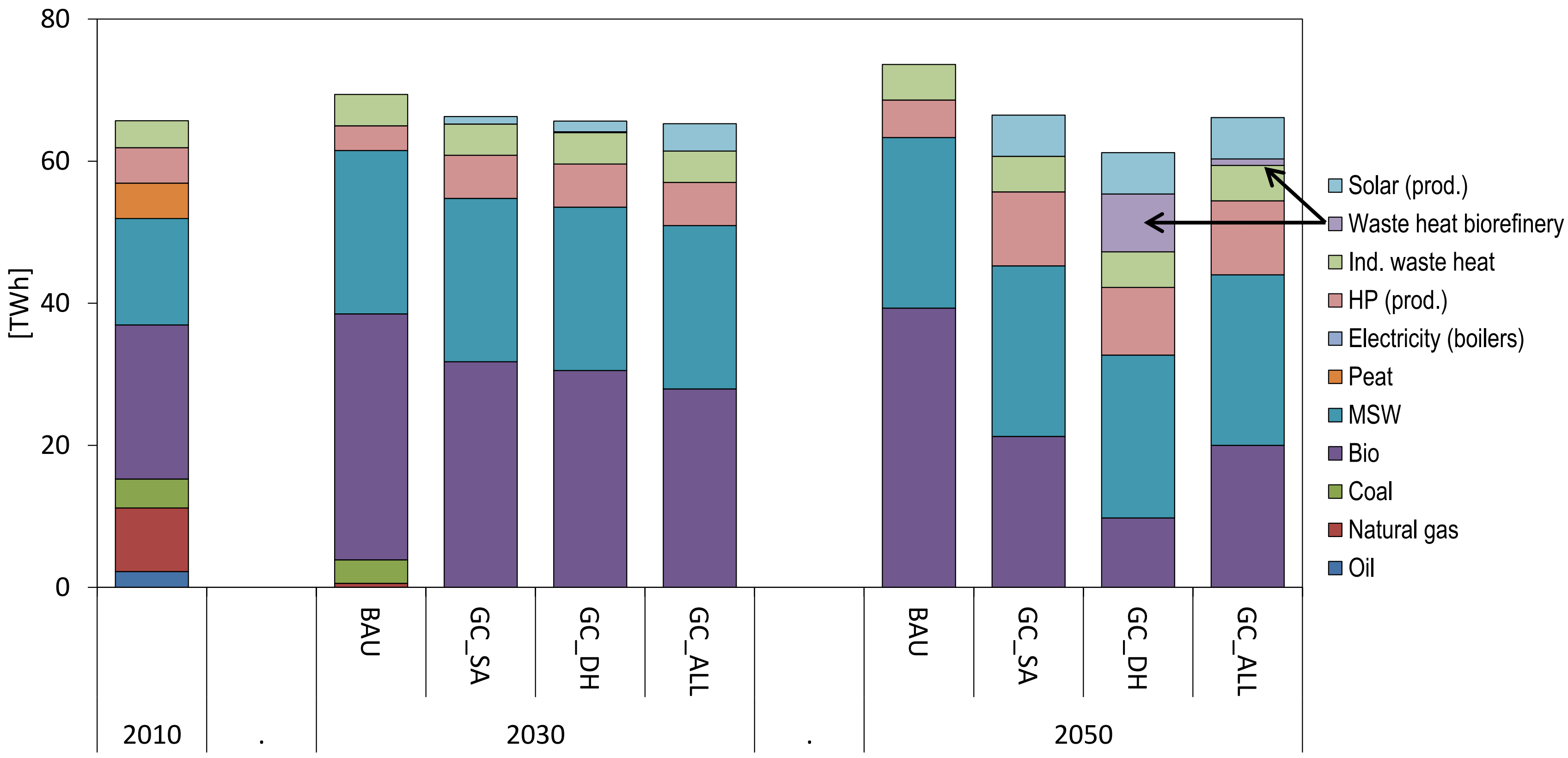
# Final energy use in the road transport sector



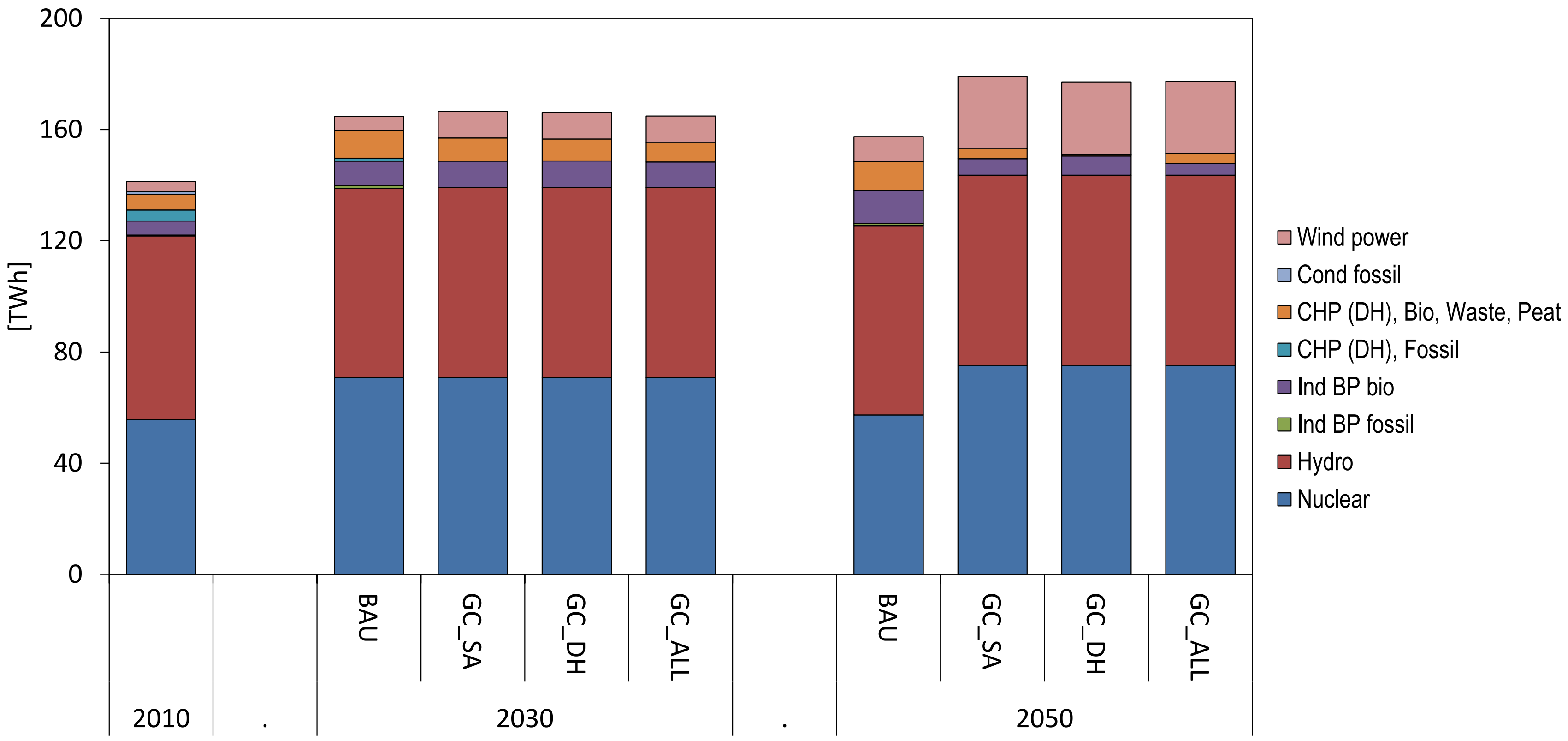
# Final energy use in the road transport sector – GC_ALL



