Electricity Scenario Illustrator

Lewis Dale & Will Kirk-Wilson

TCMF, 23rd March 2011

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Introduction

- Ofgem's RIIO framework requires network licensees to provide a well-justified business plan
- To develop such a plan we need your views on:
  - What might be the future requirements (scenarios)
  - How these might be met (responses by the network or others)
- Some parts of the plan (e.g. connections) are justified by the specific needs of individual customers …
- … but plans concerning the shared network infrastructure are more complex and require collective views.
  - To assist stakeholders, we have prepared a simple model to illustrate the benefits and implications of these works.

Our approach

- In our consultation (with workshops beginning end-March) we will describe:
  - The scenarios that we have derived
  - Our understanding of the implications for customers and other stakeholders
  - Our assessments of the transmission developments that can enhance value
- Recognising that stakeholders will wish to explore the details of our proposals by examining their own alternative scenarios/sensitivities and assessing the balance of trade-offs for themselves, this model is being distributed in advance of our consultation workshops.

Our understanding of high-level stakeholder requirements

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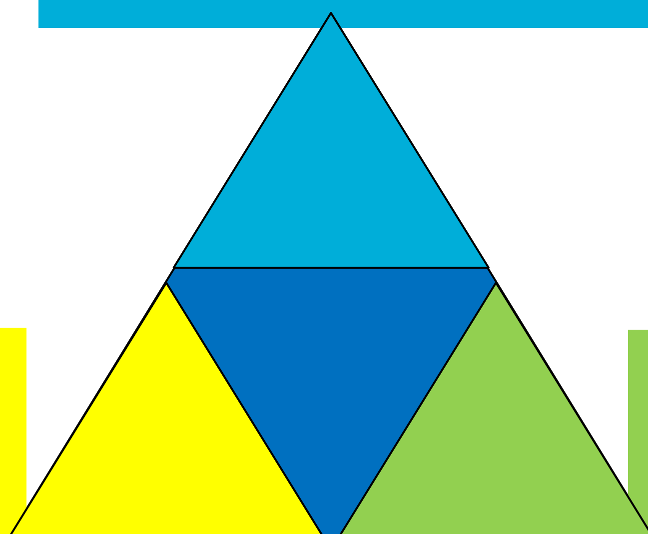
Security

