Modelling the Impact of Transmission Charging Options

Presentation to Working Group: Base Case results for Stage 1 and Stage 2

9th November 2011

Date: 21 November 2011 **Client**: Ofgem

Disclaimer

While Redpoint Energy Limited considers that the information and opinions given in this work are sound, all parties must rely upon their own skill and judgment when interpreting or making use of it. In particular any forecasts, analysis or advice that Redpoint Energy provides may, by necessity, be based on assumptions with respect to future market events and conditions. While Redpoint Energy Limited believes such assumptions to be reasonable for purposes of preparing its analysis, actual future outcomes may differ, perhaps materially, from those predicted or forecasted. Redpoint Energy Limited cannot, and does not, accept liability for losses suffered, whether direct or consequential, arising out of any reliance on its analysis.

The analysis presented in this pack is the result of Redpoint Energy's modelling and does not necessarily represent Ofgem's views. The analysis will feed into Ofgem's own assessment, which will form part of the consultation due to be published in December. The results presented in this pack were circulated with the express aim of gathering feedback from the Working Group, in order to ensure that the final results of the modelling are robust.

Objectives

- An opportunity for the Working Group to see the revised modelling results, which take into account feedback from the Working Group on the previous initial results
- Sense checking of results with a wider group
- We are looking for input from Working Group on how best to present the analysis to the wider industry

Contents

- Introduction
- Headline messages
- Tariffs under the charging options (for Imperfect foresight Stage 2)
- Imperfect foresight: Stage 1 Results
- Imperfect foresight: Stage 2 Results
- Perfect foresight results

Introduction

- This results pack presents the key results from modelling of the three Transmit options:
  - Status Quo
  - Improved ICRP
  - Socialised
- The analysis presented explores the interactions between generation investment/retirement, transmission charging and transmission reinforcement
- The results presented are for Imperfect foresight (agent simulation) and Perfect foresight
- The Imperfect foresight analysis is split into Stage 1 and Stage 2, to illustrate the impact of changes to transmission charging with and without changes to low carbon support
- For Stage 1 analysis we have assumed:
  - **Equivalent** levels of low carbon support (RO/CfDs) across the three options in order to isolate the impacts of the different charging options
- For Stage 2 results, we have assumed:
  - **Adjusted** levels of low carbon support under Socialised and Improved ICRP to deliver the same 2020 renewables and 2030 carbon intensity outcome as Status Quo
- We present the results in two periods, pre-2020 and 2021-2030, to recognise the increasing uncertainty later in the modelling horizon
- The Perfect foresight analysis is based on the Imperfect foresight Stage 2 results.

Key messages: Stage 1 – low carbon investment

- Both Improved ICRP and Socialised increase the amount of renewables deployed for the same level of support relative to the Status Quo
  - Improved ICRP 0.6 percentage points higher by 2020
  - Socialised 6.1 percentage points higher by 2020
- Improved ICRP encourages more investment in onshore wind in Northern Scotland
- Socialised also encourages significantly greater volumes of offshore wind
- Under Socialised the level of nuclear investment is lower than under SQ for the same level of support
- The increasing migration of investment to Northern Scotland (including islands) and offshore leads to higher constraint costs, particularly under Socialised, and greater levels of network reinforcements as a result

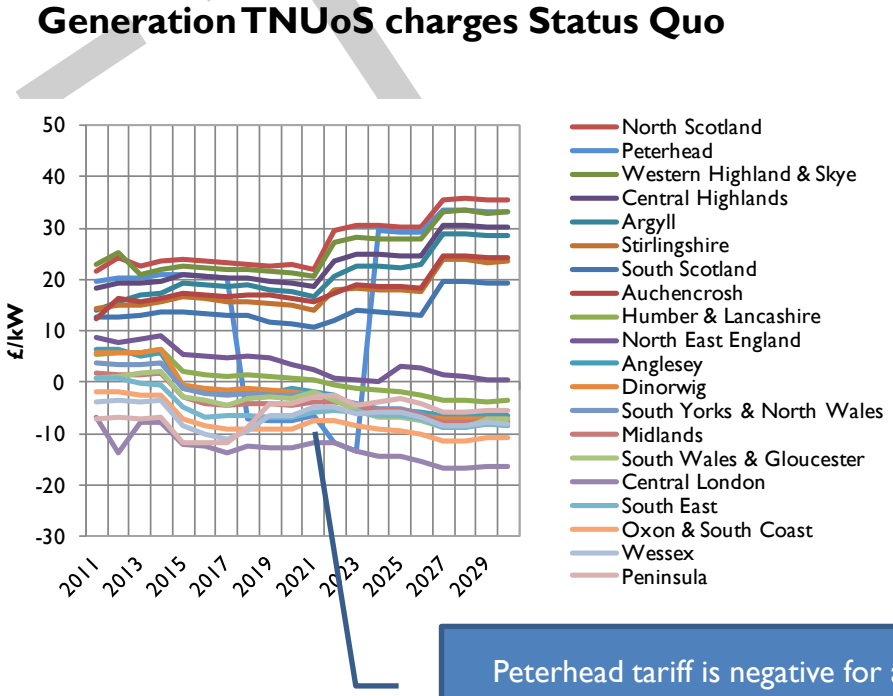
Key messages: Stage 2

- Under Stage 2, we set all three options to deliver similar levels of renewables in 2020 and carbon intensity by 2030
- The results across the transmission charging options are therefore more similar in terms of national capacity mix
- However, locational differences in investment are maintained
- The very high level of constraint costs under Socialised Stage 1 is reduced somewhat in Socialised Stage 2

Tariff summary

Generator tariffs – Status Quo

- The chart shows generator tariffs for Status Quo (2011 values are the actual published tariffs for 2011/12)
- The tariffs are the sum of wider and residual charges, and exclude local asset charges
- Status Quo tariffs for 2012/13 are similar to published 2011/12 tariffs, with the exception of Central London
- In 2015, the G:D split changes to 15:85 reducing generator tariffs in general. For Scottish generators, the commissioning of the Western HVDC link in the same year offsets the reduction in tariffs
- Further HVDC links in 2022, 2023, and 2027 produce step changes in Scottish tariffs

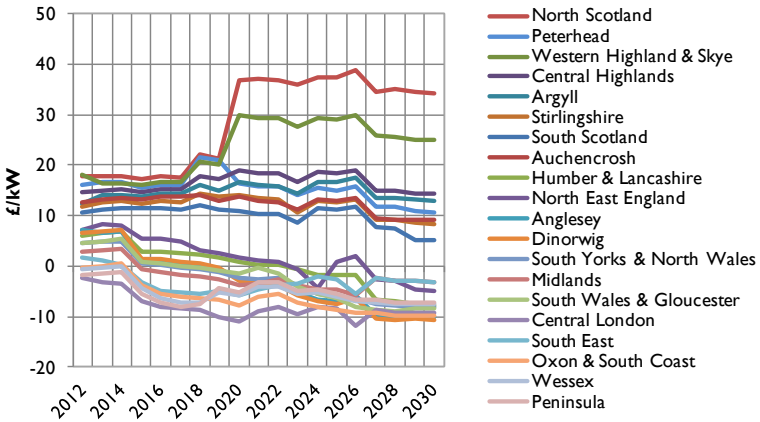


Peterhead tariff is negative for a period when there is little generation in this zone. Investors do not expect a negative generator tariff in this zone, due their foresight of the impact of future new generation

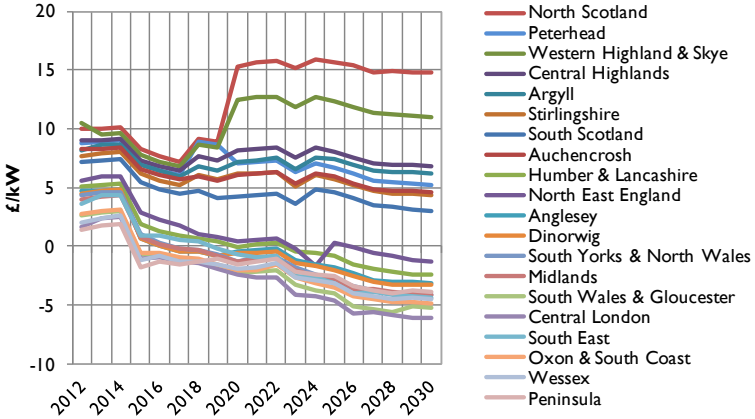
Generator tariffs – Improved ICRP[1]

- The charts show generator tariffs under Improved ICRP for the same example generators as in the previous slide
- The spread of tariffs for intermittent generators across the zones is lower than for baseload generators
- The step change in North Scotland and Western Highland & Skye is a result of the commissioning of both the second Western HVDC link and the Caithness – Moray HVDC

TNUoS charges (baseload generator)



TNUoS charges (intermittent generator)

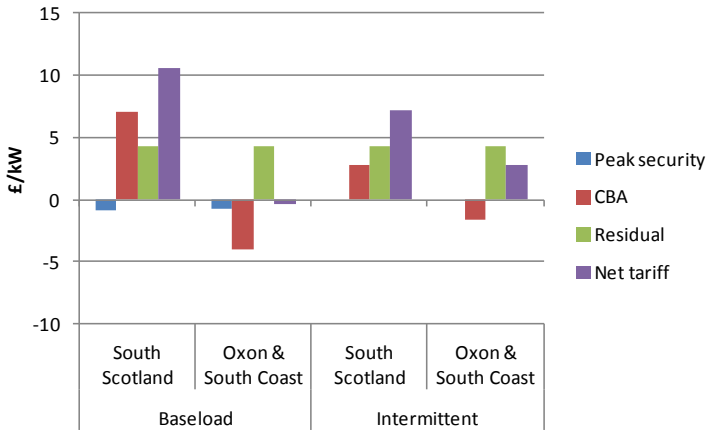


1. Tariff results are from Stage 2 analysis

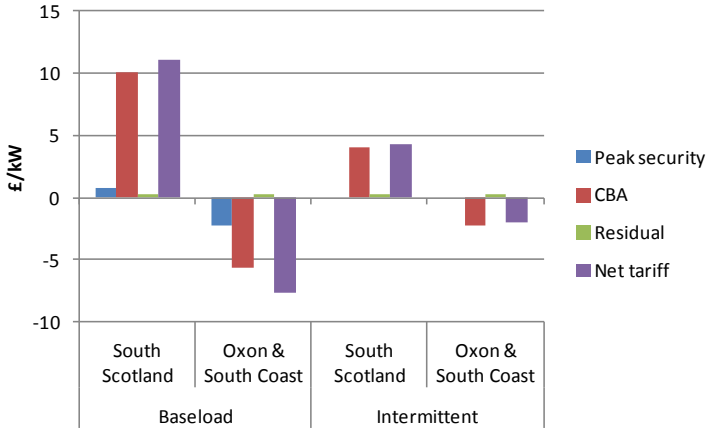
Generator tariff example – Improved ICRP

- Zonal Improved ICRP charges consist of two parts
  - Peak security tariff, based on peak period background
  - Year round tariff to based on annual background (CBA tariff)
- Tariff scaling determines differential tariff by technology
  - Demand Security: 100% thermal; 0% intermittent
  - Year round (CBA) tariff based on load factor. Assumptions for charts: 70% thermal baseload; 28% intermittent
- The CBA component is larger than the Peak Security component
- Generators with lower load factors (wind or peaking plant) therefore face reduced charges if located in a positive TNUoS zone, but a reduced benefit if located in a negative TNUoS zone

Improved ICRP tariff breakdown (2012)

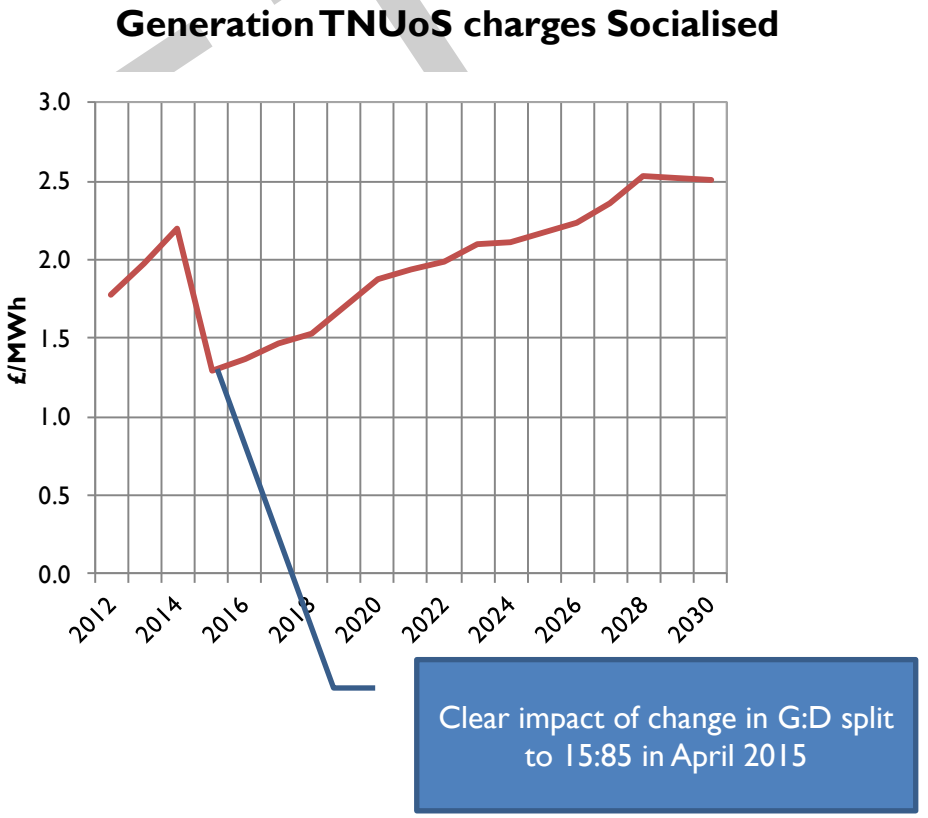


Improved ICRP tariff breakdown (2020)



Generator tariffs – Socialised[1]

- Socialised tariffs are charged on a variable (£/MWh) basis
- Socialised tariffs recover the full generator split of MAR, i.e. equivalent to sum of (Wider + Residual + Local) under Status Quo

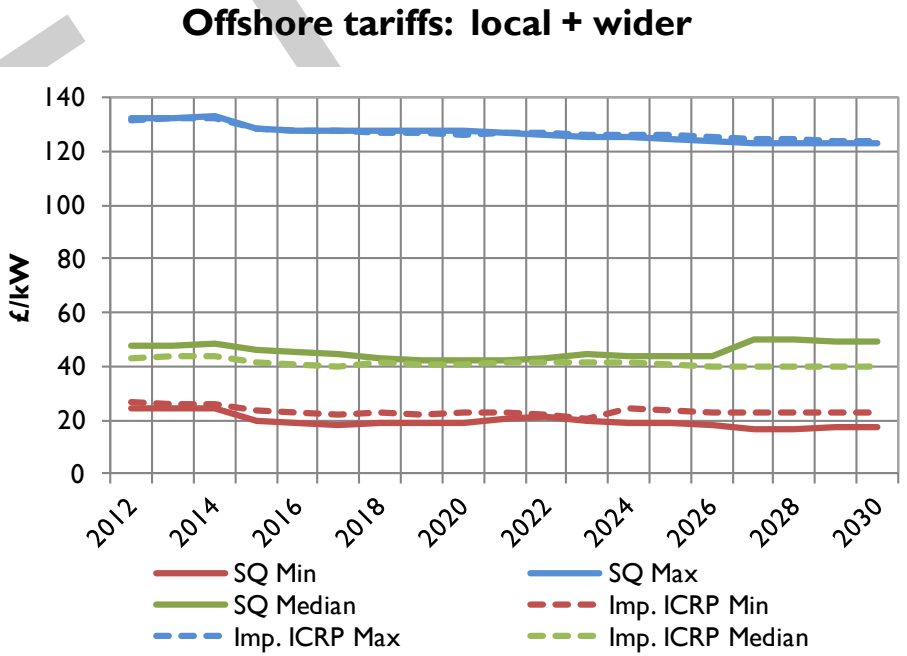


1. Tariff results are from Stage 2 analysis

Generator tariffs – offshore

- The wide spread in offshore charges is similar under Status Quo and Improved ICRP because local asset (mainly OFTO) charges do not change
- Onshore tariffs are a relatively minor component of offshore costs, however they can influence investment decisions

- Impact of fully socialised option is to reduce offshore wind tariffs. A charge of 2 £/MWh is equivalent to 6.5 £/kW at a load factor of 38%



Base Case results – Stage 1

Assumption and model changes

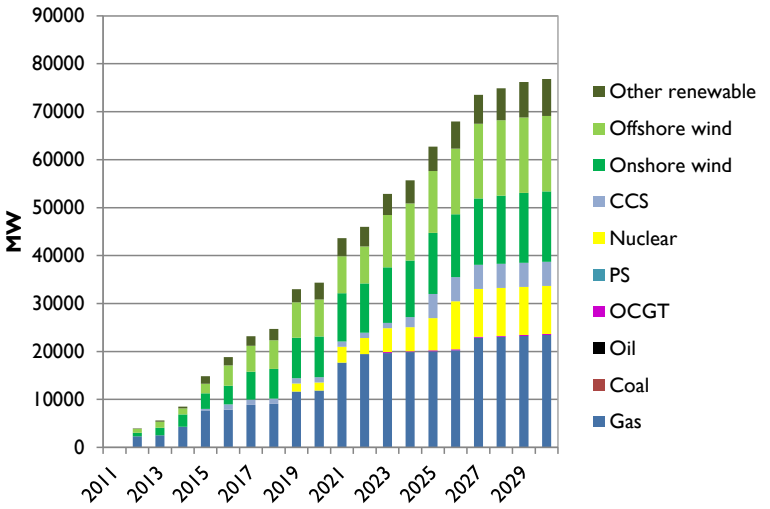
- Based on the feedback from the Working Group on the Stage 1 initial results, we have made a number changes to input assumptions
  - For further details see our meeting summary note circulated on 19 October
- In addition we are now using the full functionality of the model

