Modelling alternative fuel production technologies for Denmark

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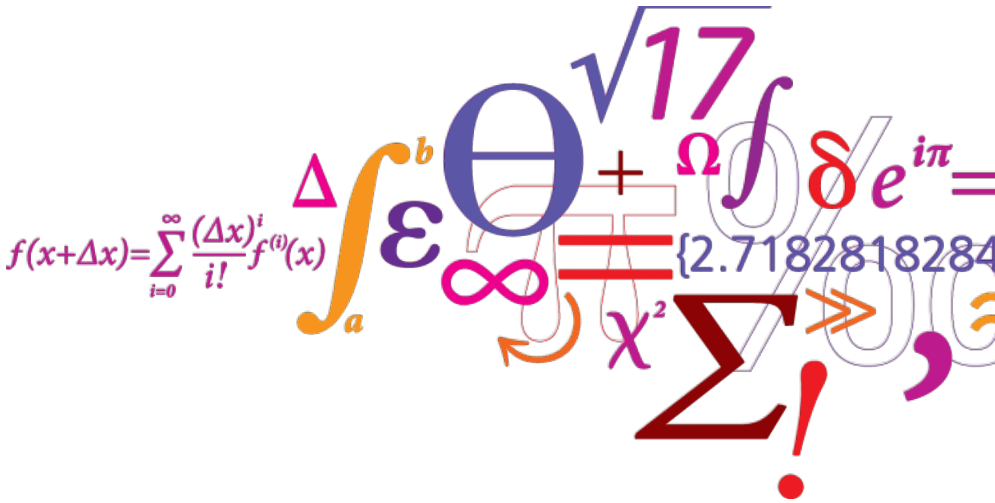

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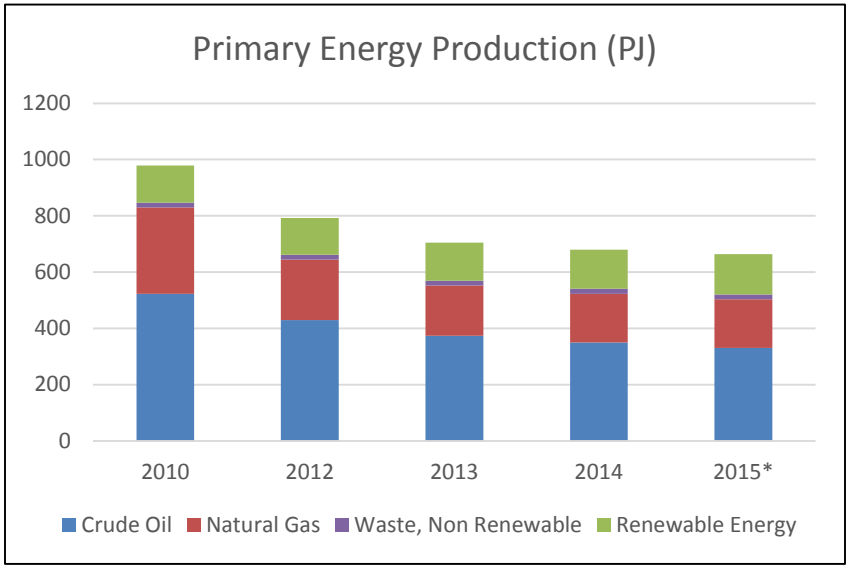
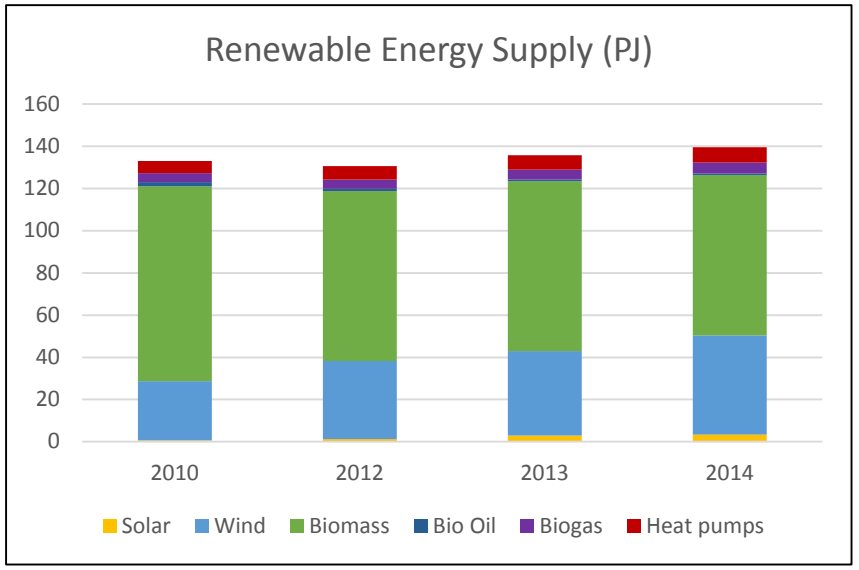
Outline

- Introduction - Danish energy in figures
- Use of residual biomass
- Alternative pathways for the use of straw
- Scenarios in TIMES-DK
- Conclusions and further work

Danish energy in figures

- Renewable energy constitutes 22% of the total energy production in 2015
- Biomass accounts for 54% of the renewable energy supply and 11% of the total production in 2014

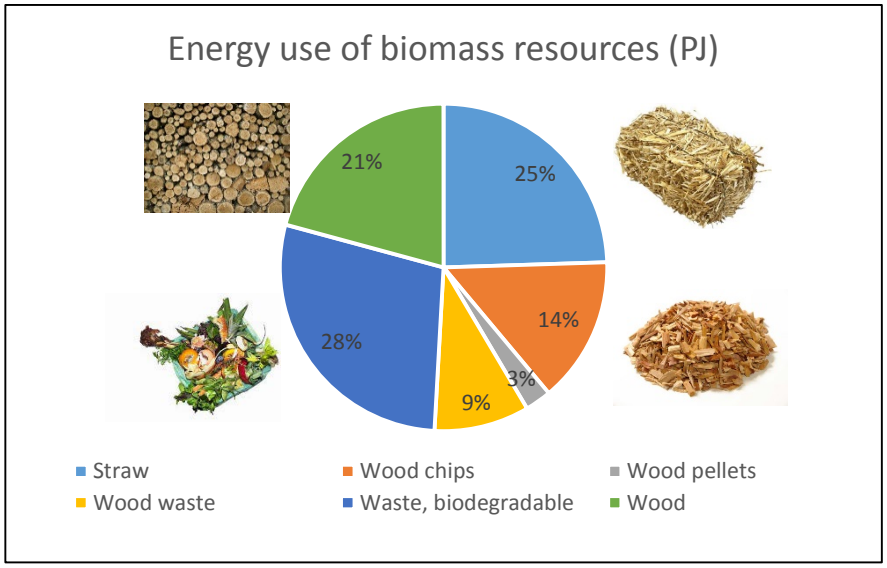




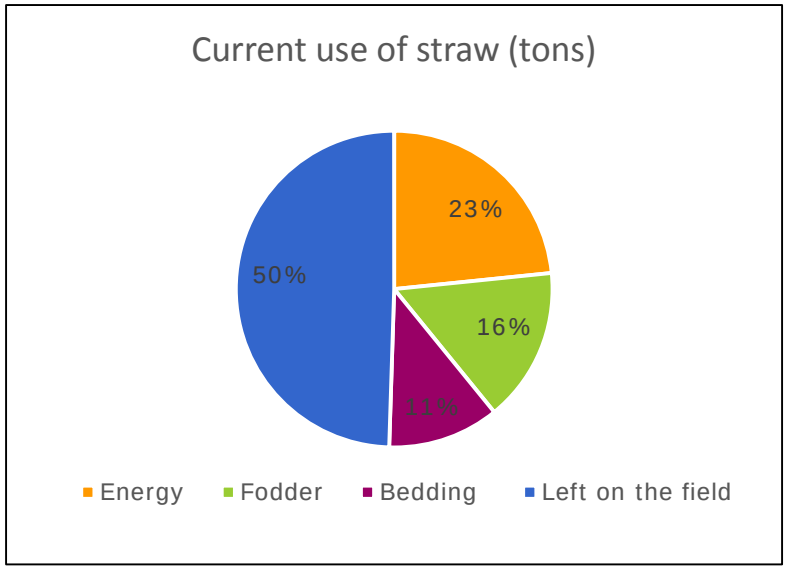
Input data retrieved from Danish Energy Agency, 2015 - http://www.ens.dk

Residual biomass in Denmark

- Straw from agriculture is one of the most abundant (and partially unused) among residual biomass resources: 90 PJ/year.
- Half of the harvested straw is left on fields, sparking the ongoing discussion on its optimal use.