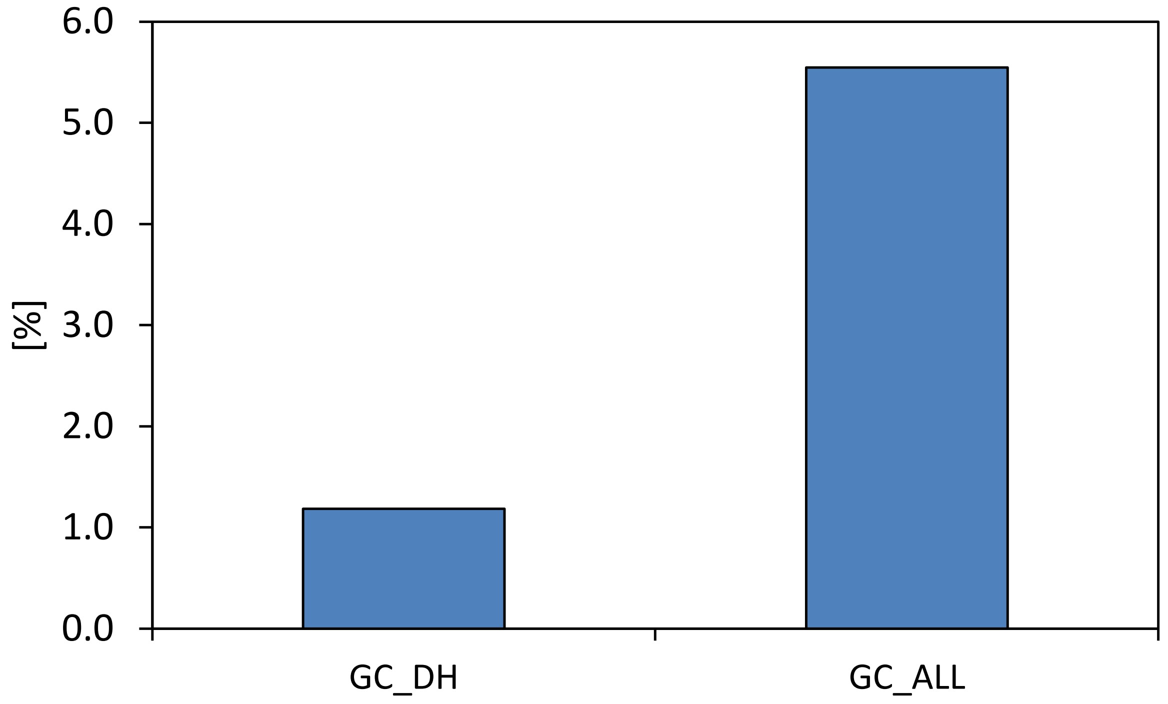
# Energy supply district heating



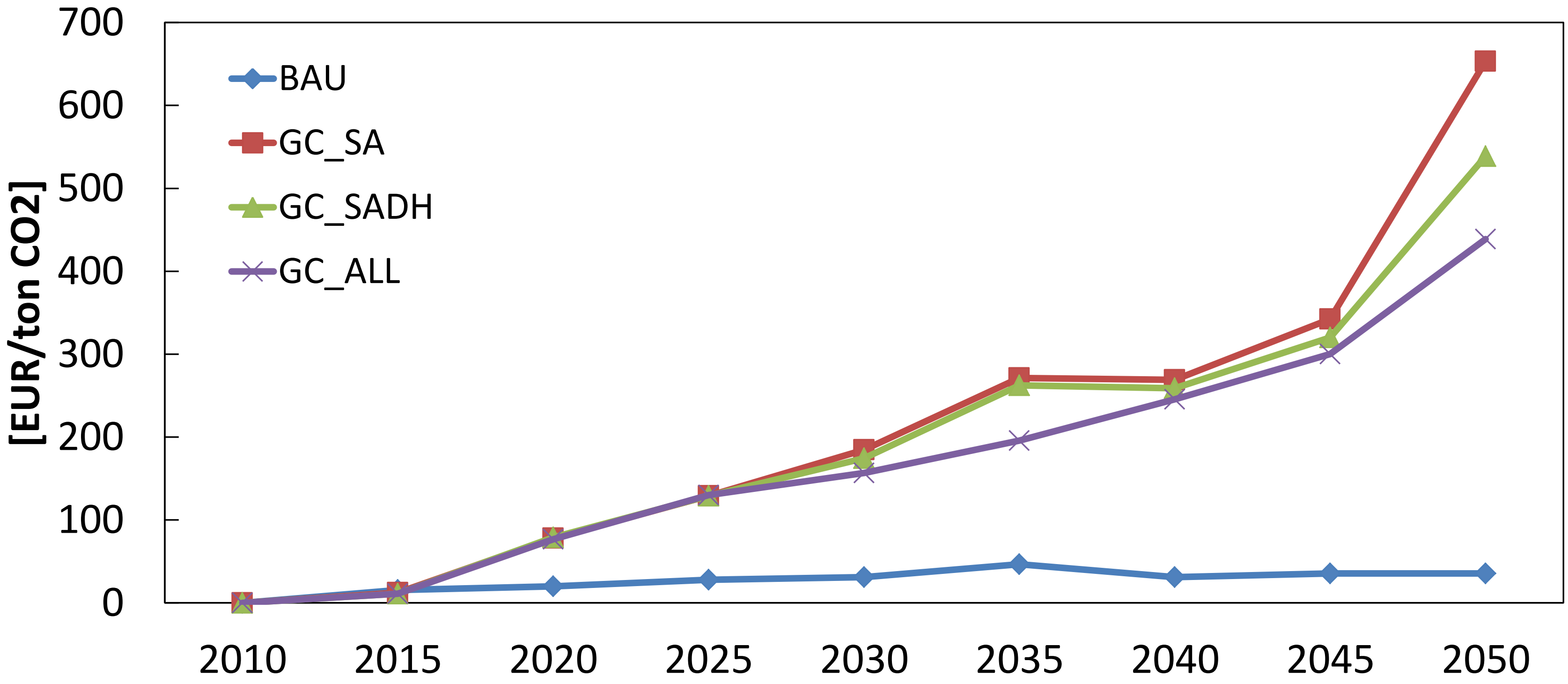
# Electricity generation



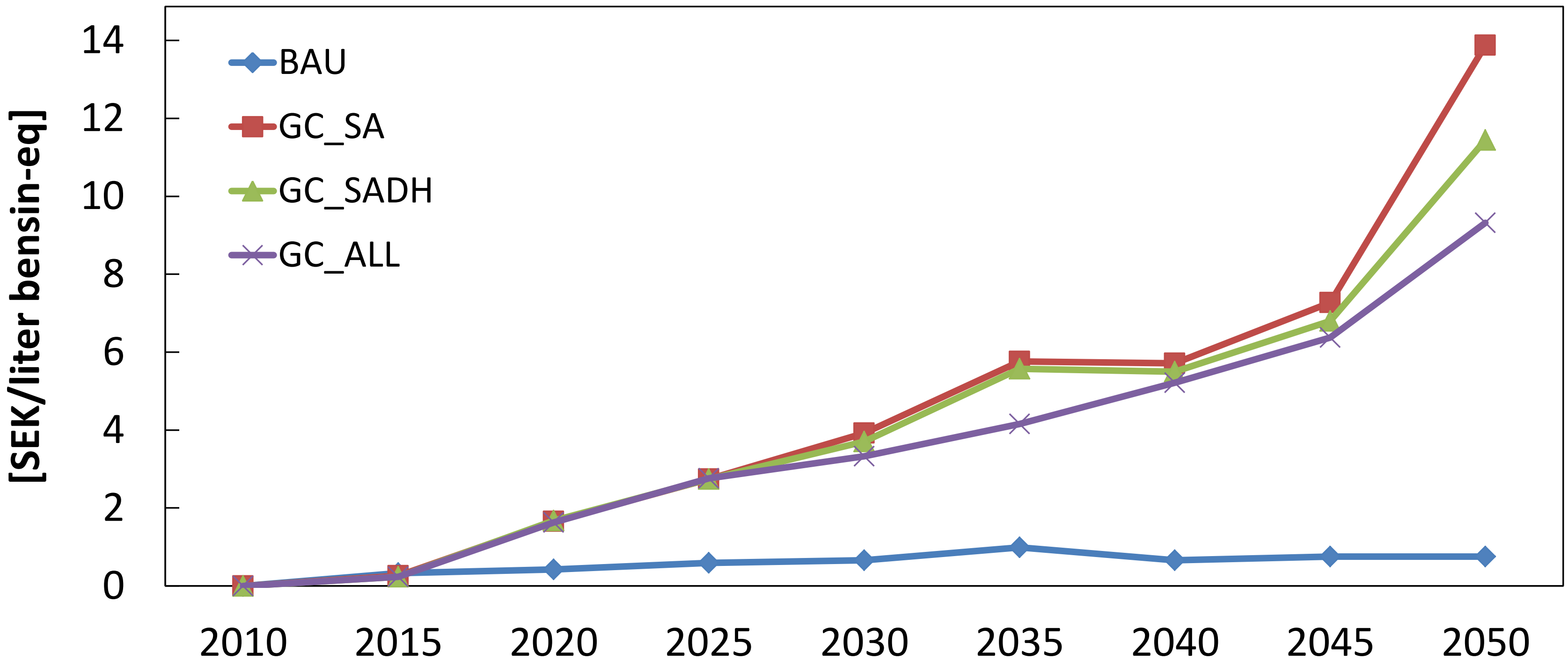
# Percentage savings of CO2 reduction cost of the system with integrated combines (GC_DH and GC_ALL) in relation to ”stand-alone” (GC_SA)



# CO2 marginal cost, EUR/ton_CO2



# CO2 marginal cost, SEK/litre gasoline_eq



# Conclusions

- Bio combines for production of 2nd gen transport biofuels are of av considerable importance for the possibilities meet ambitious climate targets at national scale
- Bio combines with integration with district heating or industrial systems ...
  - give a cost efficient energy system/lower cost of $CO_2$ reduction
    - in particular black liqour gasification