- Acceptable reliability
- Resilience



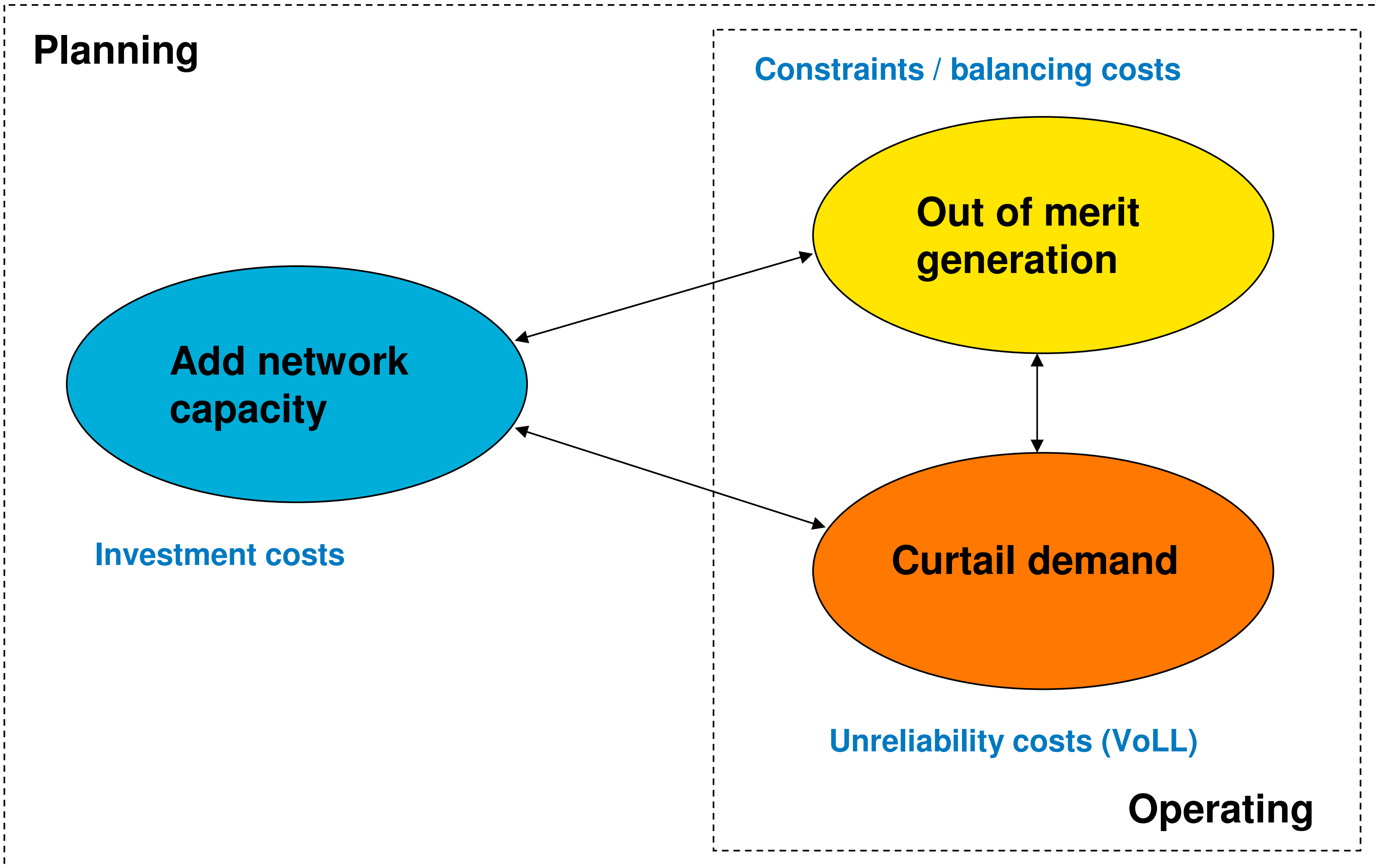
Affordability

- Efficient operations
- Value for money developments

Sustainability

- Reduce CO_2
- Renewables
- Preserved amenity

In delivering, we must consider the key network trade-offs



Generic issues we want to discuss with stakeholders

- Unsupplied energy
  - What is the appropriate cost to be attributed to curtailed load? *
  - What is the acceptable risk for different severities of potential loss of supply events?
- Operational cost
  - How to appropriately assess the cost of network limitations?
  - What are the demand-side and other balancing alternatives? And when will they be available?
- Transmission investment cost
  - What are the desired characteristics of our identified reinforcement options?
  - Should others be developed

* Ofgem have indicated in their RIIO-T1 consultation on outputs that £16/kWh may be a suitable upper bound value. As a conservative starting point we have derived what may be a useful lower bound estimate by dividing GDP by energy consumed ≈ £4/kWh.

Specific issues we want to discuss

- Have we got the right scenarios?
  - Reasonable generation/demand developments?
  - A good span of potential outcomes?
- Is our representation of future operation sufficient?
  - Consumer requirements and use patterns?
  - Fuel burn & CO_2 emission choices?
  - Wind variability & other plant availability assumptions?
  - Interconnection transfer & pump storage utilisation?
- Are the consequences of network limitations sufficiently identified?
- Are sufficient reinforcement options identified and their benefits appropriately explained?