Danish Energy Agency, 2015



Statistics Denmark, 2016

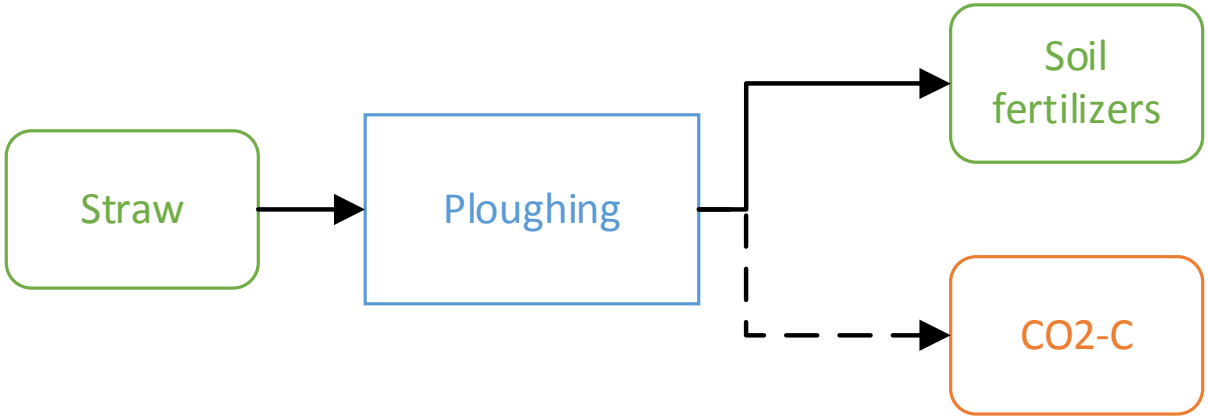
What is the optimal use of straw in the future?

A number of alternative pathways can be considered:

1. Left on the fields
2. Production of biogas - anaerobic digestion
3. Heat and power - CHP plants and boilers
4. Production of 2G bioethanol
5. Production of synthetic natural gas (SNG) - gasification
6. Production of bioalcohols and biodiesel - gasification and Fischer-Tropsch synthesis

Alternative pathways to enhance straw use

1. Straw is left on the agriculture fields with consequent beneficial soil conditioning. Additional effects are change in soil carbon balance and CO_2 emissions.

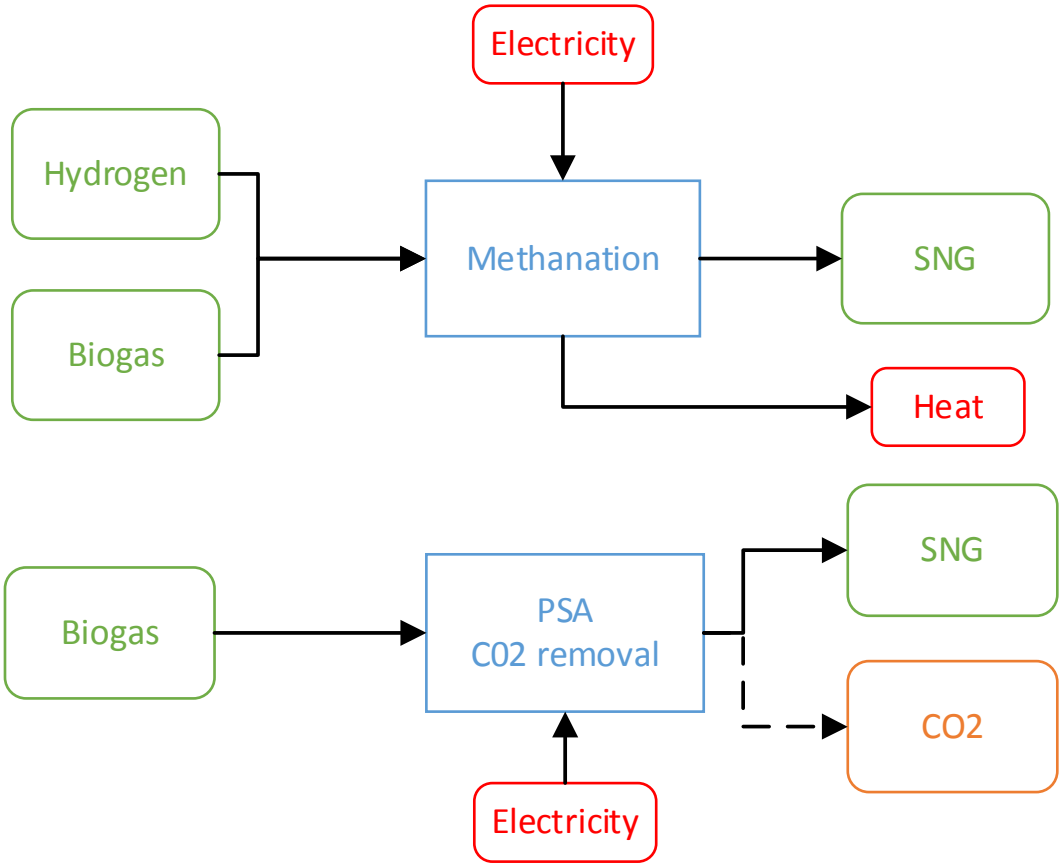


Alternative pathways to enhance straw use

2. Straw is used as feedstock in anaerobic digester for the production of biogas. Digestate is a co-product which can be spread on fields as fertilizer and thus affecting the carbon storage.

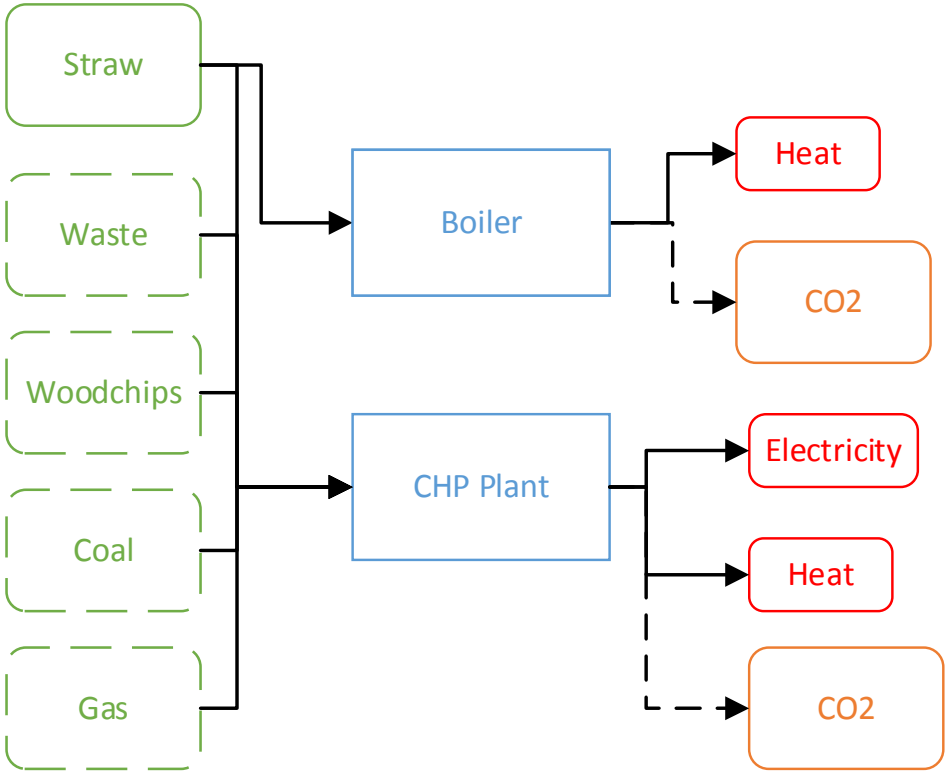
Alternative pathways to enhance straw use

