Modelling CCS, Nuclear Fusion, and large-scale District Heating in EFDA-TIMES and TIAM

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Risø DTU
National Laboratory for Sustainable Energy

Fusion in the energy systems – starting point

- Unit size 1.5 GW, similar to fission units or 2-3 large coal units
- Very large base-load units
- Steam parameters 600-800 ºC, similar to advanced coal or combined cycle gas turbines
- Suitable for large-scale combined heat and power (CHP) for urban district heating
- Suitable for catalytic hydrogen generation
- Available from 2050 onwards

Fusion Energy – an abundant energy source for the future/Fusion in the energy system, Søren B. Korsholm/Poul Erik Grohnheit. European Environment Agency, Copenhagen, 10 November 2009.

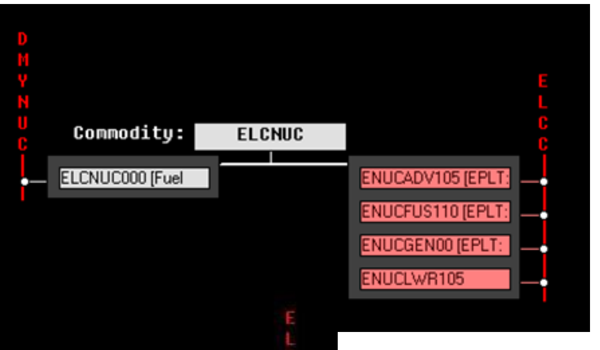
Socio-Economic Research on Fusion (SERF) under the EFDA – European Fusion Development Agreement

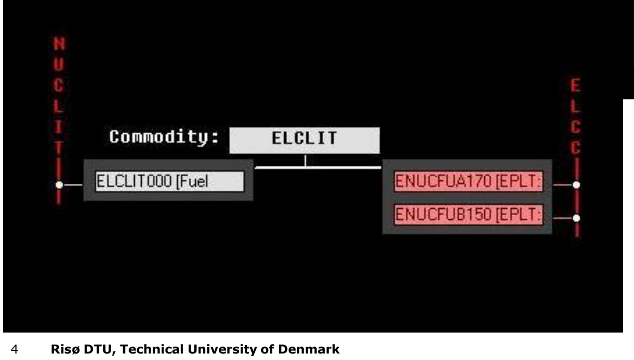
Modelling the infrastructure development for heat recovery from CCS and fusion

- The most critical parameter for CCS is the loss of thermal efficiency during carbon capture.
- CCS can be a driver for the development and expansion of large-scale district heating systems, which are currently widespread in Europe, Korea and China, and with large potentials in North America.
- If fusion will replace CCS in the second half of the century, the same infrastructure for heat distribution can be used.
- This may support the penetration of both technologies.
- EFDA-TIMES and TIAM consider trade among regions, but not the infrastructure development within each region in the optimisation.
- This issue must be modelled using very aggregated technologies and parameters

Fusion in EFDA-TIMES and TIAM

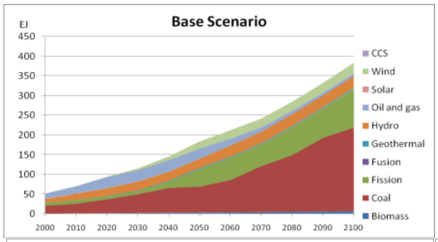
TIAM 2009:
Nuclear fuel input (uranium), but investment costs are prohibitive compared to fission.

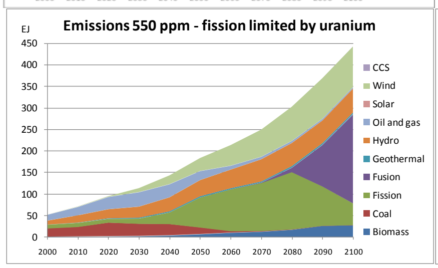


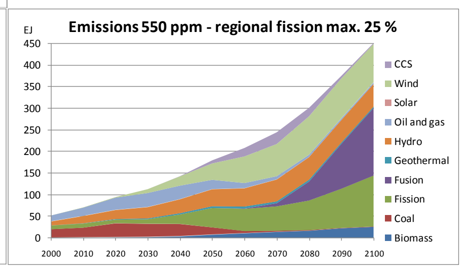


EFDA-TIMES:
Lithium is the fuel input for fusion.

