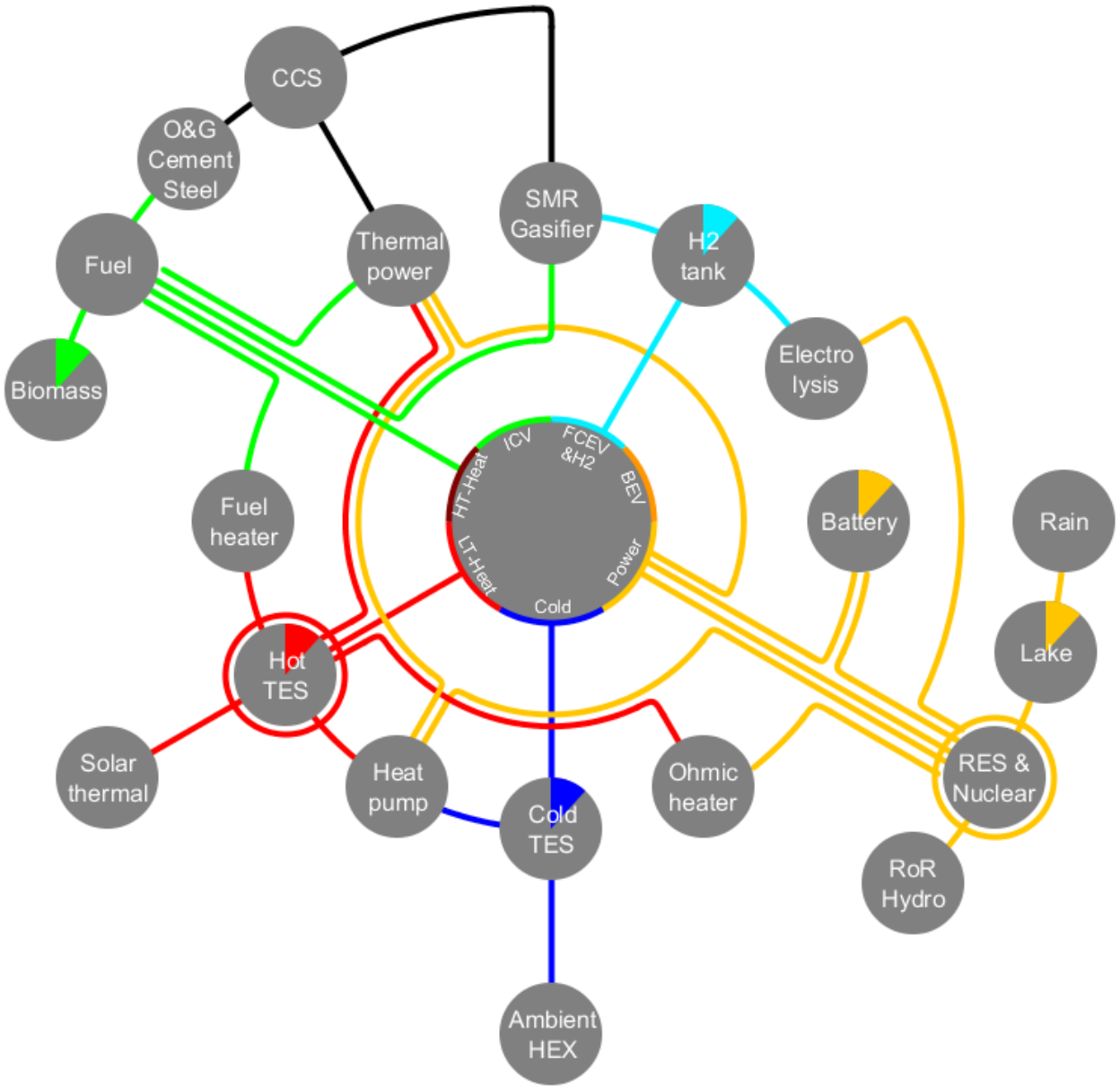
Delivering the Paris Agreement?

