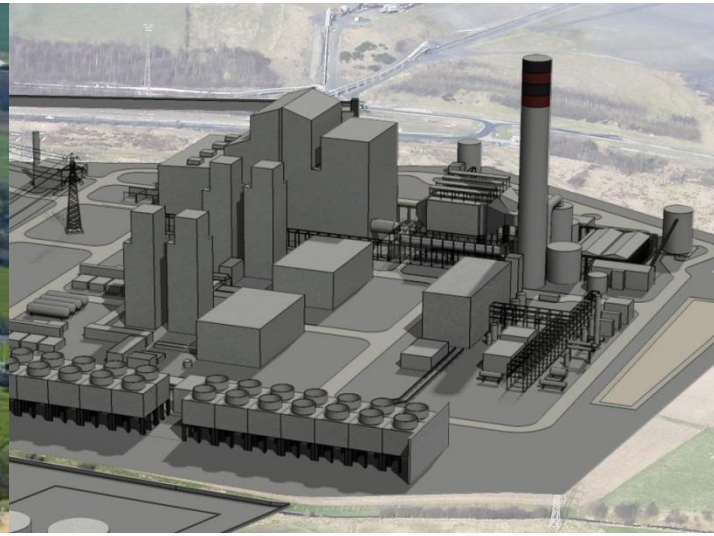
The Impact of Policy Measures on Future Power Generation Portfolio and Infrastructure – A Combined Electricity and CCTS Investment and Dispatch Model (ELCO)

9th TAI, FERC Washington DC, USA, October, 30th, 2015

Telegraph (2013)

Drax site (2013)



White Rose CCTS Project (2013)

Dipl.-Ing. Roman Mendelevitch and Dipl.-Ing. Pao-Yu Oei
DIW Berlin; Department of Energy, Transportation, and Environment
TU Berlin; Workgroup for Economic and Infrastructure Policy (WIP)

Agenda

1. Motivation
2. Model Framework
3. Case Study: UK Electricity Market Reform
4. Assumptions and Tentative Scenario Results
5. Future Work

Renewables support schemes

PROPOSED MEASURE	EXPECTED EFFECT	POSSIBLE ADVANTAGES	POSSIBLE SHORTCOMINGS
Feed-in Tariff	Feed-in tariff covers LCOE and incentivizes investment into RES technologies	Mitigation of investment risk, cost reductions achieved due to economies of scale and technological development	Difficult to set right level of FIT, too low: no investment too high: inefficient use of money, decreasing average electricity price
Feed-in-Premium	Mitigate price effect by exposure to market incentives	Favors technologies that are system-friendly and disincentives oversupply	Same as feed-in-tariff, exposure to market risk
Renewable certificates	Cost-efficient financing of RES technologies	No try and error effect	Exposure to market risk Only favors one (currently cheapest) technology

Possible instruments for reducing emission-intensive power generation (based on Oei et al. 2014)

PROPOSED MEASURE	EXPECTED EFFECT	POSSIBLE ADVANTAGES	POSSIBLE SHORTCOMINGS
ETS reform	Price signal through the introduction of market stability reserve (MSR), 900 million backloading allowances directly in MSR, start of MSR in 2017 instead of 2021	EU-wide instrument; thus, no cross-border leakage effects	Structural reforms uncertain from today's perspective; the extent of the impact is unpredictable due to high surplus of certificates
CO_2 floor price	CO_2 certificates would become more expensive	Investment security for investors	Feasible prices probably too low to result in a switch from coal towards natural gas
Minimum efficiency	Closure of inefficient power plants	More efficient utilization of raw materials	Open cycle gas turbines (OCGT) would also be affected; complex and time-consuming test and measurement processes
Flexibility requirements	Closure or singling out of inflexible power plants	Better integration of fluctuating renewable energy sources	Combined cycle gas turbines (CCGT) would also be affected; complex and time-consuming test and measurement processes

Possible instruments for reducing emission-intensive power generation (based on Oei et al. 2014)

PROPOSED MEASURE	EXPECTED EFFECT	POSSIBLE ADVANTAGES	POSSIBLE SHORTCOMINGS
Emissions performance standard (per unit; for new plants and retrofits)	Restrictions for new plants and retrofits (without CO_2 capture)	Prevention of CO_2- intensive investments	Minor short-term reduction in emissions
Emissions performance standard (emissions cap for existing plants)	Reduce load factor for depreciated coal-fired power plants (e.g. > 30y)	Preservation of generation capacities, e.g., by shifting into a strategic reserve	Negative impact on economic efficiency of power plants might lead to closure of older blocks
Capacity mechanisms	Incentive for construction of less CO_2-intensive power plants when including environmental criteria	Support of gas power plants; or moving coal power plants into a reserve to reduce their emissions and prevent supply bottlenecks	Difficult to set up critieria if payments should only be given to selected units
Climate contribution fee	Additional levy for old CO_2 intensive power plants	Limiting output of most CO_2 intensive generation facilities; preserving capacities	Older units might become uneconomic if the fee is too high