    - but also heat integration
  - but has little impact on total biomass for energy use
  - has some impact on bioprice
  - has large impact on how biomass is used
  - has cross-sectoral effects
- Important to represent bio combines with several product flows and system integration in energy system models

# *Thank you*

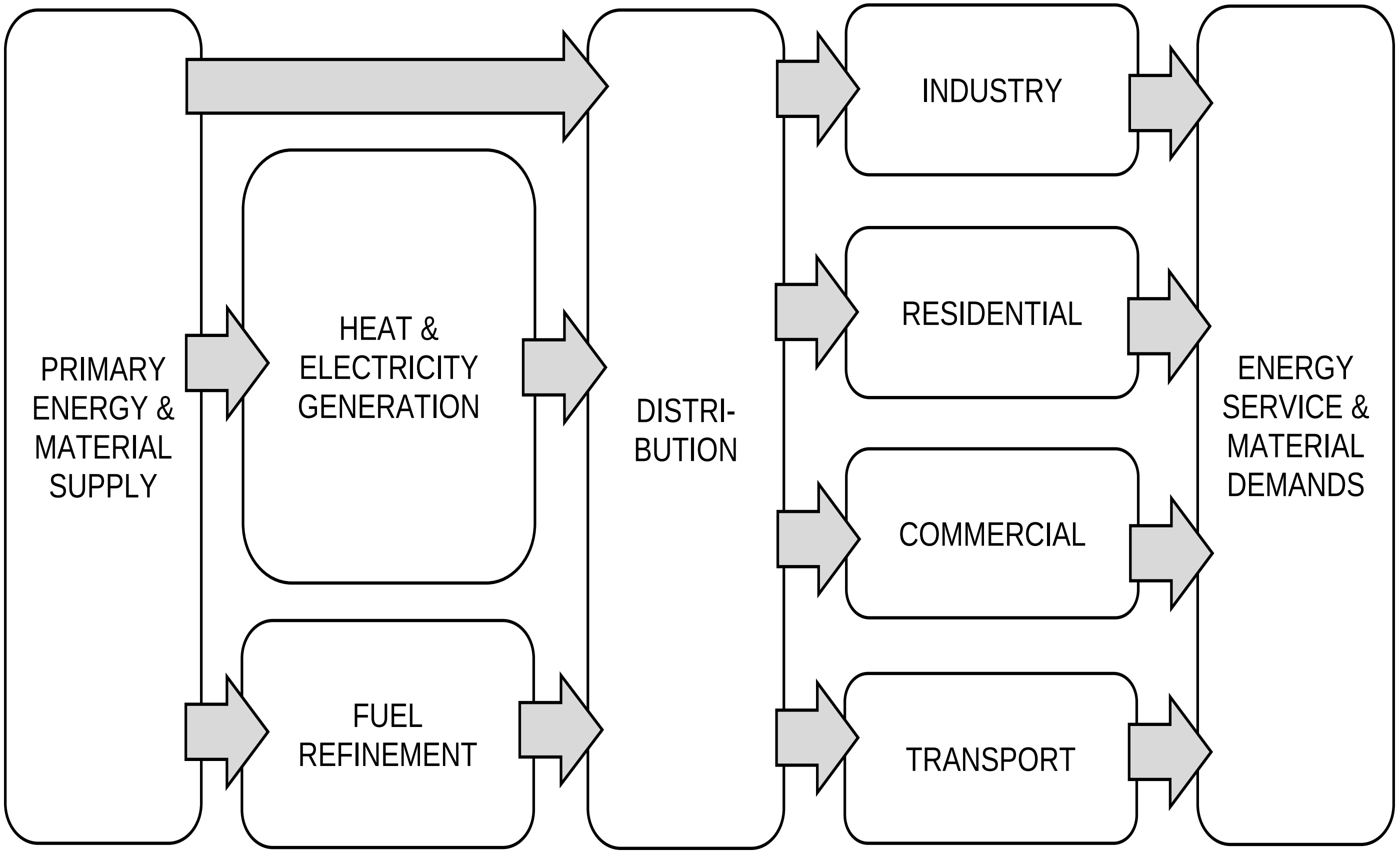
# Questions

- How does the cost-efficient supply of biomass develop until 2050 under stringent climate targets?
- What is the share of available biomass cost-efficiently used in the transport sector?
- Which biofuels are chosen?
- How does the attainment of an almost fossil-free road transport sector (oil phase-out - OP) to 2030 affect the biomass for energy markets (cost-efficient fuel and technology choices and system costs)?