Change	Impact
Adjusted the available generation projects based on feedback from the Working Group	Wider spread in renewables investment outcomes
Small increase in the nuclear CfD level	Nuclear build now occurs under all options
Transmission investment decisions are now fully endogenous	Higer constraint costs tend to be reinforced away
Further calibration of constraint costs versus PLEXOS constraint model	Higher constraint cost estimates, all other things being equal

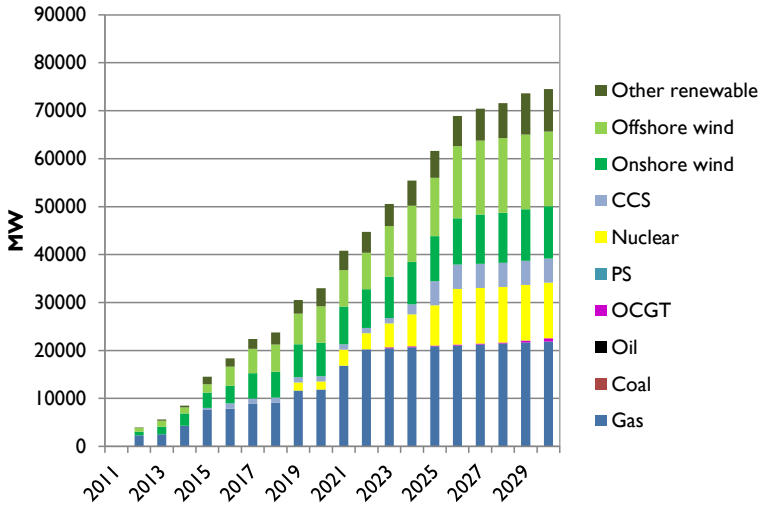
New build by generation type

- More onshore wind under Improved ICRP Stage 1 in 2020 and 2030
- More onshore and offshore wind, less nuclear build and higher CCGT investment under Socialised Stage 1

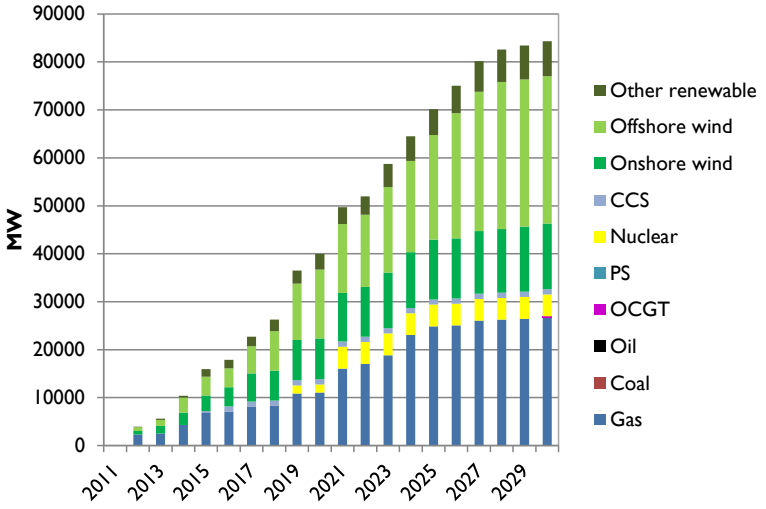
Improved ICRP



Status Quo



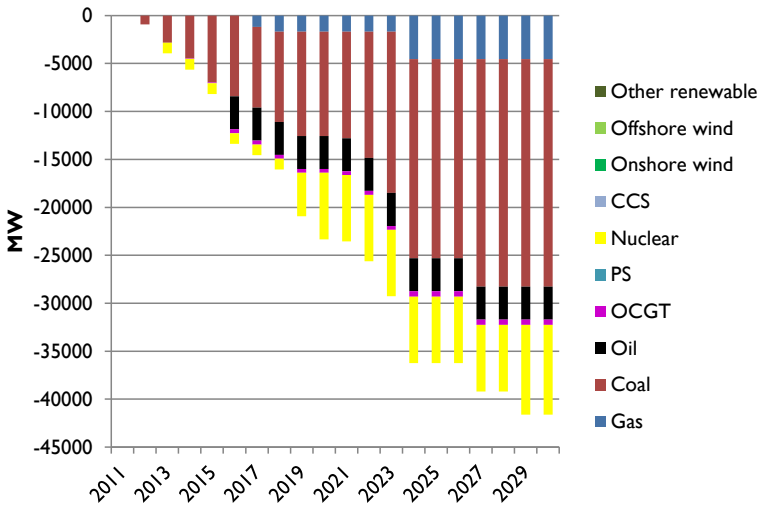
Socialised



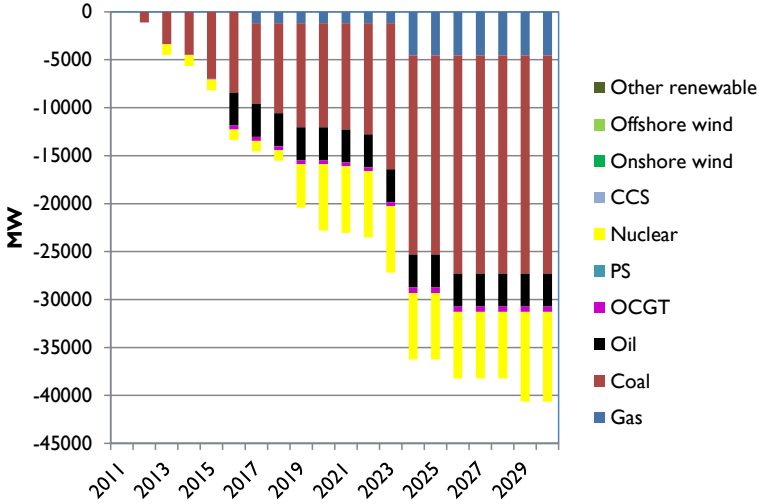
Cumulative retirements by generation type

- Majority of retirements in the near term are pre-determined: LCPD opt-out, nuclear AGRs
- Further retirements determined by earnings in wholesale market and TNUoS charges

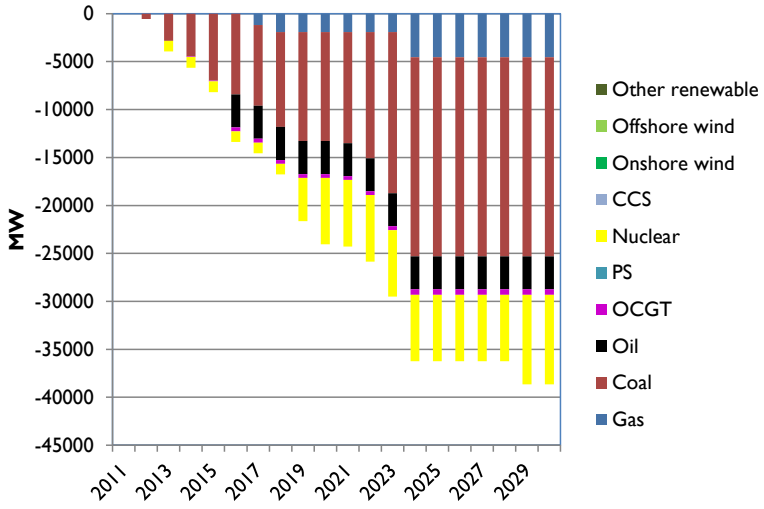
Improved ICRP



Status Quo



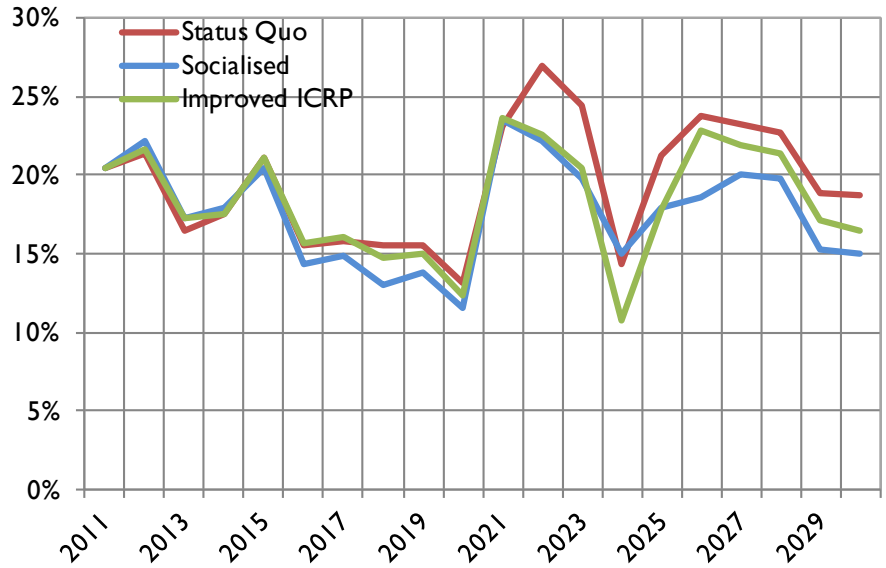
Socialised



Capacity margins

- De-rated capacity margins calculated using de-rating factors for each plant type based on expected contribution of each plant type at peak
- Thermal plant de-rated to take account of unplanned outages
- Onshore and offshore wind de-rated to 15%
- De-rated margins are very similar across policy options to 2020
- We have assumed a simple version of a capacity mechanism is implemented

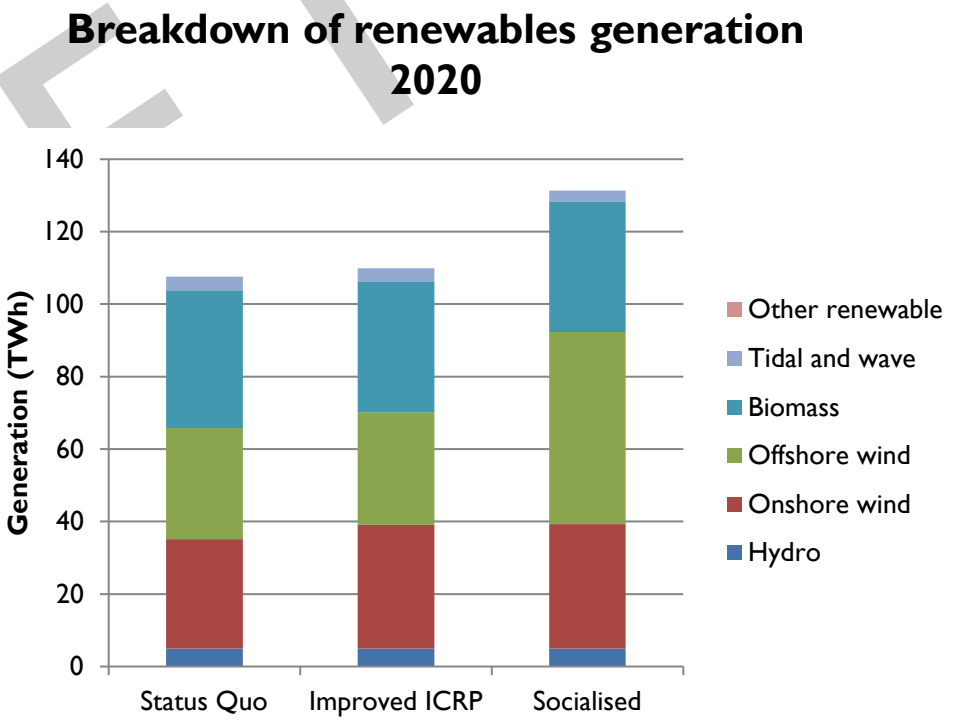
De-rated capacity margins[1]



1. De-rated capacity margin related to top 1% of winter demand (not absolute peak hour)

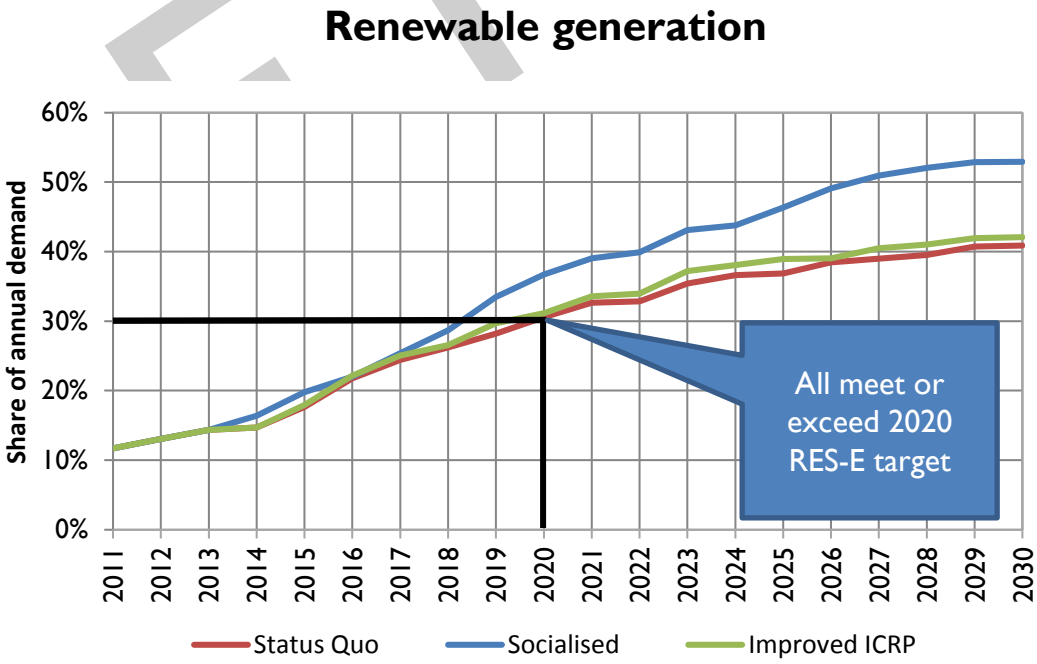
Renewable share by plant type, 2020

- Both Socialised and Improved ICRP have additional onshore wind generation by 2020 compared to Status Quo
- Offshore wind output under Socialised is double that of Status Quo
- Significant biomass generation under all policies, due to:
  - Assumptions on growth in embedded biomass
  - Assumptions on large-scale biomass co-firing/conversions
  - Large-scale dedicated biomass projects currently in TEC register proceed
- Tidal and wave contribute approximately 3 TWh under all policies



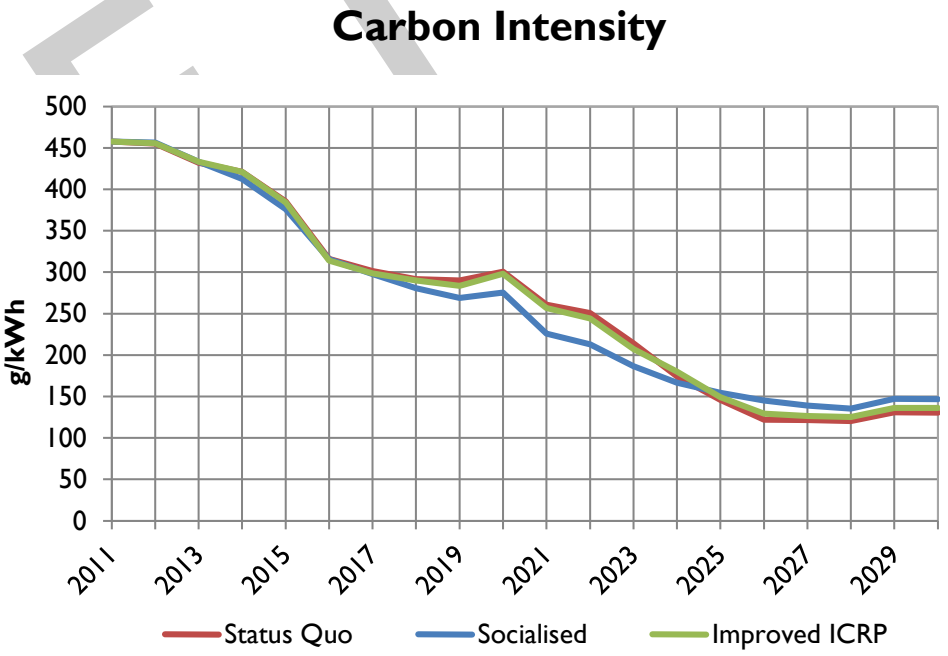
Renewable share

- Total renewable deployment higher under Socialised than Status Quo or Improved ICRP
  - mainly due to increased offshore wind deployment
- Increased renewables under Improved ICRP after 2020 compared to Status Quo
  - explained by greater onshore wind deployment, which is favoured in positive TNUoS zones