Motivation for designing a new model: The ELCO model

No model covers it all…

- Energy system models: e.g. TIMES-D: current feed-in tariffs or certificate systems BUT no feedback between CO_2 target and required RES support to achieve it
- Partial equilibrium electricity market models (e.g. Ehrenmann and Smeers 2011: resource adequacy; Allevi, Bonenti, and Oggioni 2013: environmental regulation; Gürkan and Langestraat 2014, Chen and Wang 2013: RES obligations and portfolio standards)
- Generation investment and dispatch models (e.g. Eide et al. 2014, Weber and Spiecker 2014, Leuthold et al. 2012): no particular focus on RES support and overly simplistic CCTS
- CCTS infrastructure models (e.g. Oei, Herold, and Mendelevitch 2014; Middelton et al. 2014): Neglects the electricity sector
- Kjärstad et al. (2013) is the first paper to close the gap between CCTS and electriicty market models with a softlink of Chalmers Electricity Investment Model with InfraCCS

Our model should simulate:

- regionally disaggregated electricity generation and flows
- CO_2 capture by power generation & CO_2-intensive industry, CO_2 transport & storage (incl. CO_2-EOR)
- Featuring: diffusion & curtailment constraints, environmental regulation & targets, time-specific CO_2 stream, location-specific technology costs and constraints, endogenous or exogenous feed in tariffs

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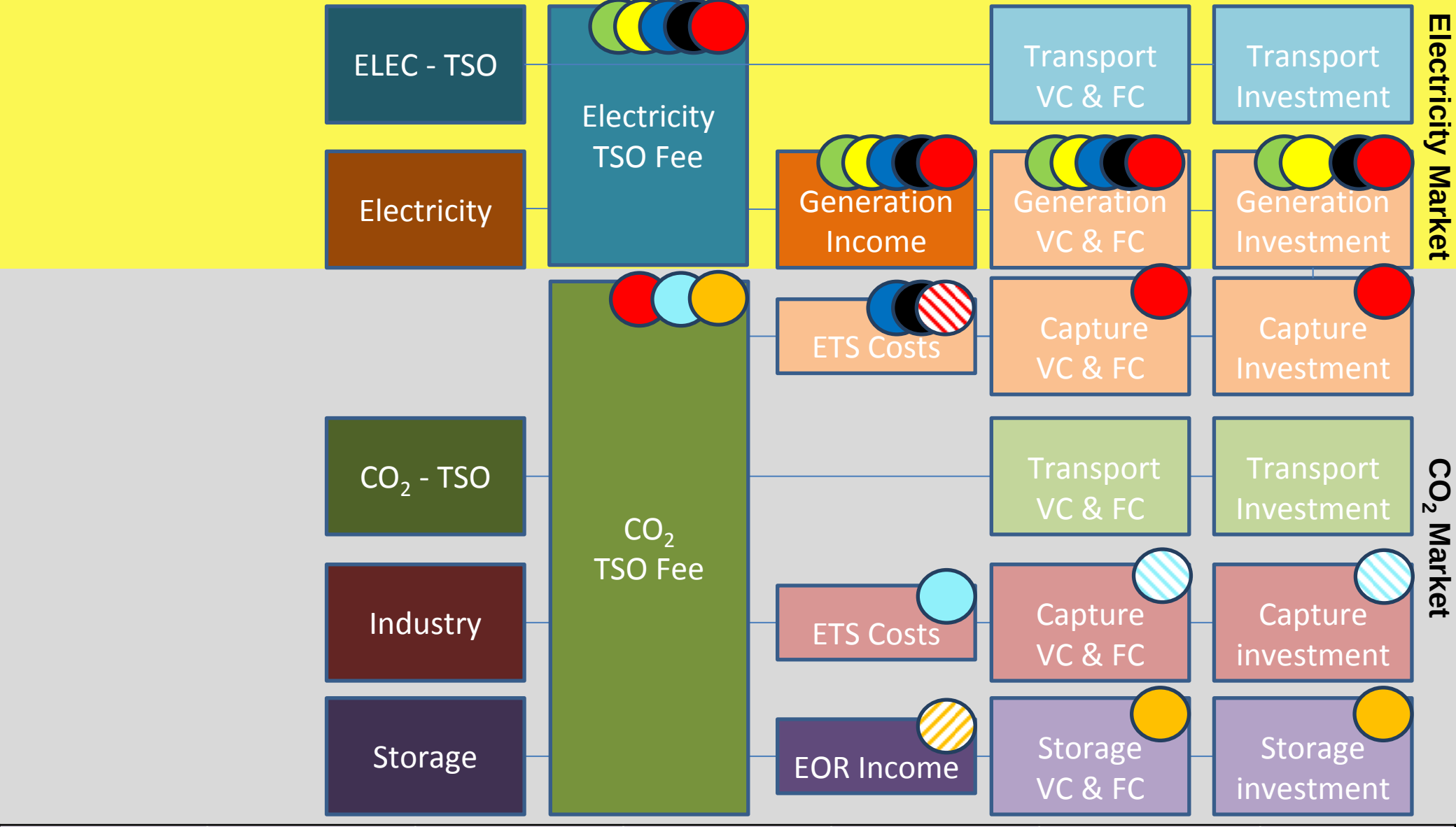

