Implications of different future energy systems on optimal waste treatment and use for energy

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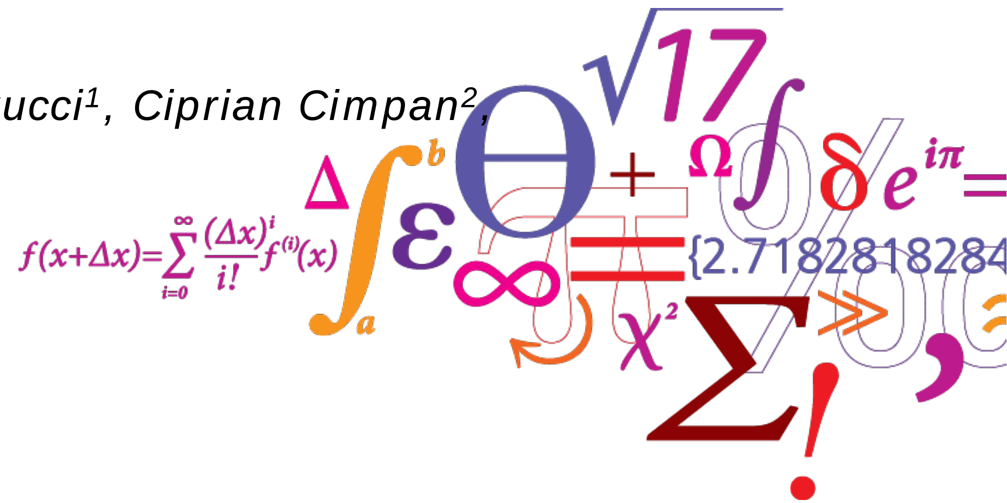

4DH conference 27th Sept 2016

DTU Management Engineering
Department of Management Engineering

Outline

- Intro
- Waste management in EU
- Projecting future waste amounts
- Optimising future waste treatment
- Conclusion

Introduction

- Revolutions in the energy sector in the future
- 100% RE in DK in 2050(!) => Need for flexibility and local energy sources

- Economic growth => More waste
- Recycling targets => Less waste

TOPWASTE
2011-2015

Main purpose:

- to contribute to **improved use of waste for energy or material recycling** integrating economic and environmental considerations including resource scarcity.

www.topwaste.dk

DTU

Alternatives for Future Waste Management in Denmark

Final Report of TopWaste

System Analysis

DTU Management Engineering

March 2016

DTU Management Engineering
Department of Management Engineering

10 Research questions

1. How much waste will we have in the future?
2. What is the impact of different energy futures on the optimal waste treatment?
3. What is the future potential for imports of combustible waste towards Denmark?
4. In which way do boundary conditions influence future waste management?
5. How should we sort our waste and what could the role of central sorting be?
6. How do we optimize the management of the main waste fractions under future framework conditions?
7. What is the role of recycling in managing supply risk of critical resources?
8. Are we running out of metals for future RE technologies?
9. What are the most important cost elements of MSW management?
10. Which organizational measures may support the achievement of the political goals as spelled out in "Denmark without Waste"?

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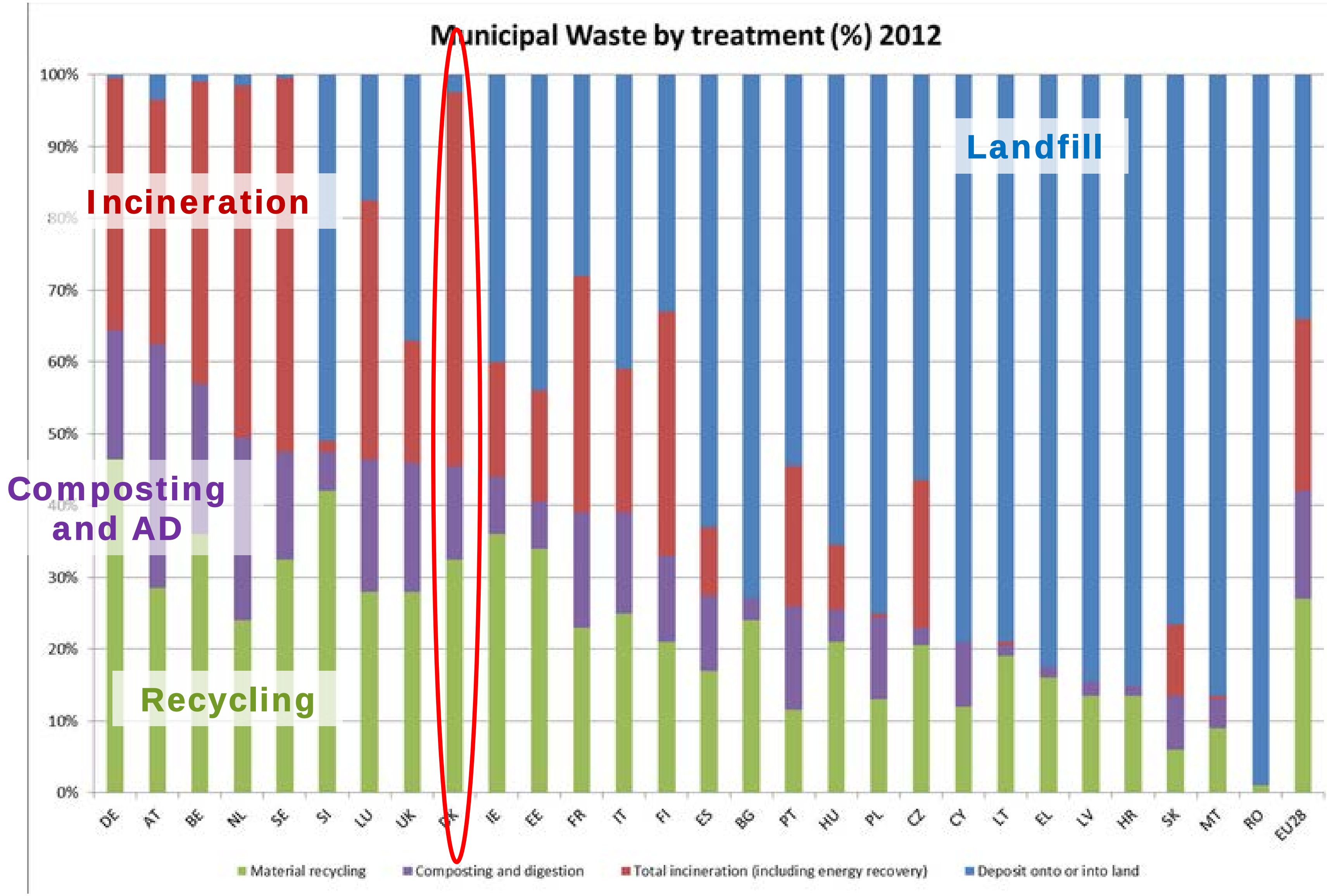
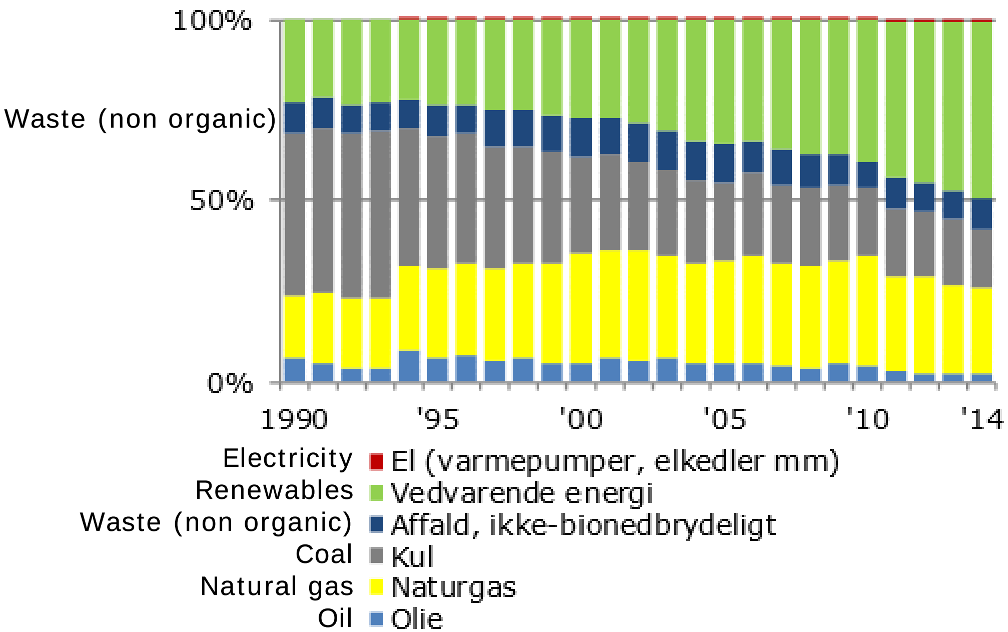
EU'S WASTE HIERARCHY
PREVENTION
1
Minimize the amount of waste through various means of control.
RE-USE
2
All waste will be re-used to the greatest extent possible.
RECYCLING
3
When raw material can be recycled, major resources are saved.
RECOVERY
4
Combustible waste is a resource for energy extraction.
DISPOSAL
5
As a final step, deposit at a refuse dump.


Municipal Waste by treatment (%) 2012
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Incineration
Landfill
Composting
and AD
Recycling
DE
AT
BE
NL
SE
SI
LU
UK
DK
IE
EE
FR
IT
FI
ES
BG
PT
HU
PL
CZ
CY
LT
EL
LV
HR
SK
MT
RO
EU28
Material recycling
Composting and digestion
Total incineration (including energy recovery)
Deposit onto or into land

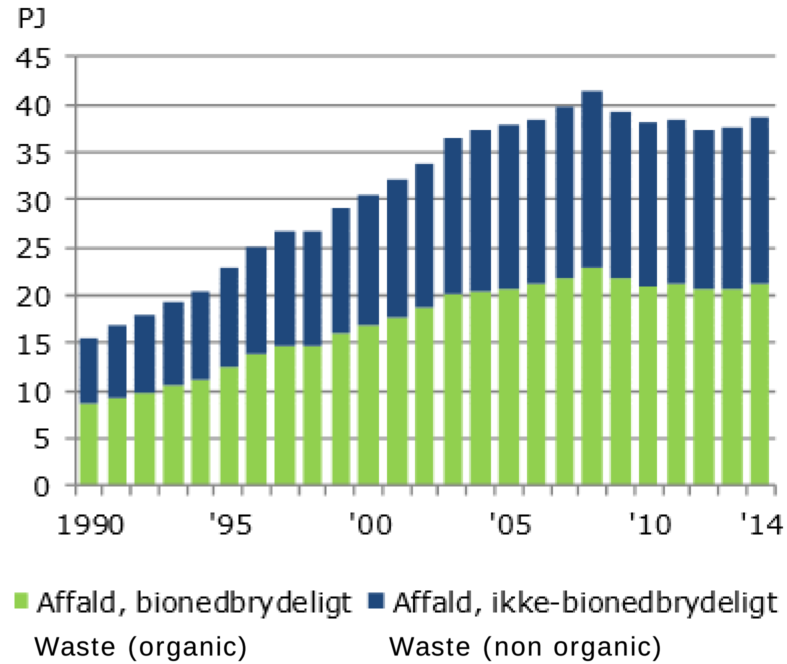
Waste use

- 5% of electricity production
- 21% of DH production

Fuel consumption for DH production

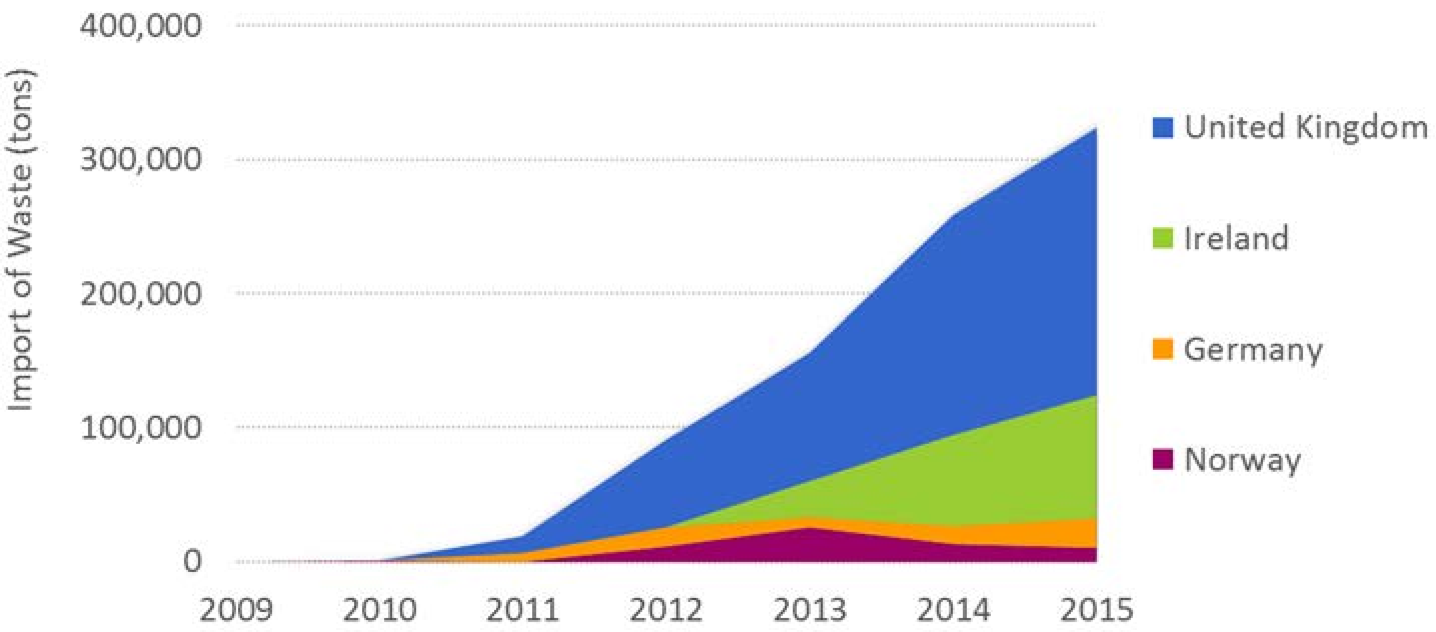


Use of waste



Import
Good or bad?