Sensitivity Analyses of Biomass and CCS in EFDA-TIMES







- ETSAP workshop Stockholm, June 2010:
  Fission limited only by uranium resources.
- Additional arbitrary constraint: Max 25% nuclear fission in all regions.
- CCS appears in the mid-21 Century, when nuclear fission is constrained

EFDA-TIMES 2010: Subtask 2.2.1 Scenarios focusing on CCS technologies

The experience from the previous studies with EFDA-TIMES show that constraints on nuclear fission are essential. Otherwise, nuclear fission will dominate the market.

Regional specific constraints on nuclear fission to be addressed in Activity 3:

- Back end of the nuclear fuel cycle: Intermediate storage, reprocessing, new reactor technology, permanent storage.
- Public acceptance/security of supply
- Posssibly binding front-end constraints, e.g. uranium resources.

Other issues:

- Sensitivity analysis on carbon capture: Costs and efficiencies
- Sensitivity analysis on regional CO2 storage capacities (GeoCapacity estimates for Europe)
- CCS as a driver for large-scale district heating systems in temperate zones
- Modelling of urban heat distribution infrastructure
- Aggregate parameters for costs and efficiencies of networks
- Sensitivity analysis on impact of intermittent generation (Activity 4)

Efficiencies for new large gas and coal fired power plants and the same technologies with CCS

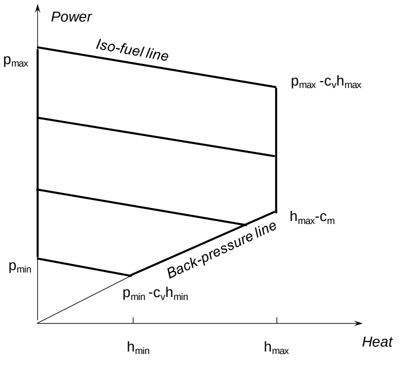
		2010	2020	2030	2040
Reference plants	NGCC	58.0	60.0	63.0	64.0
	PC	46.0	50.0	52.0	52.0
	IGCC	46.0	50.0	54.0	56.0
Post combustion, capture rate 85 %	NGCC	49.0	52.0	56.0	58.0
	PC	36.0	42.5	45.0	46.0
Pre combustion, capture rate 85 %	IGCC	38.0	44.0	48.0	50.0
Oxyfuelling plants, capture rate 94 %	NGCC	48.1	50.1	51.6	52.1
	PC	38.0	40.5	43.0	44.0

EFDA-TIMES and TIAM model development:
1. Aggregated infrastructure for heat recovery
2. Technology-specific topology and parameters

Source: "Analysis of potentials and costs of storage of CO_2 in the Utsira aquifer in the North Sea - StorageUtsira" - EU FENCO-ERANET project, 2009-2010.

CHP as a virtual heat pump

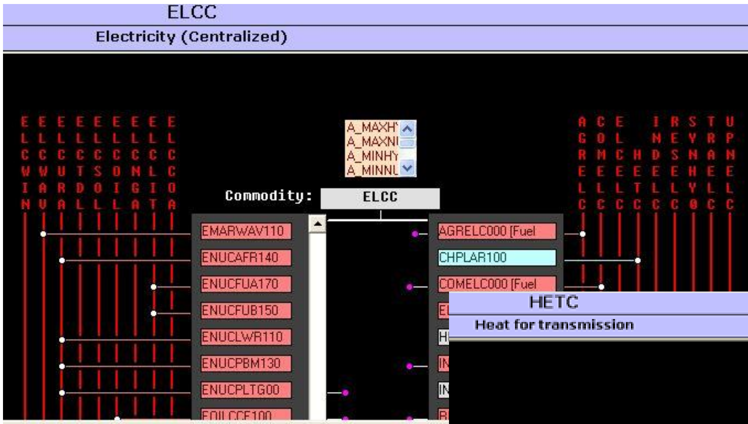
Production of electricity and heat in extraction-condensing units.



Technology	Power -loss-ratio	Effi-ciency factor
Electricity driven heat pump	n.a	3
Nuclear CHP	0.25	4
Coal/gas CHP; Fission Gen. IV and Fusion.	0.15	7
Low-temperature DH	n.a.	10
Conservative average for heat transmission	n.a.	5
CCS with heat recovery	n.a.	n.a.