Modelling least cost pathways to European energy and climate objectives

European Zero Emission Technology and Innovation Platform

The ZEP Market Economics energy system model



Holistic model including:

- Energy Sources
- Conversion
- Utilisation
- Energy Storage
- CO_2 Storage

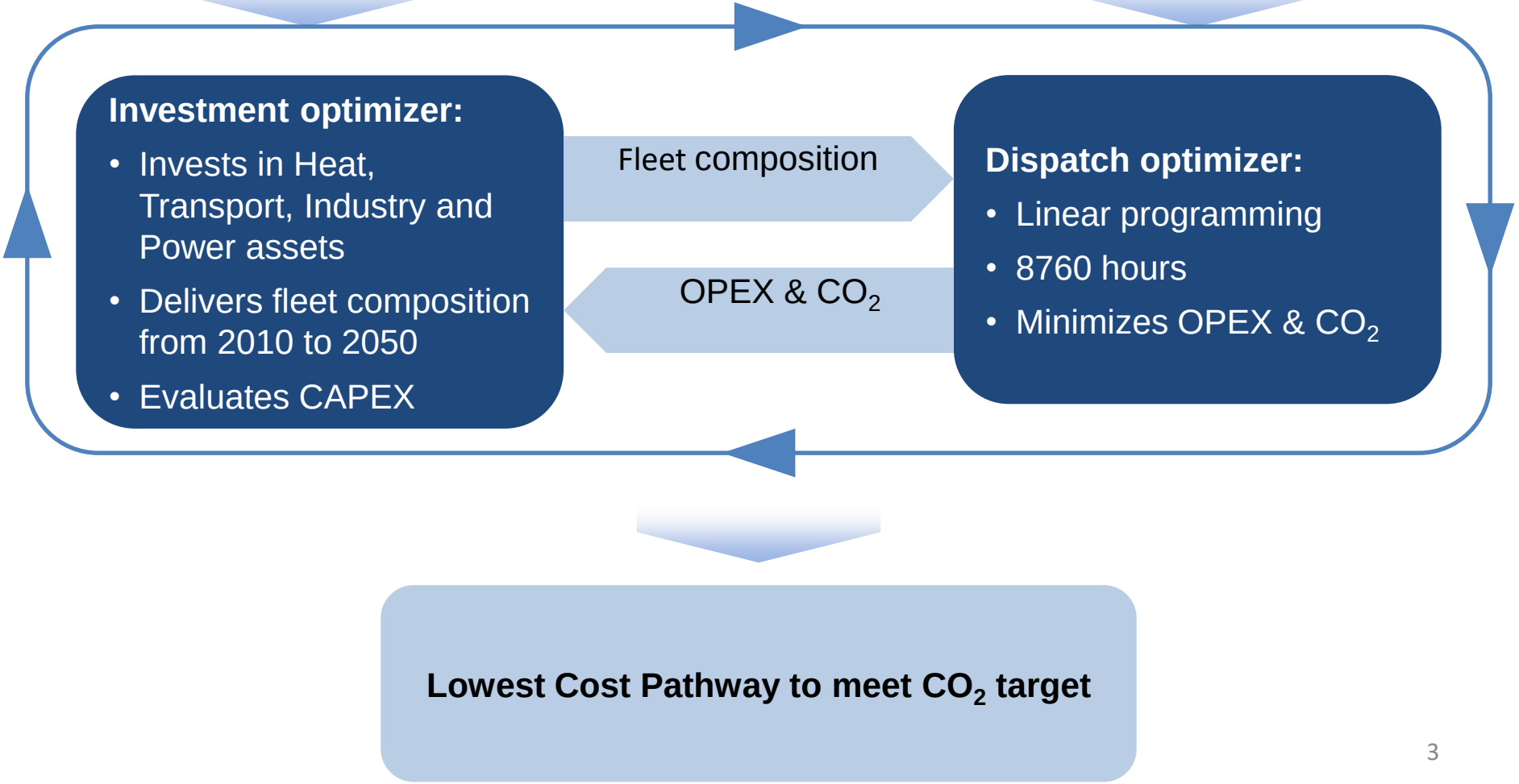
Includes for the first time:

- Heat
- Energy Intensive Industries
- Transport
- Power

Integrated Energy system model

- **Costs**
- **Efficiency**

- **Consumption**
- **Weather**



Lowest Cost Pathway to meet CO_2 target

Modelling across 10 countries (and combined)

Zero emissions platform

United Kingdom

Norway

Poland

Netherlands

Netherlands

Germany

France

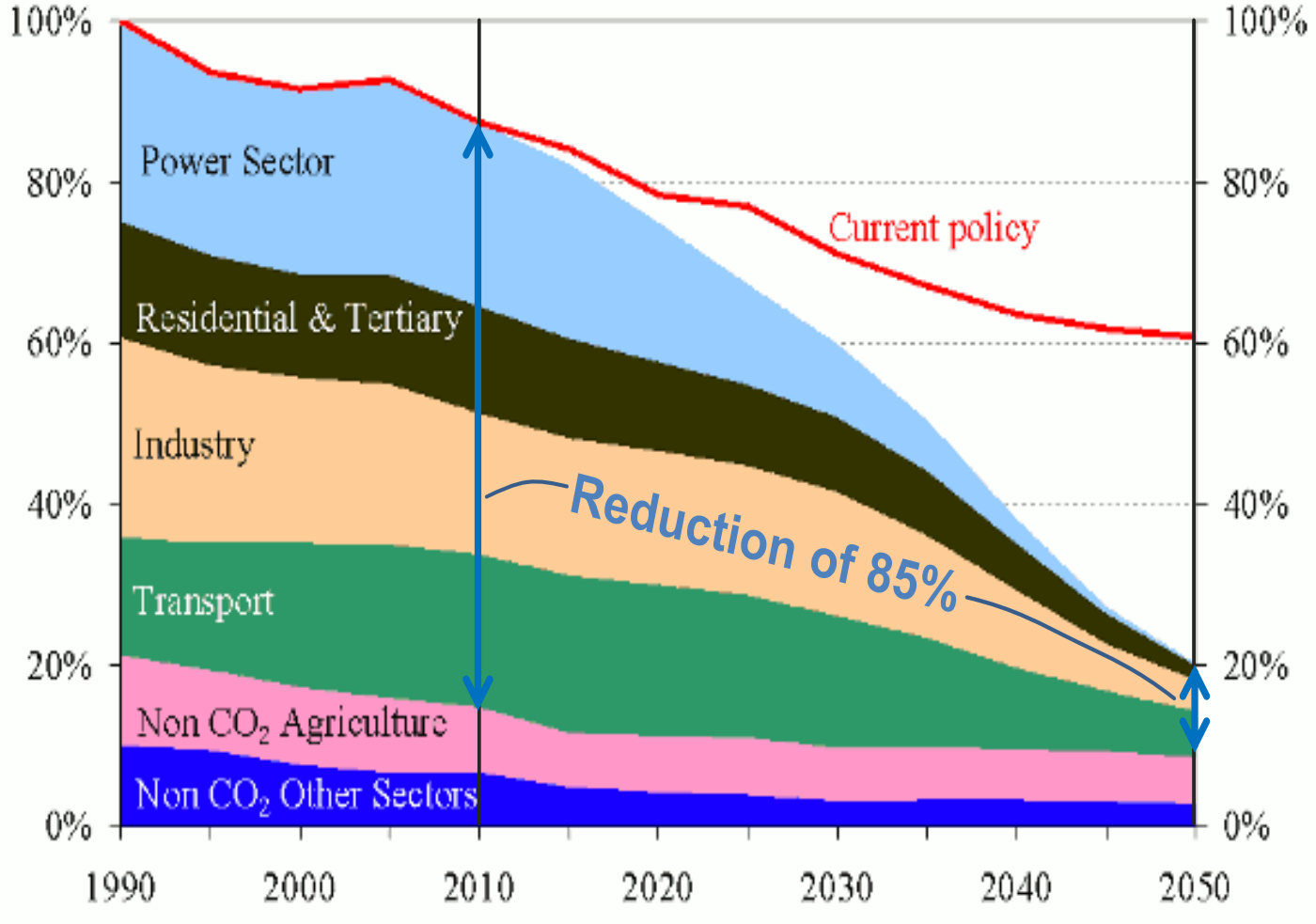
Switzerland

Spain

Italy

Greece

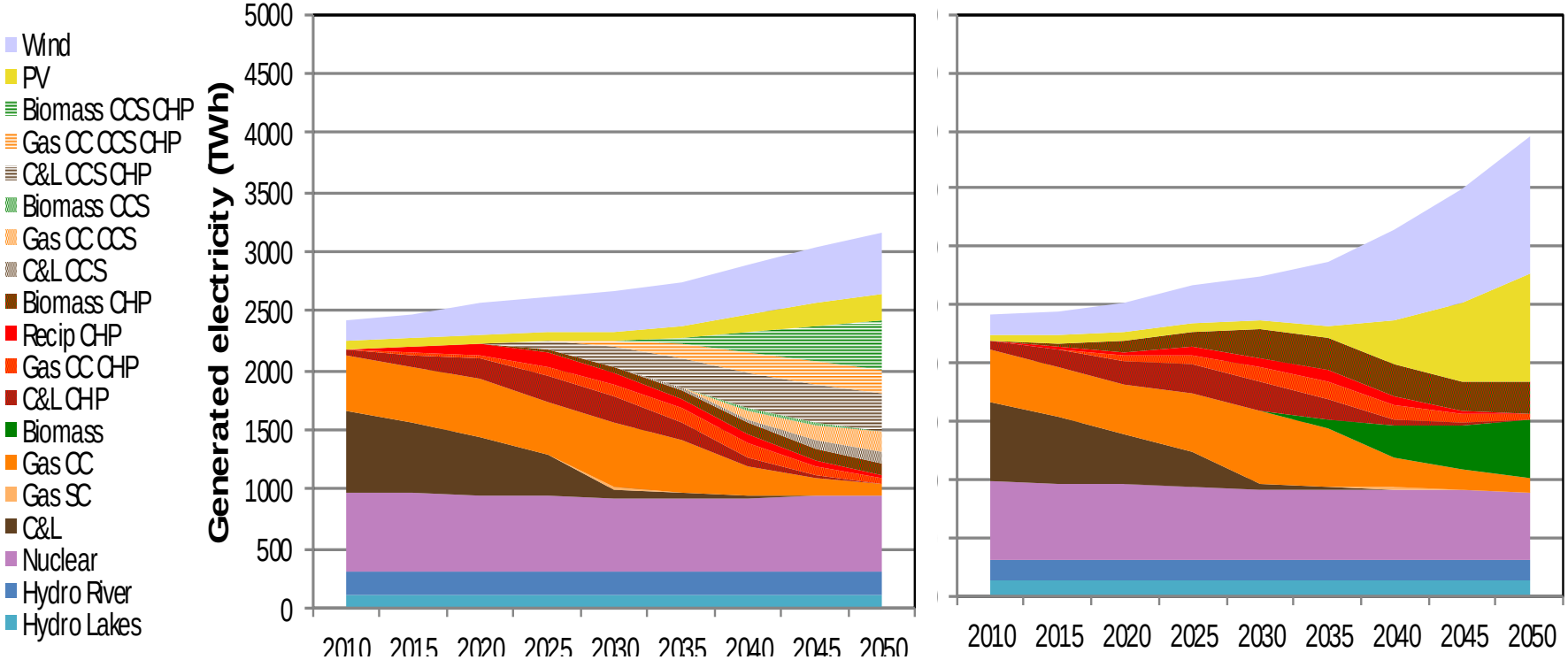
Setting the CO_2 emissions target base line



- EU 80-95% Reduction ref 1990
- This model from 2010
- This model is energy only
- 85% from 2010 to 2050 for Energy is equivalent to 80% ref 1990
- 95% reduction target overall