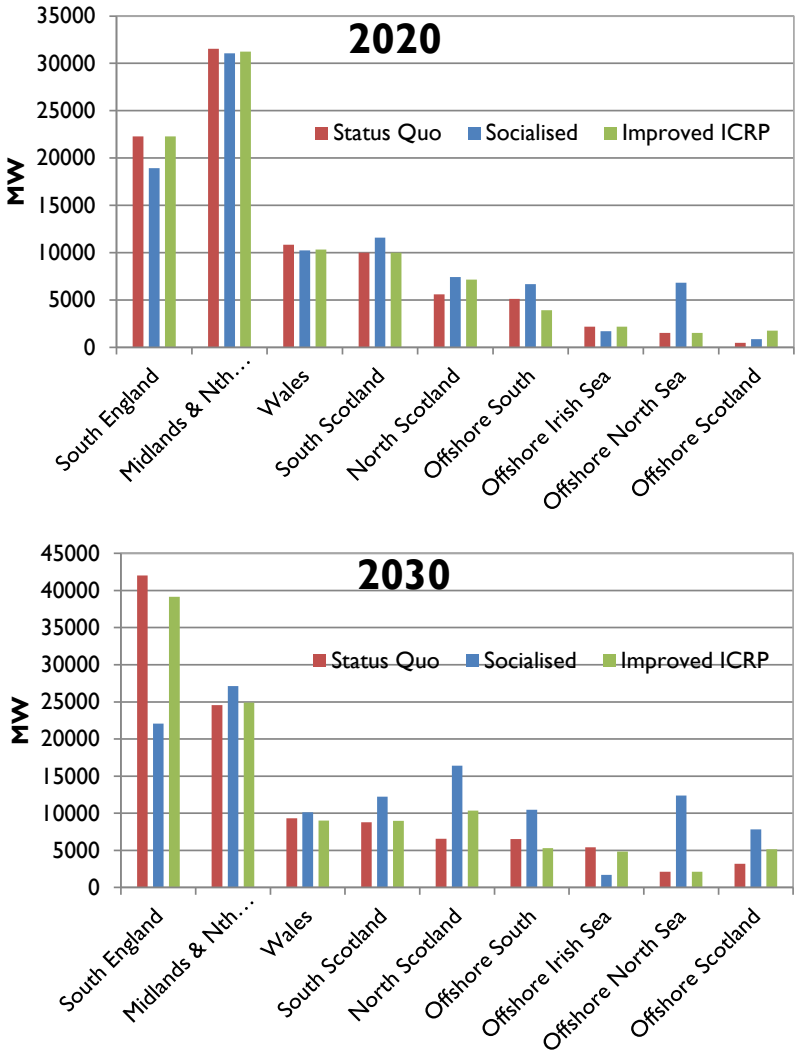
Carbon intensity

- Lower carbon intensity in 2020 under Socialised due to additional renewables
- By 2030, additional renewables under Socialised is offset by reduced nuclear and CCS capacity
  - These technologies face higher TNUoS charges under Socialised charging, so build is lower for fixed CfDs in the Stage 1 results



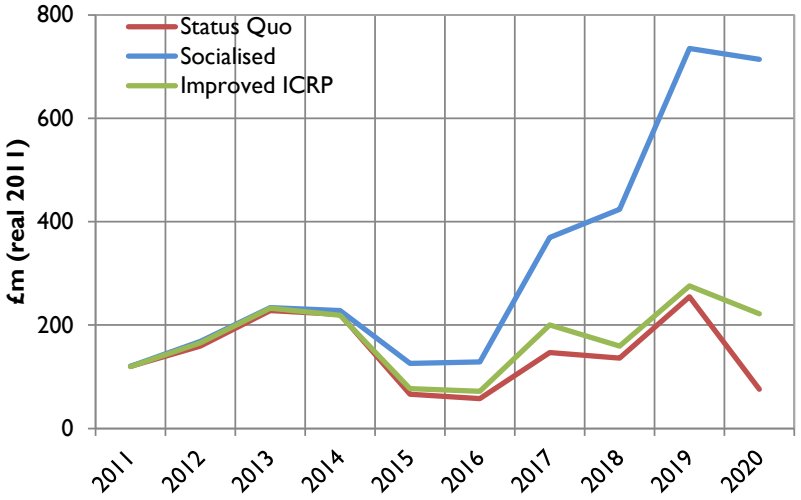
Installed capacity by location

- Differences between Status Quo and Socialised:
  - Less capacity in South England under Socialised
  - Accordingly greater capacity in North England, Wales and South Scotland
  - More build of offshore wind except for Irish Sea, which benefits least from socialisation of local asset charges
- Improved ICRP increases Scottish capacity – mainly due to additional onshore wind in North Scotland



Constraint costs

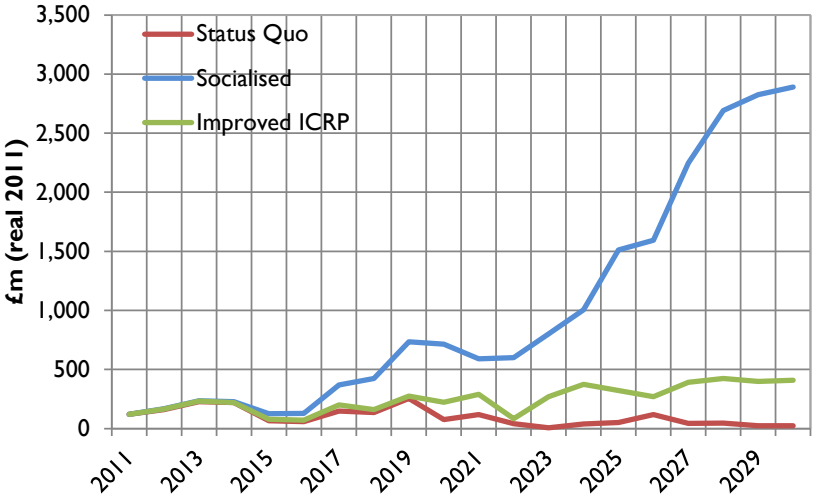
Annual constraint costs to 2020



- Constraint costs increase under Socialised mostly due to more rapid deployment of renewables, but also due to constraining off of new Scottish CCGTs

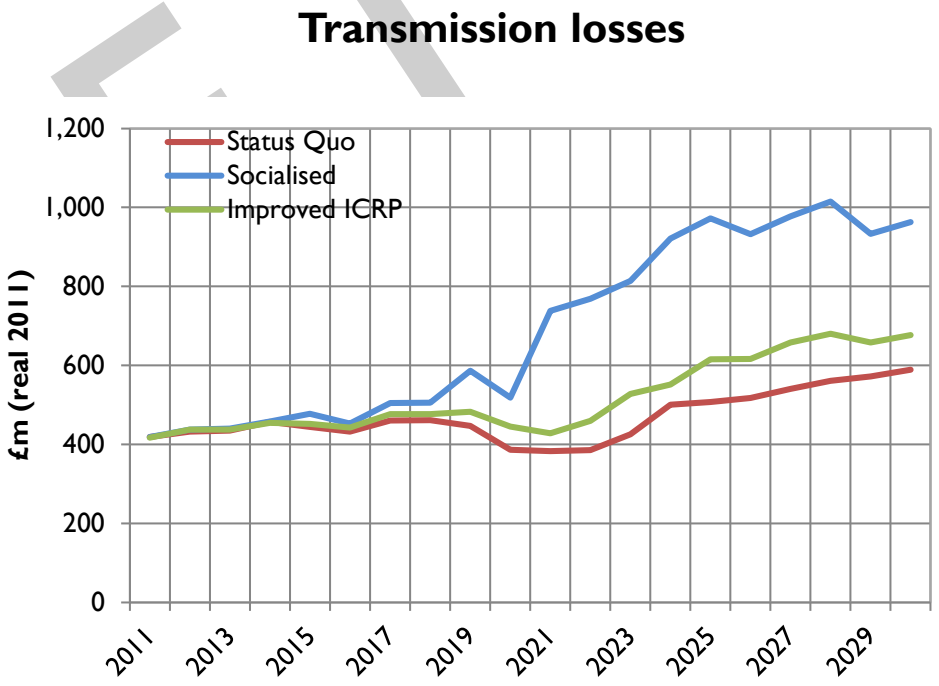
- Very high constraint costs under Socialised charging after 2020
- Higher transmission reinforcements are not able to offset this

Annual constraint costs to 2030



Transmission losses

- Transmission losses valued at system marginal price
- Costs of transmission losses higher under Socialised and Improved ICRP
- In particular, losses increase significantly in Socialised after 2020



Transmission reinforcements - HVDC

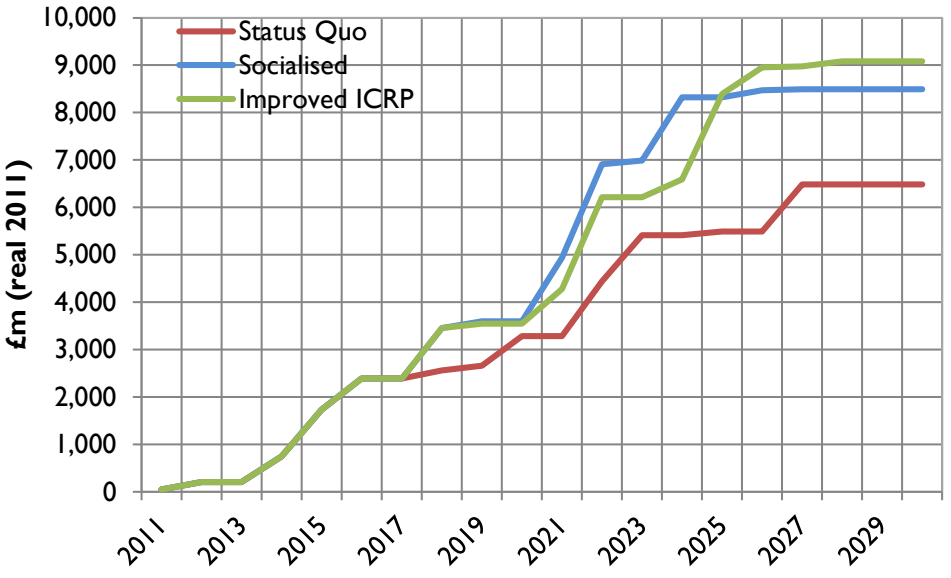
- Western HVDC link is built as soon as feasible, under all three charging options. The Western HVDC resolves the increasing constraints relating to wind deployment in Scotland
- Under all charging options all four of the Scotland-England HVDC links are built
- Status Quo reinforces latest, Socialised earliest
- Caithness-Moray is built under Improved ICRP and Socialised.

Reinforcement	Boundaries	Assumed earliest feasible date	SQ	Soc *Stage 1*	ICRP *Stage 1*
Western HVDC Link	B6, B7a	2015	2015	2015	2015
Western HVDC Link #2	B6, B7a	2020	2023	2022	2022
Eastern HVDC Link	B2, B4, B5, B6, B7a	2018	2022	2018	2018
Eastern HVDC Link #2	B6	2020	2027	2024	2025
Wylfa-Pembroke 2GW HVDC link	B202, NW2	2018	-	-	-
Caithness - Moray HVDC	B1	2017	-	2021	2022
Humber - Walpole HVDC	B8, B9, B11, B16	2020	-	2022	2025

Transmission costs (onshore)

- No variation prior to 2017
  - Assume most is committed to 2015
  - After 2015, model has to wait for key reinforcements to become available
- Costs of transmission reinforcement under Improved ICRP higher than Socialised
  - Socialised exhausts major reinforcements for north-south flows
  - Improved ICRP has earlier build of Hinckley Point – Seabank OHL

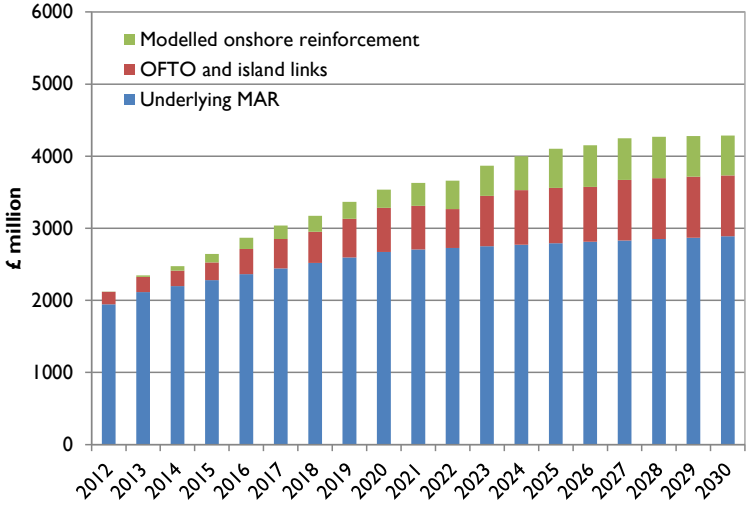
Cumulative onshore reinforcement costs



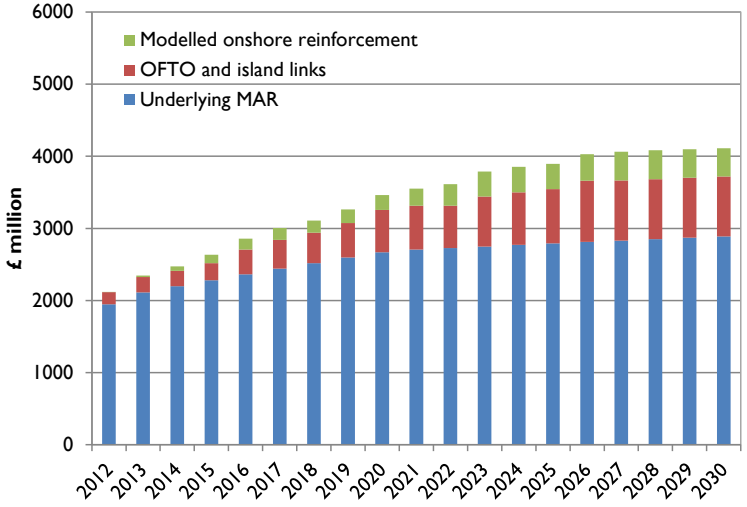
Transmission costs

- Increase in MAR broken down into constituent parts
- For Improved ICRP, additional onshore reinforcement is offset by reduced offshore transmission costs
- Significantly more offshore transmission spend under Socialised charging

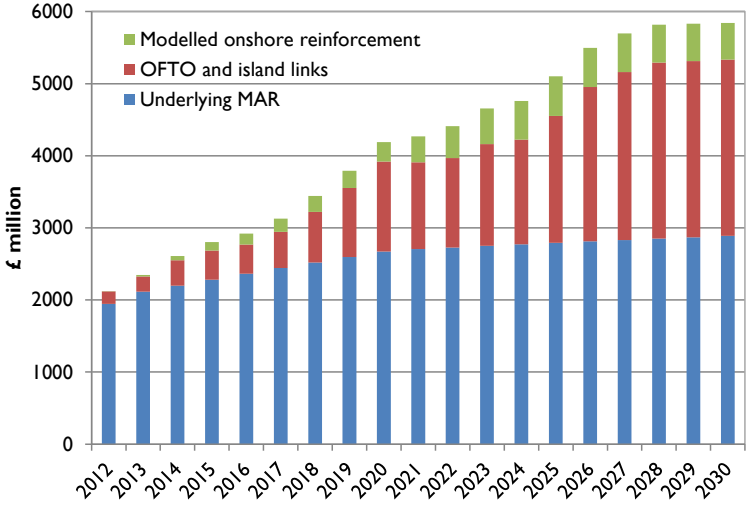
Improved ICRP



Status Quo



Socialised



Base Case results – Stage 2

Stage 2 vs. Stage 1

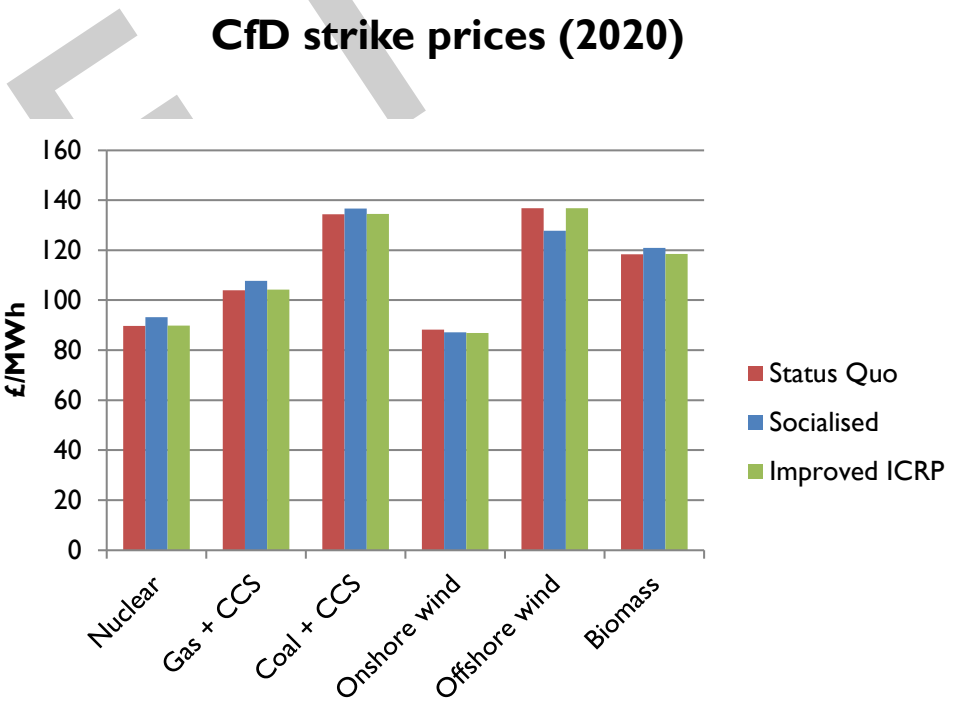
- Under Stage 2, we set the CfD levels in the three options to achieve the same levels of renewables in 2020 and carbon intensity by 2030

- Relative to the Stage 1 results, differences between the options are reduced
- Stage 2 results are more similar in terms of national capacity mix
- However locational differences in generation investment are maintained

- The reduction in renewables under Socialised Stage 2 results in significantly reduced constraint costs relative to Socialised Stage 1

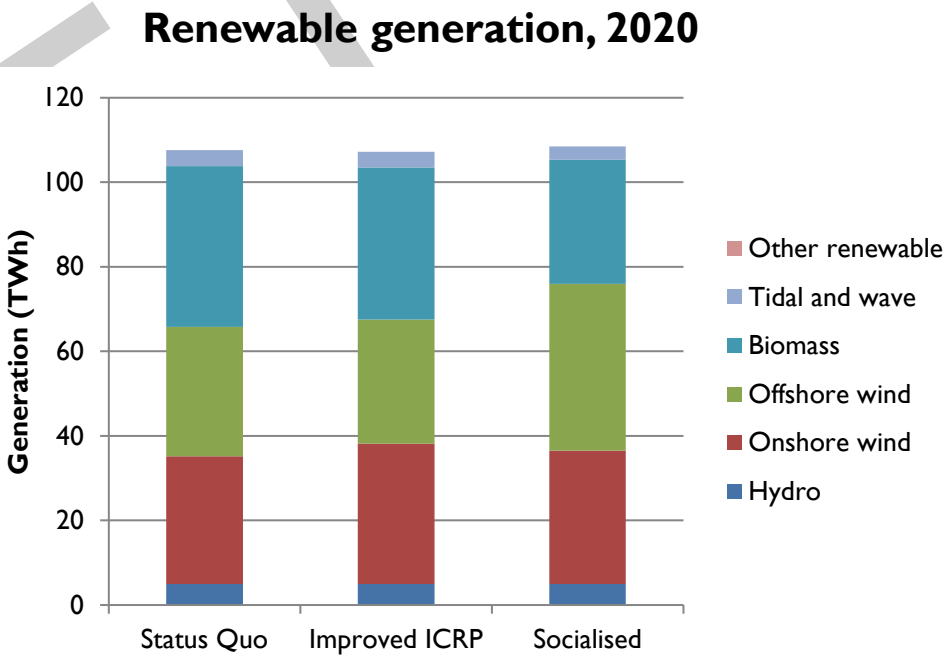
Stage 2 – adjustment to Low carbon support

- For both Improved ICRP and Socialised, CfDs are set endogenously according to the average LRMC of each technology. This should achieve an outcome comparable to – but not identical to – the low carbon targets reached in Status Quo.
- Support for all renewables until 2020 is scaled by a uniform percentage to achieve the same renewable share in 2020 as under Status Quo.
- Support for renewables from 2020 to 2030, as well as nuclear and CCS until 2030, is scaled to achieve the same carbon intensity in 2030 as under Status Quo.