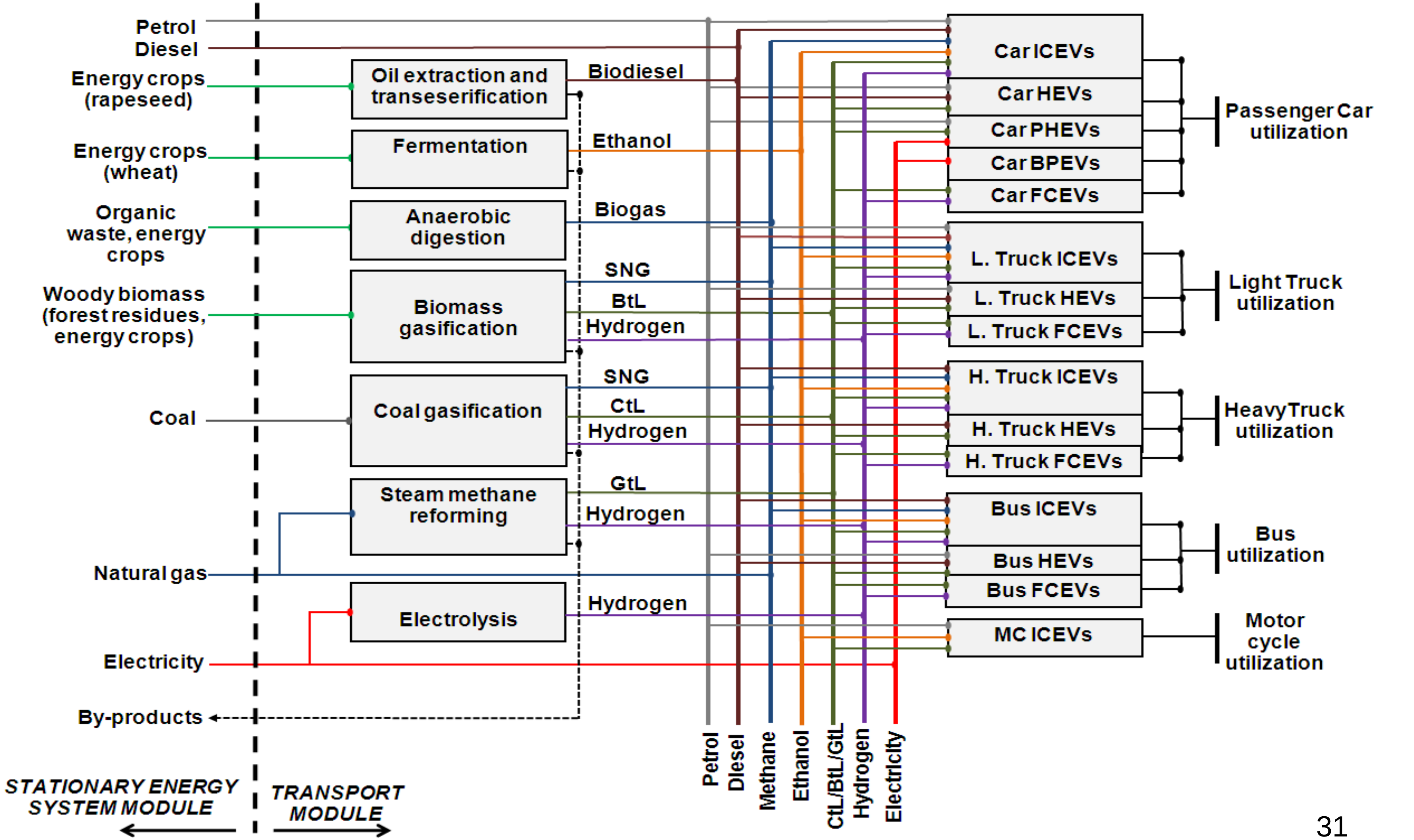
Excluding

- productive forest areas that are situated in areas of nature protection, in wet areas and peat soils with low bearing capacity,
- in areas that are located 25 meters from a lake, sea, waterline or any other ownership category than forest,
- in areas that have an uneven ground structure and/or a slope of more than $19.6^0$ according to the Swedish terrain classification scheme.
- regeneration felling areas of a size of less than 1 ha as well as hardwood stumps with attached root system.

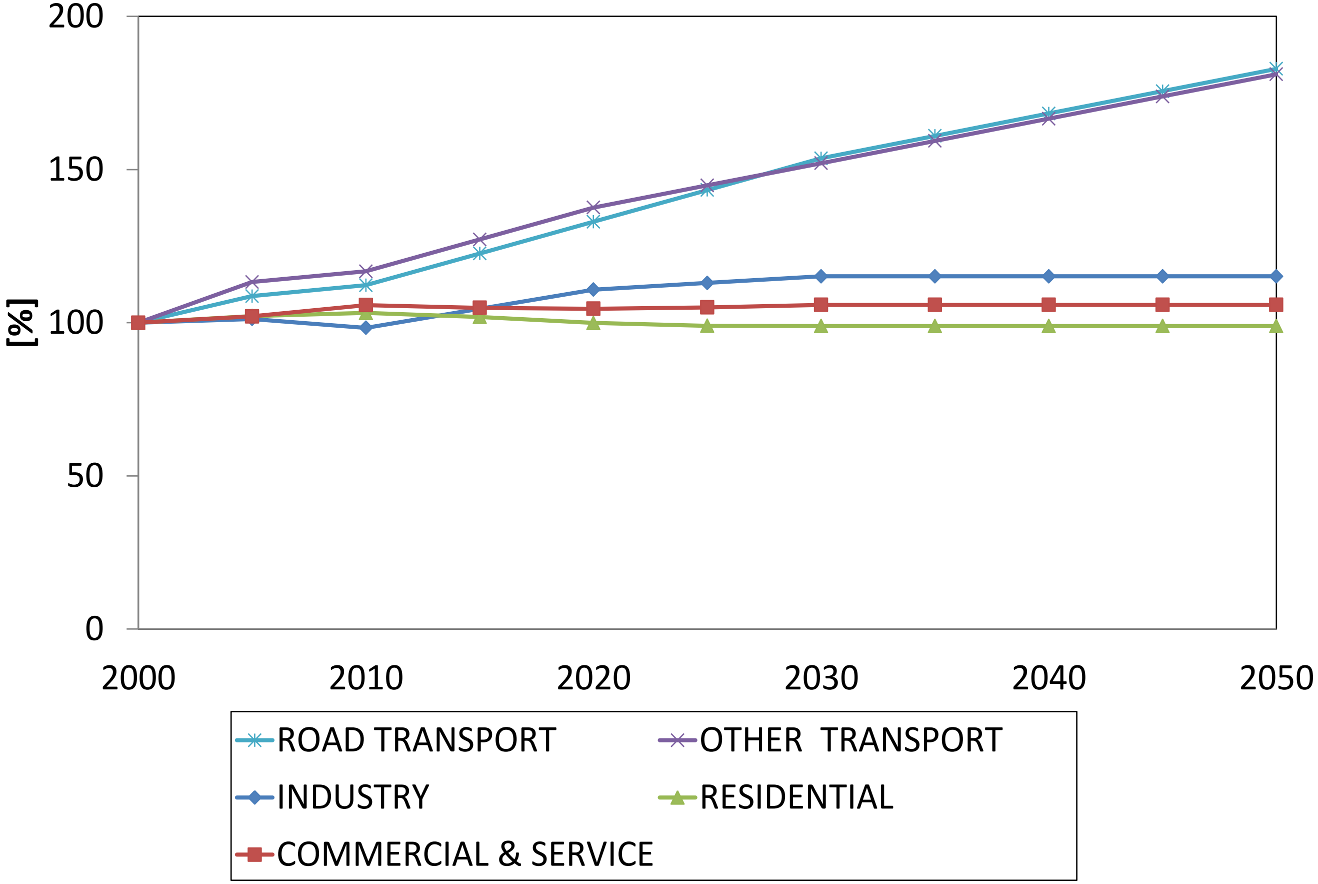
## Aggregated overview of sectors, processes and energy and material flows in MARKAL_Sweden.