RE new	NUC new	CON	FOSSIL new	FOSSIL CCTS	IND	STOR
PV, Wind on & off, Biomass, Hydro	New Nuclear	Existing Nuclear, Coal, OCGT, CCGT	New Coal, OCGT, CCGT w/o CCTS	New Coal, CCGT w/ CCTS	Cement, Steel w/ & w/o CCTS	Saline, DOGF, EOR

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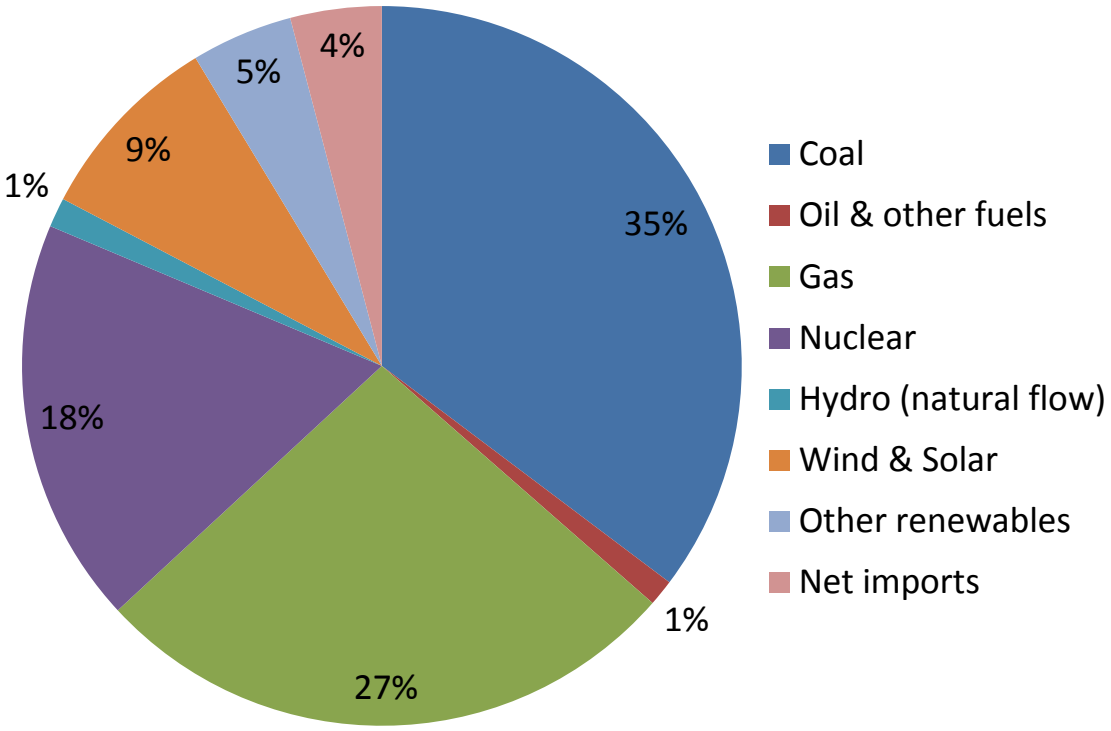
The UK electricity market is typical…