Image: BIG-Bjarke Ingels Group/Glessner and Amager Ressourcecenter



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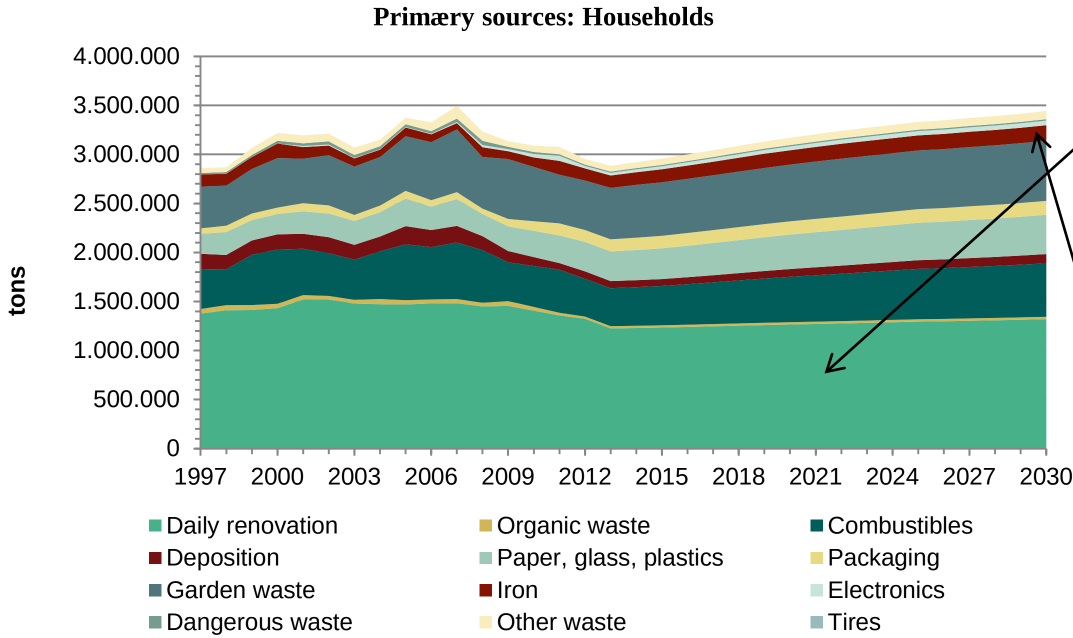
Projecting generation and treatment of waste

- A model converting **economic development** to the generation of waste
- The linking waste generation and economic development is based on analysis of data for economic development and the generation of waste (period 1994- 2013)
- Waste from **sectors** **is linked to production by sectors** and waste from **households is linked to private consumption** of categories of consumer goods
- In baseline projections, treatment of waste per fraction is assumed to be constant. (Total treatment shares change if the weights of fractions changes)
- In policy projections, treatments may be changed, sorting will move amounts of waste between fractions and waste minimization will reduce amounts of waste of specific fractions.

- The economic development is **official projections from the Danish Ministry of Finance**.

Generation of waste from primary sources, baseline projection



Waste from households.

The large group "Daily renovation" almost constant.

Most other fractions increase 1-2% p.a.

- Electronics small fraction but increase considerably (also due to increased collection).

Waste from production sectors.

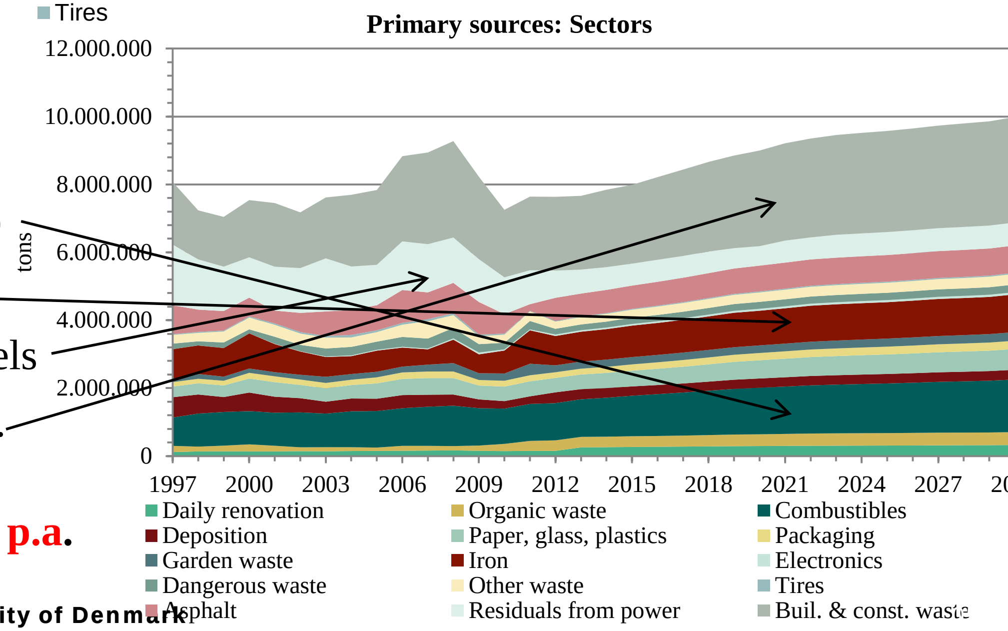
The large fractions are:

Combustibles, increases 1.7% p.a. (2015-2030)

Iron, increases 1.2% p.a.

Residuals from power plants, decreases, bio fuels

Building and const. waste , increases 2% p.a.



Total households and sectors increases 1.4% p.a.

(2015-2030) (GDP increases 1.7% p.a.)

The Resource Strategy: "Denmark without waste"

Sets targets for recycling and the collection of waste, includes very few initiatives that reduces the generation of waste.

Main focus on household waste.

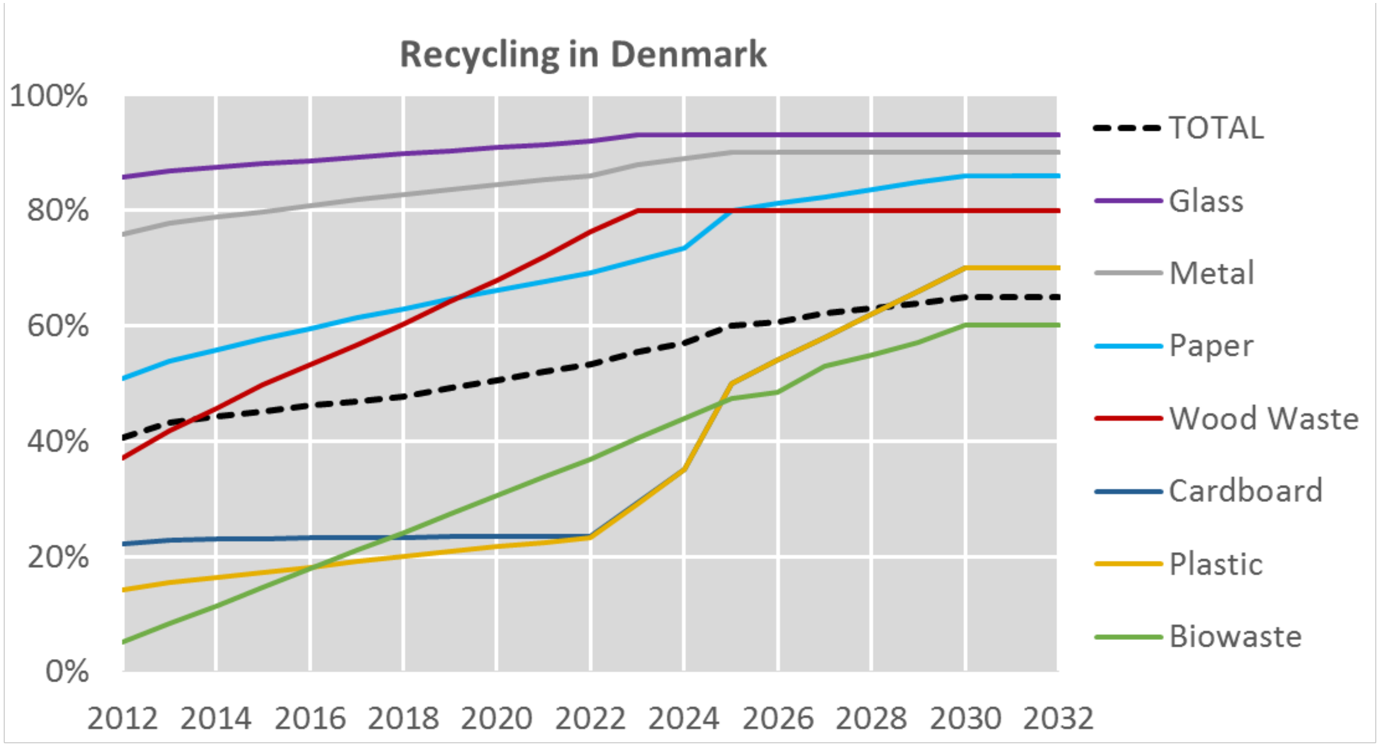
Focus on separating recyclable fractions from daily renovation and combustible fractions.

(the model allows us to move amounts between fractions, to reduce specific amounts of waste and to change treatment shares)

That is, **relative to the baseline recycling is increased and incineration decreased**, and **changes are mainly related to household waste**.

Shares	Total				Households			Sectors		
	Waste statistics	Baseline	Resource strategy		Waste statistics	Baseline	Resource strategy	Waste statistics	Baseline	Resource strategy
	2012	2030	2030		2012	2030	2030	2012	2030	2030
Recycling	64.6	**65.2**	**68.8**		39.8	**42.0**	**51.5**	74.2	73.6	74.2
Incineration	28.8	**28.8**	**25.3**		55.5	**53.0**	**43.5**	18.4	20.1	19.5
Deposition	5.1	4.4	4.4		2.9	3.0	3.5	6.0	4.9	4.8

Recyling targets for household waste



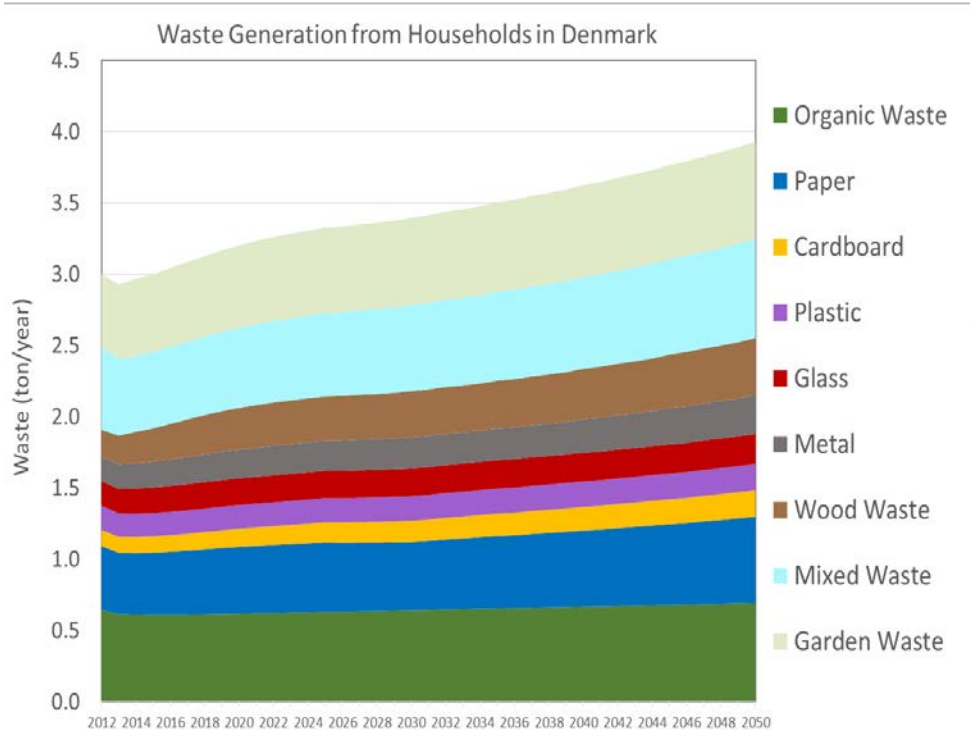
Adapted from:

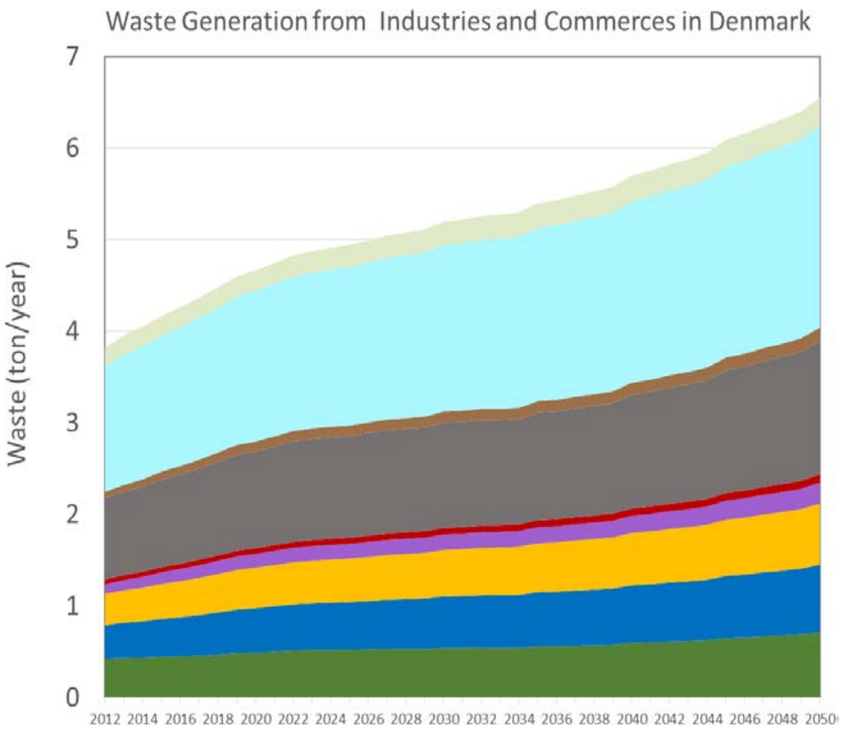
Hill, A., Dal, O., & Andersen, F. (2014). Modelling Recycling Targets: Achieving a 50% recycling rate for household waste in Denmark. Journal of Environmental Protection, 5, 627-636.

European Commission (2015). Closing the loop – An EU action plan for the Circular Economy.

Waste Prognosis in Denmark 2050

Estimation of available waste for energy recovery is key to assess the possible over-capacities in the present and the required investments in the future.



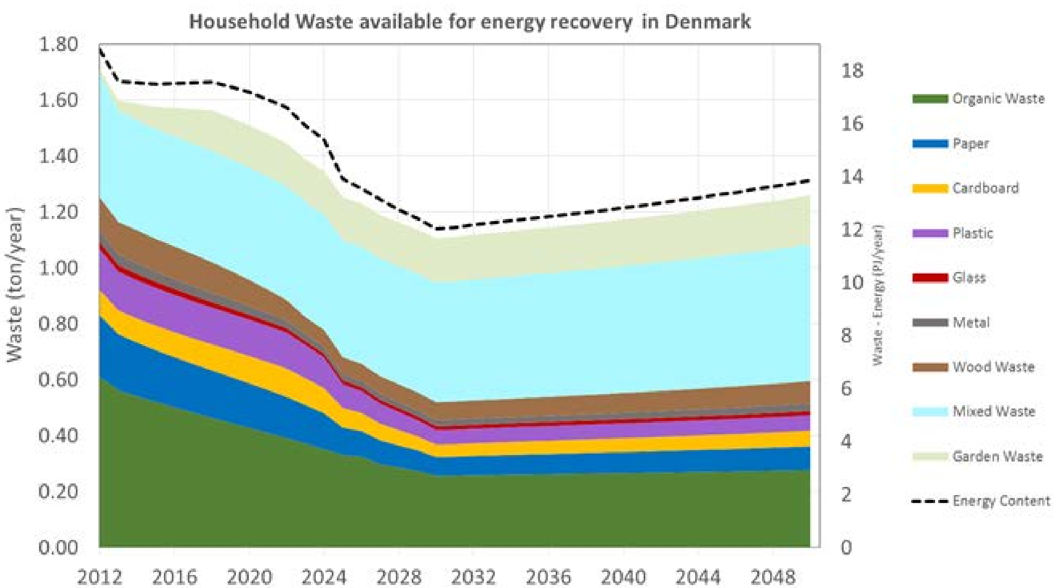


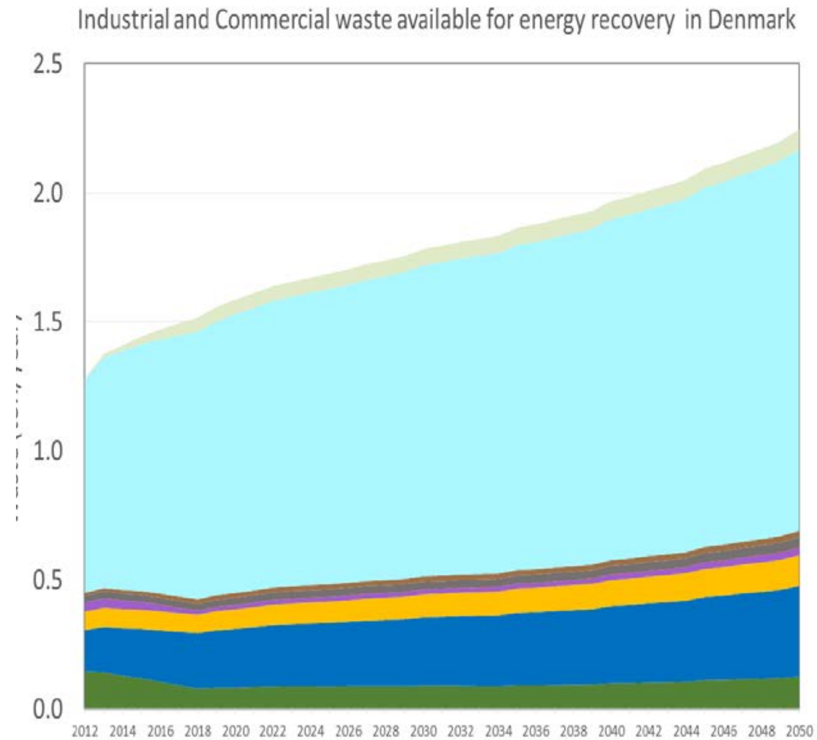
Waste for energy 2050

Govt. recycling target

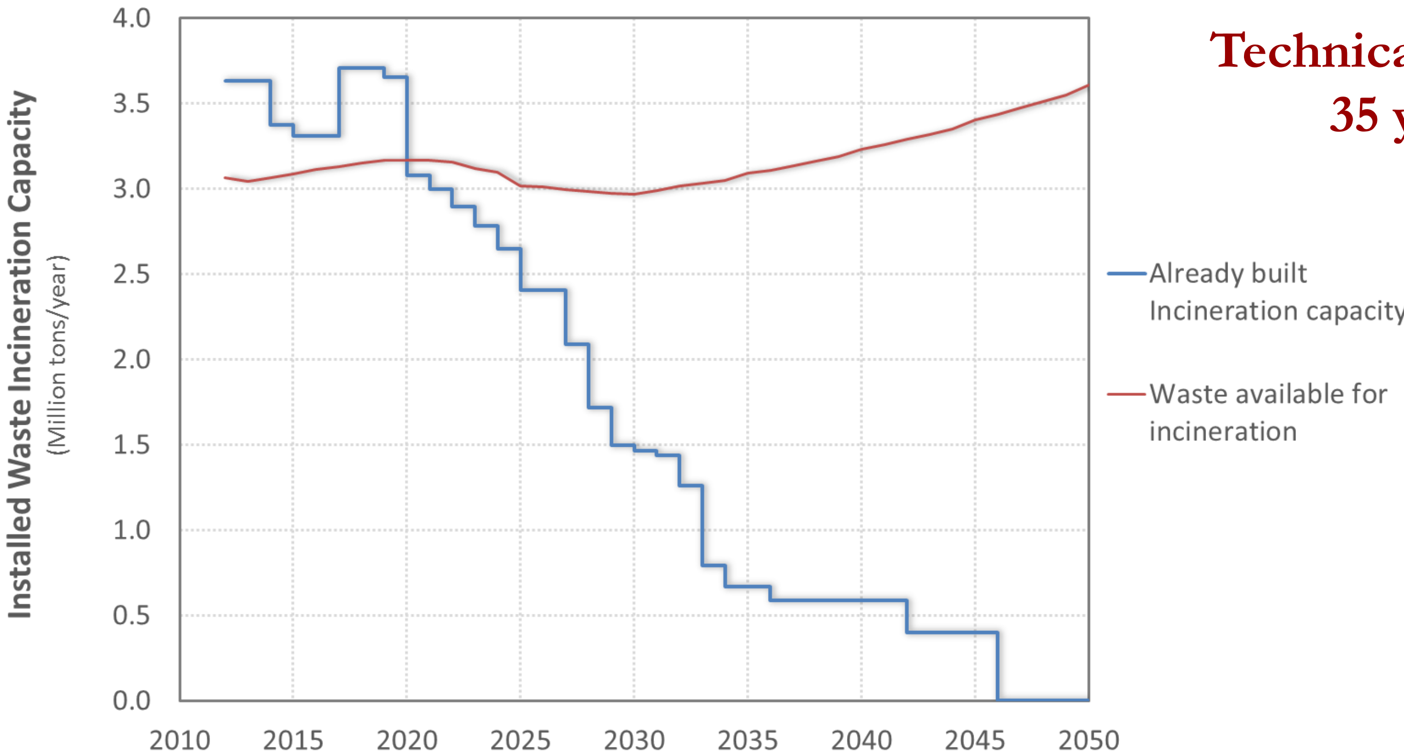
- 50% of household waste

- Separate targets e.g. 37% of OFMSW source segregated





Incineration Capacity vs. Available Waste



Technical lifetime: 35 years

Danish Energy Producers Account and BEATE database for waste incinerator plants.

Andersen, F. M., & Larsen, &. H. (2012). FRIDA: A model for the generation and handling of solid waste in Denmark. Resources, Conservation and Recycling, 65, 47–56.

Hill, A., Dal, O., & Andersen, F. (2014). Modelling Recycling Targets: Achieving a 50% recycling rate for household waste in Denmark. Journal of Environmental Protection, 5, 627-636.

European Commission (2015). Closing the loop – An EU action plan for the Circular Economy.

Conclusion

- More waste generation +
- More recycling (organics and plastic) =
- Waste with similar LHV - but most from industry

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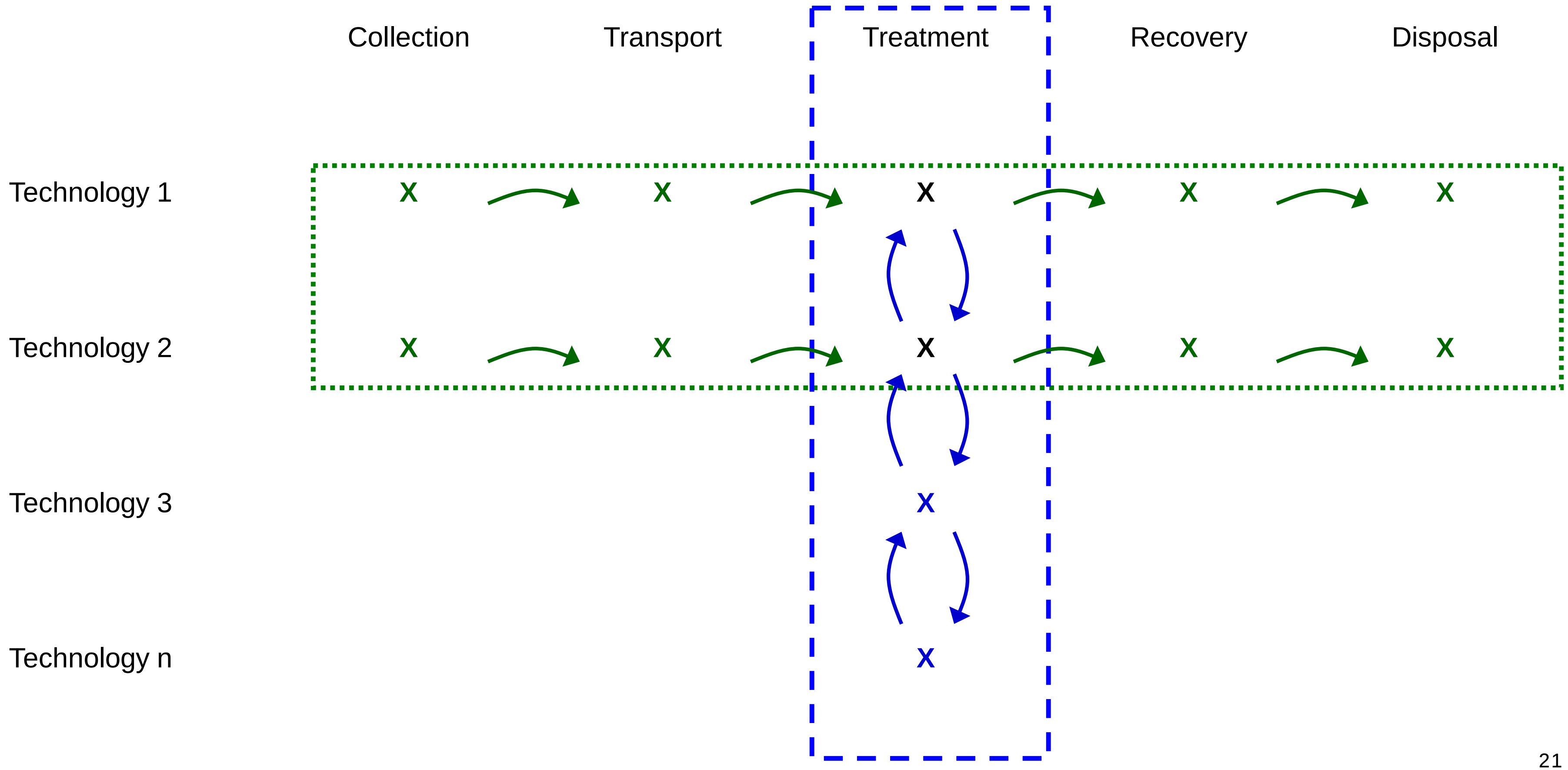
Energy System Analysis (ESA) and waste LCA