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Overview: features & limitations

Electricity Scenario Illustrator

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Overview of the electricity scenario illustrator

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- The electricity scenario illustrator (ESI) simulates merit order operation of generation resources* to meet consumer requirements*
  - For an extended period spanning the RIIO-T1 control
  - With transmission capacity* as currently established or extended by potential reinforcement schemes

* **Generation and transmission investments are set by the user – the model only illustrates how, once established, these might then be used to meet consumer needs**

- If there is insufficient generation or transmission then demand is curtailed
  - This curtailment is costed at a Value of Lost Load (default = £4/kWh approximately equal to GDP per unit of electricity consumed)

- The model reports the sensitivity of operating costs to generation and network capacity limits (e.g. in £/kW/yr)

Modelling and package approach

- The ESI is built to the principle "as simple as possible, but not simpler" and applies the 80/20 rule. E.g. seeking 80% of the answer from 20% of the potential detail.
- It is free and requires no additional proprietary product or licences other than a copy of Microsoft Excel
- All workings (outside a simple linear program code – see Appendix) are shown. Hence it should be easily customised and extended by users*.
- Scenarios based on Gone Green, Slow Progress & Accelerated Growth scenarios installed with illustrative cost and performance parameters (these chosen by package authors – no authoritative knowledge claimed!)

* Although National Grid will seek to assist users who are exploring RIIO-T1 issues with the ESI model, we cannot provide wider support for the code in this package.

National Grid has made strenuous efforts to ensure the package works reliably and functions acceptably for its intended purpose. However, we cannot provide guarantees that the algorithms and techniques are robust in all circumstances and results must, therefore, be used cautiously.

ESI features

- Consumer requirements represented by seasonal load duration curves
  - **Default = 2009/10 curves scaled by peak demand forecasts for future years**
- Wind availability represented by seasonal output duration curves by regions
  - **Default = 4 regions (Scotland, E&W onshore, offshore east, offshore west & south) derived from 10 yrs historic wind speed data**
- Generation fuel & CO2 cost assumptions are separated from BM bid & offer price assumptions (to represent alternative scheduling approaches & costs)
- Transmission capability represented by Seven Year Statement boundaries (augmented with some ‘local-issue’ boundaries)
- Interconnector and pump storage operation determined by marginal cost differences (i.e. operation is cost minimising)
- Wind availability is calculated by Monte Carlo simulation (default=100 samples/year with importance sampling of critical peak demand periods). Random numbers are fixed (until deliberately randomized) to aid comparison of scenarios.
- Check of “peak demand with low wind” and “minimum demand with high wind” cases included each year

ESI key limitations (1)

- Generation dynamic limitations are not represented
  - (no ramp rate, minimum stable generation limits, etc)
  - Hence the model will underestimate generation operating costs
- Availabilities of generation (other than wind) are represented at average seasonal values
  - this tends to underestimate the impact of network limitations
- No time step linkage and pump storage energy limits
  - so potential for overestimating capabilities of pump storage
- Assumes ideal curtailment of demand and immediate restoration
  - So potential for underestimating demand disruption
- Very limited (initially, fixed price) modelling of European market and Ireland & Northern Ireland SEM
  - gives rather simplistic modelling of interconnector operation

ESI key limitations (2)

- Boundary representation of network capacity - reflects thermal, voltage & stability limitations after current control measures (i.e. protection, switching, QBs & other Smart controls)
  - Approximates effects due to actual power sharing across circuits
  - May require recalculation for radical scenario changes and fault-level issues
  - Generally overestimates effectiveness of running certain generators out of merit to alleviate constraints
- Simple modelling of network availability - temperature effects reflected in seasonal average capabilities
  - Network unavailability due to maintenance and construction outages neglected (assumes perfect generation/network outage coordination)
  - This will tend to underestimate actual network limitations
- The in-built scenarios are currently being updated to reflect recent developments. These changes will be incorporated in due course.
- The model does not calculate the reliability implications of transmission faults

Appendix: Modeling details

Electricity Scenario Illustrator

Dispatch representations

- Load
  - Inelastic demand = peak demand x load duration curve sample value
  - Curtailment represented by generator matching demand at price = VoLL
- Wind (& wave)
  - Dispatchable capacity = installed capacity x plant availability factor x wind availability
- Other generation
  - Dispatchable capacity = installed capacity x plant availability factor
- Interconnection
  - Export = load matching dispatchable export capacity
  - Float = generator matching export load at price of remote market less cost of link losses
  - Import = generator of dispatchable import capacity at price of remote market plus cost of link losses
- Pump storage
  - Pump = load matching available pump capacity
  - Float = generator matching pump load at maximum pump price
  - Generation = generator of dispatchable capacity at generation price

NB no min or max energy stored limits enforced. User must choose suitable availabilities and prices to get desired behaviour.