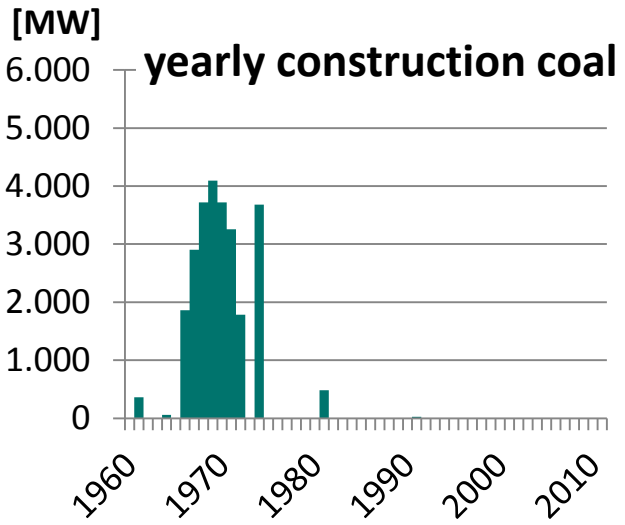
UK´s climate targets for GHG reduction:

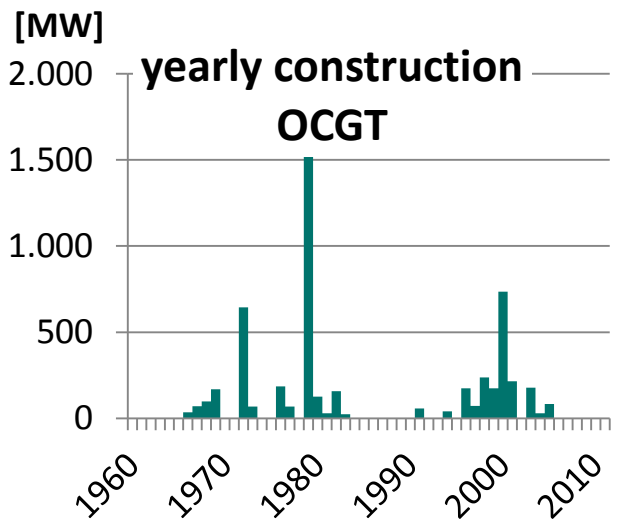
34% by 2020 & 80% by 2050 (base year: 1990).

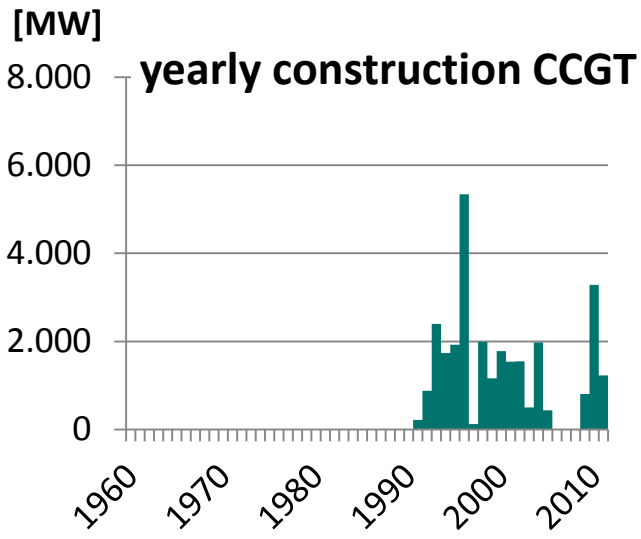


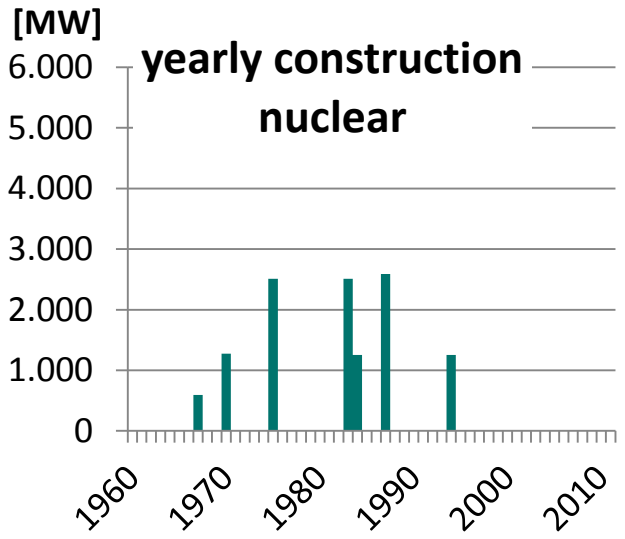
Electricity production per fuel type in 2013 for UK
Source: DECC (2014) – UK Energy Brief

…the upcoming decade becomes vital to prevent sunk investments in carbon intensive power plants.