Foreground and background scenarios

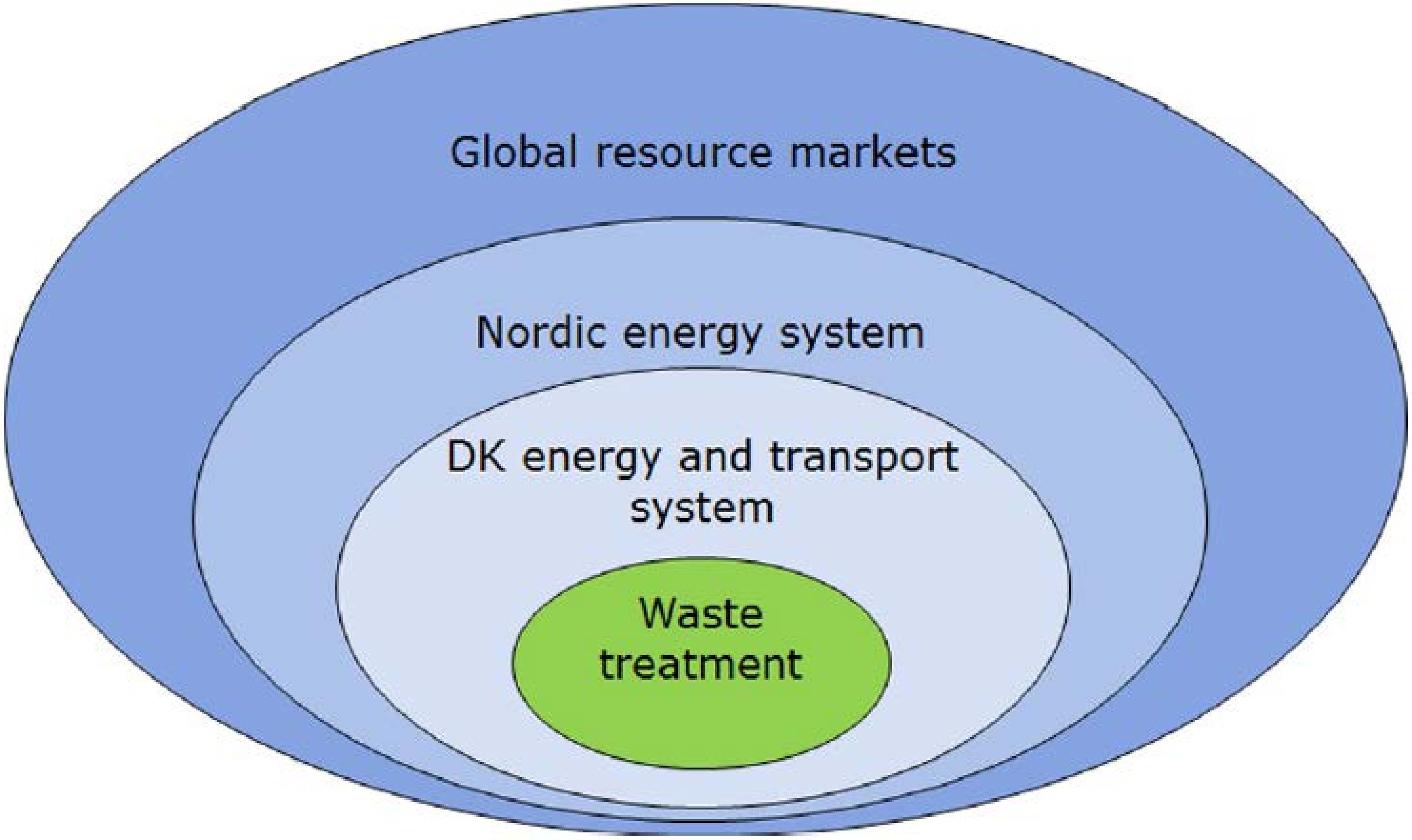
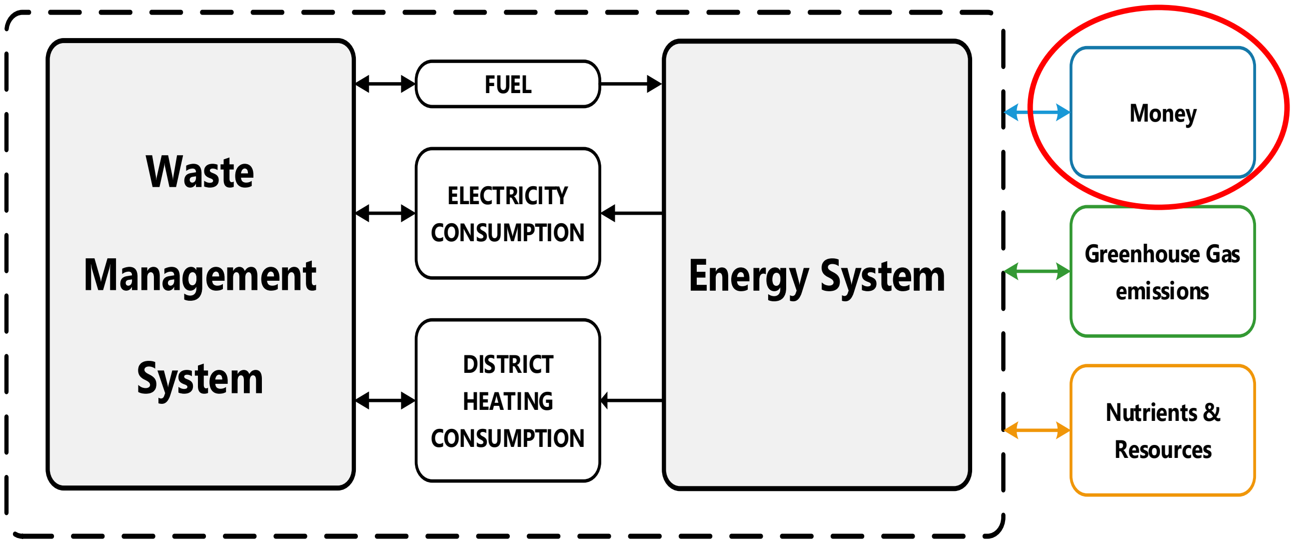


Fig. 2. Waste treatment and background systems.

Waste and energy system analysis



Models

Linear programming (GAMS)

Socio-economic cost optimisation (investments and operation)

Open source

Balmorel energy system model

- Nordic countries and Germany (Electricity regions and DH areas)
- Hourly time variations (demands and fluctuating production (e.g. wind))
- Input: Demands, production tech's, costs (fuel, tech's),
- Output: Investments and operation (production, storage, transmission)
- Output for OptiWaste: electricity prices (and mixed long term marginals)

OptiFlow waste management (WM) model

- Denmark (66 areas) (heat and waste transport)
- Hourly time variations (electricity prices) and weekly (waste and heat)
- Input: Waste amounts, WM tech's, costs & prices, transport distances
- Output: Investments and operation (production, storage, transport)

Waste treatment options (OptiFlow)

- Fixed source seggregation of organic waste for co-digestion
- Biogas for Ngas grid or CHP
- No import or export of waste allowed

Household waste

- Residual waste for MRF or incineration (CHP (L/M/S) or boiler)
- MRF => material recycling, RDF (CHP or boiler), dry AD + incineration
- Free movement within DK

Industrial waste

- Residual for RDF or incineration (CHPs or boilers)

Background data and results (Balmorel)

Future Scenarios

	DKWind Flex H2	**DKWind** Unflex H2	**DKBio+** Bioref DK	**DKBio+** Bioref -DK
SE, NO, FI (*CNBS*), DE (*Ref*)			2050 Bio	
SE, NO, FI (*CNES*), DE (*Ref*)	2050 Wind			
	Flexible H2 production	Unflexible H2 production	Biorefineries placed in DK	Biofuels imported

CNBS: Carbon Neutral Biomass Scenario

CNES: Carbon Neutral Electricity Scenario

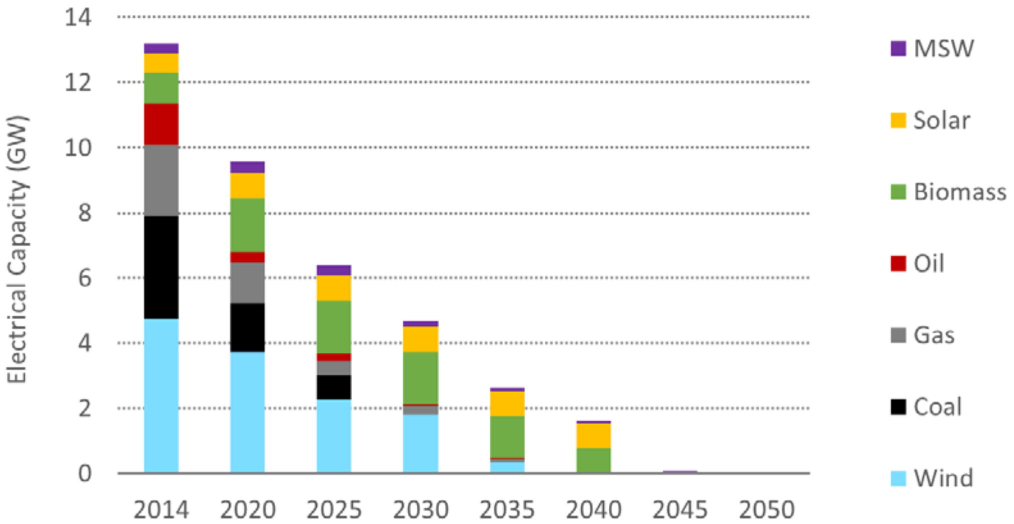
http://www.iea.org/etp/nordic/

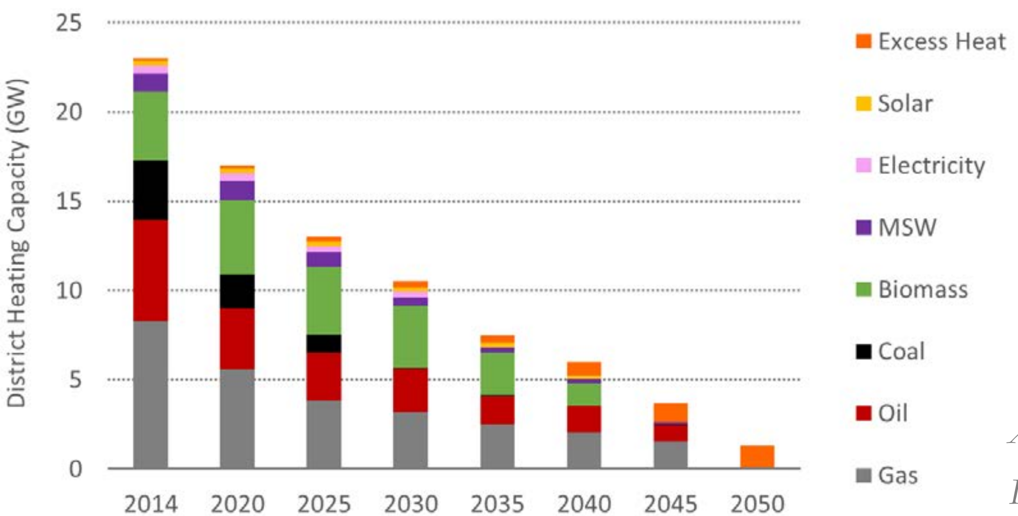
DKWind: Danish Wind Scenario

DKBio+: Danish Biomass + Scenario

http://www.ens.dk/politik/dansk-klima-energipolitik/regeringens-klima-energipolitik/scenarieanalyse