Acknowledgement: William Orchard, 11th IAEE European Conference, Vilnius, September 2010.

Aggregate technologies for large-scale CHP and heat transmission/distribution I



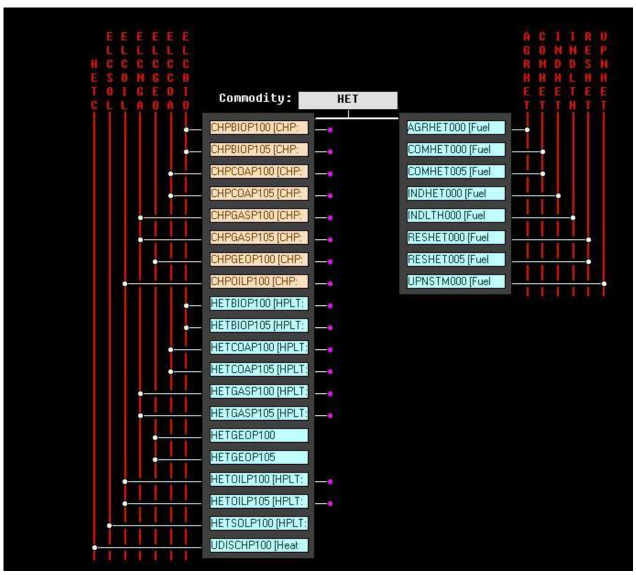
New Processes
Large CHP/"virtual heat pump"
Heat transmission
New commodity
HETC

Aggregate technologies for large-scale CHP and heat transmission/distribution II

HETC (new) Heat supply from large CHP to urban grids. Regional constraints depending on climate and heat market in Base scenario.

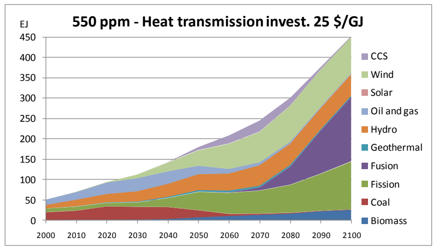
HET (current) All heat – from rooftop solar panels to institutional distribution network and small district heating grids.

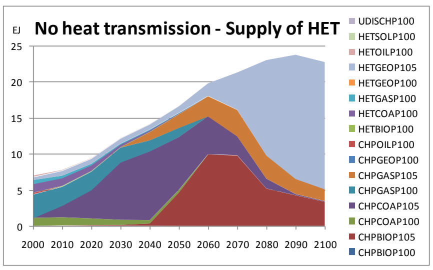
Next step: Adding intermediate heat network(s),

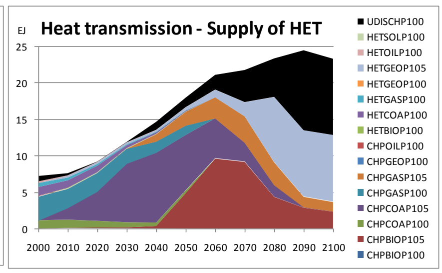


Adding large scale heat transmission infrastructure – some results

- The global market for electricity in 2090 is 376 EJ; fusion is 2 EJ larger in 2090 when heat transmission is available, but the pattern of the global electricity supply is unchanged.
- The total market for heat is 24 EJ in 2090; heat transmission will mainly replace geothermal heat.







Risø International Conference, May 2011

Submitted paper
Long-term modelling of Carbon Capture and Storage, Nuclear Fusion, and large-scale District Heating

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Main characteristics of fusion:

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  Similar to fission units or 2-3 large coal units, i.e. Very large base-load units
- Steam parameters 600-800 ºC.
  Similar to advanced coal or combined cycle gas turbines. Suitable for large-scale combined heat and power (CHP) for urban district heating. Suitable for catalytic hydrogen generation
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CCS properties:

- Economies of scale
- Infrastructure requirements
- Efficiency loss in electricity generation, which may be recovered for heat distribution
- Important before 2050

Heat infrastructure in TIMES – next steps

- Further parameter studies focusing on the new topology elements
- Make fusion effective in TIAM – and add the infrastructure topology
- Test of the full supply chain for all end-use heat technologies – comparing EFDA-TIMES and TIAM
- More detailed representation of heat and electricity infrastructure
- Infrastructure (network and storages) for intermittent electricity generation
- Better representation of CCS and the heat infrastructure in the Pan European model