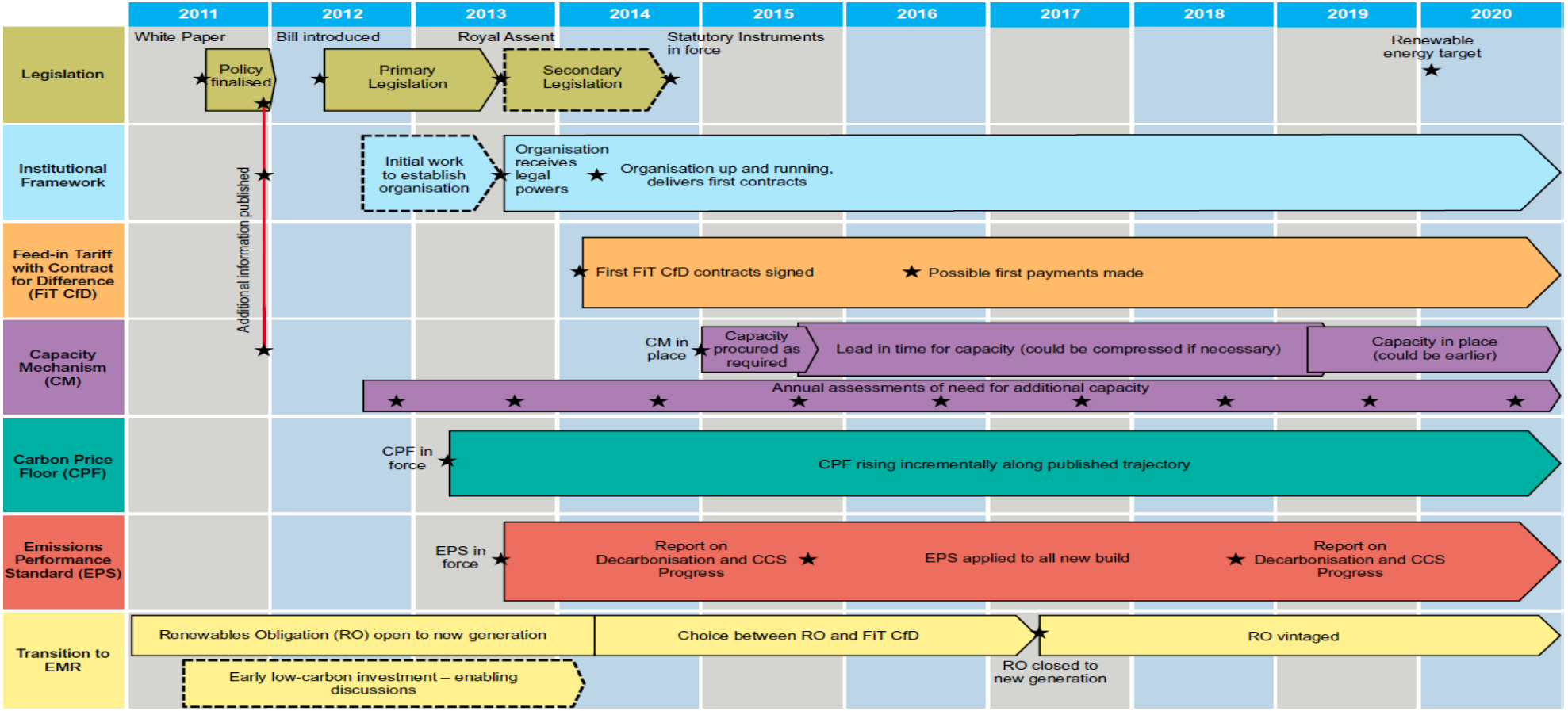




Source: Own illustration based on Platts (2011)

The Electricity Markets Reform (EMR) in UK comprises of several instruments:

- **Contract for Differences**
- **Capacity Markets**
- **Emissions Performance Standard (EPS)**
- **Carbon Floor Price**



Source: DECC (2012)

Motivation and research question

EMR is controversially discussed, e.g. by (Pollitt and Haney 2013)

- **as a whole, it is not a consistent strategy to achieve the three main energy policy priorities of competitiveness, energy security and decarbonization**
- **will increase the wholesale electricity price and the consumers energy bill substantially**
- **removes ability to react quickly to new information, and competition in planning for the future; generation mix will no longer be decided based on price signals but be determined by the government.**

Wrong incentives through the EMR might lead to sunk investments in carbon intensive power plants. These lead to a risk of induced welfare losses as well as breeched climate targets (see e.g. Johnson et al. 2014).

→ We want to analyze the measures of the UK-EMR, specifically the Carbon Price Floor (CPF), Emissions Performance Standard (EPS) and Contracts for Differences (CfD), and how they will influence the construction of new generation capacities, with a special focus on CCTS.