Electricity Generation in 10 countries

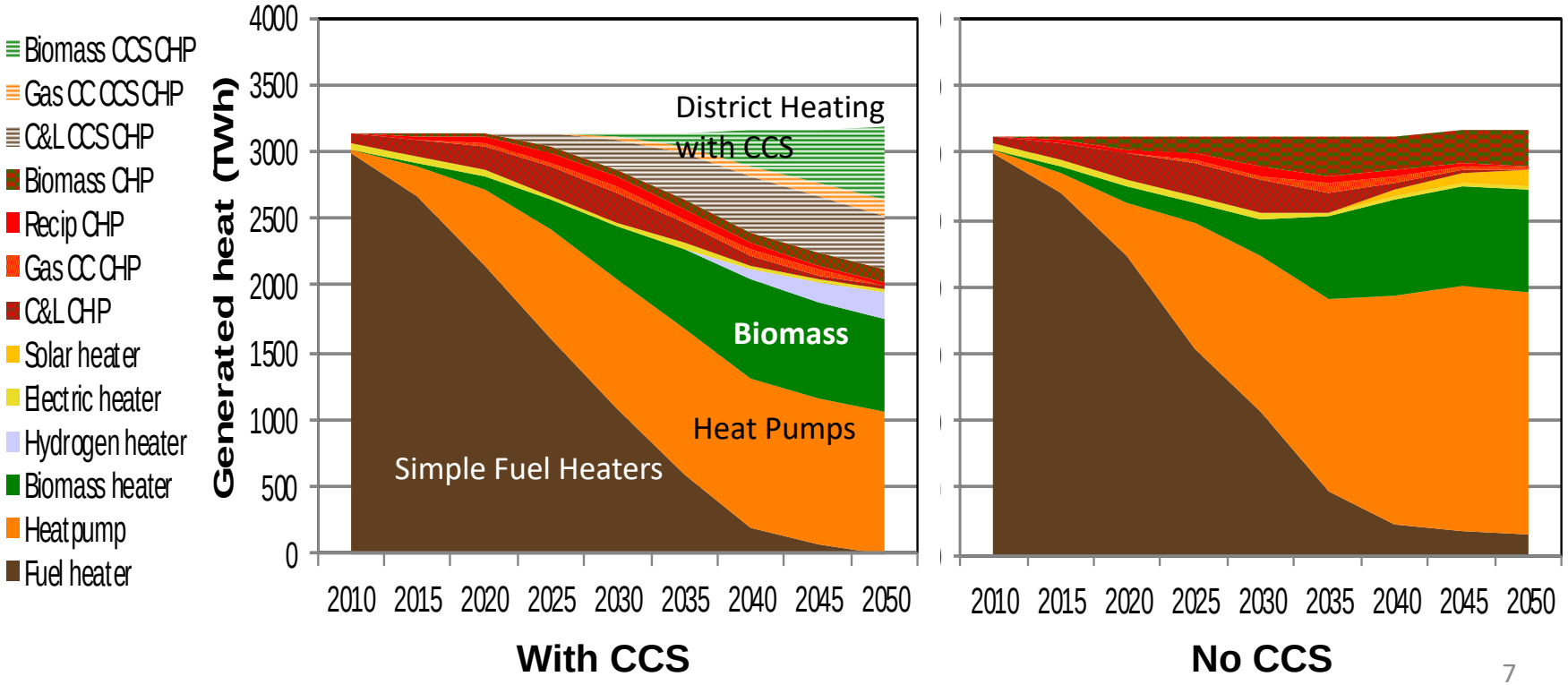
- Model chooses dispatchable power to better integrate Solar and Wind
- With CCS, the backup power does not emit CO_2
- Growth in demand for electricity, transport and heat