2. Biogas can be upgraded to natural gas quality (SNG) either through CO_2 removal or by methanation with hydrogenation.



Alternative pathways to enhance straw use

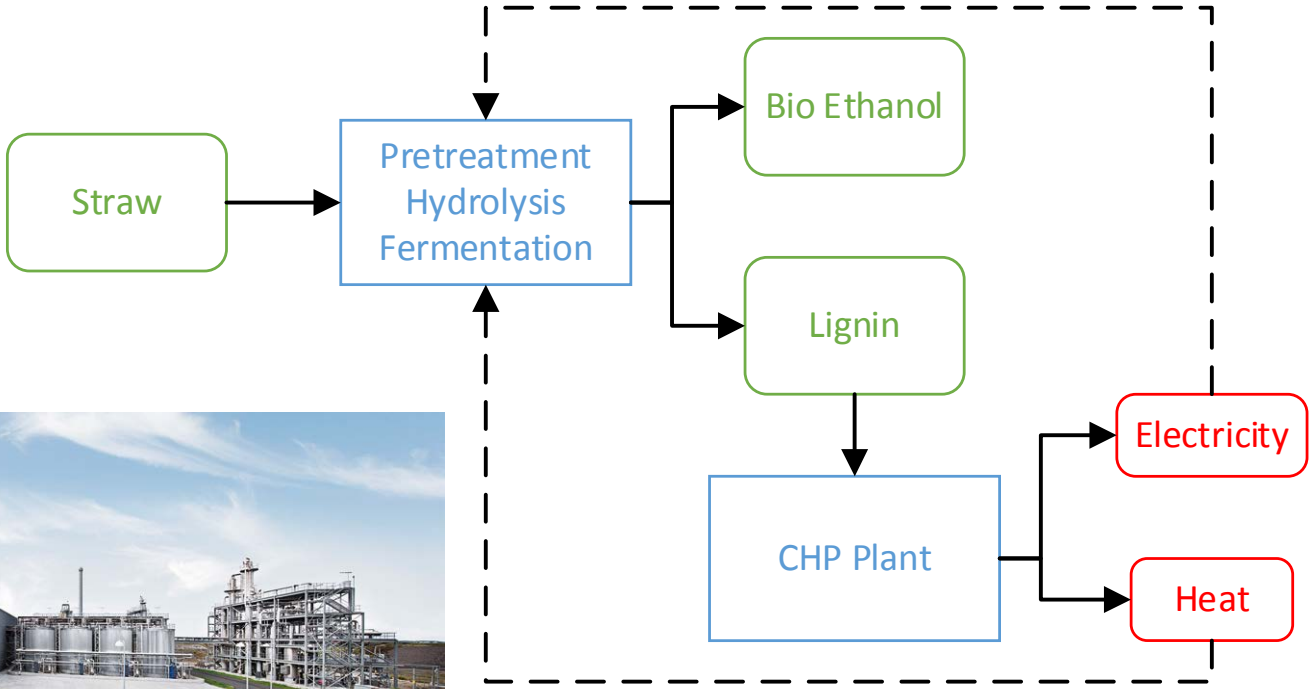
3. Straw can be combusted in district heating and individual boilers for the production of heat, and used in combined heat and power plants for production of heat and electricity.



Avedøre Power Station, planning full conversion from coal to biomass - woodchips and straw (Copenhagen, Denmark)

Alternative pathways to enhance straw use

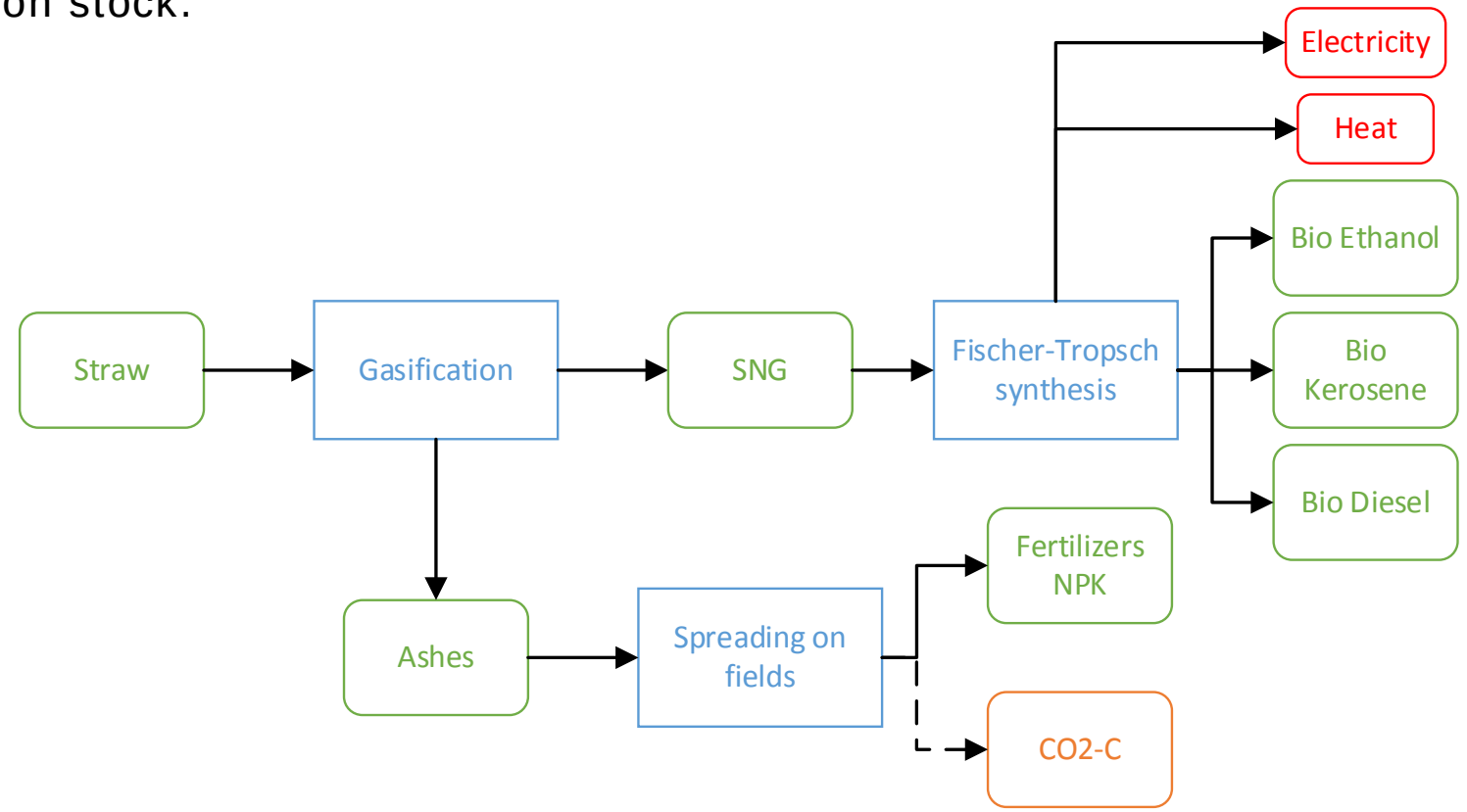
4. Straw can undergo hydrolysis and fermentation for the production of bioalcohols, like bioethanol. Lignin is a co-product, which can be used for CHP production.



Inbicon, bioethanol production from lignocellulosic biomass (Kalundborg, Denmark)

Alternative pathways to enhance straw use

5. Laboratory/pilot biomass to liquid (BTL) technology in which straw undergoes thermal gasification and the output gas is used to synthetize bioalcohols and biodiesel. Ashes can be used as fertilizer and impact the carbon stock.