Installed and planned capacity



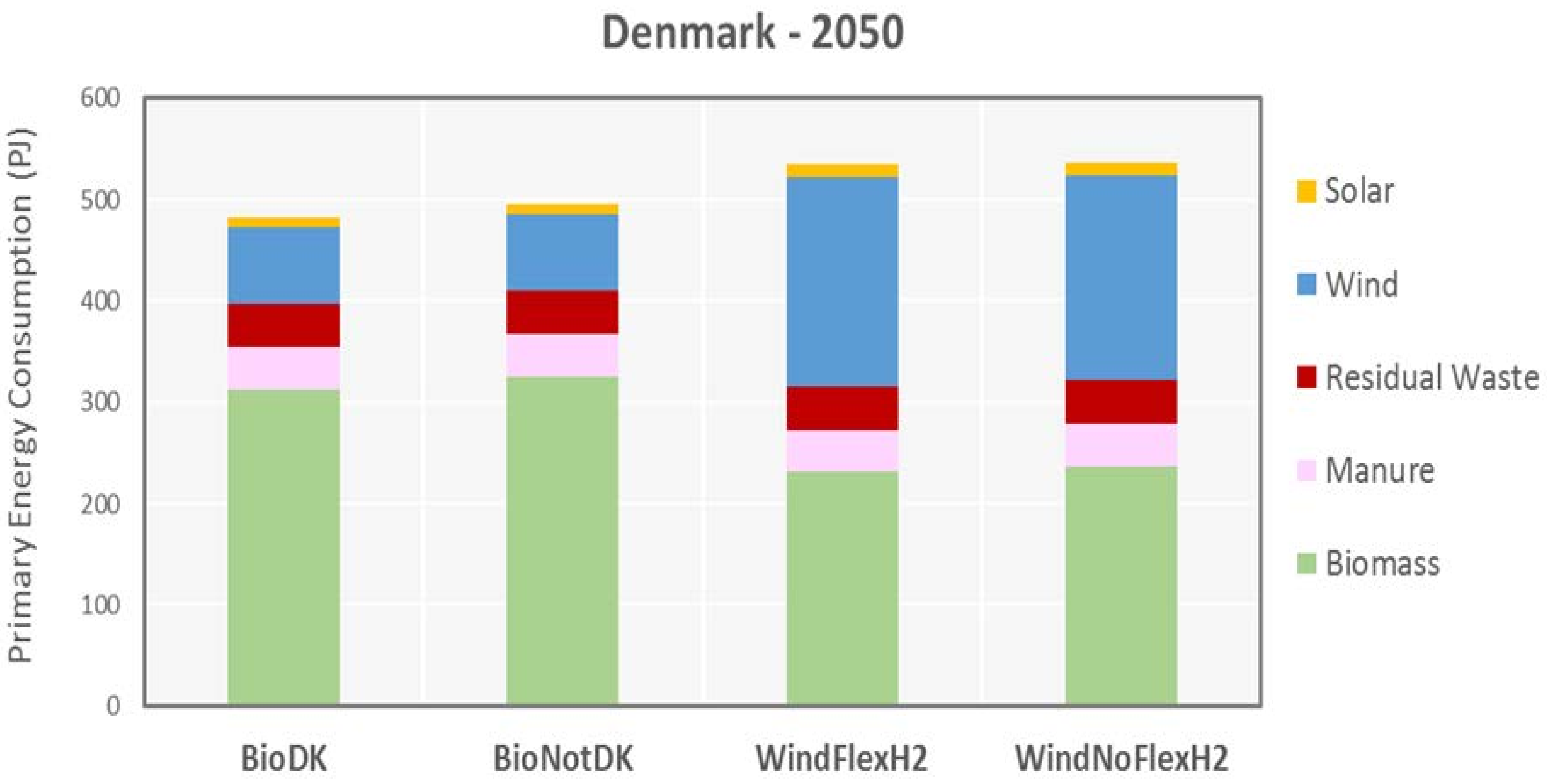


Adapted from:

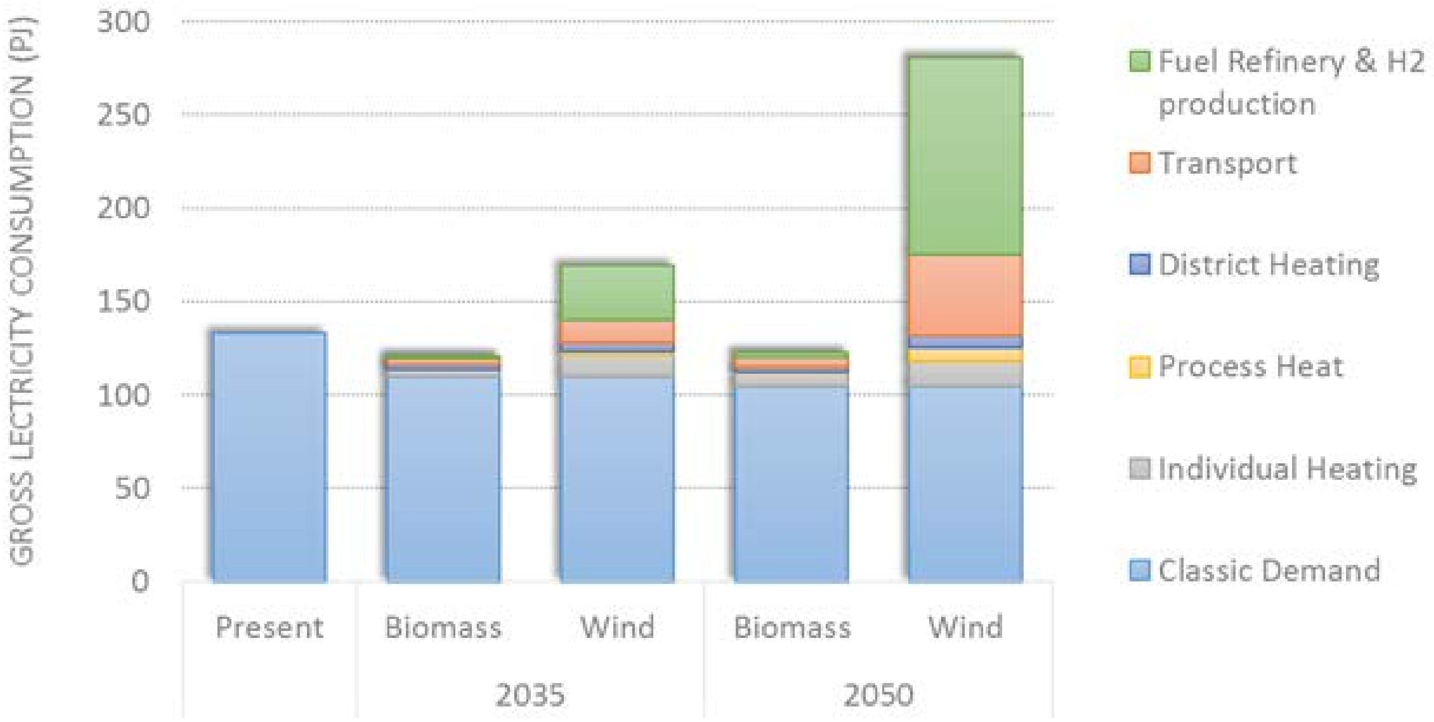
Danish Energy Producers Account 2014.

Energinet.dk (2016). Technology Data for Energy Plants.