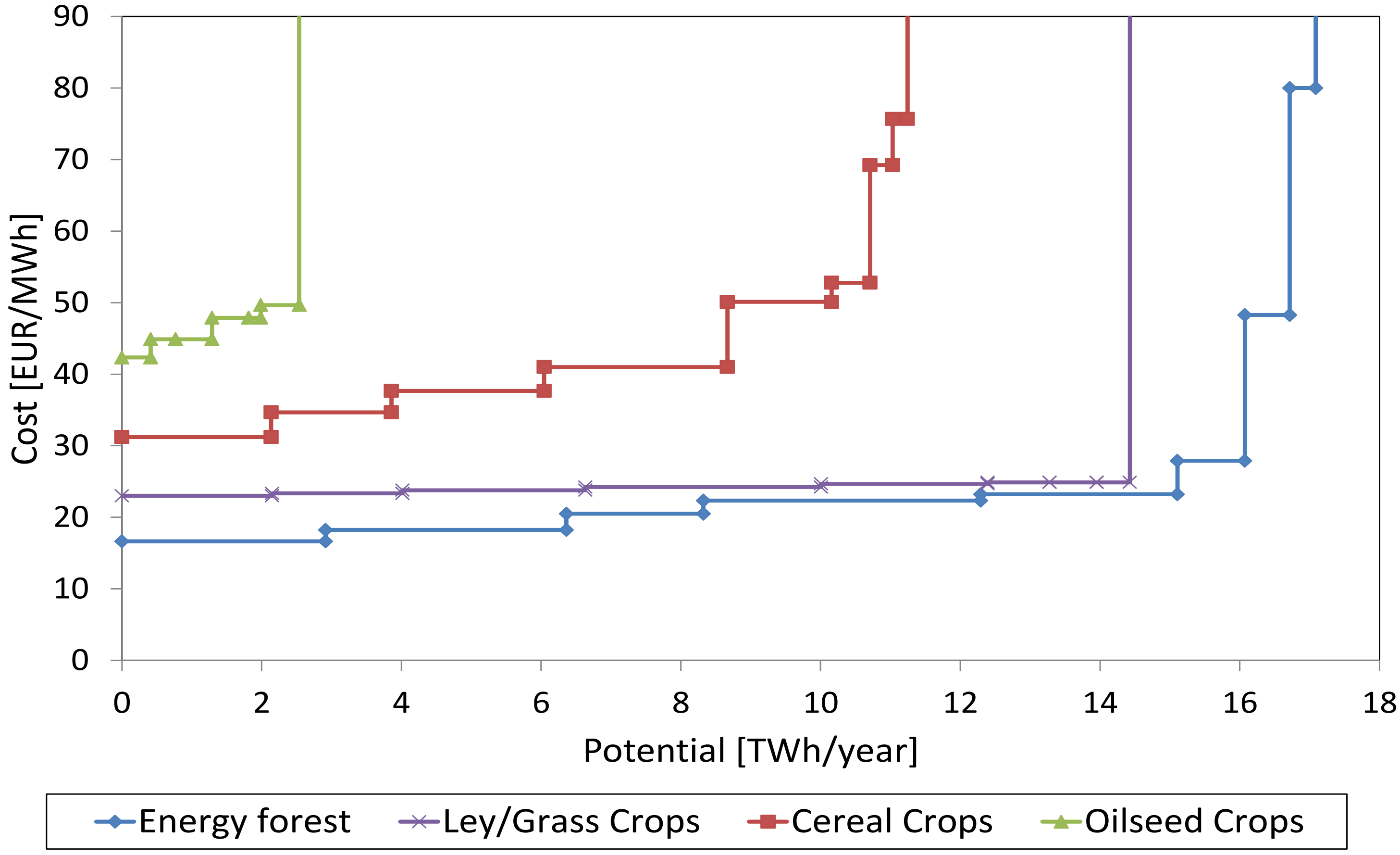


# Transport module



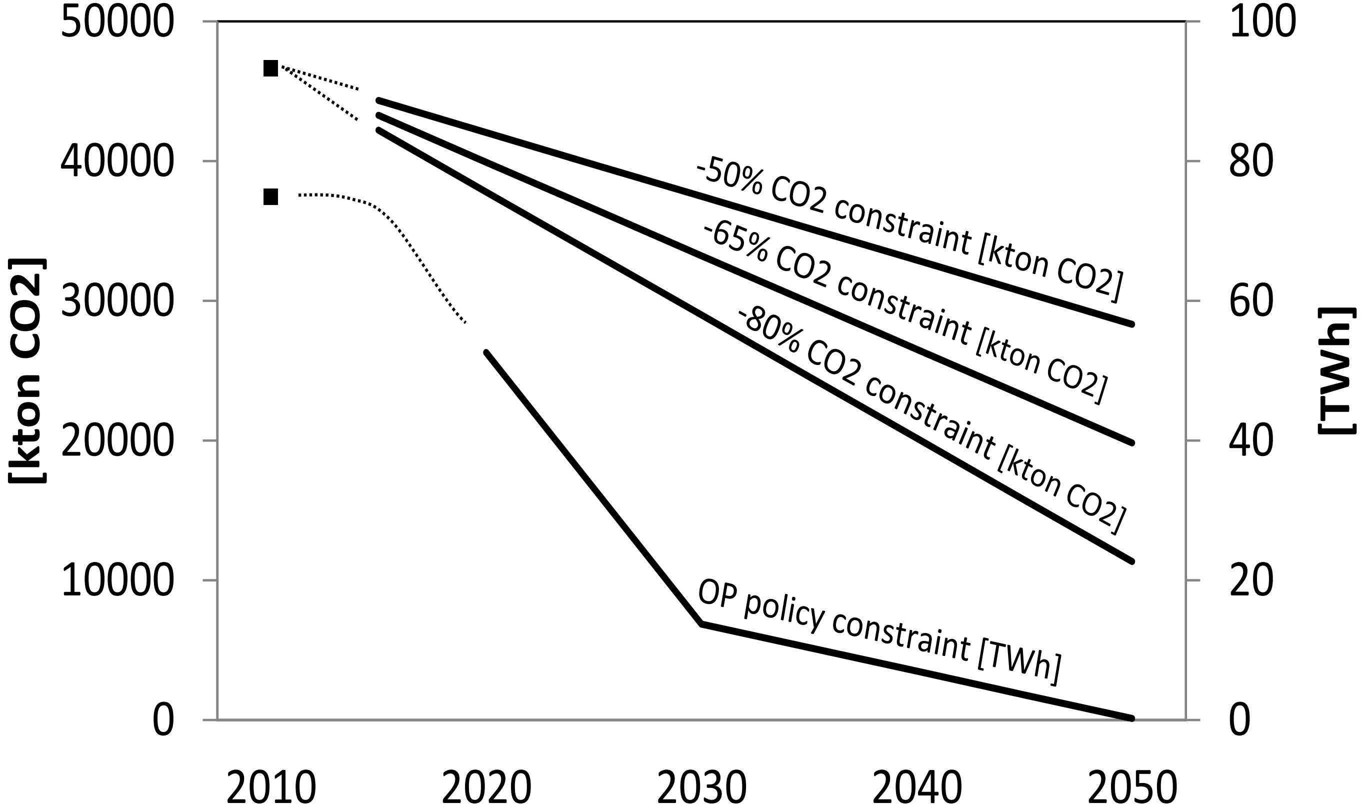
Aggregated view of assumed reference energy service demand developments expressed with demand levels of 2010 as base.