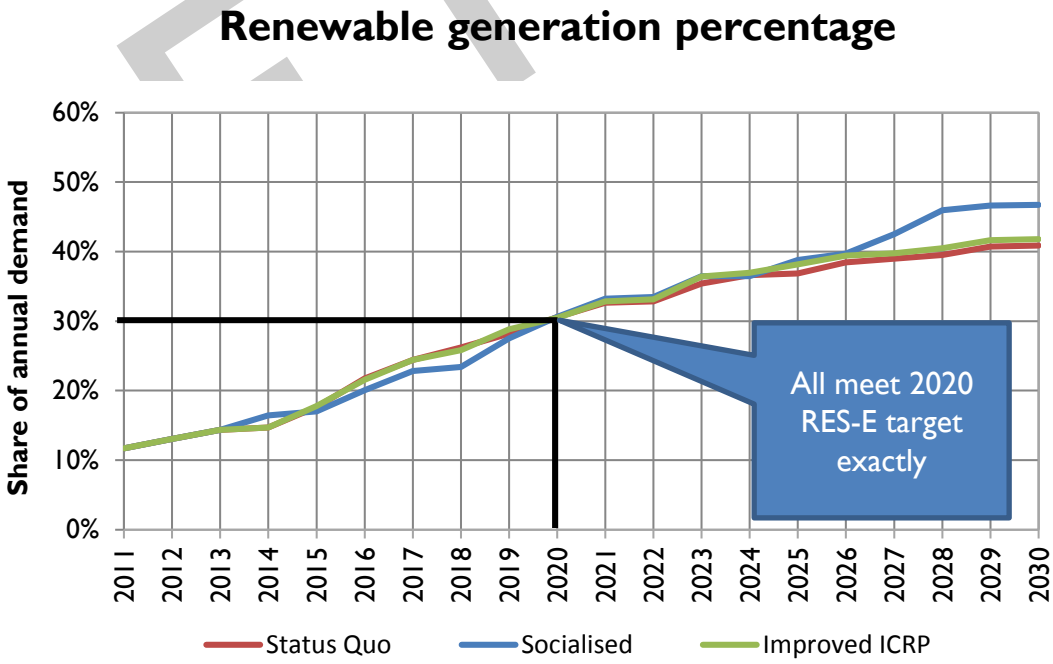
Renewables share by plant type, 2020

- The target 2020 renewables share is fixed under the Stage 2 modelling, but the mix of different renewables types is not
- Some tendency for Stage 2 results to retain the relative proportions of renewables (but not absolute amounts) from Stage 1
- Socialised and Improved ICRP both have less biomass
- Greatest onshore wind deployment under Improved ICRP
- Almost 10TWh of additional offshore wind generation under Socialised



Renewable share

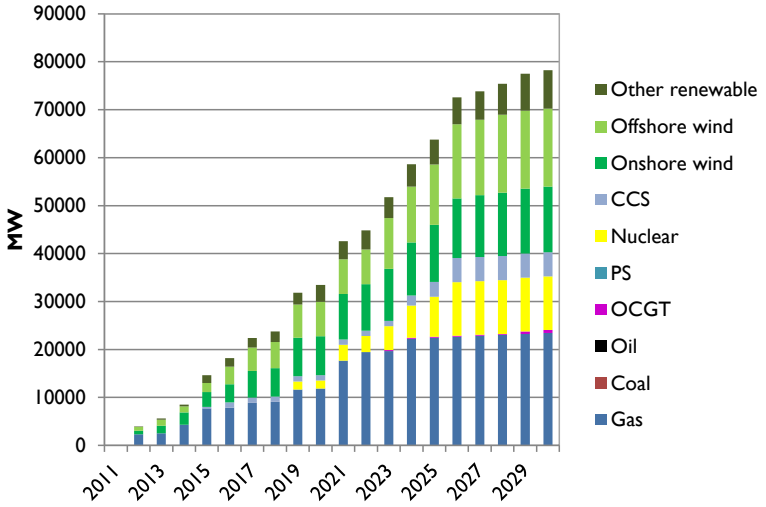
- Total renewable deployment in 2020 very similar across all three options – since support levels have been adjusted to achieve this outcome under Stage 2 modelling
- Increased renewables under Socialised after 2025
- This is offset by relatively less CCS and nuclear under Socialised Stage 2 to achieve same 2030 carbon intensity



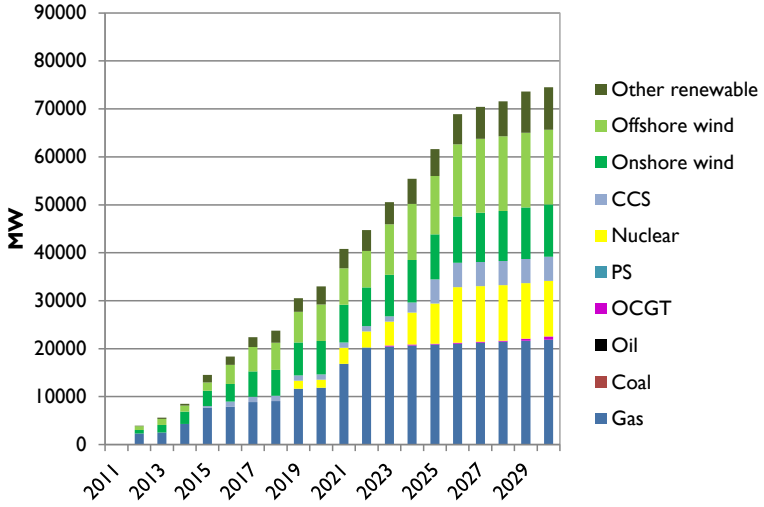
New build by generation type

- Differences in new build are smaller under Stage 2 than Stage 1
- Under Socialised Stage 2, more onshore and offshore wind and less CCS and nuclear compared to Status Quo

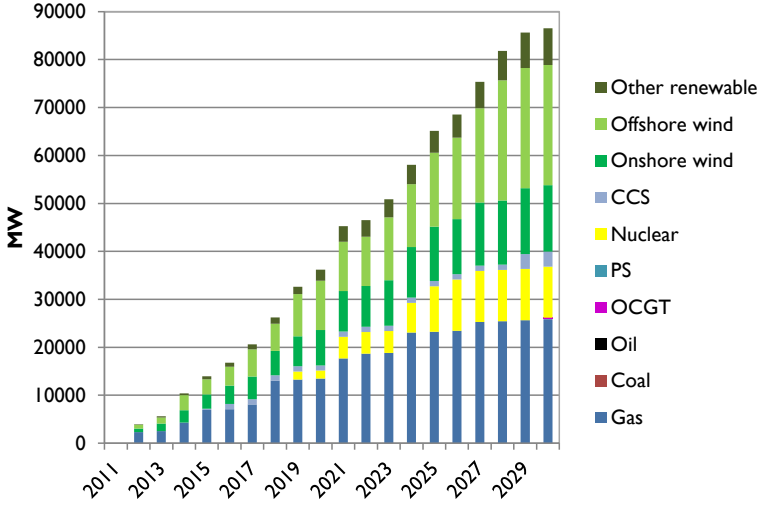
Improved ICRP



Status Quo

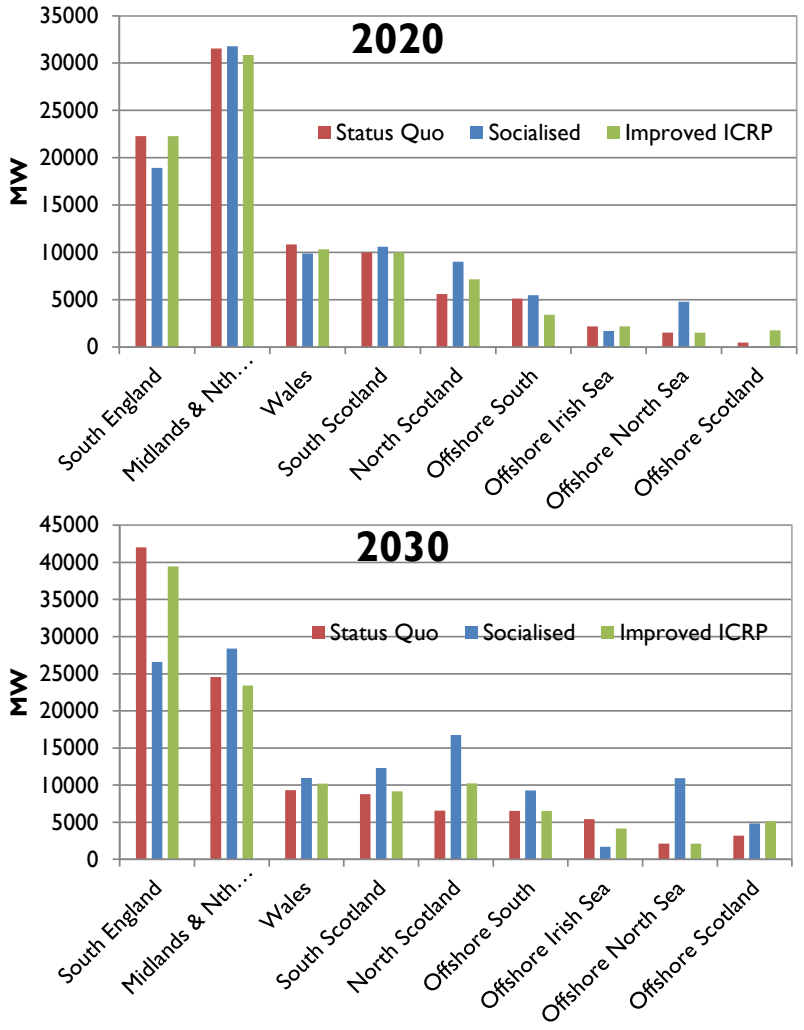


Socialised



Installed capacity by location

- Differences between Status Quo and Socialised:
  - Less capacity in South England under Socialised
  - Accordingly greater capacity in North England, Wales, South Scotland and North Scotland
  - More build of offshore wind in the North Sea (in particular, Dogger Bank and Hornsea) with relatively high transmission costs
- Improved ICRP increases Scottish capacity
  - mainly due to additional onshore wind
  - also additional Scottish offshore wind - lower onshore TNUoS charges make this more appealing



Change in build relative to Status Quo – CCGT

- Limited variations in new CCGT Capacity under Improved ICRP
- Significant locational differences in CCGT build under Socialised charging
  - CCGT geographical spread under Socialised is determined predominately by gas exit charges
- Whereas Socialised Stage 1 had significantly more CCGT, Socialised Stage 2 CCGT build is more similar in aggregate to Status Quo

Status Quo	2015	2020	2025	2030
CCGT - South England	1,600	4,800	12,800	12,800
CCGT - Midlands & Nth England	3,270	3,270	3,270	3,270
CCGT - Wales	2,060	2,060	2,060	2,060
CCGT - South Scotland	0	0	0	0
CCGT - North Scotland	0	0	0	0

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
CCGT - South England	0	0	0	0
CCGT - Midlands & Nth England	0	0	1,600	1,600
CCGT - Wales	0	0	0	0
CCGT - South Scotland	0	0	0	0
CCGT - North Scotland	0	0	0	0

Socialised (change from Status Quo)	2015	2020	2025	2030
CCGT - South England	-800	-3,200	-9,600	-9,600
CCGT - Midlands & Nth England	0	1,600	3,200	4,800
CCGT - Wales	0	0	0	0
CCGT - South Scotland	0	1,600	4,000	4,000
CCGT - North Scotland	0	1,600	4,800	4,800

Change in build relative to Status Quo – onshore wind

- Reduction in onshore wind in both Improved ICRP and Socialised Stage 2 results compared with equivalent Stage 1 results
- Wind capacity is lost from the least favourable location under each of the options (central Wales – connected into Midlands & Nth England)
- Reminder: all English wind is assumed to be embedded
- North Scotland wind category includes build on Scottish islands

Status Quo	2015	2020	2025	2030
Onshore wind - South England	42	98	134	348
Onshore wind - Midlands & Nth England	221	605	1,087	1,650
Onshore wind - Wales	51	118	161	420
Onshore wind - South Scotland	1,696	3,984	5,368	5,723
Onshore wind - North Scotland	1,215	2,147	2,648	2,767

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
Onshore wind - South England	0	0	0	0
Onshore wind - Midlands & Nth England	-137	-411	-685	-685
Onshore wind - Wales	0	0	0	0
Onshore wind - South Scotland	0	0	46	176
Onshore wind - North Scotland	55	1,564	3,124	3,273

Socialised (change from Status Quo)	2015	2020	2025	2030
Onshore wind - South England	0	0	0	0
Onshore wind - Midlands & Nth England	-137	-411	-822	-959
Onshore wind - Wales	0	0	0	0
Onshore wind - South Scotland	-229	-1,007	-1,362	-687
Onshore wind - North Scotland	139	1,818	4,101	4,605

Change in build relative to Status Quo – offshore wind

- Reductions in offshore wind build from Socialised Stage 1 to Socialised Stage 2 occurs in Offshore South, Irish Sea and North Sea
- Under Improved ICRP Stage 2, Offshore Scotland maintains increased levels over Status Quo, with reductions in Irish Sea and North Sea

Status Quo	2015	2020	2025	2030
Offshore wind - Offshore South	1,045	4,245	5,145	5,645
Offshore wind - Offshore Irish Sea	233	1,633	3,033	4,857
Offshore wind - Offshore North Sea	425	1,275	1,875	1,875
Offshore wind - Offshore Scotland	0	450	2,105	3,195

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
Offshore wind - Offshore South	0	-1,700	-1,200	0
Offshore wind - Offshore Irish Sea	0	0	0	-1,250
Offshore wind - Offshore North Sea	0	0	0	0
Offshore wind - Offshore Scotland	180	1,300	1,640	1,940

Socialised (change from Status Quo)	2015	2020	2025	2030
Offshore wind - Offshore South	370	370	670	2,770
Offshore wind - Offshore Irish Sea	765	-493	-1,893	-3,717
Offshore wind - Offshore North Sea	295	3,248	4,581	8,803
Offshore wind - Offshore Scotland	0	-450	-110	1,630

Change in build relative to Status Quo – nuclear

- Status Quo and Improved ICRP Stage 2 have very similar nuclear build
- Under Socialised Stage 2, nuclear build is more widely distributed around England and Wales than under Status Quo

Status Quo	2015	2020	2025	2030
Nuclear - South England	0	1,670	8,350	11,600
Nuclear - Midlands & Nth England	0	0	0	0
Nuclear - Wales	0	0	0	0
Nuclear - South Scotland	0	0	0	0
Nuclear - North Scotland	0	0	0	0

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
Nuclear - South England	0	0	0	-1,600
Nuclear - Midlands & Nth England	0	0	0	0
Nuclear - Wales	0	0	0	1,200
Nuclear - South Scotland	0	0	0	0
Nuclear - North Scotland	0	0	0	0

Socialised (change from Status Quo)	2015	2020	2025	2030
Nuclear - South England	0	0	-1,670	-4,920
Nuclear - Midlands & Nth England	0	0	1,600	1,600
Nuclear - Wales	0	0	1,200	2,400
Nuclear - South Scotland	0	0	0	0
Nuclear - North Scotland	0	0	0	0

Change in build relative to Status Quo – CCS

- The tables include the CCS demo plants, the assumptions for which are constant across all options
- Less CCS built under Socialised Stage 2
- This offsets the greater levels of renewables compared to Status Quo

Status Quo	2015	2020	2025	2030
Coal + CCS - South England	0	0	0	0
Coal + CCS - Midlands & Nth England	0	800	4,740	4,740
Coal + CCS - Wales	0	0	0	0
Coal + CCS - South Scotland	300	300	300	300
Coal + CCS - North Scotland	0	0	0	0

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
Coal + CCS - South England	0	0	0	0
Coal + CCS - Midlands & Nth England	0	0	-1,940	0
Coal + CCS - Wales	0	0	0	0
Coal + CCS - South Scotland	0	0	0	0
Coal + CCS - North Scotland	0	0	0	0

Socialised (change from Status Quo)	2015	2020	2025	2030
Coal + CCS - South England	0	0	0	0
Coal + CCS - Midlands & Nth England	0	0	-3,940	-1,940
Coal + CCS - Wales	0	0	0	0
Coal + CCS - South Scotland	0	0	0	0
Coal + CCS - North Scotland	0	0	0	0