Modelling in TIMES-DK

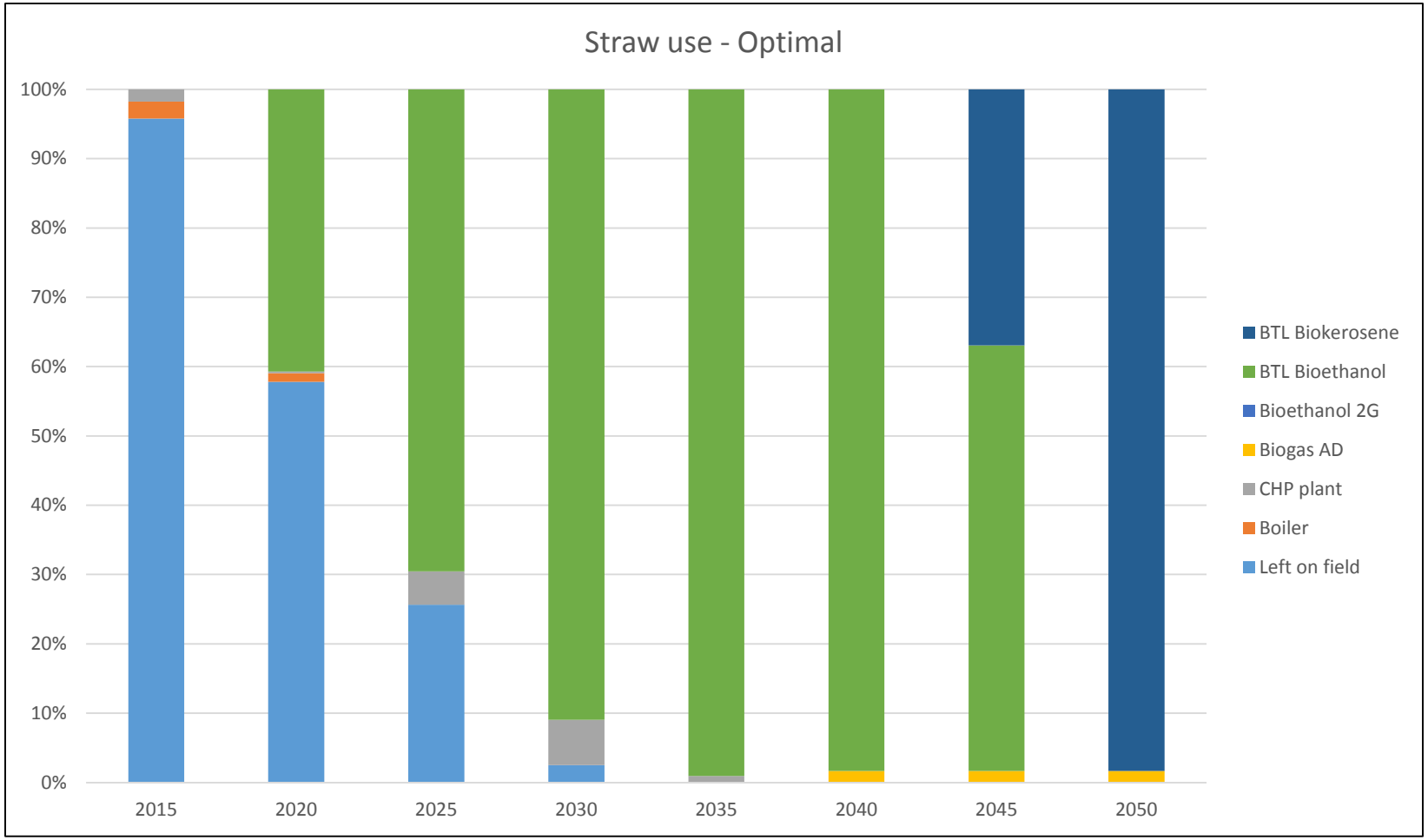
Main assumptions

- Least-cost optimization of the energy system for the period 2015-2050
- Biomass resource potentials correspond to current availability (no imports assumed)
- Fertilizers NPK are valued at current market price
- CO_2 target in all scenarios for 100% fossil-free system 2050 (industrial, residential and transport sector)
- Additional target for transport sector - 10% renewable in 2020

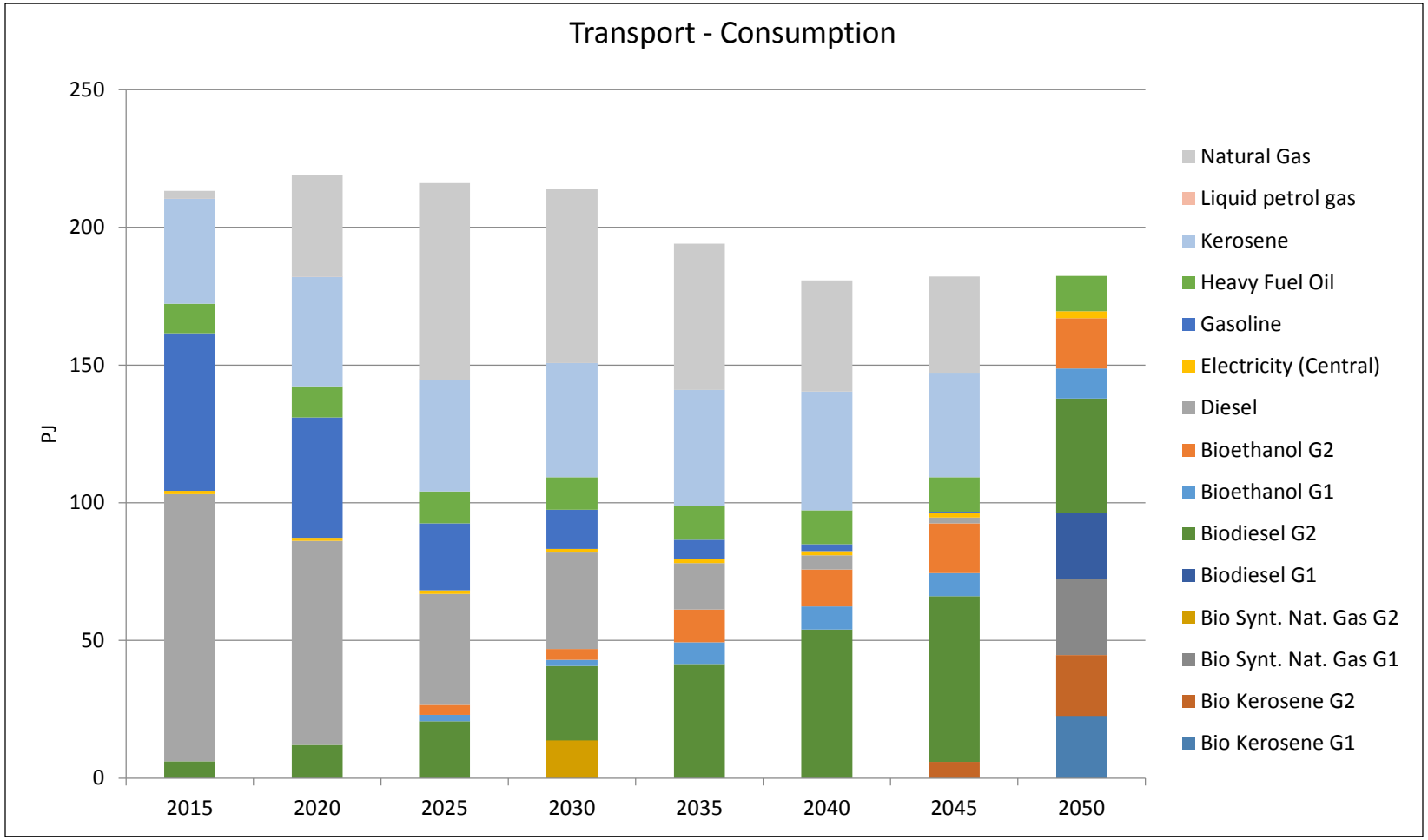
Technology scenarios

1. **AGR**: all straw potential is used only in the agriculture sector
2. **BGA**: all straw potential is used only for biogas production
3. **CHP**: all straw potential is used only in the heat and power sector
4. **ETOH**: all straw potential is used only for bioethanol production
5. **BTL**: all straw potential is used only in BTL technology
6. **OPT**: optimal (least-cost) combination where all straw is used