Supply curves for energy crops.

Policy scenarios




CO2 emission and OP policy constraints.
Marks in 2010 indicate levels based on statistics.

# Main analysis scenario
## GLOB_CA (GLOBal Climate Action)

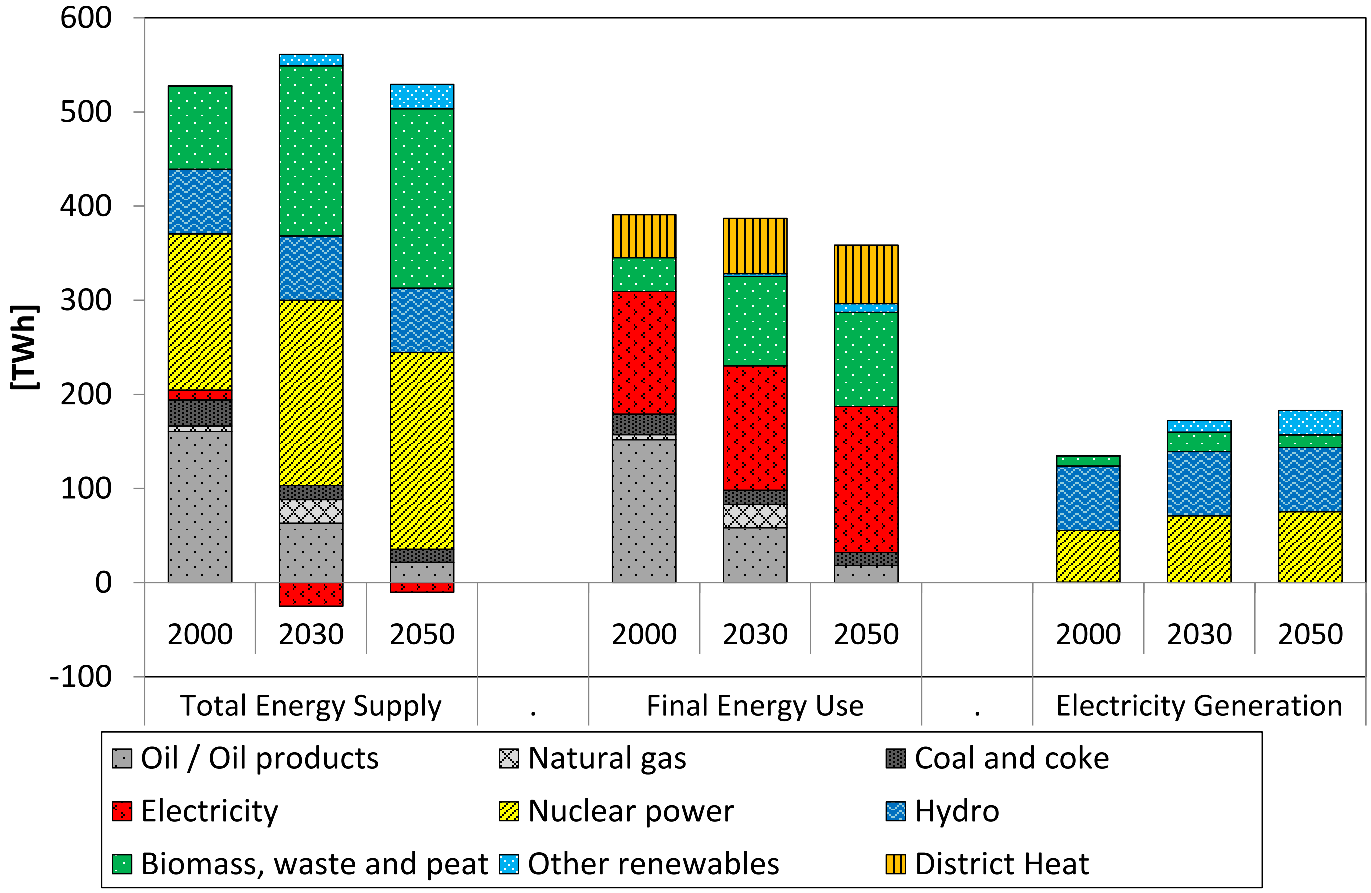
- Reflects a situation in which Sweden and the rest of world pursue ambitious climate targets.
- $CO_2$ emissions of the modeled system, i.e. the entire Swedish energy system (incl. transport), constrained to be reduced by 80% to 2050 (compared to the 1990 emission level).
- Linear reduction from model year 2015 to 2050 applied
- Emission cap, gradually decreasing
- Fossil fuel prices are based on the “450 scenario” of IEA´s World Energy Outlook

# Alternative scenarios

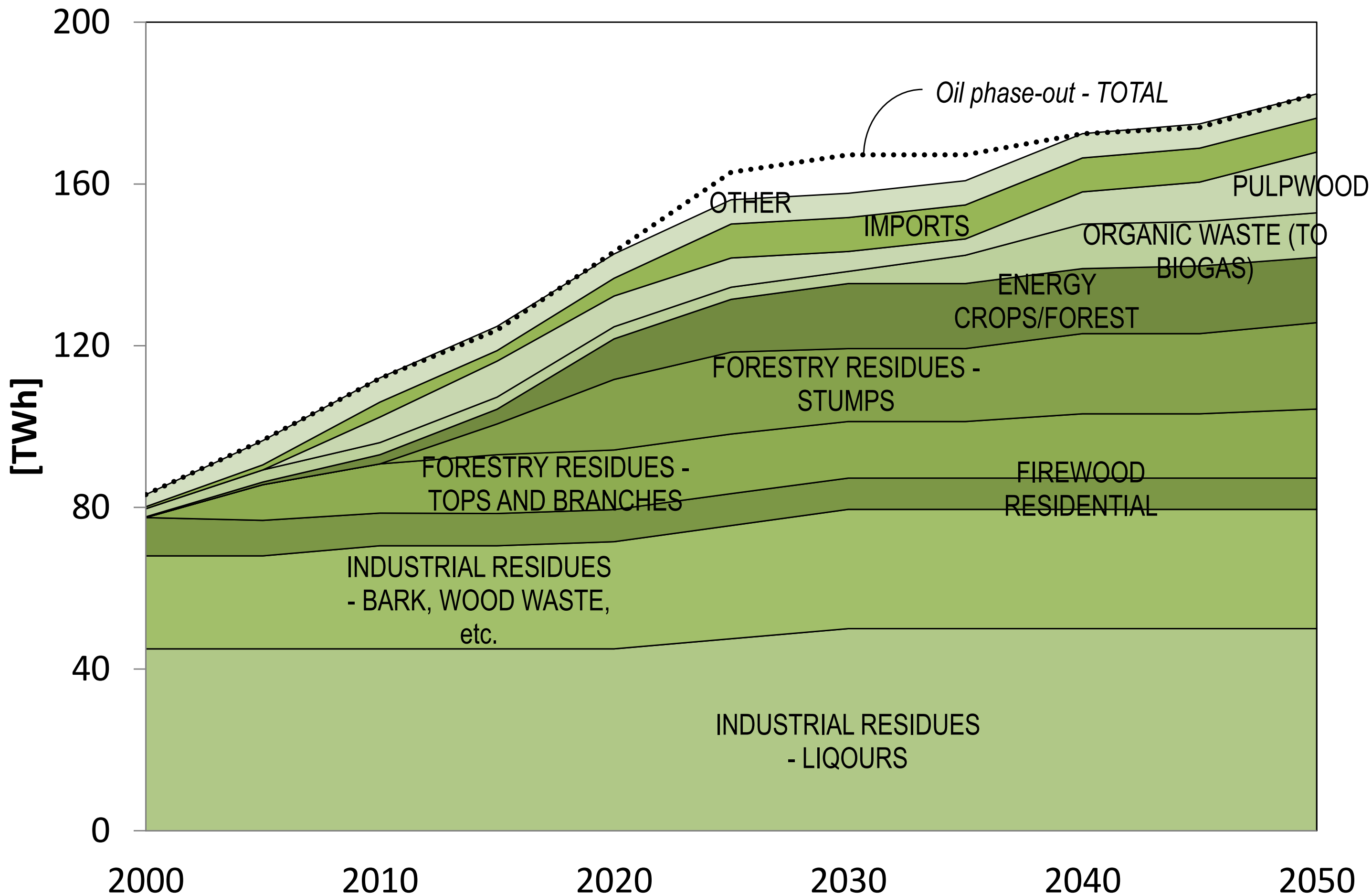
- “NAT_CA” (National climate action). Higher import fossil fuel prices
- “CO2_LR65” and “CO2_LR50” (Low reduction for $CO_2$, -65% and -50%)
- “2GEN_HC” (High cost for second generation biofuels)
- “EV_HC” (High costs for electric vehicles).
- “BIO_LS” (Low supply for biomass): no stumps
- “MET_NO” (No high blend methanol fuels)
- “TRAF_SG” (Slow traffic growth)
- “NUC_PO” (Nuclear phase-out until2030)
- “PULP_SD” (Mechanical pulp shut-down)