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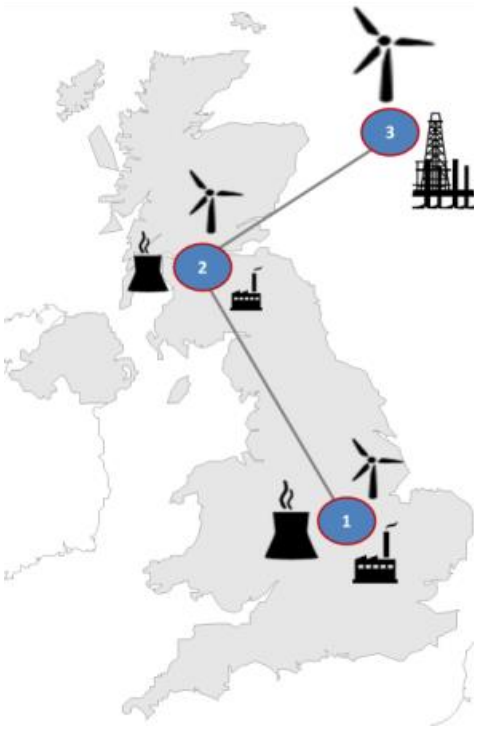
Assumptions for a Tentative Scenario

- **Electricity sector**
  - RE-Diffusion: Exponential growth depending on starting capacity
  - CfD: Exogenous strike price projections for 2015 and 2020
  - Nuclear: Max 5 GW new capacity
  - CO_2 target: 90% reduction until 2050 (base 1990)
  - CO_2 certificate price: from 20€/t in 2015 to 80€/t in 2050
  - No specific RE-Target
  - EPS: 450 gCO_2/kWh for new capacity
  - Demand Reduction: 20% until 2050

- **Steel and Cement sector**
  - CO_2 Emissions Reduction: 40% until 2050

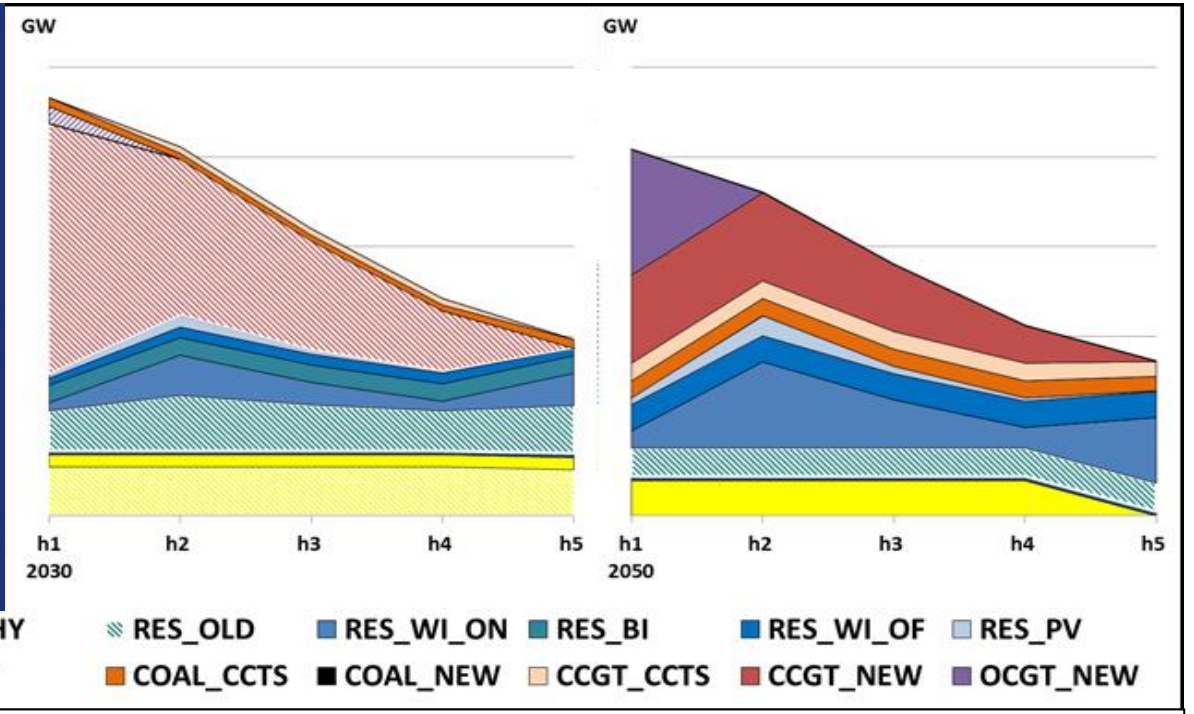
- **Storage**
  - Oil: price 65€/bbl, CO_2 efficiency: 3bbl/tCO_2
  - Available storage types: offshore CO_2-EOR, DOGF, Saline Aquifer