With CCS **No CCS**

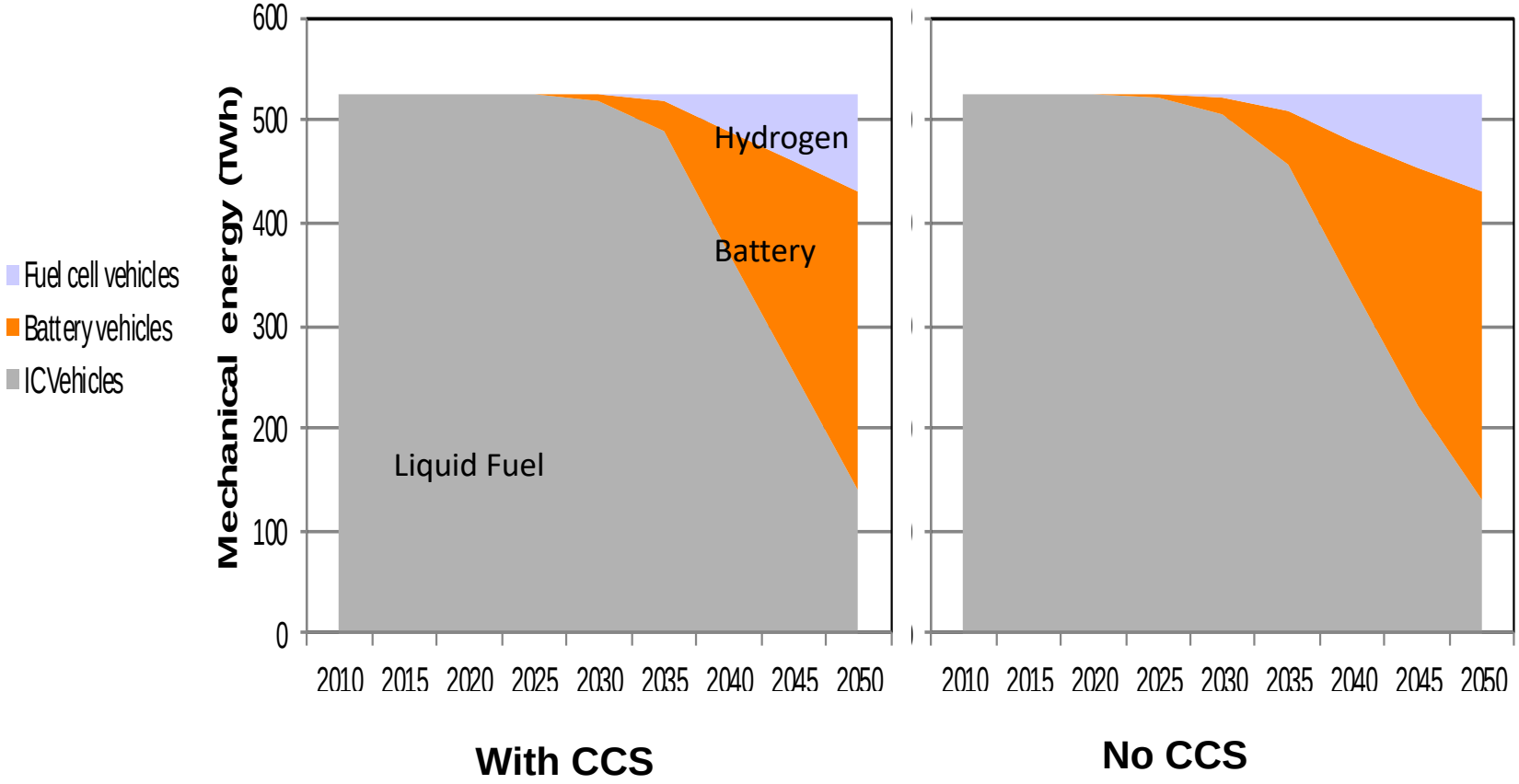
Generated Heat in 10 Countries

- For many countries, heat is currently the most important CO_2 emitter and, at a system level, heat can help integration of RES because it can be stored cheaply
- The model chooses replaces simple Gas, Oil and Coal heating with District Heating, CHP, Heat Pumps, Biomass Solar Thermal and Hydrogen
- Centralised Heat and CO_2 capture eliminates almost all emissions from this, the biggest and most-distributed sector
- Without CCS simple fuel heaters remain in place to 2050 and beyond