# Results

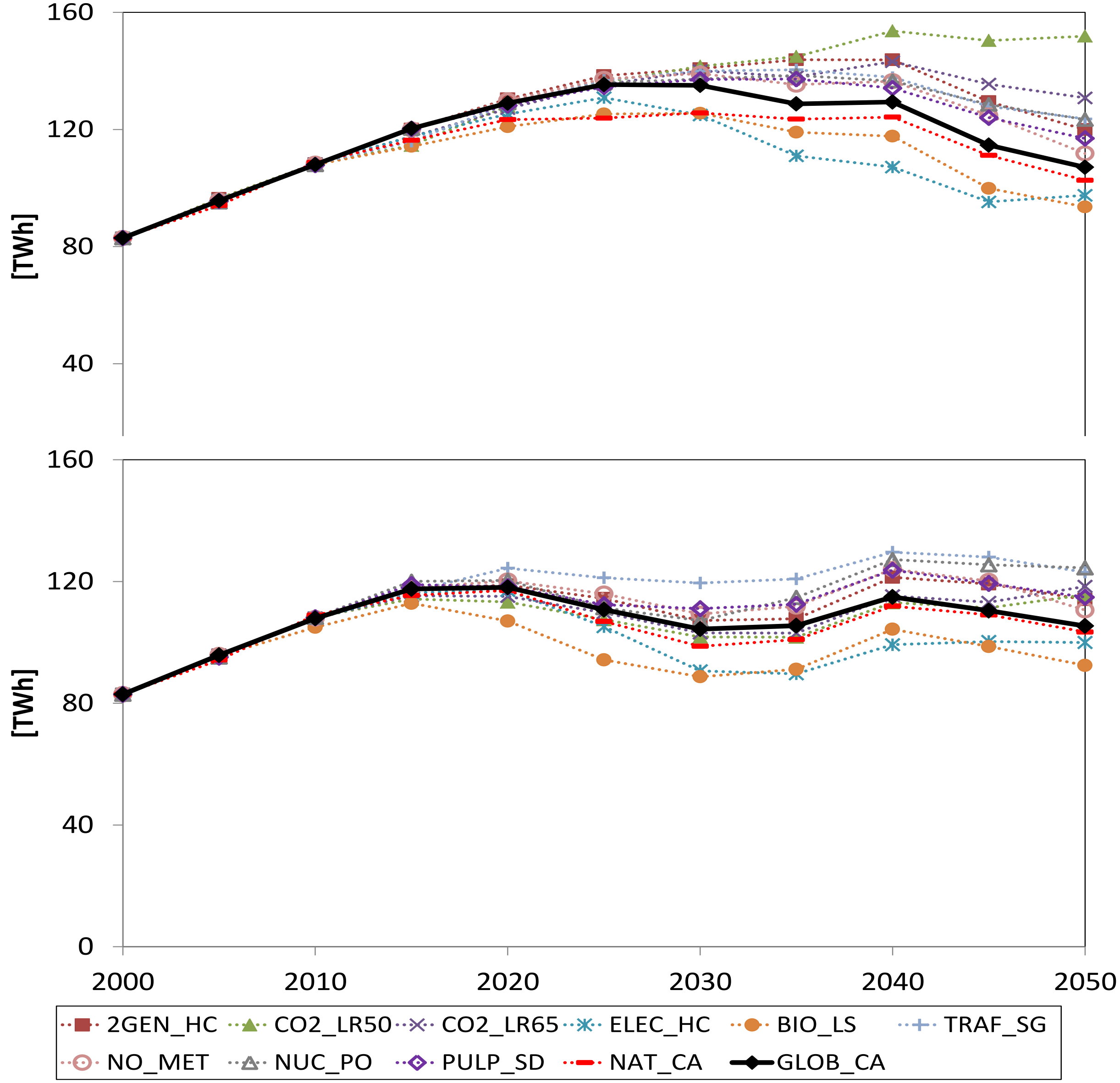
# Total energy supply, final energy use and electricity generation for main analysis scenario GLOB_CA.



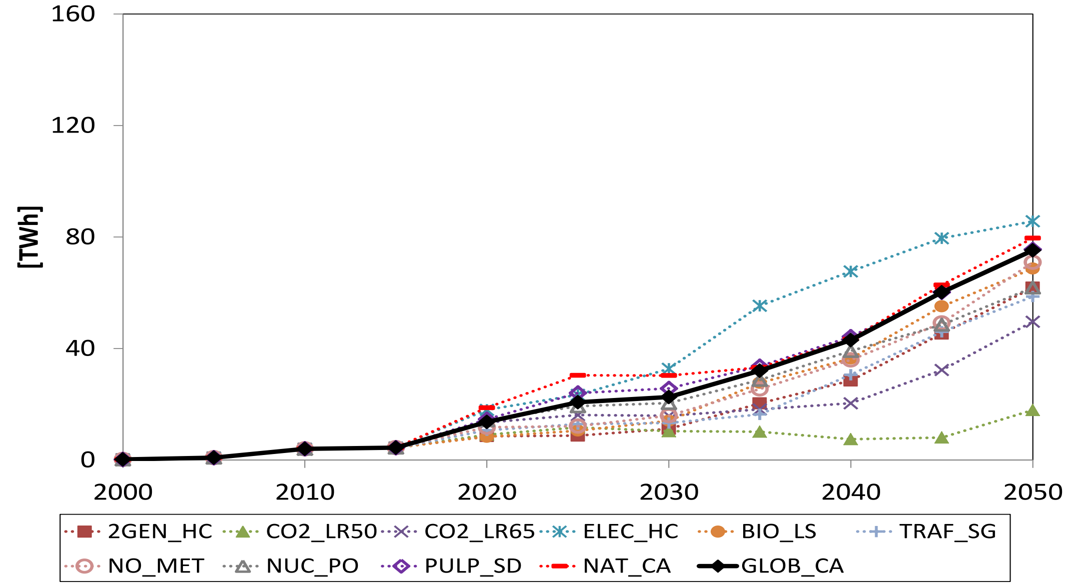

*Nuclear power is for "total energy supply" represented in gross values (input energy), while for "electricity generation" in net production (electricity output). For "total energy supply", "electricity" represents net import (negative values imply export).*