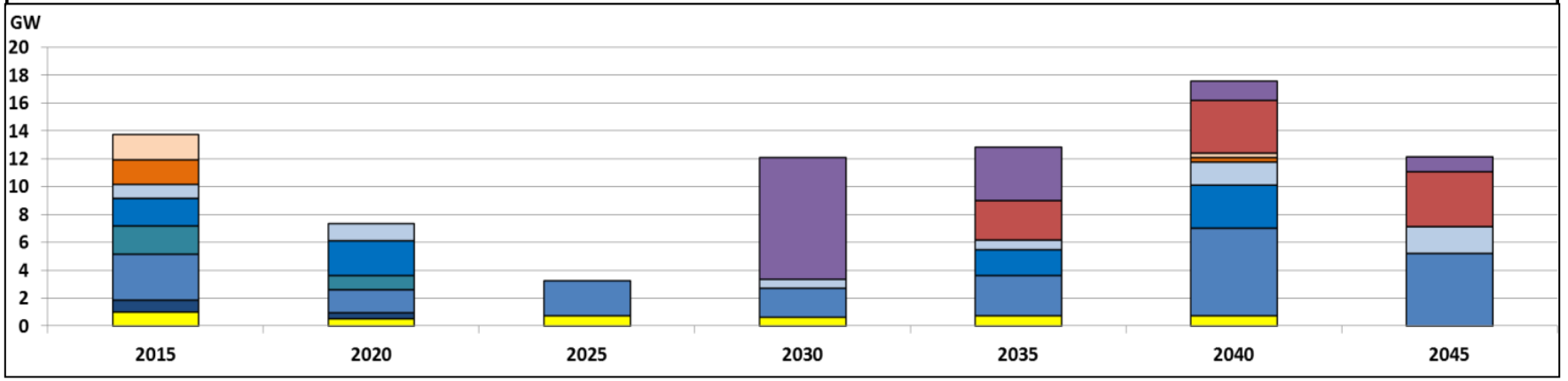


- **General** 2015-2050 in 5 year steps; 5 weighted time slices; 3 nodes; no line congestion