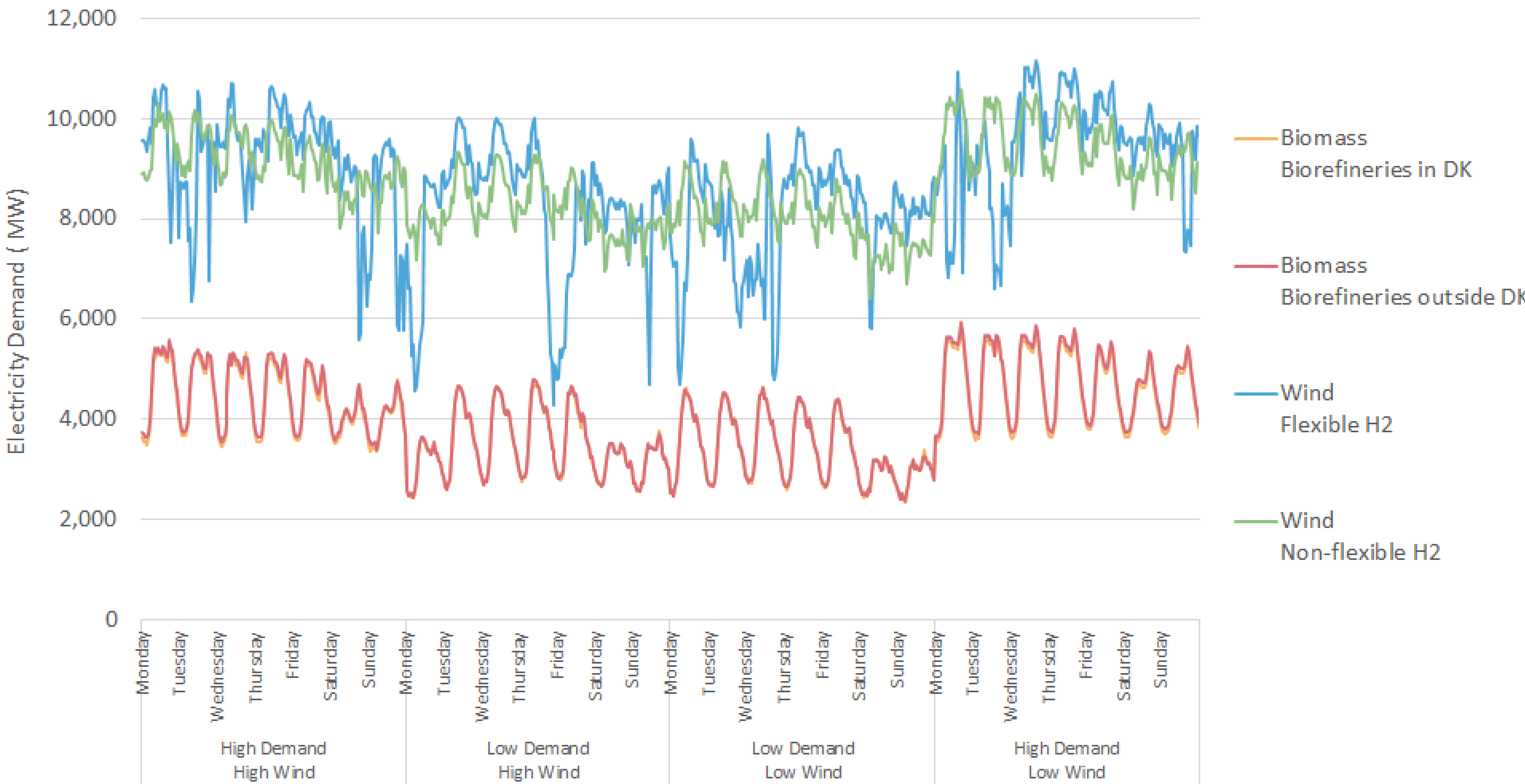
Primary energy consumption



Electricity demand



Electricity demand - cumulative



Electricity and heat prices

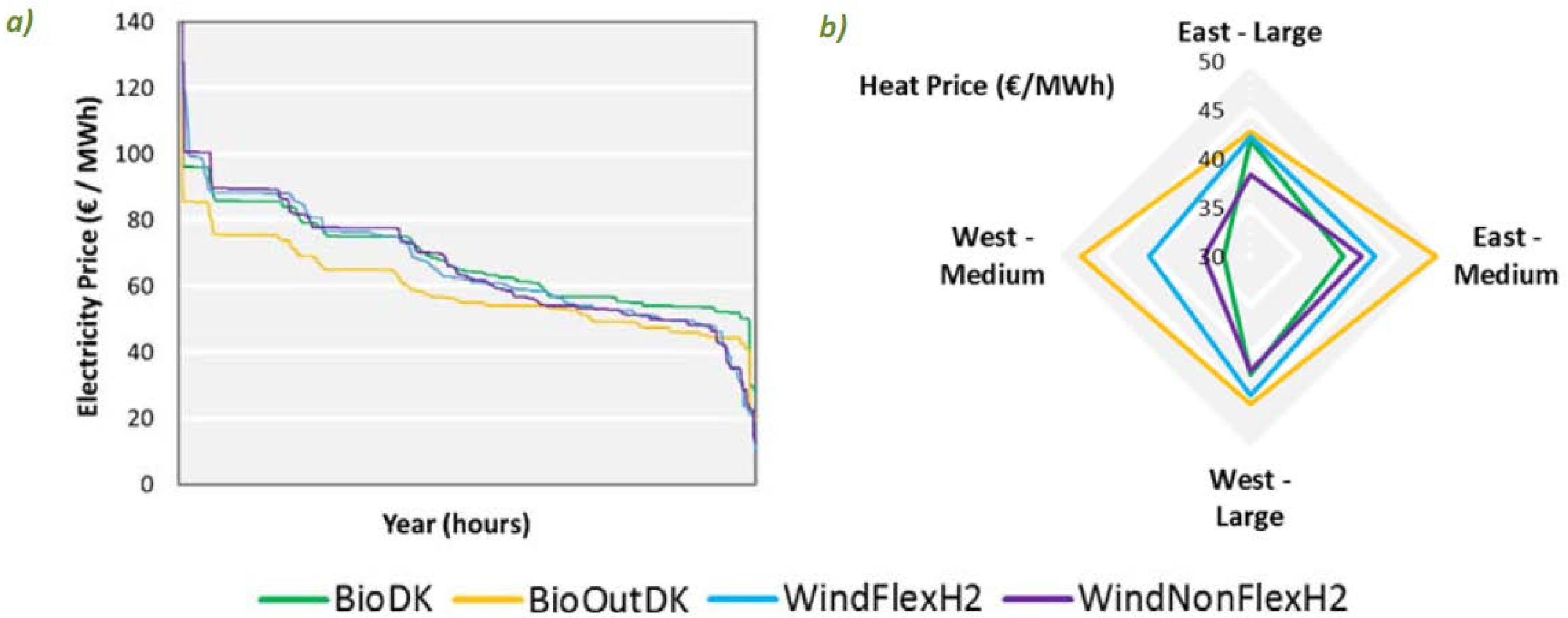
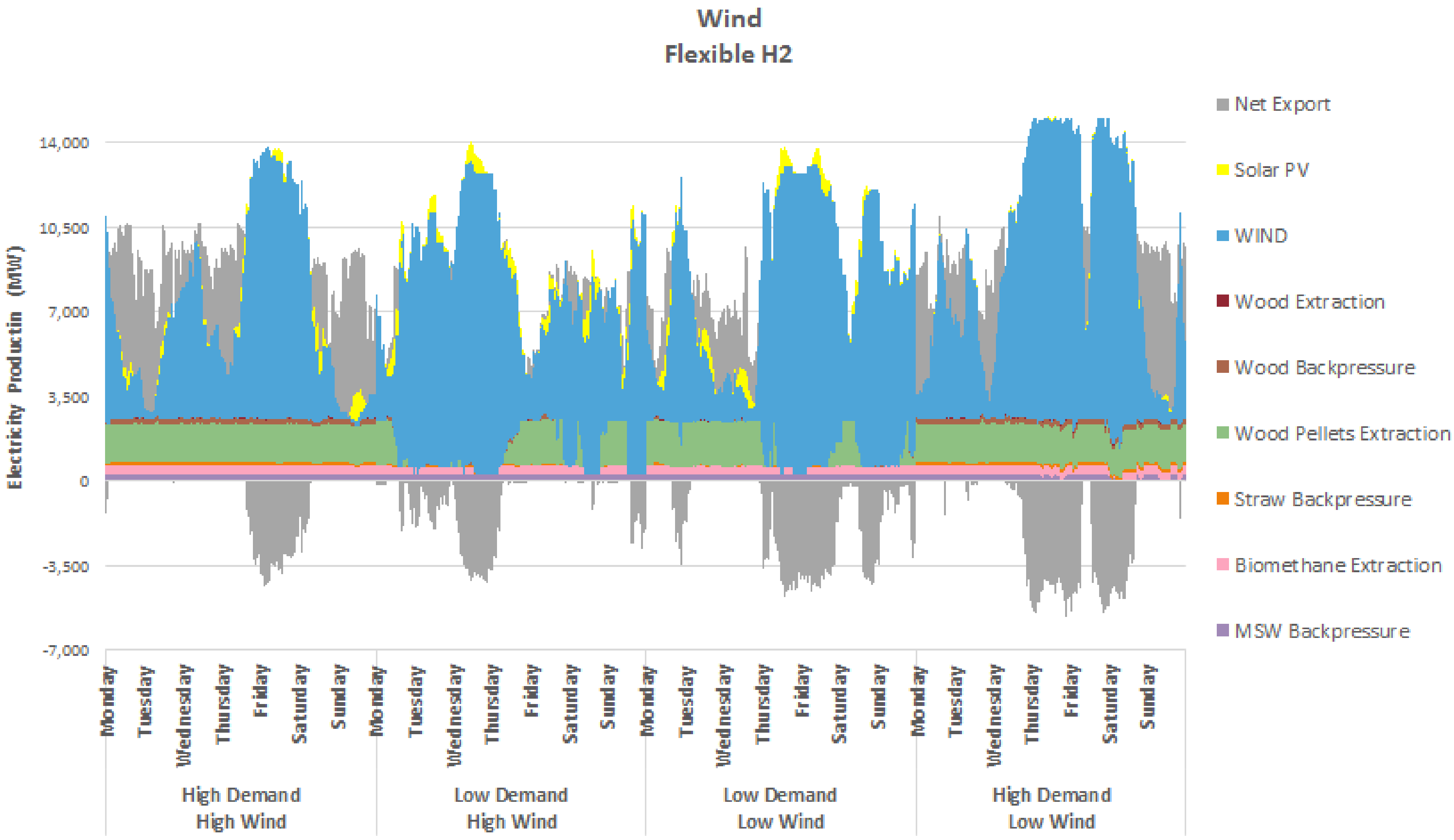


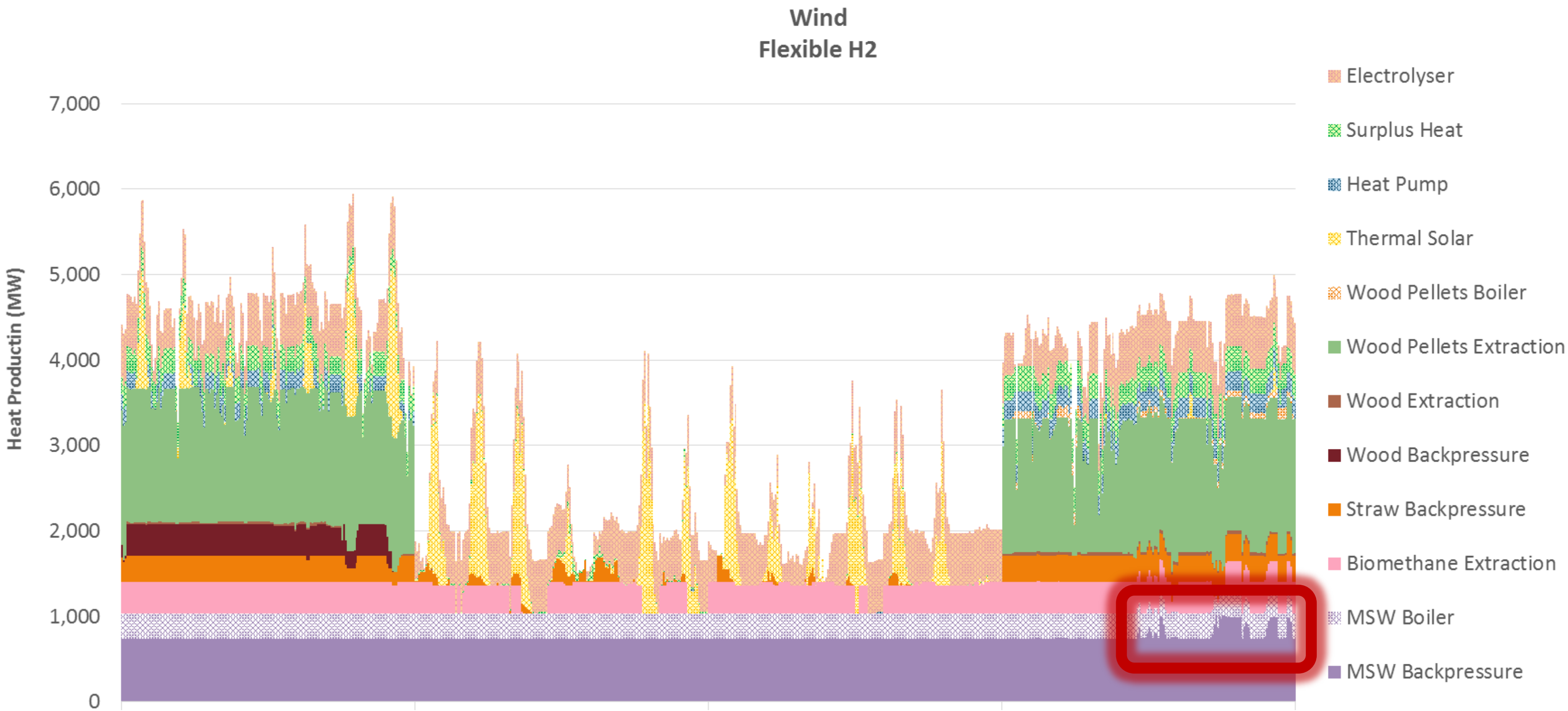
Figure 3.4. 2050 Energy scenarios: a) Power Price duration curve b) Average District Heating price during winter time in large and medium District Heating networks, where incineration plants are mainly located