Linear program (LP) formulation

- The LP is a simple re-startable dual formulation using sparse matrix arithmetic:
  - LP variables are network & generation capacity sensitivity prices
  - LP constraints represent the requirement that dispatched generators must receive revenues greater than or equal to their short-run marginal costs (srmcs).
  - Starting from a network unconstrained merit order solution, the LP seeks to minimise the cost of network infringements
- To avoid unbounded solutions, generation SRMCs must be positive.
  - Balancing mechanism bids and offers can be negative prices if required. (These prices are applied as a post-processing calculation to the LP srmc –based dispatch)

Getting started

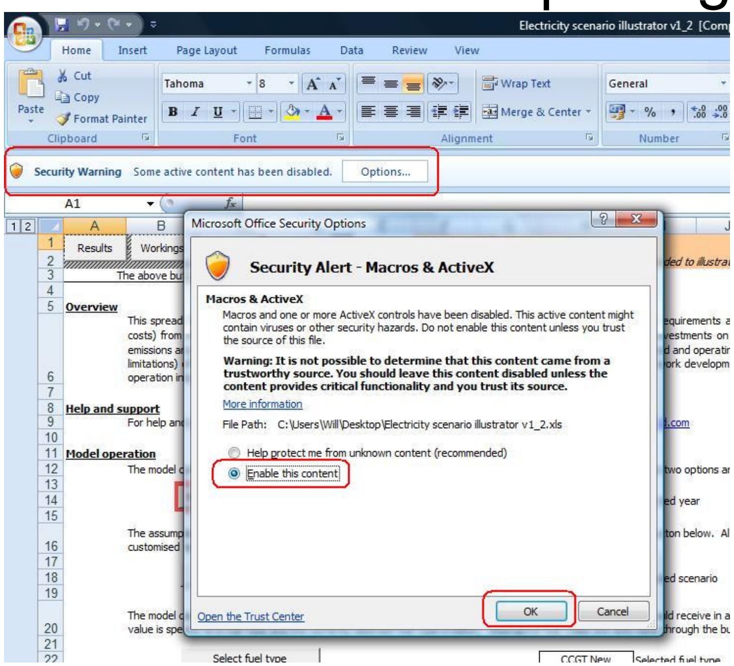
Electricity Scenario Illustrator

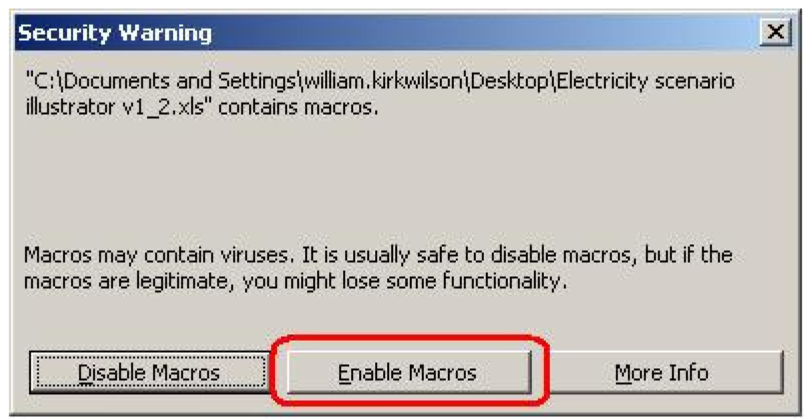
Introducing the model

- Model can be downloaded from

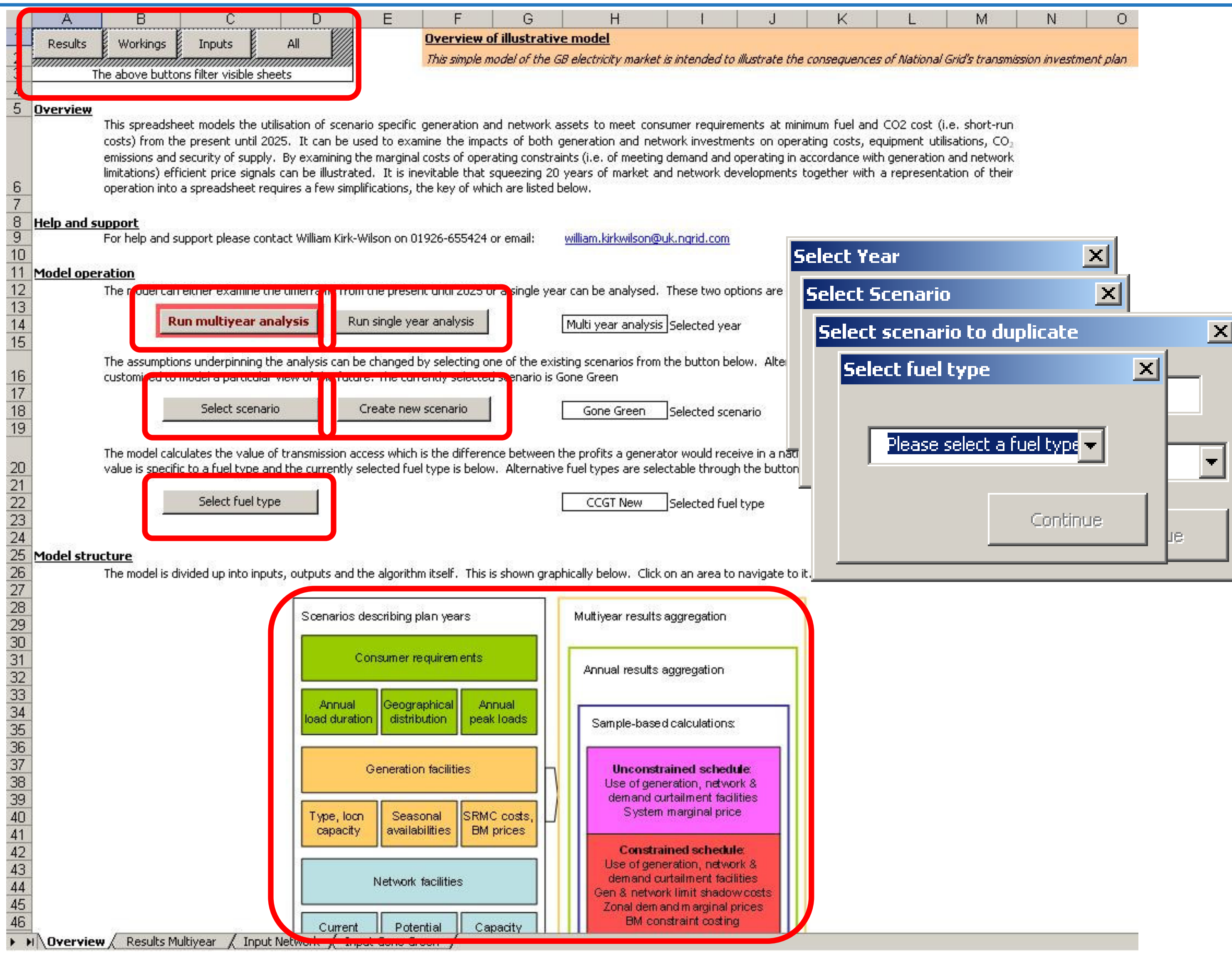
  http://www.talkingnetworkstx.com/electricity1.aspx