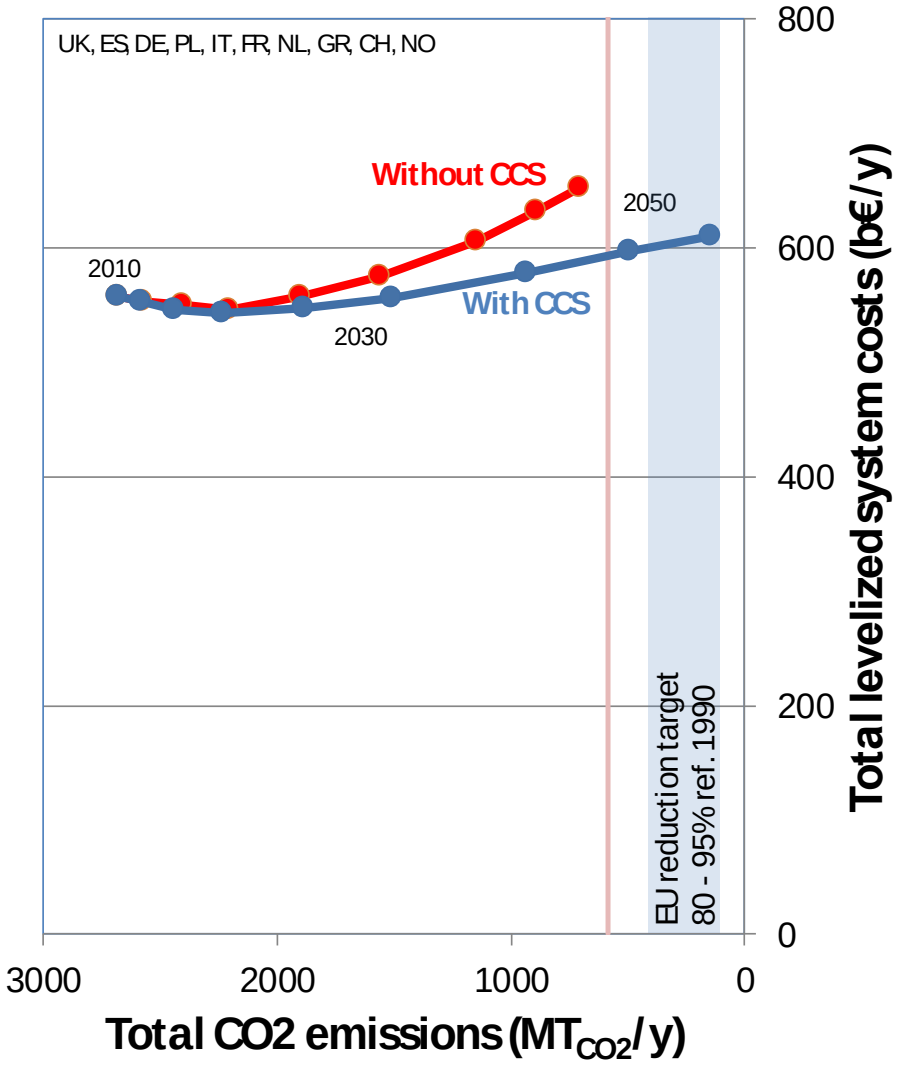


Transport in 10 Countries

- Transport makes distributed emissions. Switching to Electricity and Hydrogen can centralise emissions sources for CO_2 capture, if available
- Only road transport is considered in this model; 75% conversion limit at 2050
- Early adopters: Norway & Switzerland because low CO_2 in electricity used



Cost benefit for emissions reduction in 10 countries



- Fuel savings, efficiency improvements and technology cost reduction give fairly flat costs curves. No inflation (2010 Euros)
- District Heating and CHP give cost reductions in early years
- **95% emission reduction can only be achieved with CCS**
- Without CCS emissions in 2050 are 3-4 times higher
- **Saving up to 2050 with CCS = more than 1 Trillion Euro for EU as a whole**
- Saving 50 Billion Euro per year ongoing across the 10 countries modelled
- **Early investment in CO_2 hubs and clusters has strong business case**

Conclusions

- 2050 reduction targets can only be achieved with CCS
- Without CCS, emissions would be 3-4 times higher in 2050
- Value of CCS to EU of 1 Trillion Euros, up until 2050
- CCS worth 50 Billion Euro per year from 2050 onwards (10 countries)
- Future of Energy Intensive Industries in Europe relies on CCS
- Infrastructure investment required for reductions before 2030
- Business case for Member States to invest in Hubs/Clusters (now!)
- CCS facilitates over-achievement against EU renewables targets
- Bioenergy with CCS is key to negative emissions needed for Paris Agreement