Electricity production



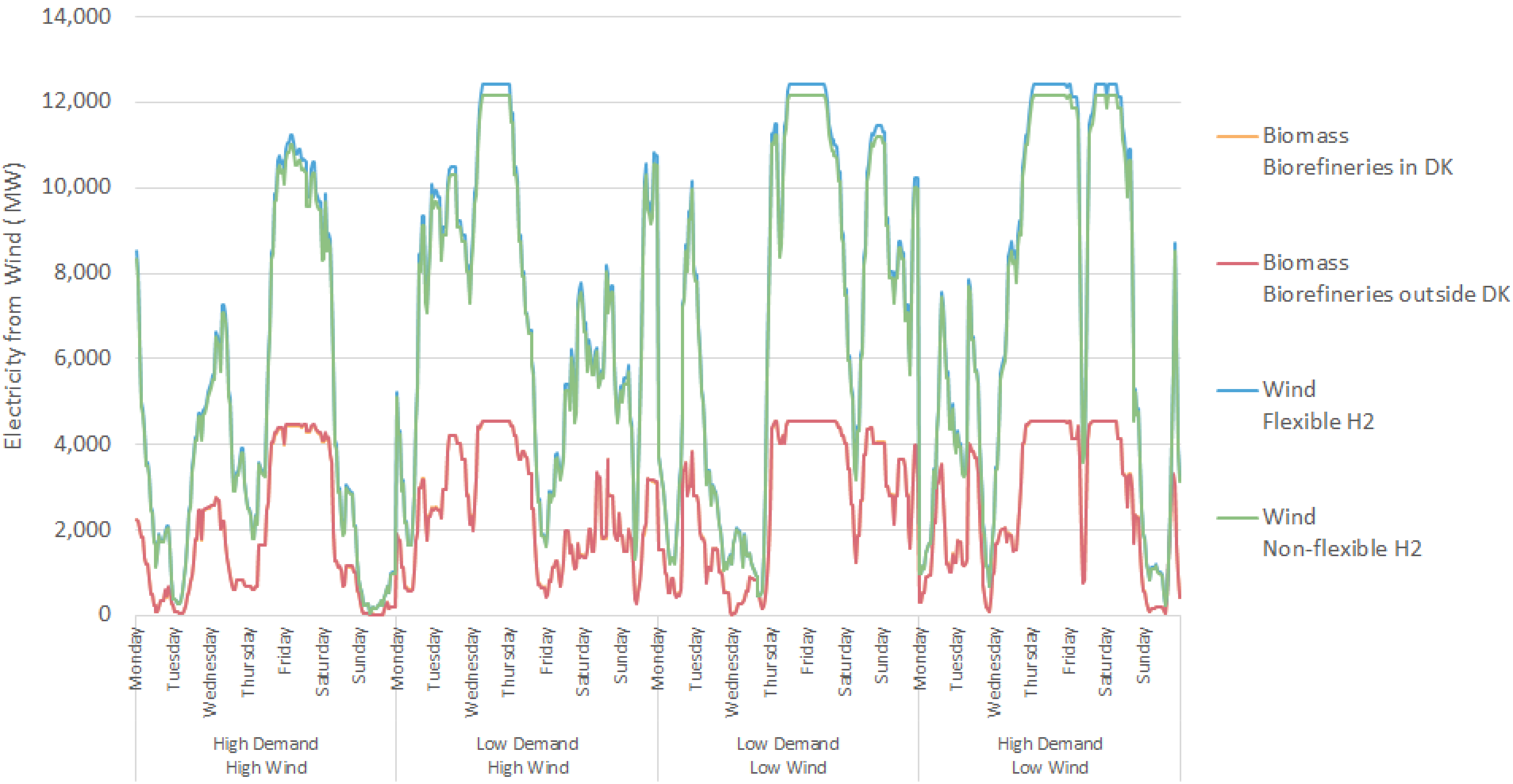
Introduction of by-pass

Heat Production in Denmark



Periods with low electricity prices and high DH demand

Electricity from wind

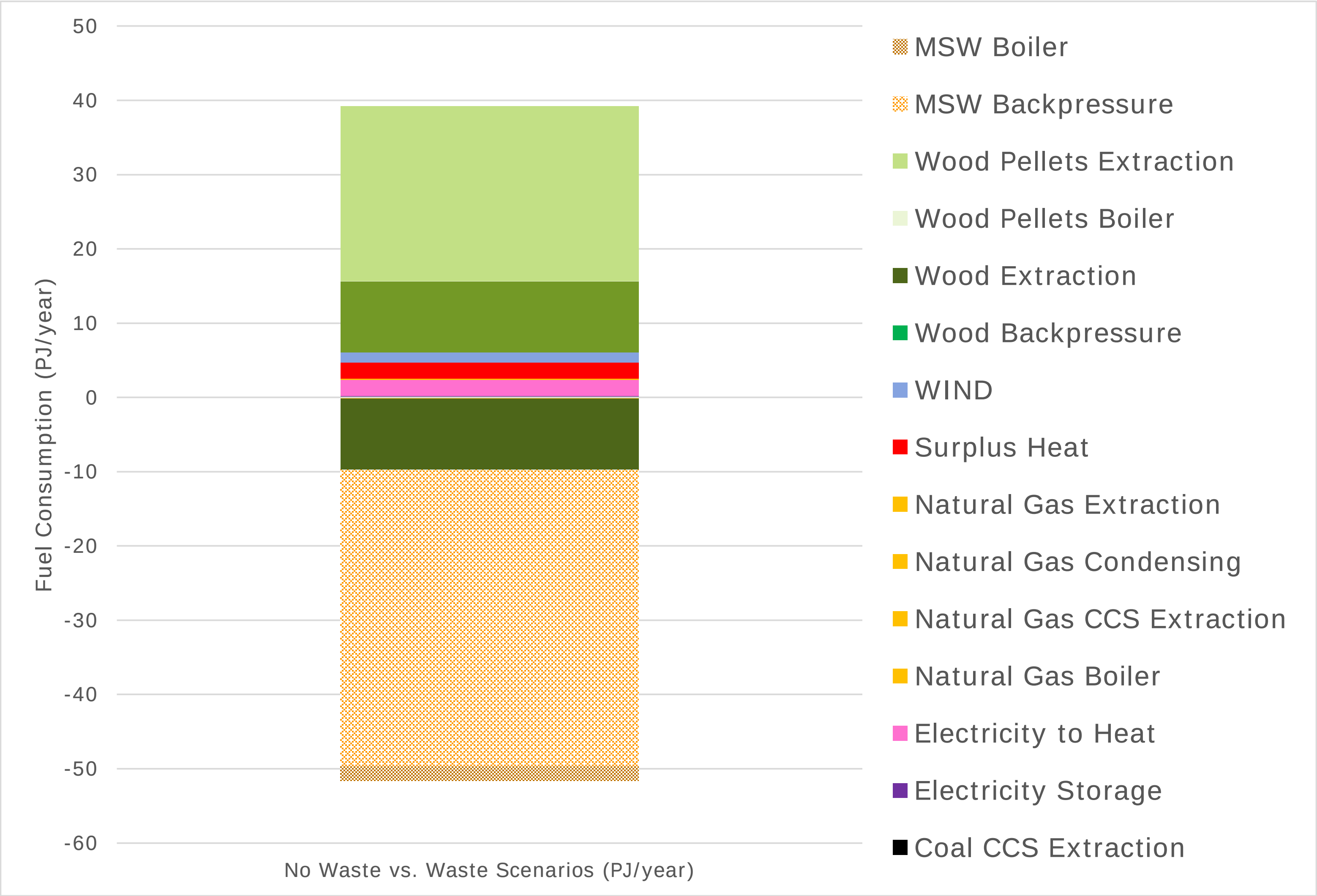


Heat price € 2012/MWh in winter time 2050

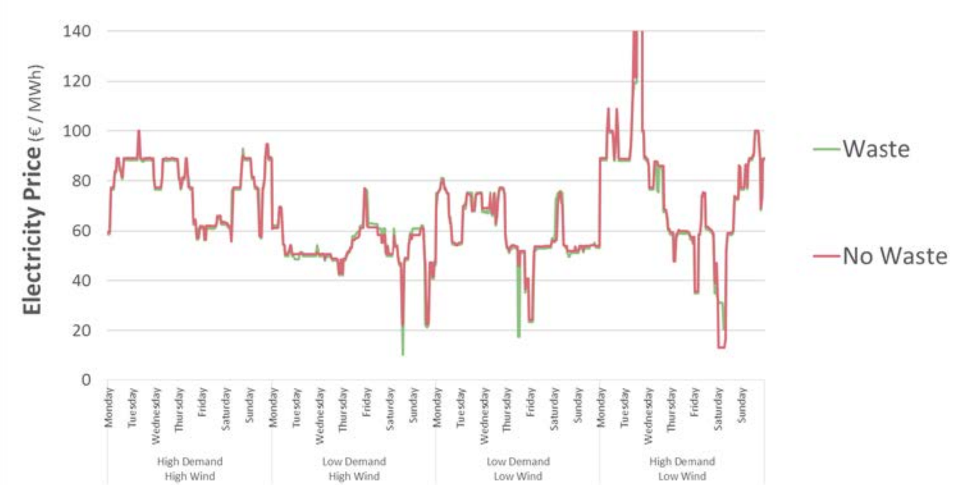
	Biomass Biorefineries in DK	Biomass Biorefineries outside DK	Wind Flexible H_2	Wind Non-flexible H_2
East - Large	37	47	42	38
East - Medium	38	43	43	41
East - MedSmall	47	45	35	33
East - Small	48	45	40	38
East - Rural	49	48	48	48
West - Large	39	49	44	42
West - Medium	29	40	40	35
West - MedSmall	48	46	42	42
West - Small	48	45	45	45
West - Rural	49	49	37	41

Foreground data and results (OptiWaste)

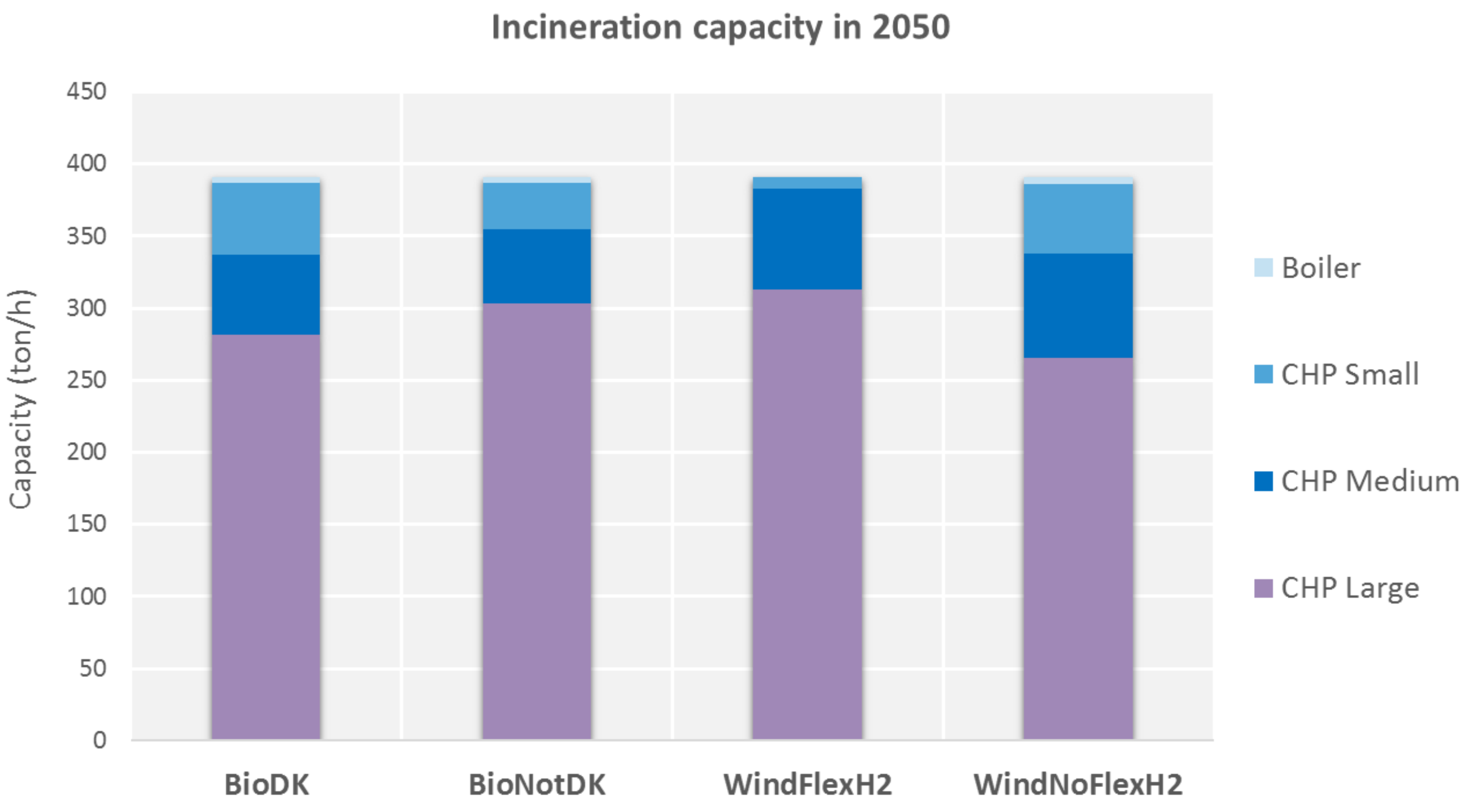
No waste for energy in 2050?



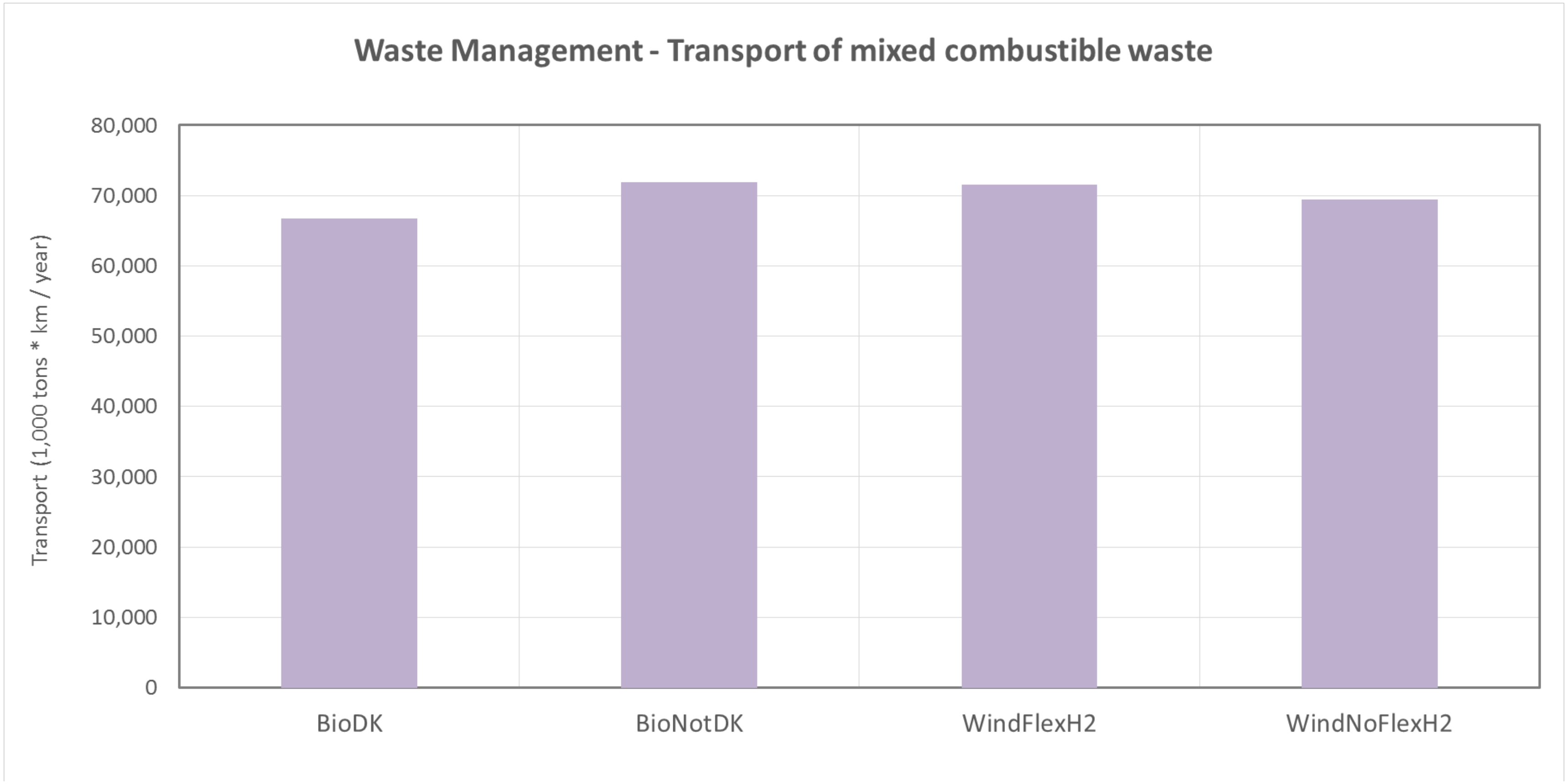
No waste for energy in 2050?