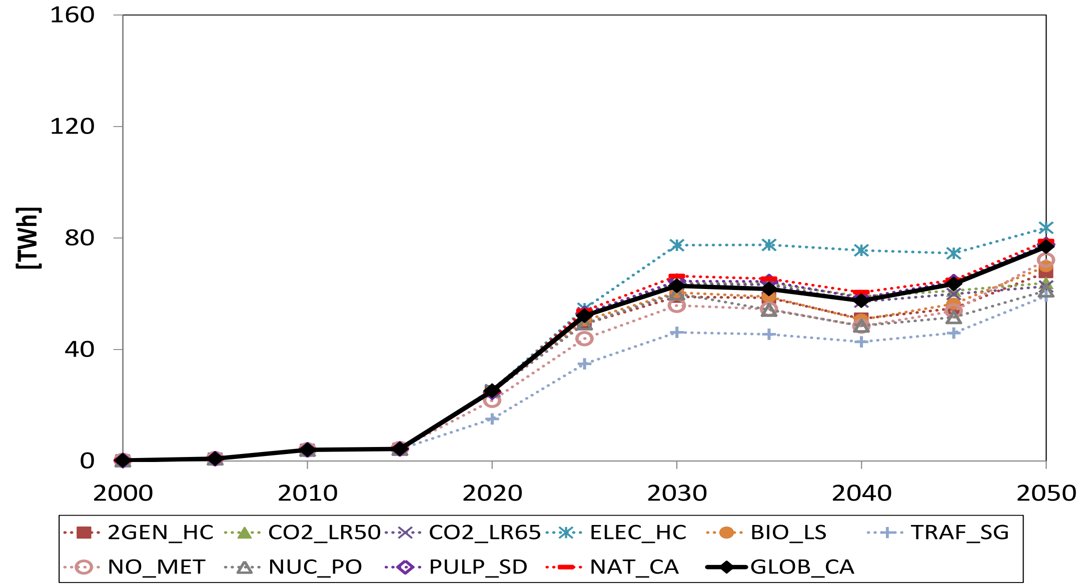



Cost-efficient biomass utilization (excluding peat and combustible municipal waste) in scenario GLOB_CA.
Dotted line shows total biomass utilization with OP policy applied.

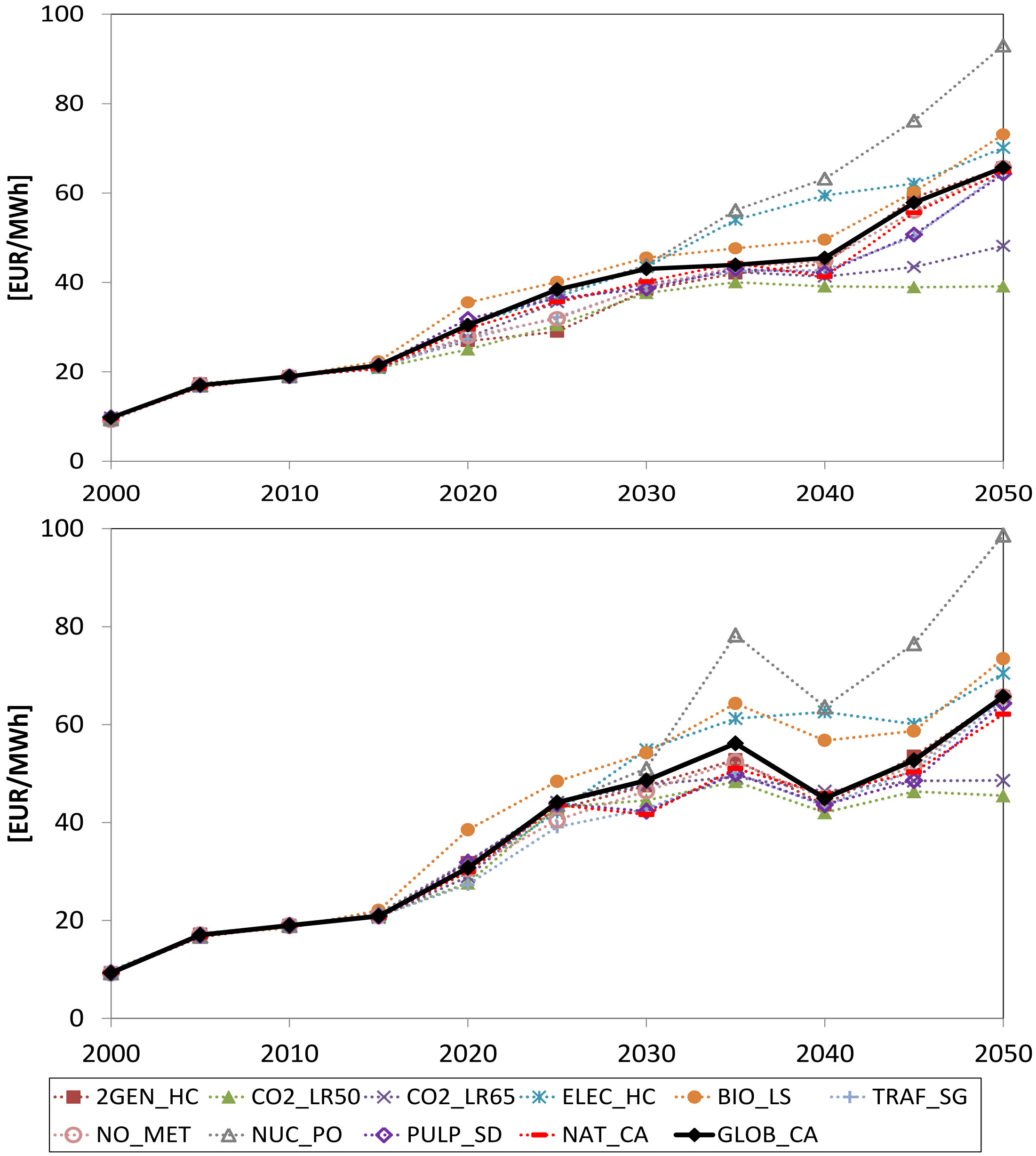



Biomass use for heat and electricity production in different scenarios, without OP policy (top) and with OP policy (bottom).




Biomass use for transport biofuel production in different scenarios, without OP policy (top) and with OP policy (bottom).




Biomass marginal cost in different scenarios, without OP policy (top) and with OP policy (bottom)

# Findings - *so far*

- Total bioenergy utilization increases by 63% to 2050 (under system-wide $CO_2$ reduction of 80%)
  - including utilization of stumps and energy crops
- Biomass use in CHP peaks around 2030 in most scenarios
- Transport sector accounts for 41% of total in 2050
  - corresponding to 42 TWh transport biofuels
- Strong resource competition
  - marginal biomass costs more than triples
  - very large deployment of plug-in hybrid vehicles in transport sector

# Cont´d work

- Better representation of polygeneration options
- Improved representation of biowaste flows (possibly)

Tack!