- Excel model
- Enable macros on opening



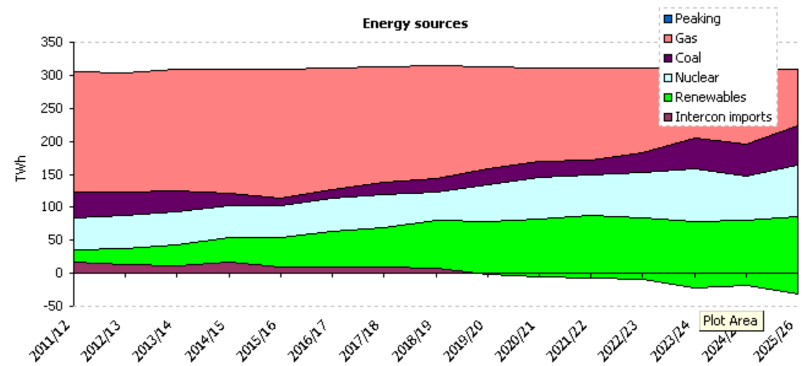


Navigating the model - Overview

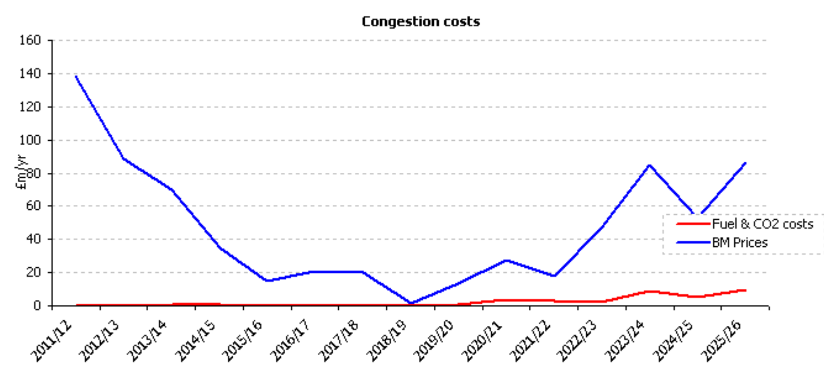


Navigating the model – Results (1)

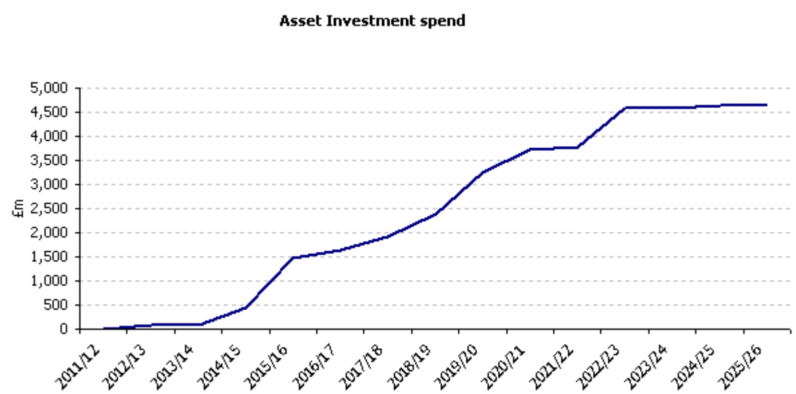
- Where the energy is being supplied from