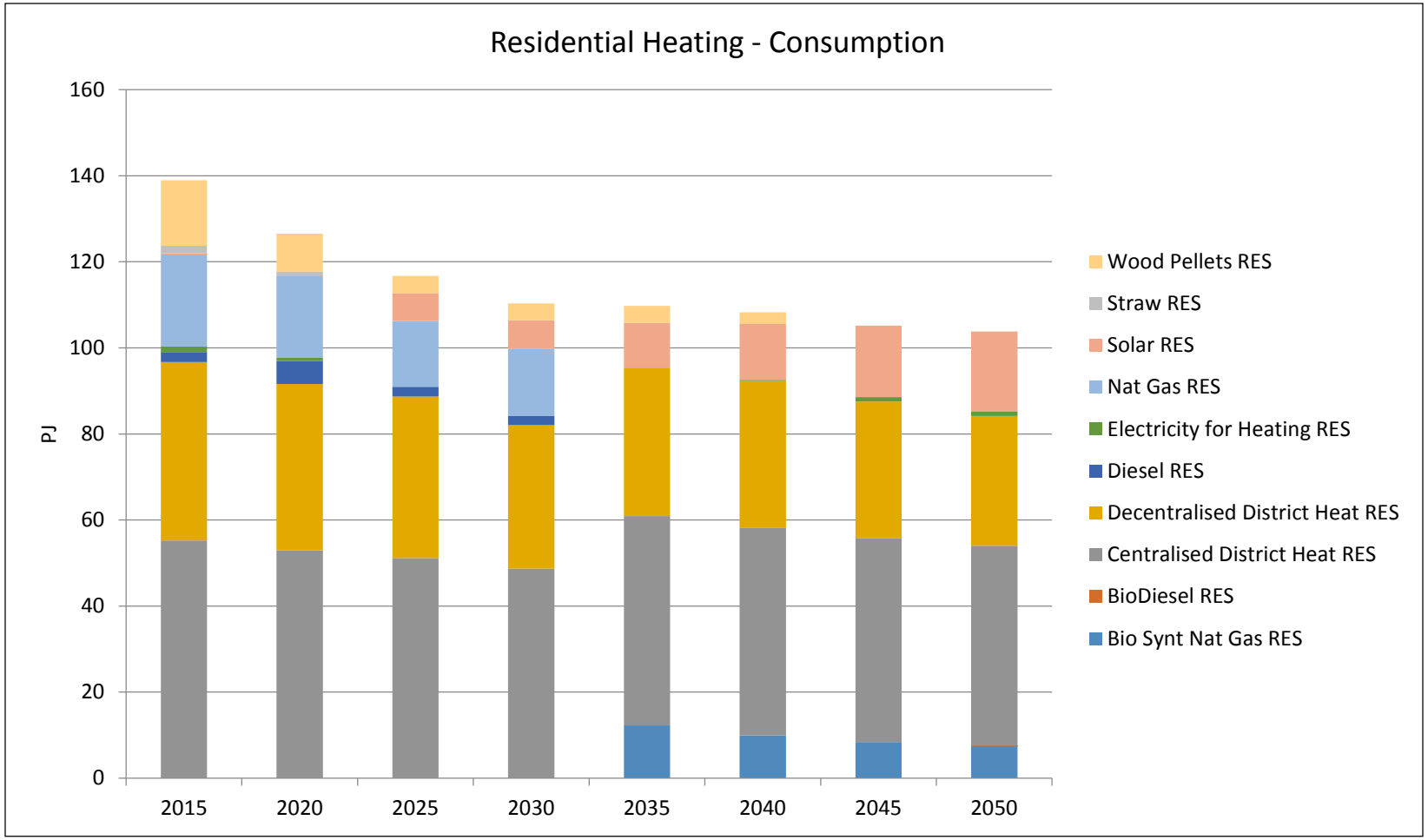
Optimal scenario - Straw



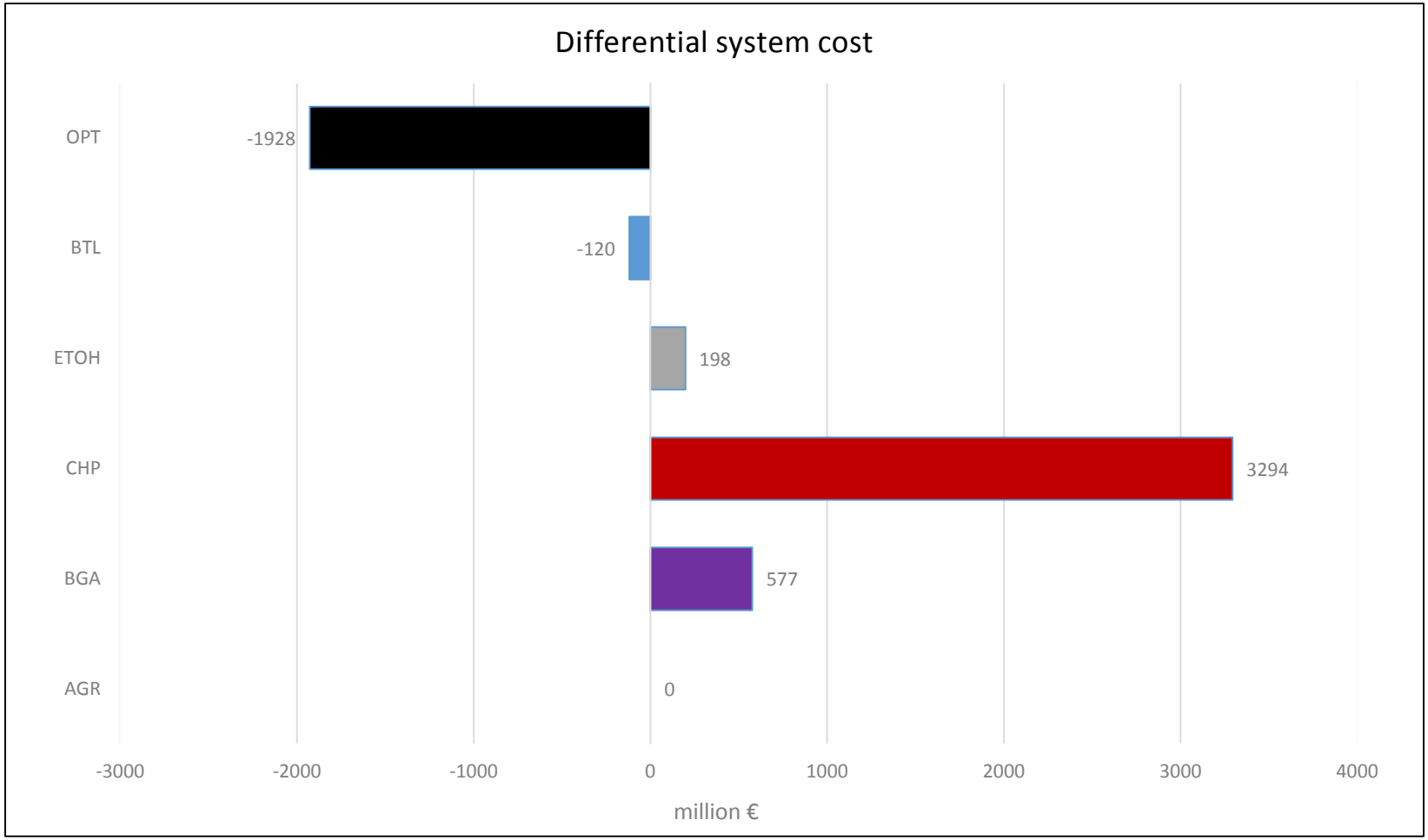
Optimal scenario - Transport sector



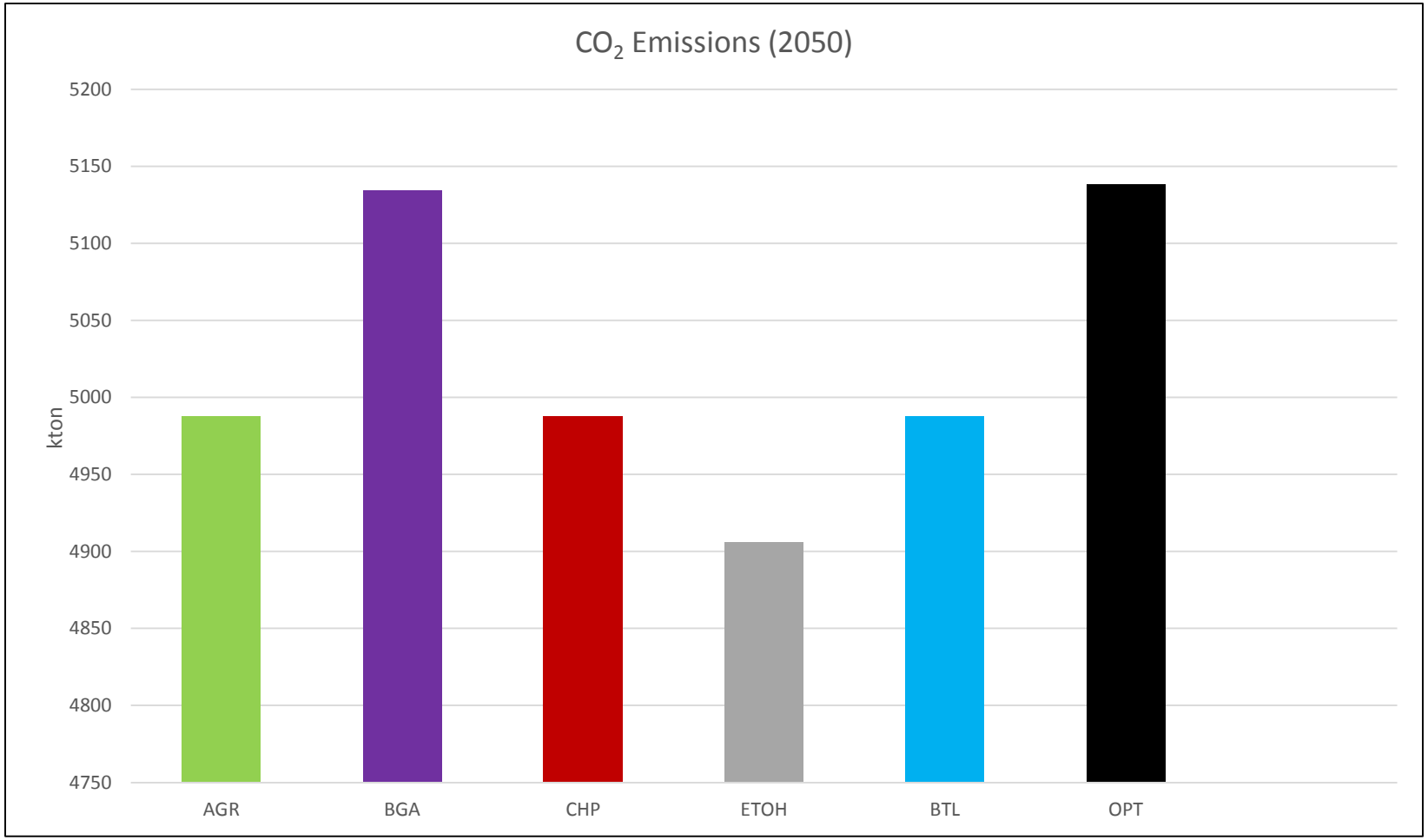
Optimal scenario - Residential heating



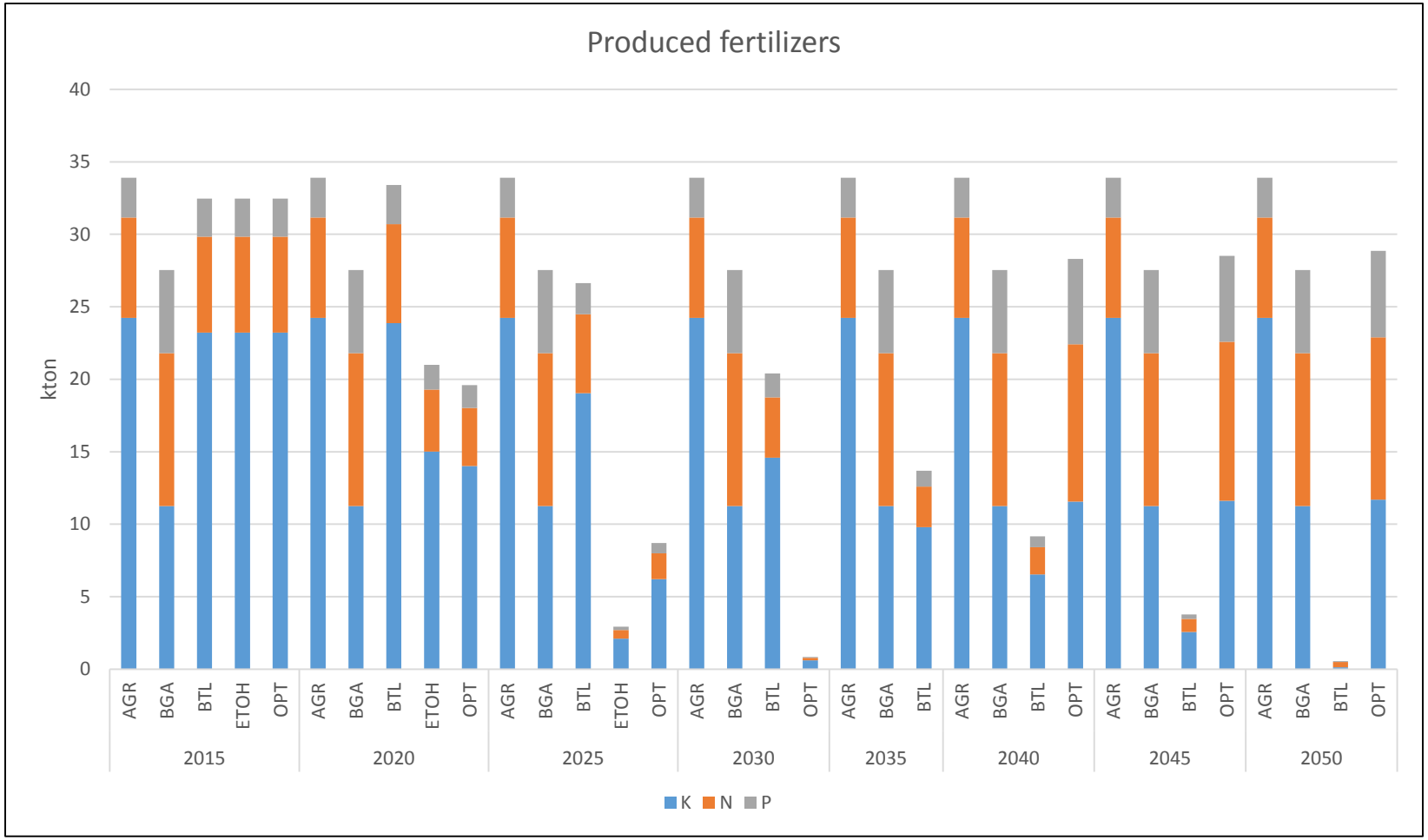
Scenario results - Cost



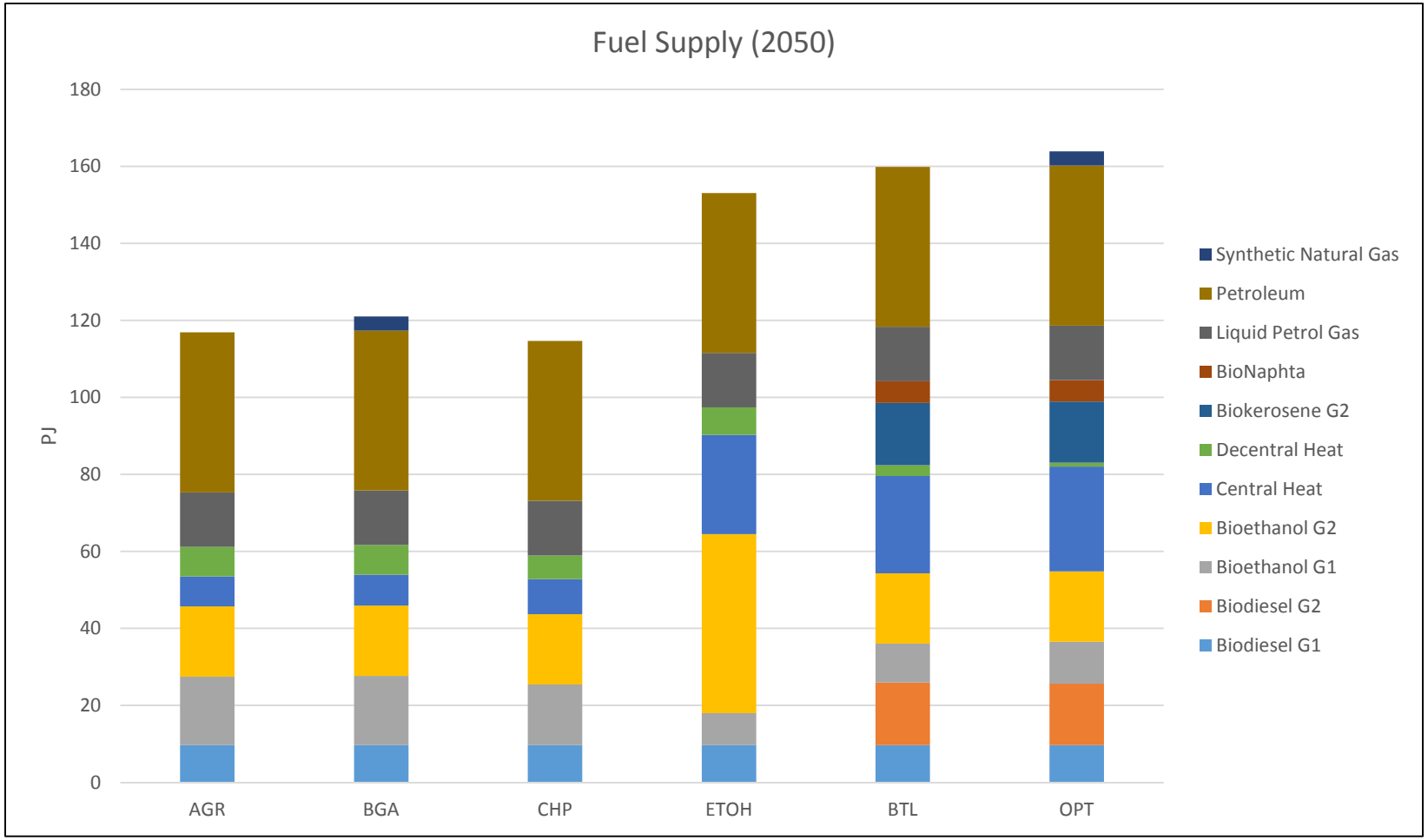
Scenario results - CO_2 Emissions