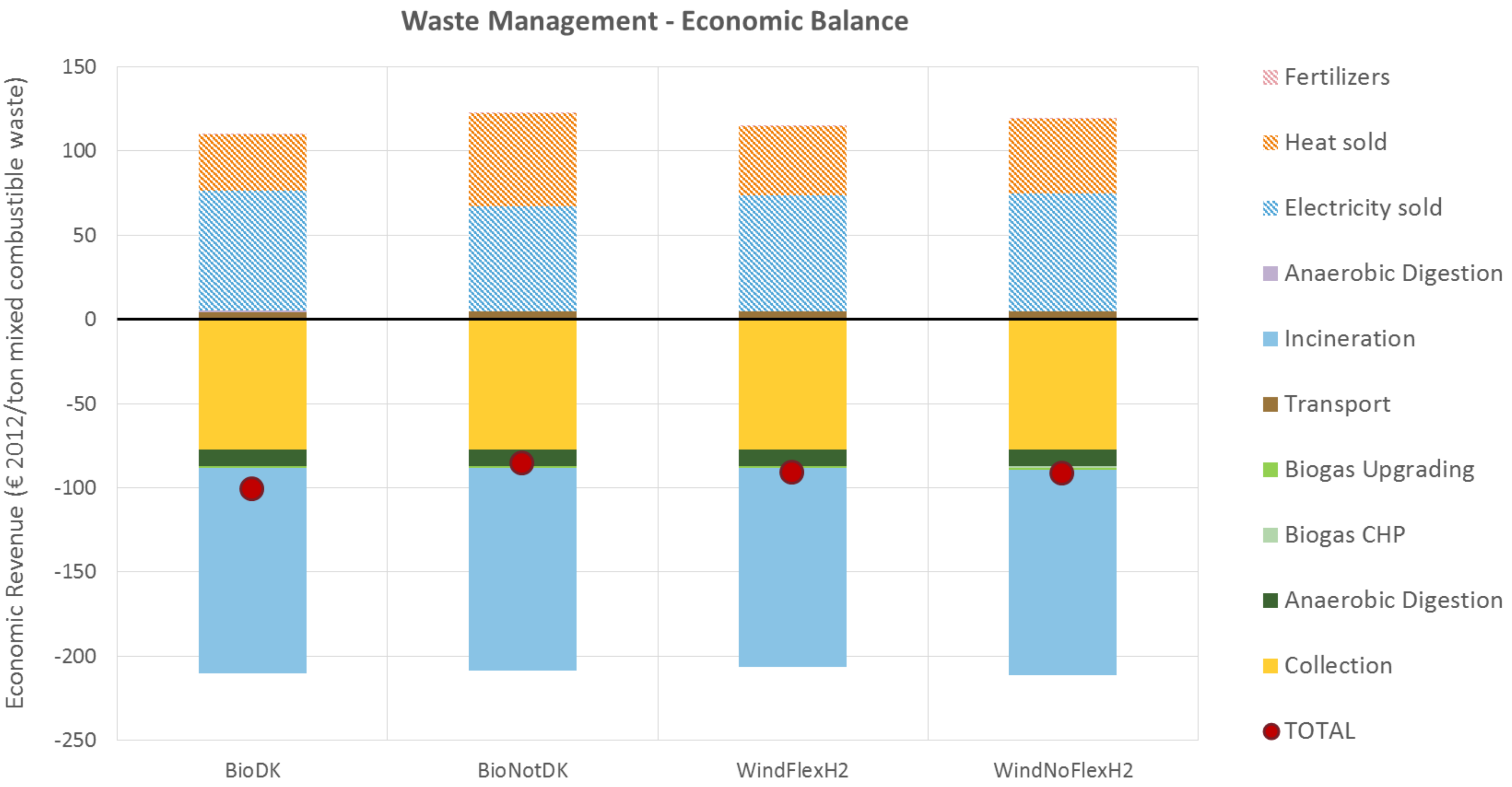
WtE capacity



Transport (kt*km / year)

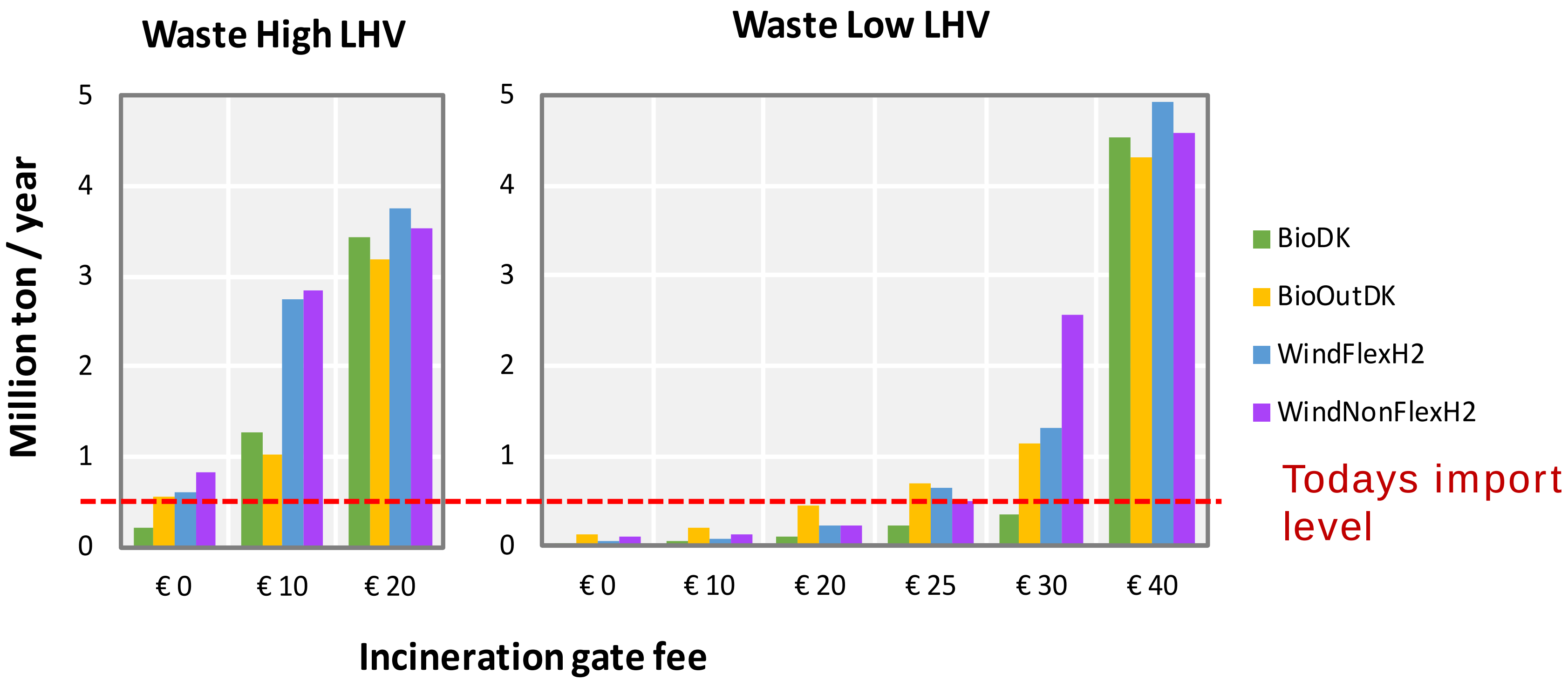


Costs EUR / t



Waste Management - Economic Balance
Economic Revenue (€ 2012/ton mixed combustible waste)
150
100
50
0
-50
-100
-150
-200
-250
BioDK
BioNotDK
WindFlexH2
WindNoFlexH2
Fertilizers
Heat sold
Electricity sold
Anaerobic Digestion
Incineration
Transport
Biogas Upgrading
Biogas CHP
Anaerobic Digestion
Collection
TOTAL

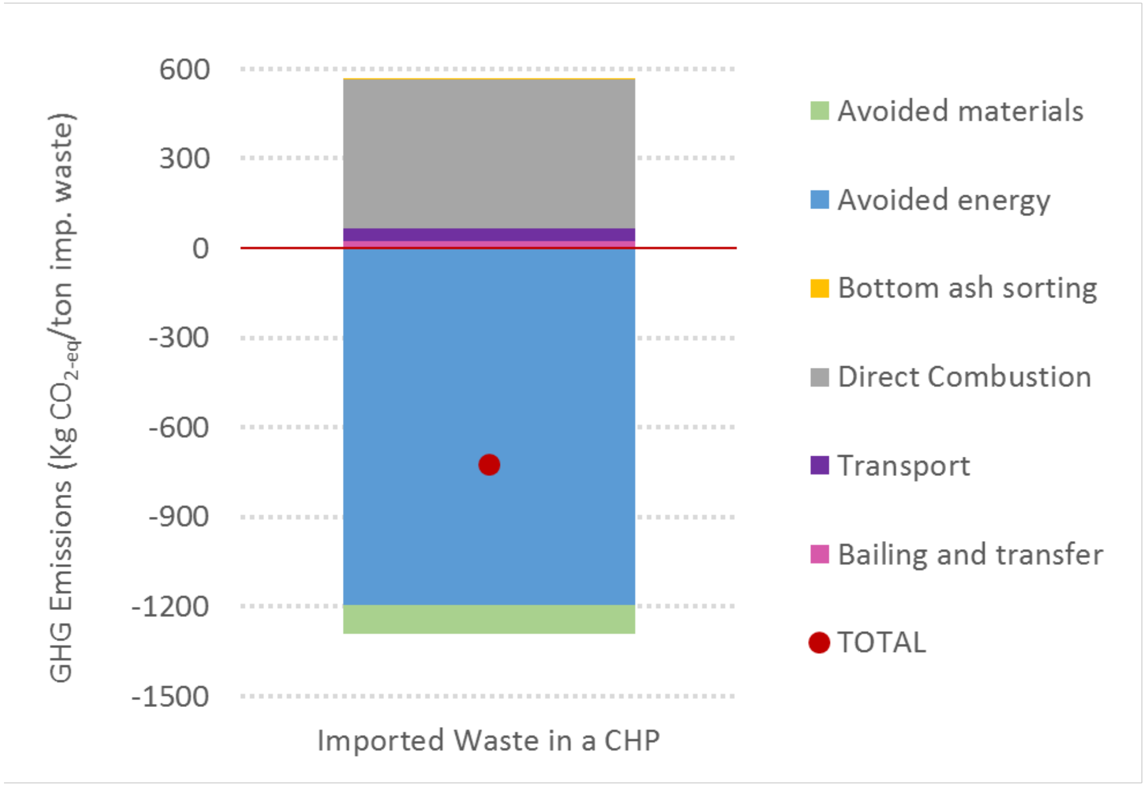
Results - Feasibility of planned incineration over-capacity (2050) due to import



The possibility to import may break potential incineration lock-in and promote recycling in some areas

Import may be economically feasible without taxes and subsidies - but whether it is environmentally feasible depends on the alternative future treatment

GHG emission from import of waste



Cimpan, C., Rothmann, M., Hamelin, L. & Wenzel, H. 2015. ***Towards increased recycling of household waste: Documenting cascading effects and material efficiency of commingled recyclables and biowaste collection***. Journal of Environmental Management 157, 69-83

Modelling conclusion

- Waste heat from biofuel production may play an important role in the future
- The main use of waste is always in large scale CHP plants
- It is more feasible to have small and medium scale incineration in the BioDK and WindNoFlexH2
- When transportation costs are included, more small scale incineration plants become feasible
- Decreased costs of MRF+RDF plants or increased prices for recyclables (as well as decreased source seggregation) may increase central sorting and use of RDF
- Very high imports at high gate fees (even without use of heat)
- Import may be economically feasible without taxes and subsidies - but whether it is environmentally feasible depends on the alternative future treatment

Overall conclusion

- There is residual waste left after recycling. It is better to use this for energy than disposal.
- Recycling and use of waste for energy may compliment each other to reduce resource consumption
- Proper planning/regulation is needed

- Adequate waste forecasting tools are important: how much waste will be available? Of which type?
- Establish ambitious long-term recycling targets, so that the available waste for energy can be known beforehand.
- In case of overcapacity: economy of scale of energy plants might lead to less recycling.

Possibilities in EU?

1. **Waste minimization!!**
2. **Recycling!** (Source segregation and MRF's)
3. Biogas and fertilizer from source segregated organic fraction e.g. co-digested with manure
4. Waste incineration combined with biogas production (central sorted organic fraction and waste water)
5. Incineration located at industrial areas and district heating grids (Maybe with import/export)
6. Efficient landfill gas collection and utilisation

- In the long term: thermal gasification and biofuel production?

Waste management policies

Goal

- promoting the waste hierarchy and efficient resource management - also across borders

Measures

- Bans (e.g. on disposal of organic waste or incineration of recyclables)
- Taxes/ gate fees
  - ensuring that disposal is more expensive than incineration
  - and incineration is more expensive the lower the energy recovery
  - ensuring competition on energy recovery efficiency - not on gate fees
  - (transport costs will automatically ensure local utilisation if available)
- Support mechanisms
  - Ensuring cheap loans (recycling plants and industries, efficient WtE plants, district heating networks)
- Enabling framework
  - Promoting recycling markets within EU (standards, qualities, sustainability indicators)

Thank you for your attention!