Results of a Tentative Scenario: The Electricity Sector…

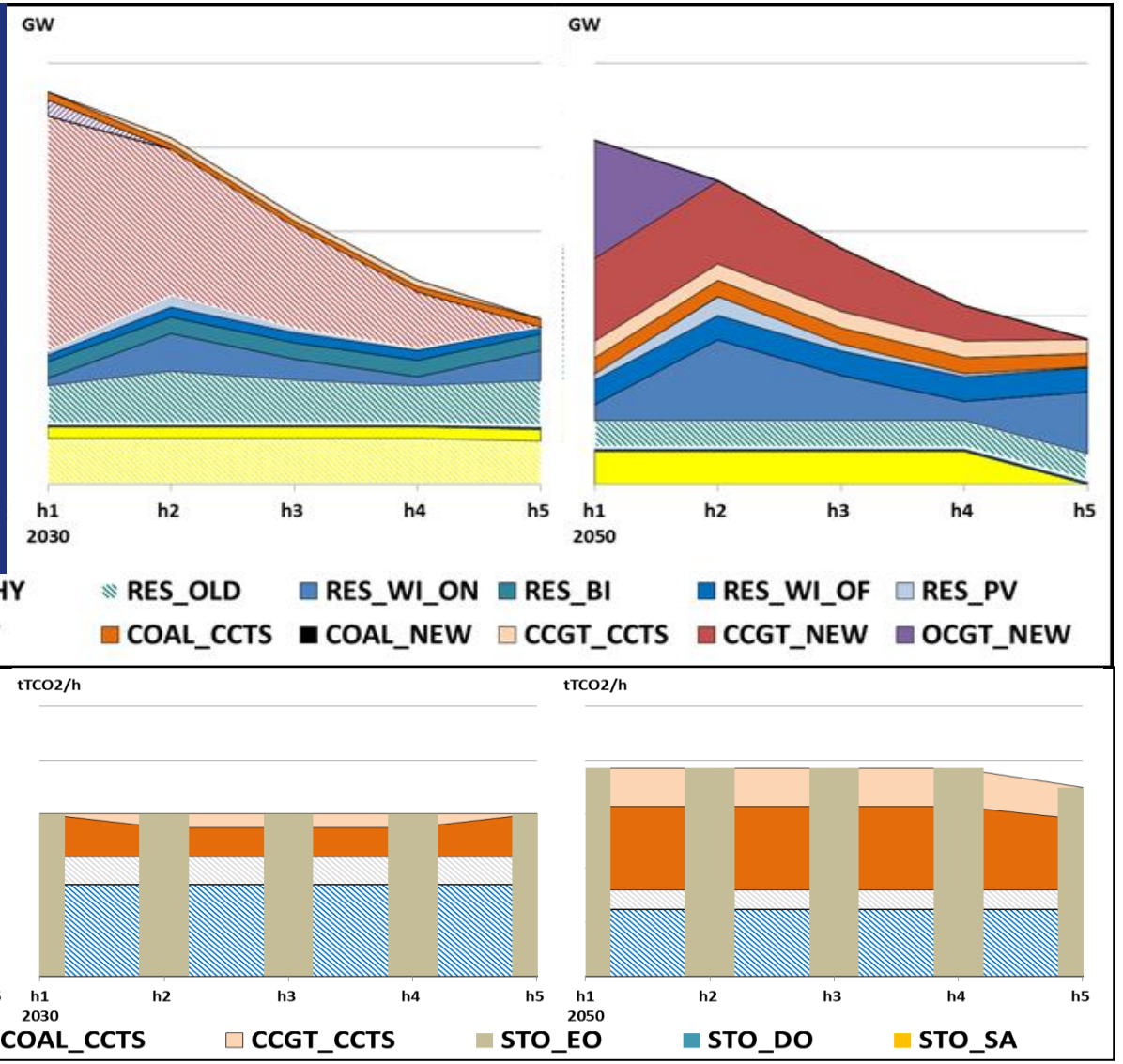
- Diversified electricity portfolio in 2050: RES-E (46%), gas (26%), nuclear (15%), and CCTS (13%)
- Constant growth of renewables
- CfD covers more than 70% of the market in 2050; its expenses rise to 23 bn. € in 2050 (equivalent to a tax of 100 €/MWh)
- Investments only in CO_2-EOR storage, regardless of additional incentives from the energy market
- CO2 flow from industry is more constant than from electricity sector





Results of a Tentative Scenario: …including the CCTS chain

- Diversified electricity portfolio in 2050: RES-E (47%), gas (25%), nuclear (14%), and CCTS (14%)
- Constant growth of renewables
- CfD covers more than 70% of the market in 2050; its expenses rise to 23 bn. € in 2050 (equivalent to a tax of 100 €/MWh)
- Investments only in CO_2-EOR storage, regardless of additional incentives from the energy market
- CO2 flow from industry is more constant than from electricity sector



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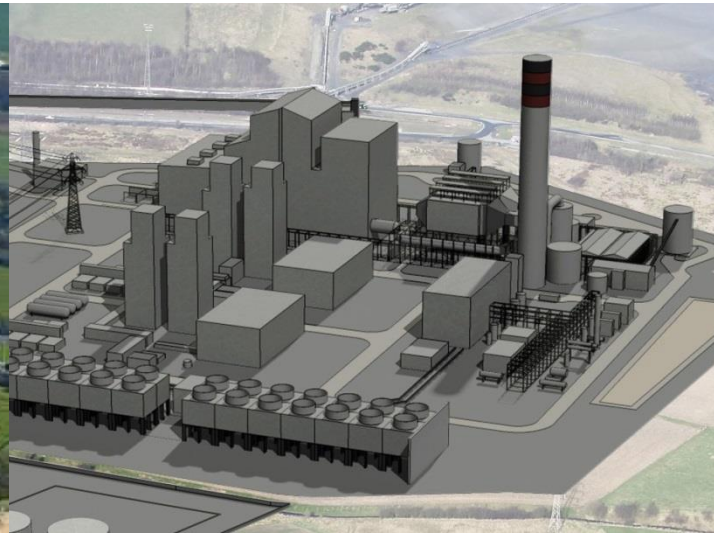
Next steps

- **Compare the costs of different incentive schemes and analyze their effects on the deployment of different low carbon technologies, with a special focus on CCTS with and without the option for EOR.**
- **Further consider the role of industry CCTS**
- **Study the feedback effects between the CfD scheme and the electricity price, and investigate the incentives of the government which acts along the three pillars of energy policy: cost-efficiency, sustainability and security; in a two-level setting**
- **Use our results to draw conclusions and possible policy recommendations for low carbon support schemes in other counties**

Thank you for your attention!!!

Telegraph (2013)

Drax site (2013)



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