Scenario results - Fertilizers



Scenario results - Fuel supply



Discussion

- The economic assessment on the optimal use of straw highlights that a combination of technologies (**BTL** and **biogas**) is the most cost efficient while using straw for heat and power is the least attractive solution.

- However, the choice may have a minor impact on the rest of the energy system.

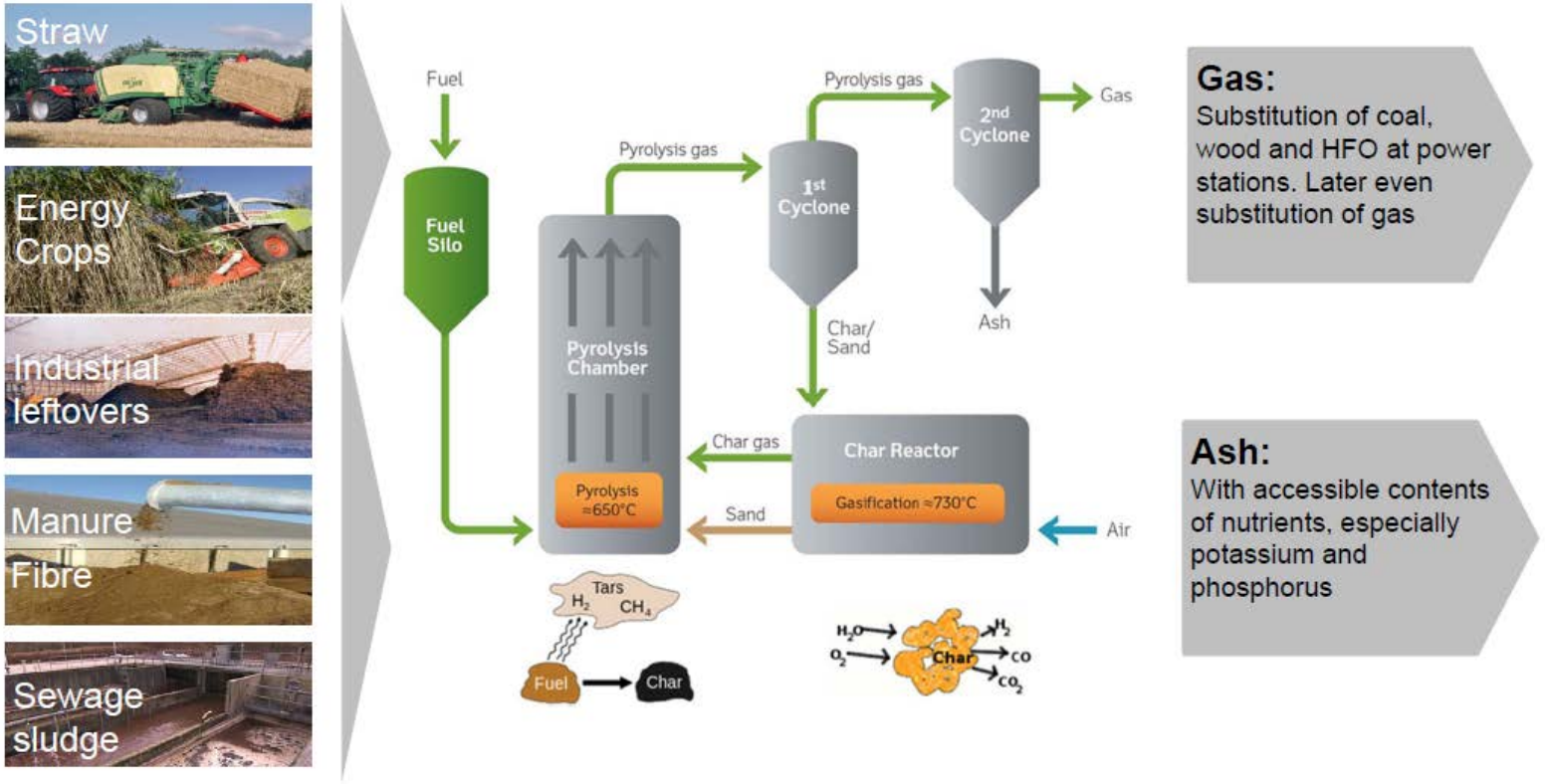
- **Uncertainty** on cost and efficiencies of emerging technologies.

- Potential variability in the **availability** of straw across and within years (weather, cultivations, crops rotations)

- Wider **environmental** considerations with respect to the use of biomass may have an impact on the optimal solution.