Change in retirements relative to Status Quo

Status Quo	2015	2020	2025	2030
Coal - South England	-2,995	-4,453	-4,453	-4,453
Coal - Midlands & Nth England	-1,940	-4,381	-10,986	-12,973
Coal - Wales	-363	-363	-1,932	-1,932
Coal - South Scotland	-1,673	-1,673	-3,386	-3,386
Coal - North Scotland	0	0	0	0

Status Quo	2015	2020	2025	2030
CCGT - South England	0	0	-806	-806
CCGT - Midlands & Nth England	0	0	-2,054	-2,054
CCGT - Wales	0	0	-515	-515
CCGT - South Scotland	0	0	0	0
CCGT - North Scotland	0	-1,180	-1,180	-1,180

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
Coal - South England	0	0	0	0
Coal - Midlands & Nth England	0	0	0	-968
Coal - Wales	0	0	0	0
Coal - South Scotland	0	0	0	0
Coal - North Scotland	0	0	0	0

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
CCGT - South England	0	0	0	0
CCGT - Midlands & Nth England	0	0	0	-810
CCGT - Wales	0	-515	0	0
CCGT - South Scotland	0	0	0	0
CCGT - North Scotland	0	0	0	0

Socialised (change from Status Quo)	2015	2020	2025	2030
Coal - South England	0	0	0	0
Coal - Midlands & Nth England	0	976	0	1,987
Coal - Wales	0	0	0	0
Coal - South Scotland	0	0	0	0
Coal - North Scotland	0	0	0	0

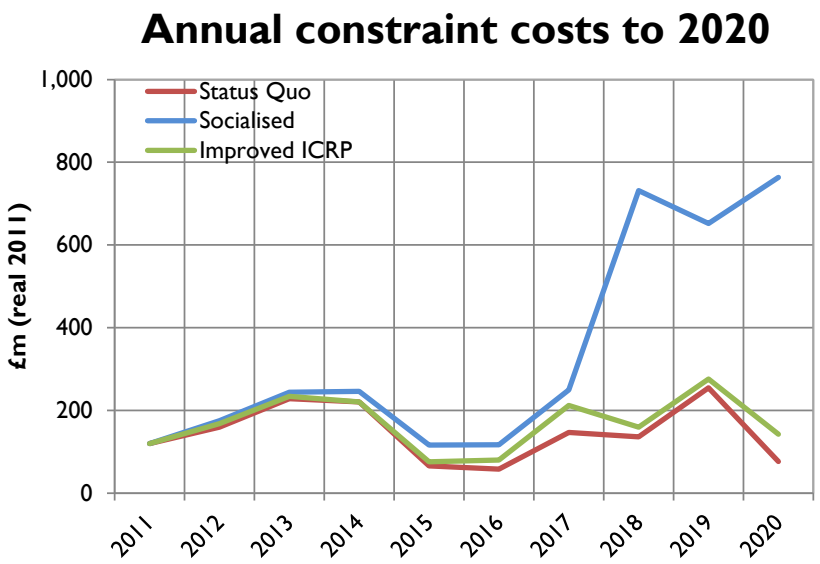
Socialised (change from Status Quo)	2015	2020	2025	2030
CCGT - South England	0	0	0	0
CCGT - Midlands & Nth England	0	-1,039	-810	-810
CCGT - Wales	0	-515	0	0
CCGT - South Scotland	0	0	0	0
CCGT - North Scotland	0	0	0	0

Transmission reinforcements - HVDC

- Western HVDC link is built as soon as feasible in all cases. Under all charging options all four of the Scotland-England HVDC links are built
- Under Improved ICRP the HVDC reinforcements occur earlier than in Socialised. Improved ICRP has more Scottish onshore wind earlier, making reinforcement of Scottish boundaries beneficial earlier

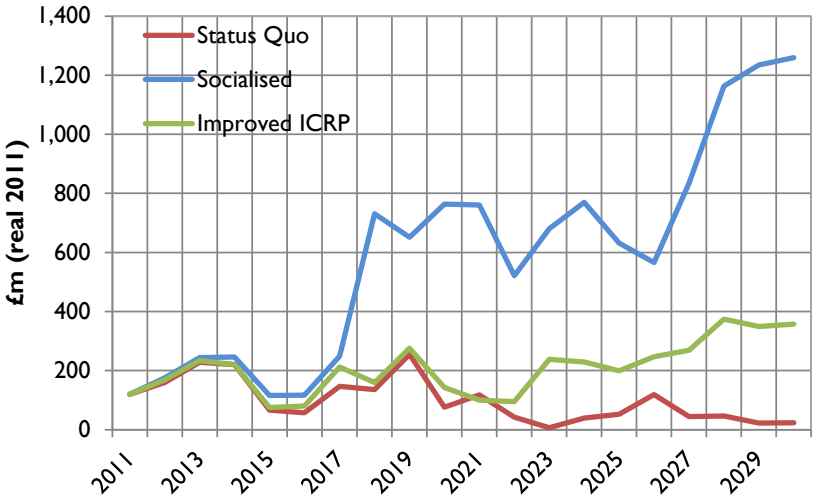
Reinforcement	Boundaries	Assumed earliest feasible date	SQ	Soc *Stage 2*	ICRP *Stage 2*
Western HVDC Link	B6, B7a	2015	2015	2015	2015
Western HVDC Link #2	B6, B7a	2020	2023	2022	2020
Eastern HVDC Link	B2, B4, B5, B6, B7a	2018	2022	2022	2018
Eastern HVDC Link #2	B6	2020	2027	2025	2024
Wylfa-Pembroke 2GW HVDC link	B202, NW2	2018	-	-	-
Caithness - Moray HVDC	B1	2017	-	2022	2020
Humber - Walpole HVDC	B8, B9, B11, B16	2020	-	2023	2027

Constraint costs



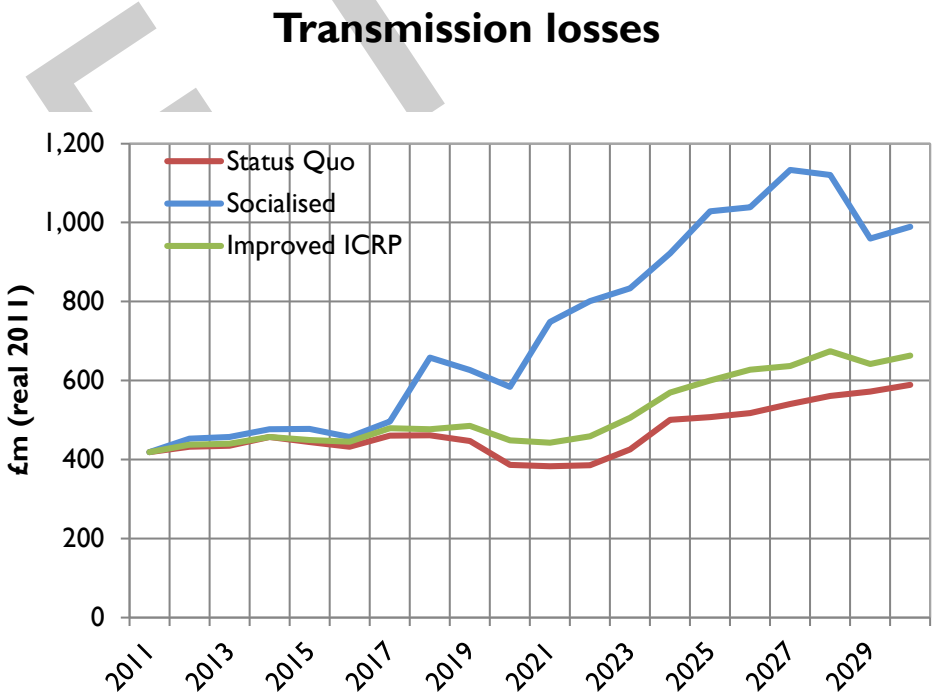
- Rapid increase in constraint costs under Socialised charging after 2017

- Little difference in constraint cost estimates before 2017
- Socialised costs increase, but less so than under Stage 1 due to lower wind deployment



Transmission losses

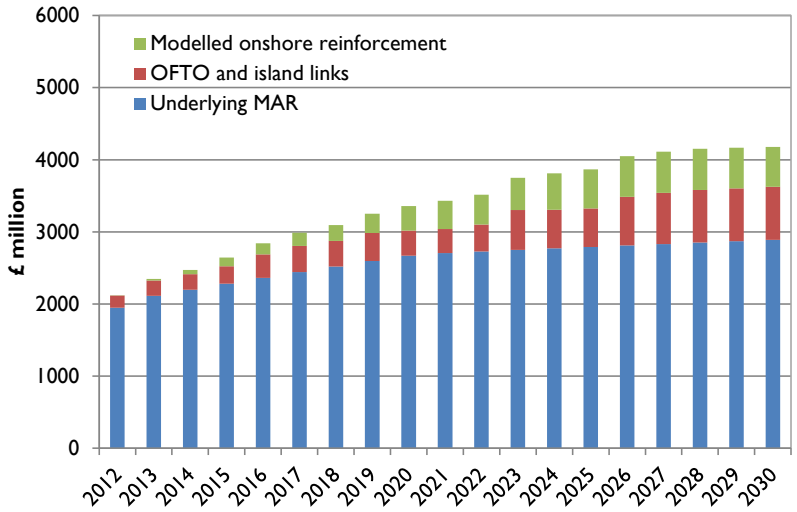
- Transmission losses valued at system marginal price
- Costs of transmission losses higher under Socialised and Improved ICRP
- In particular, losses increase significantly in Socialised after 2020



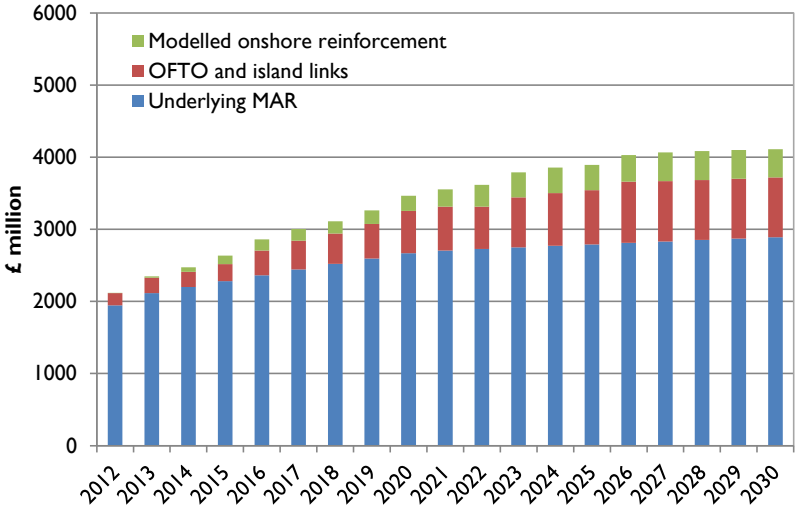
Transmission costs

- Increase in MAR broken down into constituent parts
- As for Stage 1, significantly more offshore transmission spend under Socialised charging
  - also more onshore reinforcement, particularly between 2020 and 2025

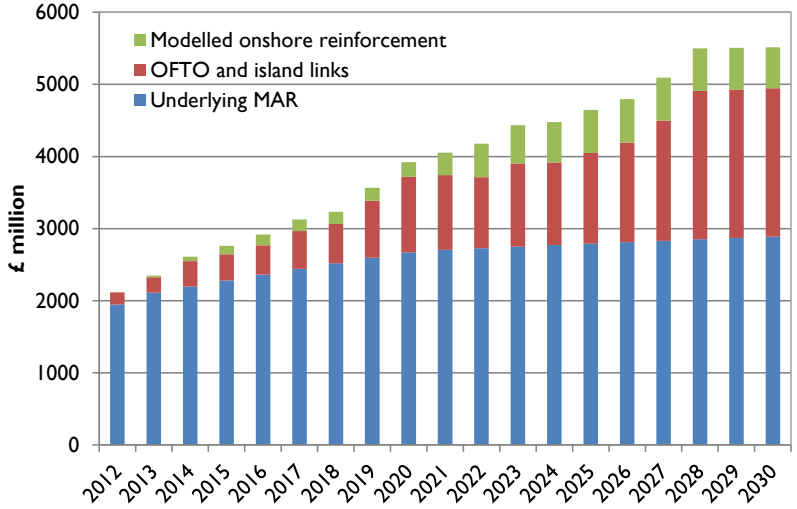
Improved ICRP



Status Quo



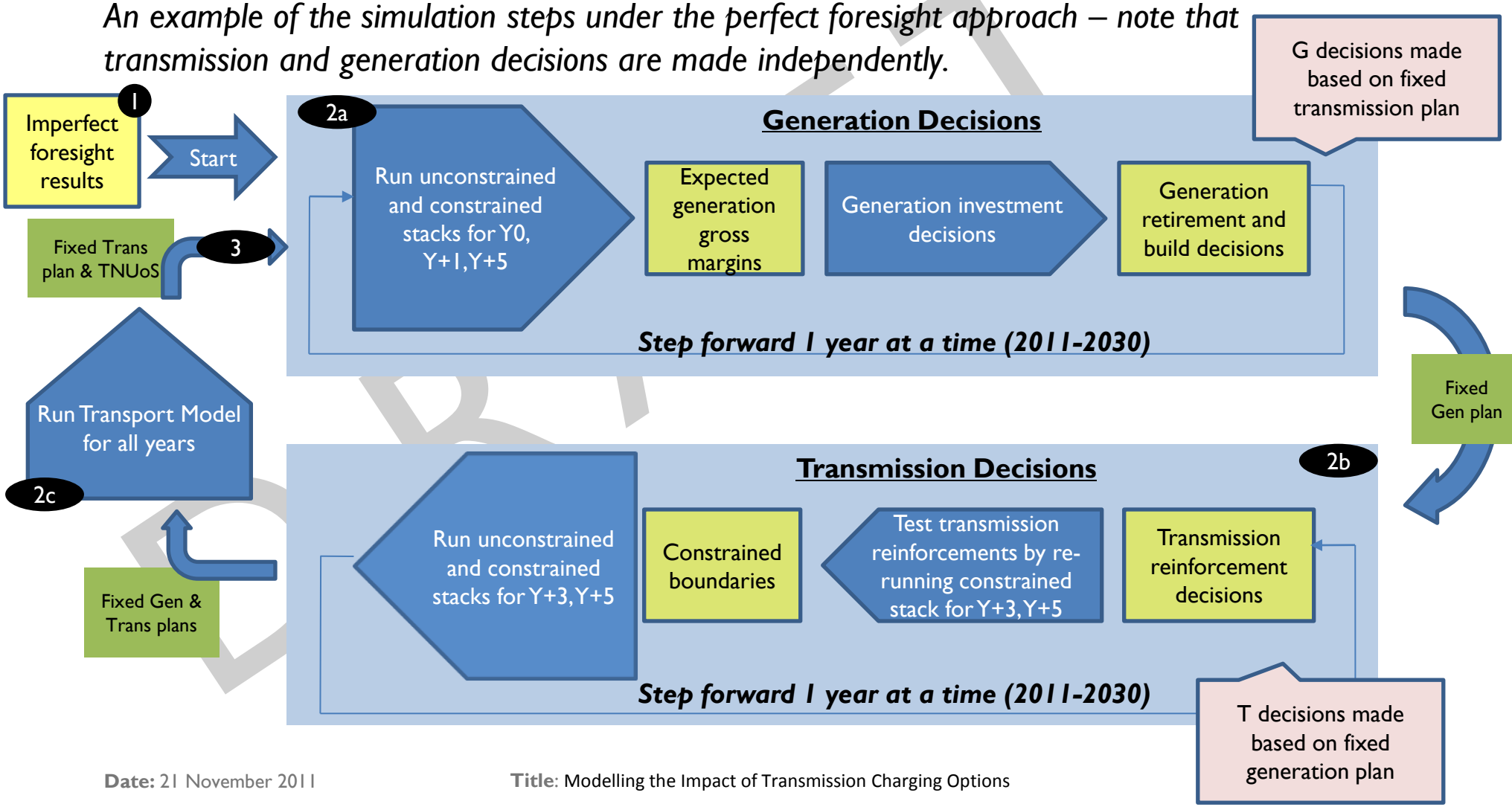
Socialised



Perfect Foresight approach

Simulation steps (perfect foresight)

An example of the simulation steps under the perfect foresight approach – note that transmission and generation decisions are made independently.