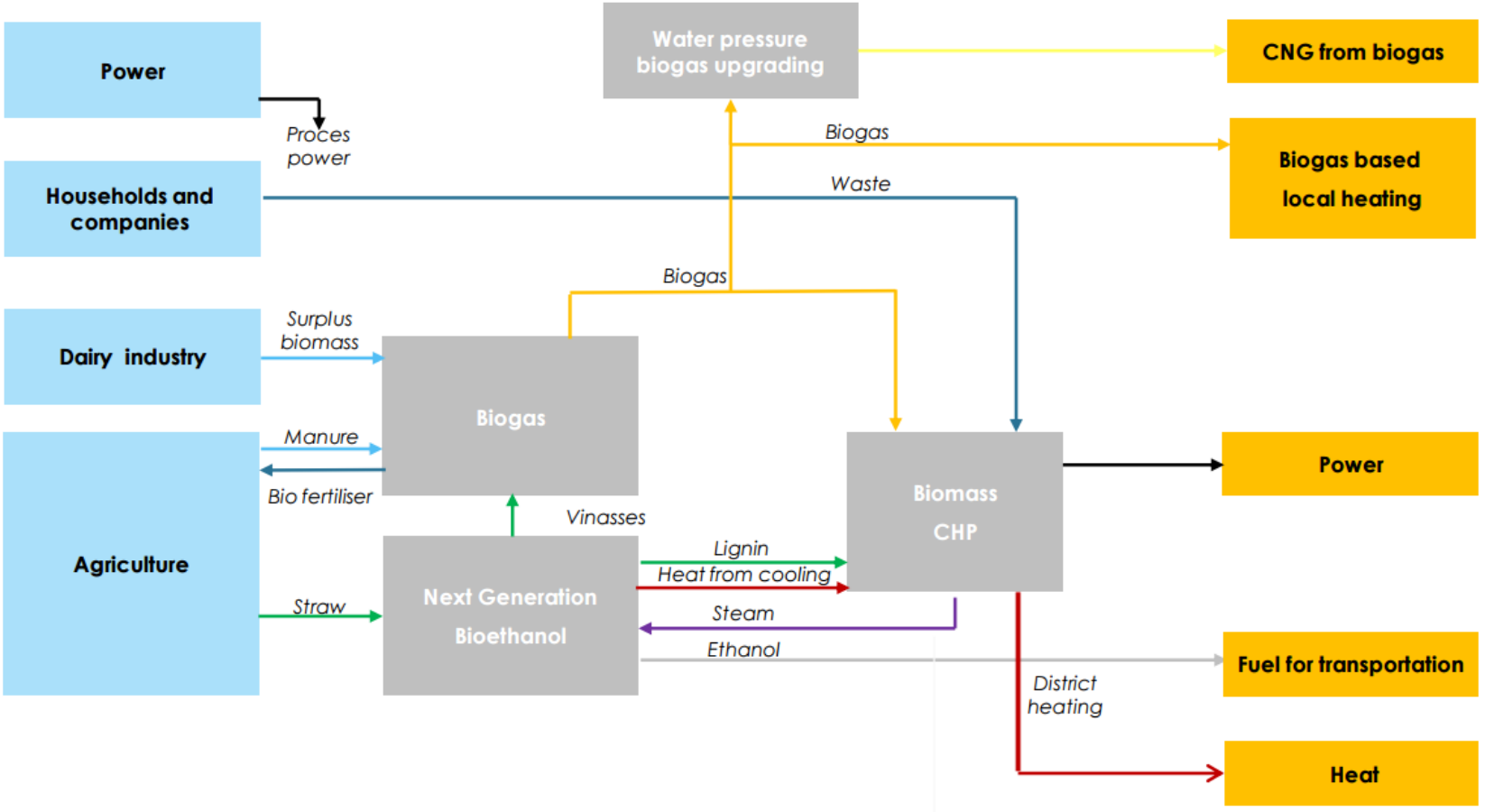
Further work

Pyroneer: small-scale gasifier (6 MW demonstration plant)



Further work

Maabjerg Energy Concept: co-production of biogas, bioethanol, waste treatment, power and district heating.



Further work

Introducing more environmental considerations in TIMES-DK:

What is the impact on the sustainability and GHG emissions in the agriculture and transport sectors if biogenic emissions, use of land as well as soil and water pollution are taken into account?

Thank you for your attention !
Suggestions and questions?

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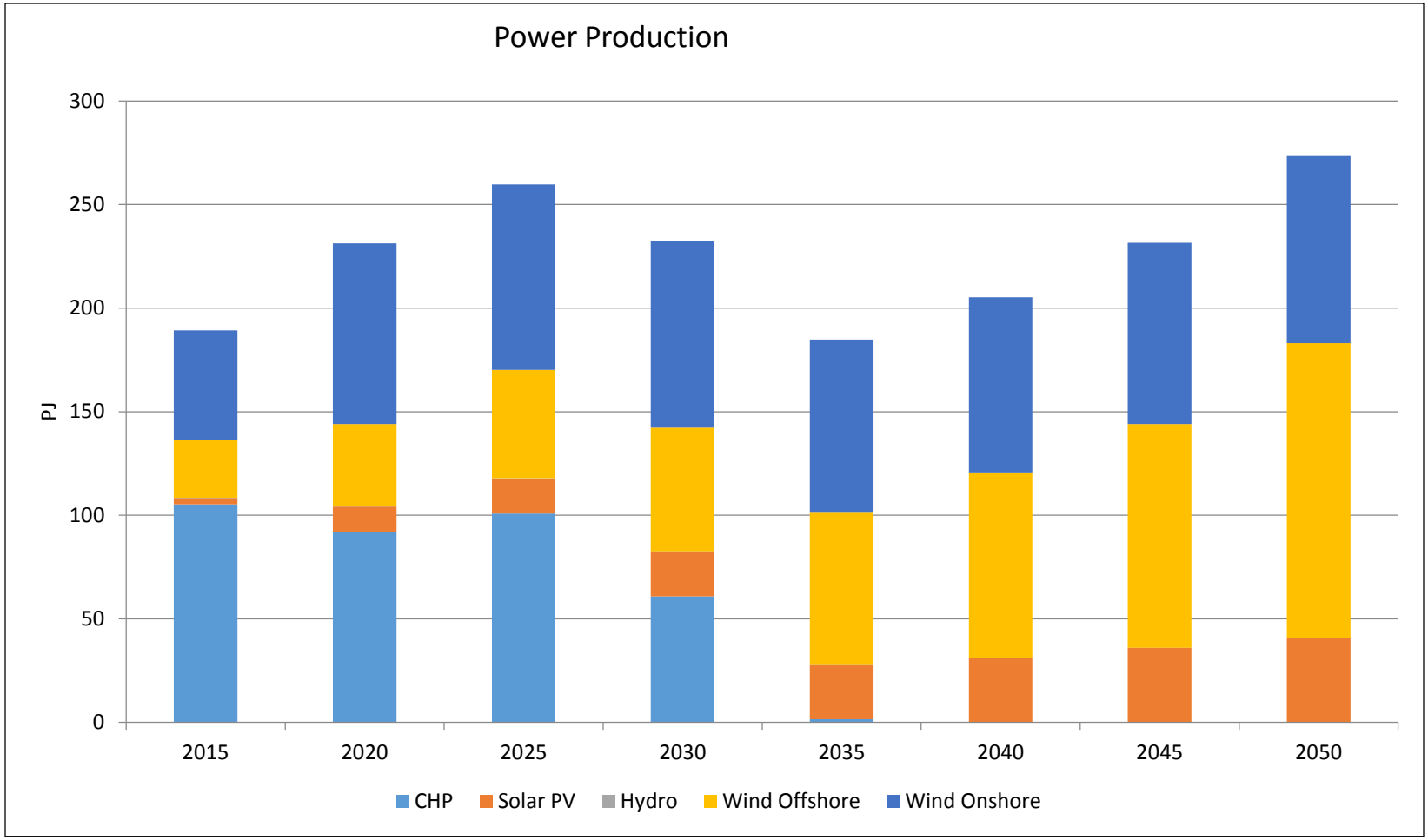
Power Production
300
250
200
150
100
50
0
PJ
2015
2020
2025
2030
2035
2040
2045
2050
CHP
Solar PV
Hydro
Wind Offshore
Wind Onshore