Simulation steps (perfect foresight)

The steps in the diagram in the preceding slide are described here

1. Imperfect Foresight results are used as a starting point for the Perfect Foresight model
2. Run the three model components iteratively in the order below
   a. Generation investment/retirement decisions (2011-2030)
   b. Transmission investment decisions (2011-2030).
   c. Transport model (2011-2030)
3. Begin the next iteration, using the results of step 2 as inputs
4. Run until model converges (generation and transmission investment decisions are stable) or max of 5 iterations

Perfect Foresight results

Perfect Foresight

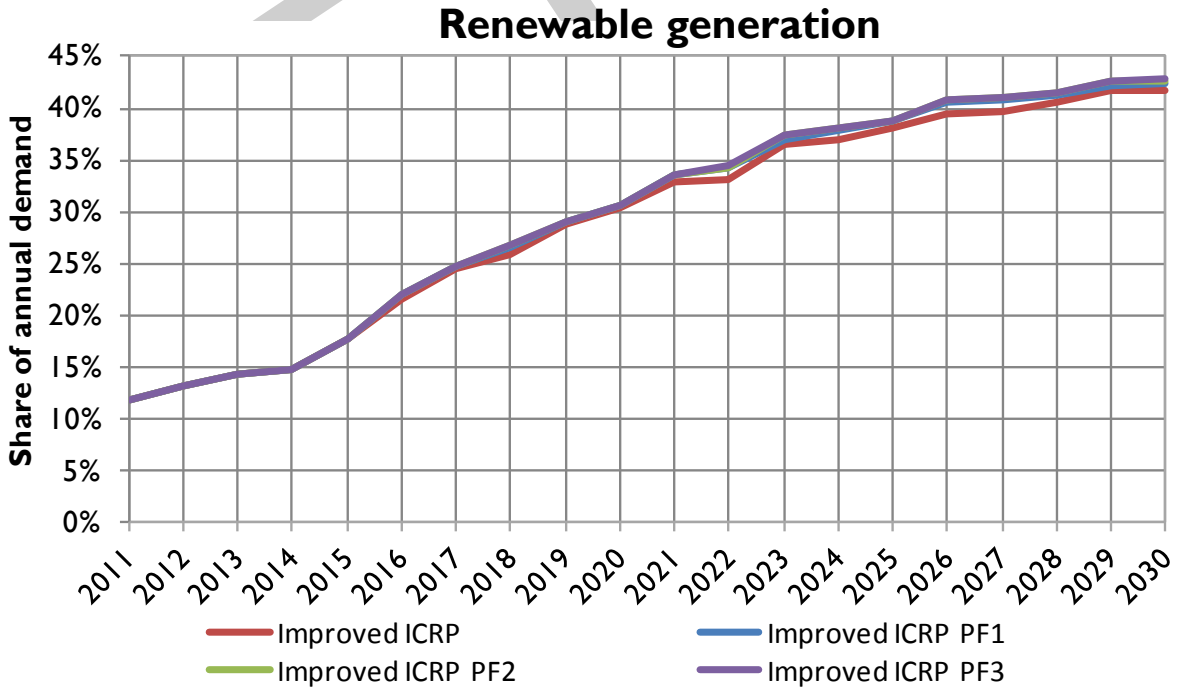
- We find that Perfect Foresight produces convergent results on two of the three options: Improved ICRP and Socialised
- Compared to Imperfect foresight, these results indicate lower constraint costs in some years as transmission investment is brought forward and Scottish wind build reduces slightly
- Under Status Quo, we find that the Perfect Foresight iterations do not converge to a single result.
  - Our analysis suggests that we flip between two results due to a feedback loop between wind in Scotland, HVDC investment and tariffs
- We note that the two extremes of Status Quo Perfect Foresight results are above and below the Imperfect foresight world in term of renewables (specifically Scottish wind).

Improved ICRP

- Perfect Foresight iterations show some convergence under Improved ICRP
- Changes in renewables build and in transmission reinforcements between iterations are small
- Convergence is not complete – changes in timing of retirements and investments for thermal capacity do occur, but have limited directional effect on the overall results

Renewable share

- Total renewable deployment changes at Iteration 1, but is stable thereafter
- Overall, renewables generation is higher under Perfect Foresight both before and after 2020
- Reduction in onshore wind, but increase in biomass capacity



Change in Scottish onshore wind

- Onshore wind build is relatively consistent over all Perfect Foresight iterations
- Implies that feedback between wind build and tariffs is not strong

- Reduced onshore wind in Scotland is offset by gains in central Wales wind (shown under Midlands & North England)

Scottish wind

Onshore wind North Scotland	2015	2020	2025	2030
Improved ICRP	1,270	3,711	5,773	6,041
Improved ICRP PF1	1,215	3,321	5,383	5,809
Improved ICRP PF2	1,215	3,321	5,021	5,671
Improved ICRP PF3	1,215	3,321	5,021	5,671

Onshore wind South Scotland	2015	2020	2025	2030
Improved ICRP	1,696	3,984	5,415	5,899
Improved ICRP PF1	1,696	3,984	5,415	5,899
Improved ICRP PF2	1,696	3,984	5,415	5,899
Improved ICRP PF3	1,696	3,984	5,415	5,899

Change in onshore wind (PF3)

PF3 (change from Imperfect foresight)	2015	2020	2025	2030
Onshore wind - South England	0	0	0	0
Onshore wind - Midlands & Nth England	0	411	548	548
Onshore wind - Wales	0	0	0	0
Onshore wind - South Scotland	0	0	0	0
Onshore wind - North Scotland	-55	-390	-752	-369

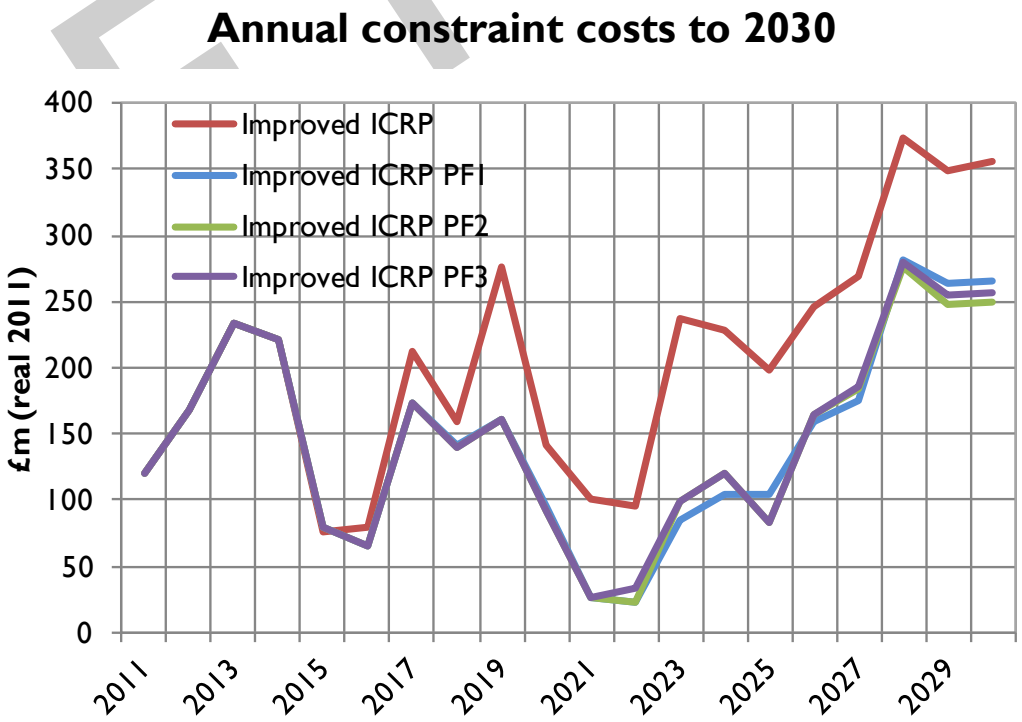
Transmission reinforcements - HVDC

- No change in HVDC reinforcements between iterations, but there are differences compared to Imperfect Foresight

Reinforcement	Boundaries	Improved ICRP	Improved ICRP PF1	Improved ICRP PF2	Improved ICRP PF3
Western HVDC Link	B6, B7a	2015	2015	2015	2015
Western HVDC Link #2	B6, B7a	2020	2020	2020	2020
Eastern HVDC Link	B2, B4, B5, B6, B7a	2018	2018	2018	2018
Eastern HVDC Link #2	B2, B4, B5, B6, B7a	2024	2025	2025	2025
Wylfa-Pembroke 2GW HVDC link	B202, NW2	-	-	-	-
Caithness - Moray HVDC	B1	2020	2019	2019	2019
Humber - Walpole HVDC	B8, B9, B11, B16	2027	2025	2025	2025

Constraint costs

- All Perfect foresight iterations have lower constraint costs than Imperfect Foresight
- Reduced onshore wind, similar HVDC reinforcements

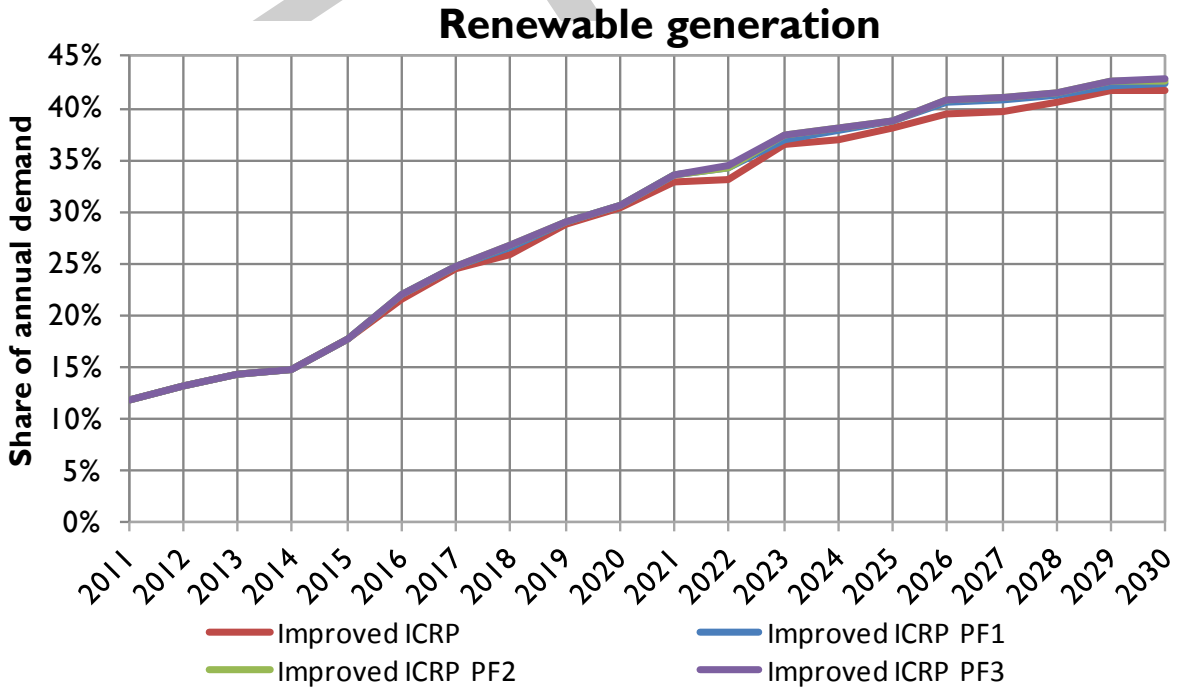


Socialised

- We expect feedback between Perfect Foresight iterations to be weaker under Socialised.
- Knowledge of future tariffs does not change expectations significantly
- We observe complete convergence in Perfect Foresight results under Socialised
  - However there are differences from the Imperfect Foresight results

Renewable share

- Total renewable deployment changes at Iteration 1, but is stable thereafter
- Overall, renewables generation is higher under Perfect Foresight both before and after 2020
- Reduction in onshore wind, but increase in biomass capacity



Change in Scottish onshore wind

- Onshore wind build is consistent over all Perfect Foresight iterations
- Expected result, as no feedback between investment in wind and tariffs

Scottish wind

Onshore wind North Scotland	2015	2020	2025	2030
Socialised	1,355	3,966	6,750	7,372
Socialised PF1	1,355	3,966	6,784	7,452
Socialised PF2	1,355	3,966	6,784	7,452
Socialised PF3	1,355	3,966	6,784	7,452

Onshore wind South Scotland	2015	2020	2025	2030
Socialised	1,467	2,978	4,006	5,035
Socialised PF1	1,467	1,949	2,978	4,006
Socialised PF2	1,467	1,949	2,978	4,006
Socialised PF3	1,467	1,949	2,978	4,006

Change in onshore wind (PF3)

PF3 (change from Imperfect foresight)	2015	2020	2025	2030
Onshore wind - South England	0	0	0	0
Onshore wind - Midlands & Nth England	0	0	0	0
Onshore wind - Wales	0	0	0	0
Onshore wind - South Scotland	0	-1,029	-1,029	-1,029
Onshore wind - North Scotland	0	0	35	80

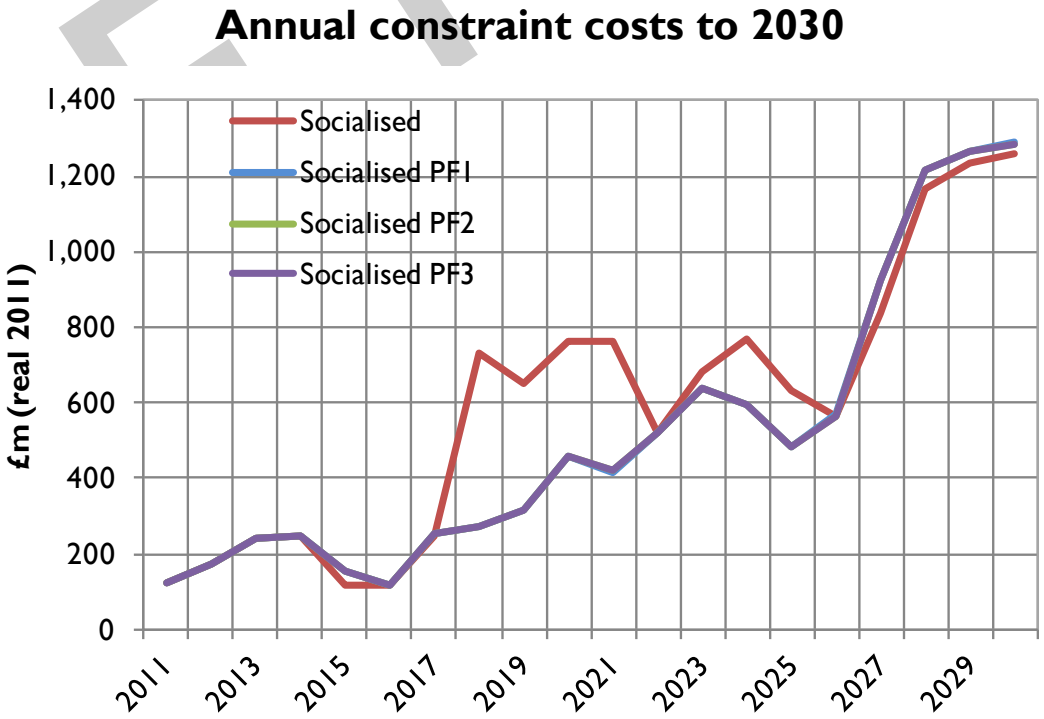
Transmission reinforcements - HVDC

- Imperfect Foresight and Perfect Foresight are similar
- Perfect Foresight has earlier investment in two of the HVDC bootstraps, which is part of the explanation for lower constraint costs from 2019 (the other reason is the reduction in onshore wind)
- No change in HVDC reinforcements between iterations

Reinforcement	Boundaries	Socialised	Socialised PF1	Socialised PF2	Socialised PF3
Western HVDC Link	B6, B7a	2015	2015	2015	2015
Western HVDC Link #2	B6, B7a	2022	2022	2022	2022
Eastern HVDC Link	B2, B4, B5, B6, B7a	2022	2019	2019	2019
Eastern HVDC Link #2	B2, B4, B5, B6, B7a	2025	-	-	-
Wylfa-Pembroke 2GW HVDC link	B202, NW2	-	-	-	-
Caithness - Moray HVDC	B1	2022	2019	2019	2019
Humber - Walpole HVDC	B8, B9, B11, B16	2023	2020	2020	2020

Constraint costs

- All Perfect foresight iterations have lower constraint costs than Imperfect Foresight for most of the period
- Mainly a result of reduced onshore Scottish wind and earlier reinforcements
- All PF results lie exactly on top of each other

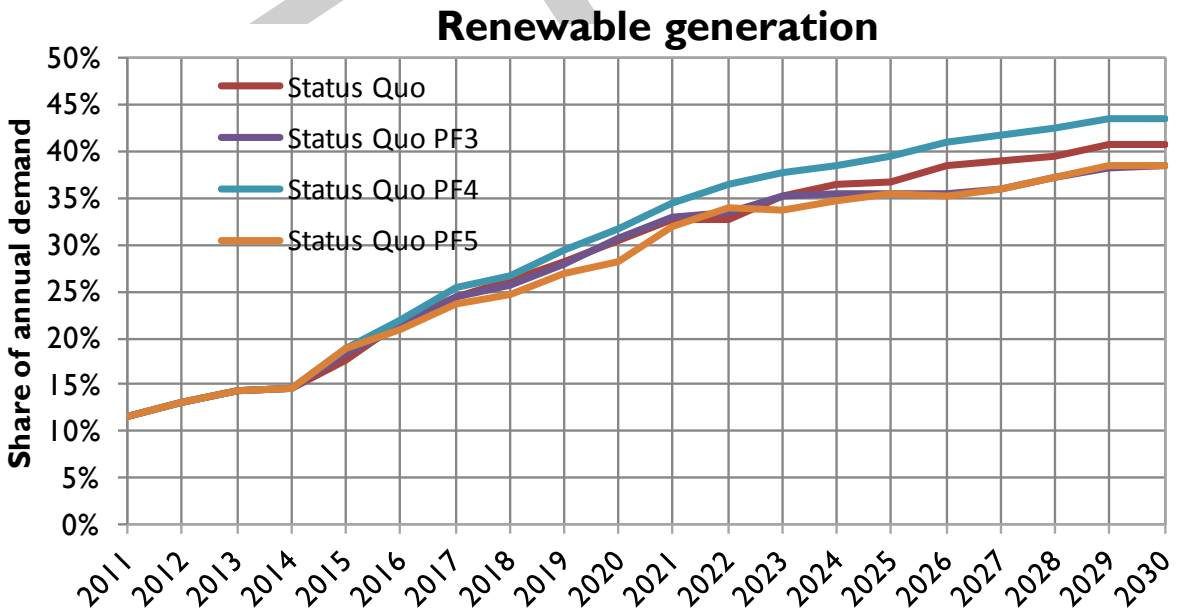


Status Quo

- For Status Quo we ran five iterations of Perfect foresight, with the first iteration using the Imperfect Foresight results as a starting point
- The results did not demonstrate convergence, in fact the differences between consecutive iterations increase in later iterations
- Analysis of the results suggests that the major driver of differences is the interaction between wind build in Scotland and HVDC reinforcement of Scottish & Northern England boundaries. The feedback is through the mechanism of changing generator TNUoS in Scotland
- We major on the results from iterations 3 to 5, where differences are most extreme

Renewable share

- Total renewable deployment flips between iterations
- Iteration 4 has the highest renewables penetration
- In the following slides we describe the underlying causes and the consequences of this



Change in Scottish onshore wind

- Onshore wind build is relatively consistent over early iterations
- Major switch comes at iteration 3
- Iteration 4 is then the highest of all iterations
- Iteration 5 returns to results similar to Iteration 3
- This is a result of feedback between onshore wind build, HVDC reinforcement and TNUoS in Scotland

Onshore wind North Scotland	2015	2020	2025	2030
Status Quo	1,215	2,147	2,648	2,767
Status Quo PF1	1,101	1,863	2,298	2,493
Status Quo PF2	1,101	1,847	2,388	2,548
Status Quo PF3	1,061	1,350	1,656	1,751
Status Quo PF4	1,270	3,711	5,773	6,366
Status Quo PF5	927	1,117	1,402	1,497

Onshore wind South Scotland	2015	2020	2025	2030
Status Quo	1,696	3,984	5,368	5,723
Status Quo PF1	1,683	3,978	5,355	5,830
Status Quo PF2	1,683	3,978	5,368	5,858
Status Quo PF3	1,467	1,921	1,921	1,921
Status Quo PF4	1,696	3,984	5,415	5,899
Status Quo PF5	1,467	1,467	1,467	1,467

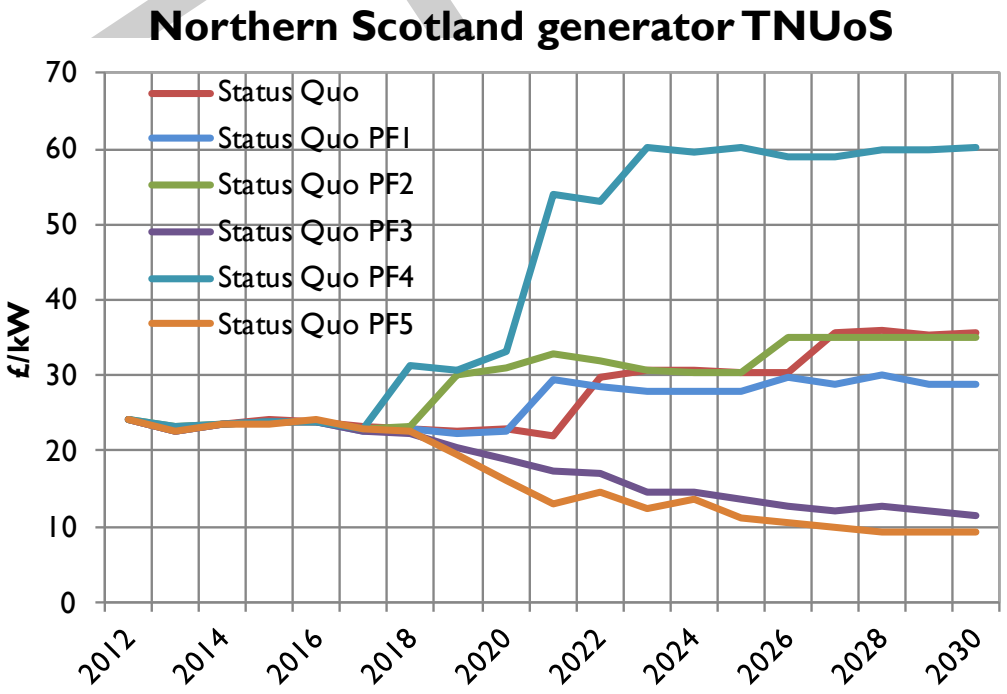
Transmission reinforcements - HVDC

- We observe an iterative pattern in HVDC reinforcements
- Iterations 3 and 5 have less Scottish wind, and therefore require less reinforcement
- Iteration 4 has the highest level of Scottish wind and the most reinforcements

Reinforcement	Boundaries	Status Quo	Status Quo PF1	Status Quo PF2	Status Quo PF3	Status Quo PF4	Status Quo PF5
Western HVDC Link	B6, B7a	2015	2015	2015	2015	2015	2015
Western HVDC Link #2	B6, B7a	2023	2026	2021	-	2020	-
Eastern HVDC Link	B2, B4, B5, B6, B7a	2022	2021	2019	-	2018	-
Eastern HVDC Link #2	B2, B4, B5, B6, B7a	2027	-	2026	-	2023	-
Wylfa-Pembroke 2GW HVDC link	B202, NW2	-	-	-	-	-	-
Caithness - Moray HVDC	B1	-	-	-	-	2021	-
Humber - Walpole HVDC	B8, B9, B11, B16	-	-	-	-	2023	-

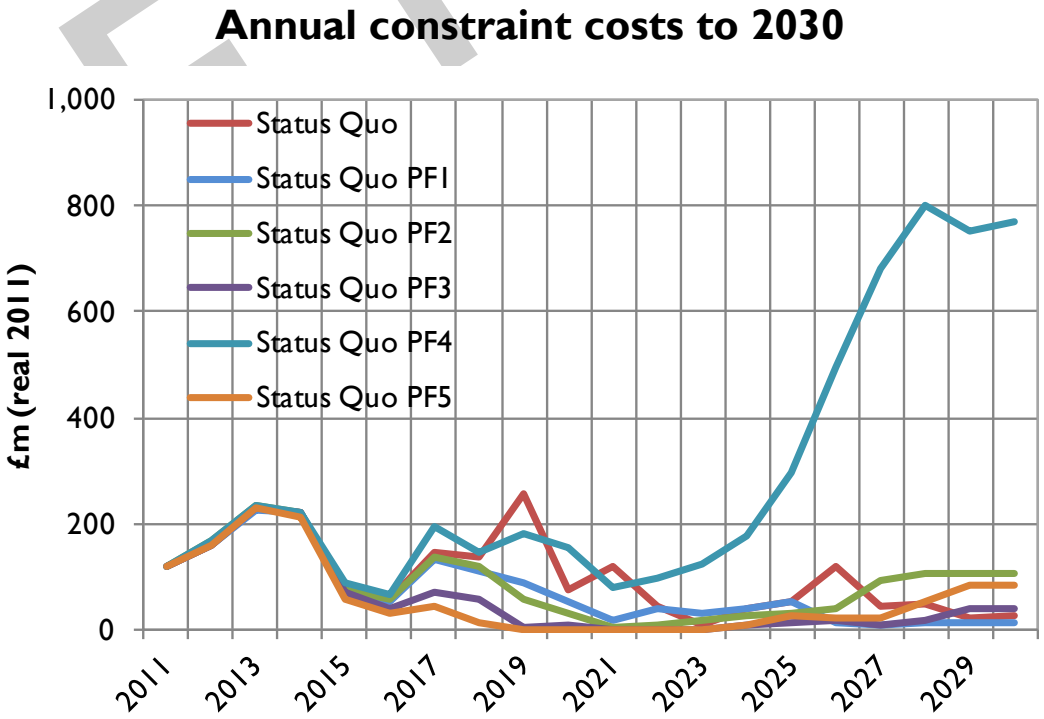
Tariff example: zone 1 (Northern Scotland)

- Tariffs are calculated as the final step in the iteration – they feed into the following iteration
- Early iterations are fairly similar to Imperfect Foresight result
- Iteration 3 has low tariffs, due to low HVDC investment (Western HVDC only)
- These low tariffs favour the greater deployment of Scottish onshore wind seen Iteration 4
- High Scottish wind in Iteration 4 drives low wind build in Iteration 5



Constraint costs

- Early iterations typically have lower constraint costs than under Imperfect Foresight
- Iteration 4 is the extreme result again - increase in Scottish onshore is the major factor responsible
- Iteration 5 has lowest constraint costs of all, even with lowest HVDC reinforcement



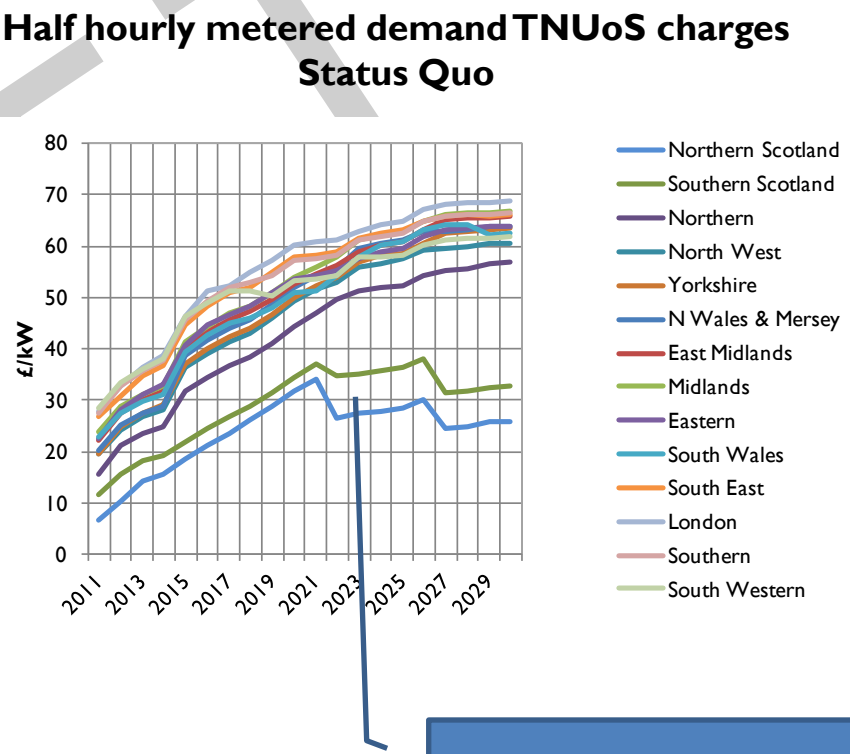
Next steps

- Presentation at Stakeholder event in Glasgow, 17 November
- Modelling of sensitivities as agreed with Ofgem
  - Two policy option sensitivities
  - Commodity price sensitivities
- Drafting of final report

Appendix – additional materials

Demand tariffs – Status Quo

- The chart shows tariffs for half hourly metered demand under Status Quo
- Tariffs for 2011 are the 2011/12 published demand tariffs
- The increase in tariffs is driven by the increase in MAR, which itself is driven by increasing expenditure by the TOs - this includes generation related expenditure (onshore transmission reinforcements, OFTOs, HVDC bootstraps) as well as non-generation spend
- The change in the G:D split to 15:85 amplifies the increase

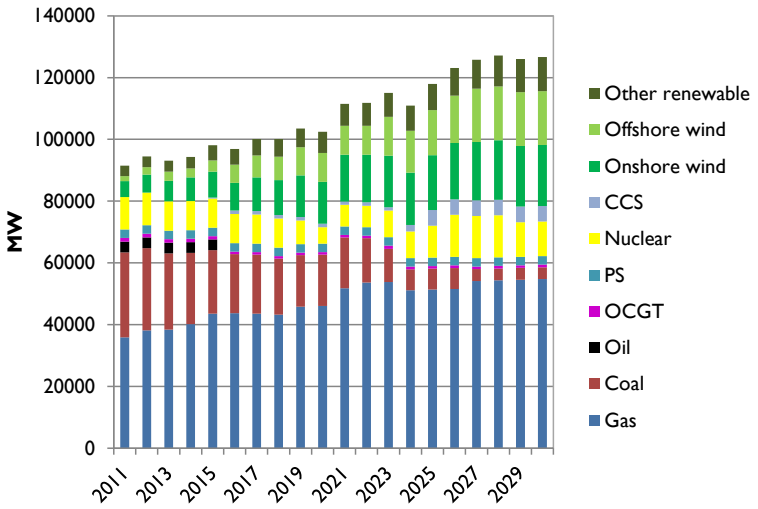


Commissioning of HVDCs reduces Scottish demand tariffs

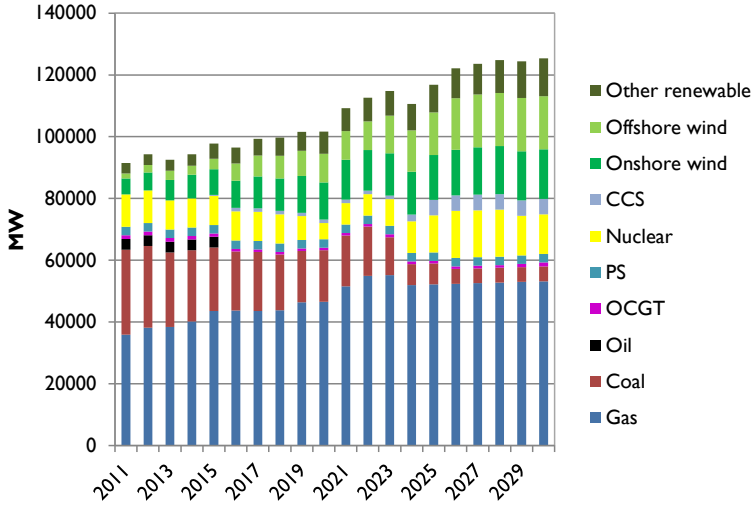
Capacity mix by generation type

- Socialised has the highest deployment of offshore wind: 16 GW in 2020 and 32 GW in 2030
- Increase in CCGT capacity after 2020 under Socialised charging to cover lack of nuclear build

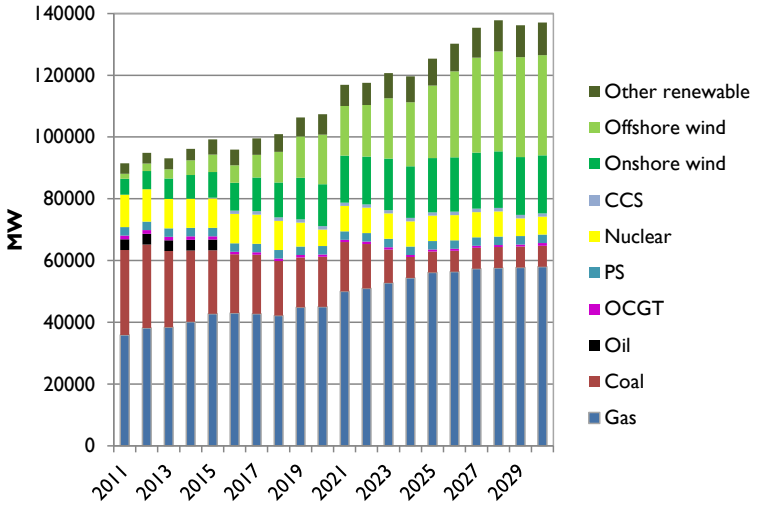
Improved ICRP



Status Quo



Socialised



Change in retirements relative to Status Quo

Status Quo	2015	2020	2025	2030
Coal - South England	-2,995	-4,453	-4,453	-4,453
Coal - Midlands & Nth England	-1,940	-4,381	-10,986	-12,973
Coal - Wales	-363	-363	-1,932	-1,932
Coal - South Scotland	-1,673	-1,673	-3,386	-3,386
Coal - North Scotland	0	0	0	0

Status Quo	2015	2020	2025	2030
CCGT - South England	0	0	-806	-806
CCGT - Midlands & Nth England	0	0	-2,054	-2,054
CCGT - Wales	0	0	-515	-515
CCGT - South Scotland	0	0	0	0
CCGT - North Scotland	0	-1,180	-1,180	-1,180

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
Coal - South England	0	0	0	0
Coal - Midlands & Nth England	0	0	0	-968
Coal - Wales	0	0	0	0
Coal - South Scotland	0	0	0	0
Coal - North Scotland	0	0	0	0

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
CCGT - South England	0	0	0	0
CCGT - Midlands & Nth England	0	0	0	0
CCGT - Wales	0	-515	0	0
CCGT - South Scotland	0	0	0	0
CCGT - North Scotland	0	0	0	0

Socialised (change from Status Quo)	2015	2020	2025	2030
Coal - South England	0	0	0	0
Coal - Midlands & Nth England	0	-488	0	1,987
Coal - Wales	0	0	0	0
Coal - South Scotland	0	0	0	0
Coal - North Scotland	0	0	0	0

Socialised (change from Status Quo)	2015	2020	2025	2030
CCGT - South England	0	0	0	0
CCGT - Midlands & Nth England	0	-229	0	0
CCGT - Wales	0	-515	0	0
CCGT - South Scotland	0	0	0	0
CCGT - North Scotland	0	0	0	0

Change in build relative to Status Quo – CCGT

- No difference between Status Quo and Improved ICRP until after 2020
- Significant additional CCGT build under Socialised charging
  - As noted earlier, required in the absence of nuclear build
  - CCGT geographical spread is determined predominately by gas exit charges in the absence of locational transmission charges

Status Quo	2015	2020	2025	2030
CCGT - South England	1,600	4,800	12,800	12,800
CCGT - Midlands & Nth England	3,270	3,270	3,270	3,270
CCGT - Wales	2,060	2,060	2,060	2,060
CCGT - South Scotland	0	0	0	0
CCGT - North Scotland	0	0	0	0

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
CCGT - South England	0	0	-800	0
CCGT - Midlands & Nth England	0	0	0	1,600
CCGT - Wales	0	0	0	0
CCGT - South Scotland	0	0	0	0
CCGT - North Scotland	0	0	0	0

Socialised (change from Status Quo)	2015	2020	2025	2030
CCGT - South England	-800	-3,200	-9,600	-9,600
CCGT - Midlands & Nth England	0	800	4,800	5,600
CCGT - Wales	0	0	0	0
CCGT - South Scotland	0	1,600	4,000	4,000
CCGT - North Scotland	0	0	4,800	4,800

Change in build relative to Status Quo – onshore wind

- More onshore wind build under Improved ICRP
  - Two-part charging regime favours wind over thermal plant in positive TNUoS zones
- Onshore wind in North Scotland greater again under Socialised charging, due to a significant reduction in the tariffs

Status Quo	2015	2020	2025	2030
Onshore wind - South England	42	98	134	348
Onshore wind - Midlands & Nth England	221	605	1,087	1,650
Onshore wind - Wales	51	118	161	420
Onshore wind - South Scotland	1,696	3,984	5,368	5,723
Onshore wind - North Scotland	1,215	2,147	2,648	2,767

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
Onshore wind - South England	0	0	0	0
Onshore wind - Midlands & Nth England	0	0	0	0
Onshore wind - Wales	0	0	0	0
Onshore wind - South Scotland	0	0	46	176
Onshore wind - North Scotland	55	1,564	3,292	3,599

Socialised (change from Status Quo)	2015	2020	2025	2030
Onshore wind - South England	0	0	0	0
Onshore wind - Midlands & Nth England	-137	-274	-685	-822
Onshore wind - Wales	0	0	0	0
Onshore wind - South Scotland	0	0	-401	-755
Onshore wind - North Scotland	139	1,818	4,136	4,393

Change in build relative to Status Quo – offshore wind

- Under Improved ICRP, onshore charges for intermittent generators in Scotland are lower
  - This benefits Scottish offshore wind despite unchanged local charges
- Under Socialised, local asset charges are socialised – this has the biggest impact on offshore wind, which is no longer exposed to OFTO costs, relatively benefiting those further offshore

Status Quo	2015	2020	2025	2030
Offshore wind - Offshore South	1,045	4,245	5,145	5,645
Offshore wind - Offshore Irish Sea	233	1,633	3,033	4,857
Offshore wind - Offshore North Sea	425	1,275	1,875	1,875
Offshore wind - Offshore Scotland	0	450	2,105	3,195

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
Offshore wind - Offshore South	0	-1,200	-1,200	-1,200
Offshore wind - Offshore Irish Sea	0	0	0	-574
Offshore wind - Offshore North Sea	0	0	0	0
Offshore wind - Offshore Scotland	270	1,300	1,940	1,940

Socialised (change from Status Quo)	2015	2020	2025	2030
Offshore wind - Offshore South	870	1,570	1,870	3,970
Offshore wind - Offshore Irish Sea	907	-493	-1,893	-3,717
Offshore wind - Offshore North Sea	470	5,292	8,803	10,248
Offshore wind - Offshore Scotland	0	400	880	4,617

Change in build relative to Status Quo – nuclear

- Under Socialised, TNUoS tariffs at the new nuclear sites are higher than under Status Quo
- Under Improved ICRP, there is no difference in the location and timing of new nuclear plant until 2024

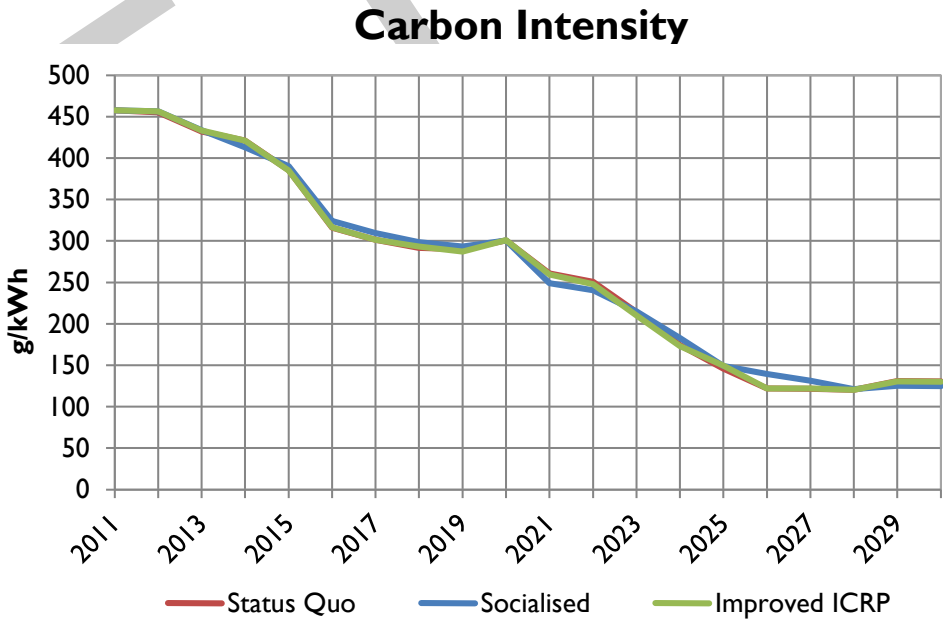
Status Quo	2015	2020	2025	2030
Nuclear - South England	0	1,670	8,350	11,600
Nuclear - Midlands & Nth England	0	0	0	0
Nuclear - Wales	0	0	0	0
Nuclear - South Scotland	0	0	0	0
Nuclear - North Scotland	0	0	0	0

Improved ICRP (change from Status Quo)	2015	2020	2025	2030
Nuclear - South England	0	0	-1,670	-1,600
Nuclear - Midlands & Nth England	0	0	0	0
Nuclear - Wales	0	0	0	0
Nuclear - South Scotland	0	0	0	0
Nuclear - North Scotland	0	0	0	0

Socialised (change from Status Quo)	2015	2020	2025	2030
Nuclear - South England	0	0	-5,010	-8,260
Nuclear - Midlands & Nth England	0	0	0	0
Nuclear - Wales	0	0	1,200	1,200
Nuclear - South Scotland	0	0	0	0
Nuclear - North Scotland	0	0	0	0

Carbon intensity

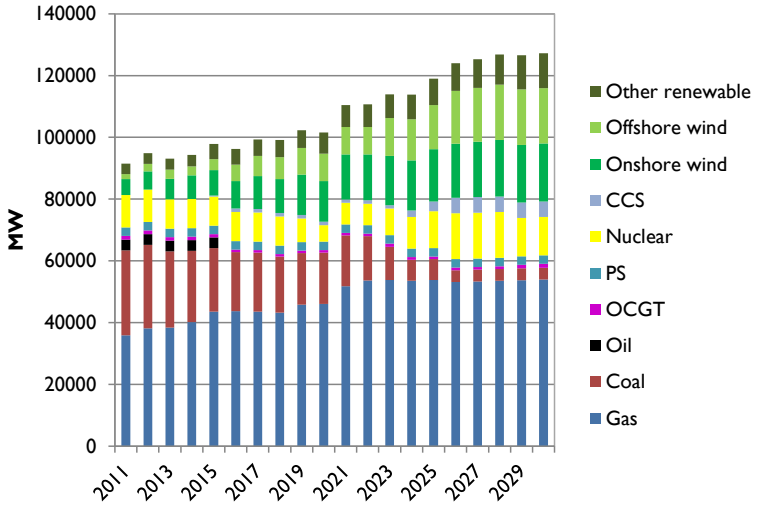
- Similarity of carbon intensity in 2030 is set as a boundary of the Stage 2 modelling
- This is achieved while allowing differences in plant mix, as noted above



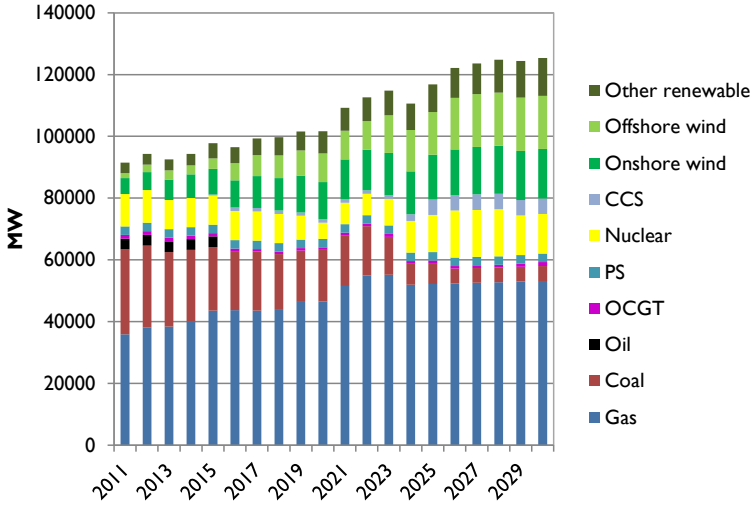
Capacity mix by generation type

- Generation mix more similar between all three options in Stage 2 compared to Stage 1

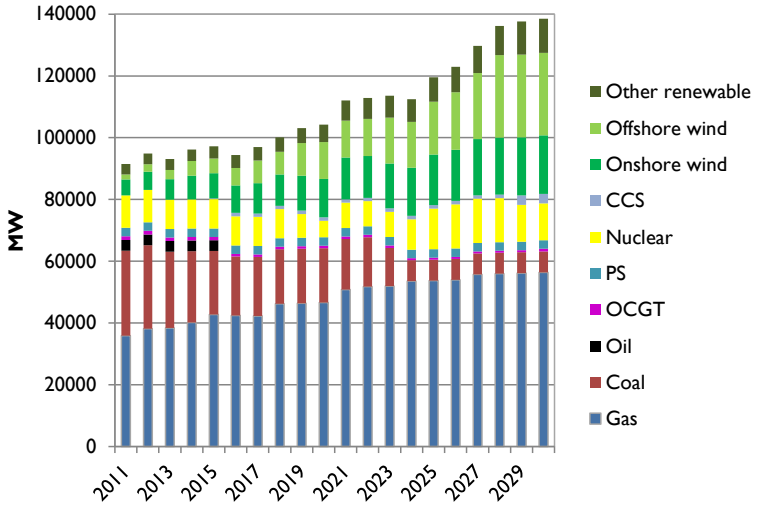
Improved ICRP



Status Quo



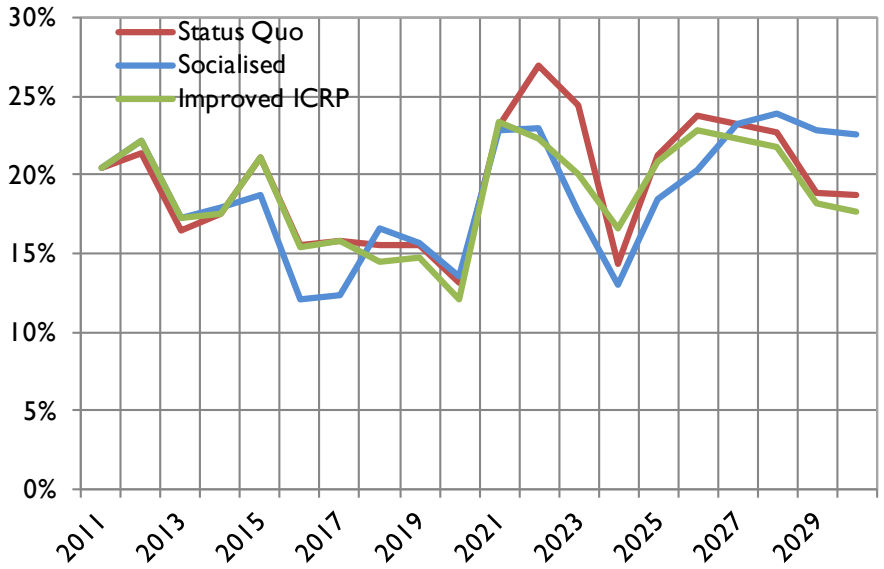
Socialised



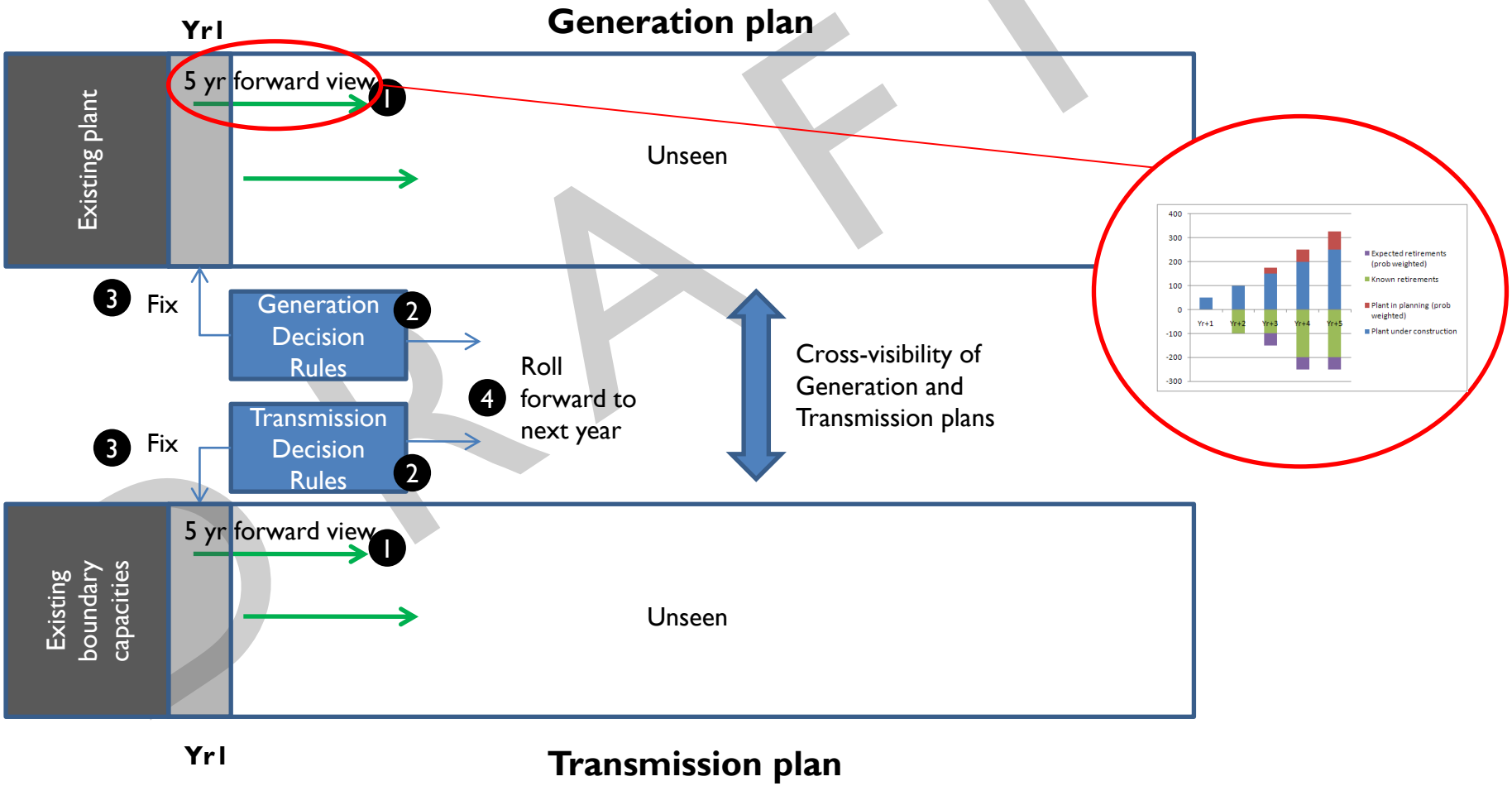
Capacity margins

- De-rated capacity margins are similar across the three policy options to 2020
  - Exception is Socialised in 2016 and 2017 due to closure of Deeside (negative TNUoS in Status Quo) and less CCGT build in South England
- More than 3GW of new CCGT build in Status Quo in 2022 drives higher capacity margins at this time

De-rated capacity margins

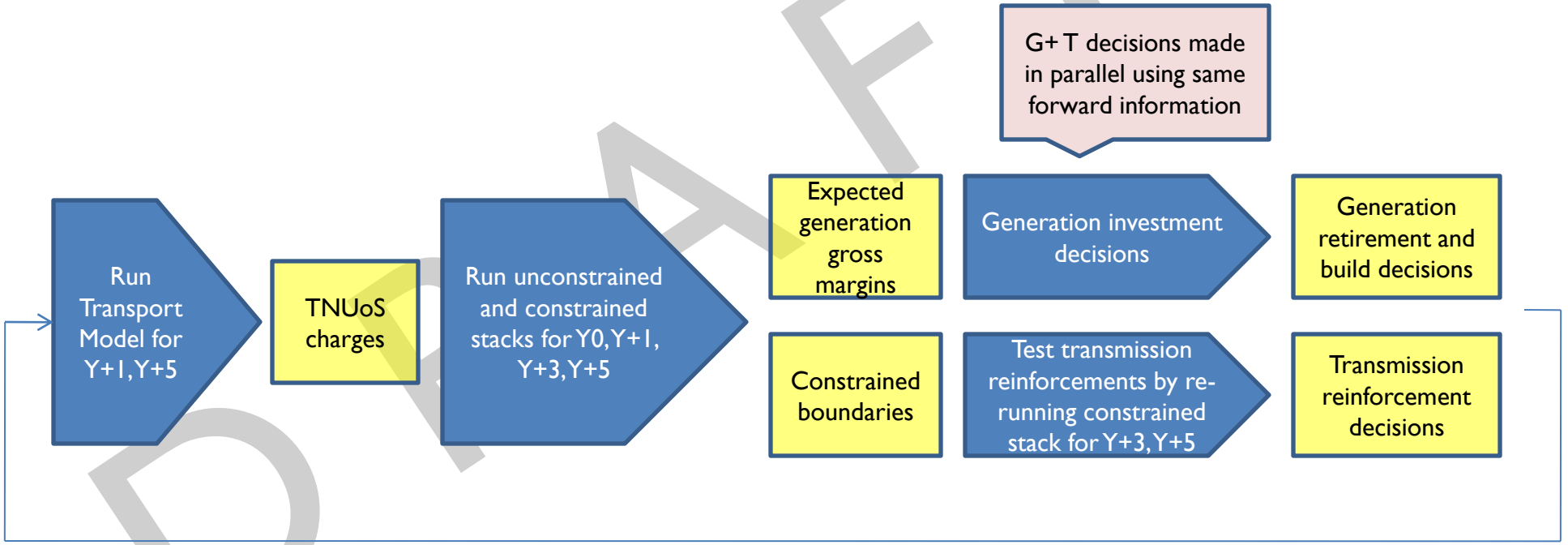


Agent simulation/non-perfect foresight



Simulation steps (non-perfect foresight)

An example of a simulation step assuming 5 year forward look ahead for decision making.



Perfect foresight - overview