- Extra cost due to network system limitations

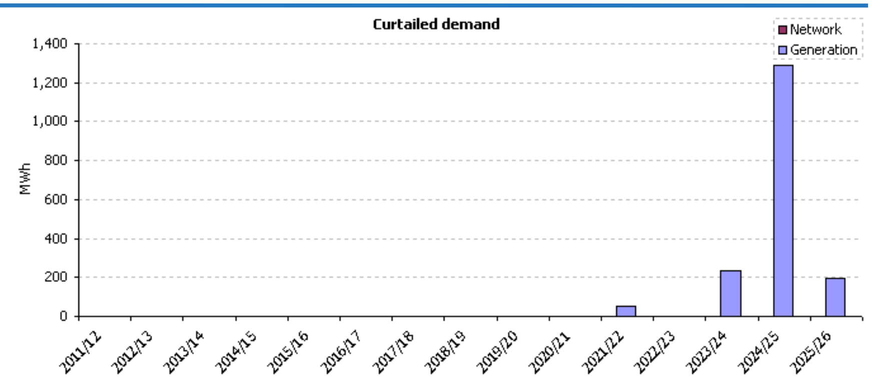


- NG reinforcement spend

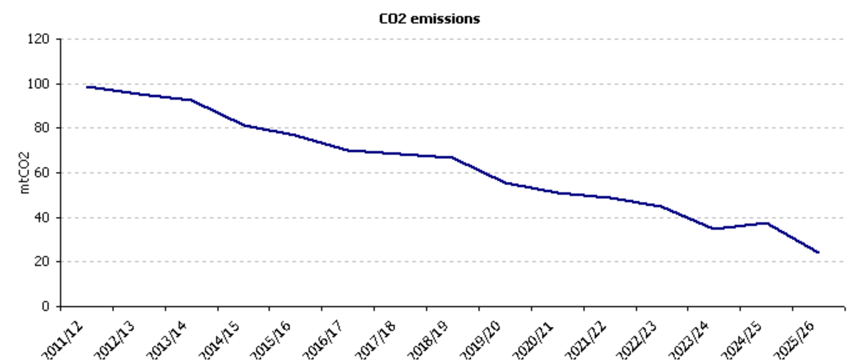


Navigating the model – Results (2)

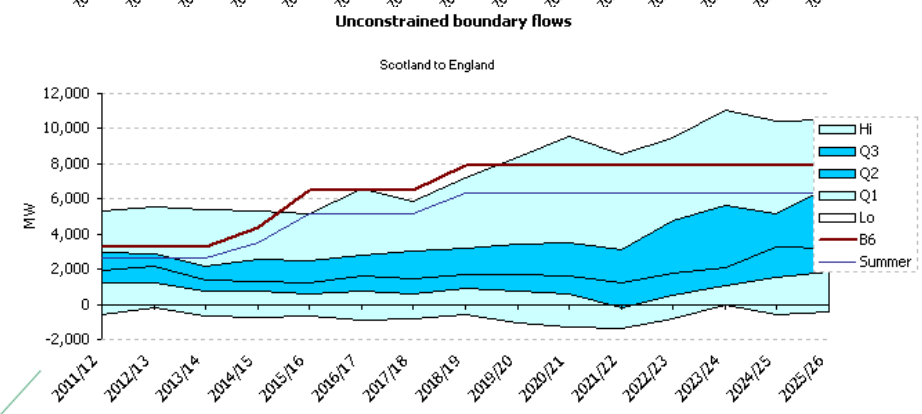
- Demand not supplied due to network or generation constraints



- Forecast CO_2 emissions



- Unconstrained boundary flows



Navigating the model – Input scenario assumptions

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Results | Workings | Inputs | All

Gone Green scenario. Generation & Demand
Current market prices + Government guide CO2 price

Basic cost assumptions

		£/MWh @ 100% eff	
Gas p/th	58	19.80	Uses 1 therm = 29.3 kWh
Coal £/t	75	11.19	Assumes 1 t coal = 24GJ = 6.7MWh
Oil £/barrel	62.5	39.00	Assumes 7.3 barrels per toe and 1 toe = 42GJ = 11.7 MWh
Distillate £/t	560	44.80	Assume 1 t = 45GJ = 12.5MWh
VLL £/MWh	4000		
CO2 £/t	26		

Conversion efficiencies

CCGT	55%
CCGT New	58%
CCGT CCS	50%
Coal	35%
Coal CCS	30%
Oil	35%
OCGT	30%
CHP	90%
Pump_storage_eff	70%
Intercon_loss	2.5%

CO2 emissions

	g/MJ	t CO2/MWh @ 100% eff		t CO2/MWh (e)
gas	55	0.198	CCGT	0.360
coal	90	0.324	Coal	0.926
oil	70	0.252	Oil	0.720

Prices & Availabilities

ROC £35 0.6 1.6

Fuel Type	Fuel grouping	V_avail	SA_avail	S_Avail	CO2 t/MWh	CO2 £/MW	Fuel	SRMC	Bid	Offer
Hydro	Renewables	75%	50%	25%	0.00	£0.00	£0.00	£0.00	-£35.00	£0.00
Offshore Wind	Renewables	100%	100%	100%	0.00	£0.00	£0.00	£0.00	-£35.00	£0.00
Onshore Wind	Renewables	100%	100%	100%	0.00	£0.00	£0.00	£0.00	-£35.00	£0.00
Wave & Tidal	Renewables	100%	100%	100%	0.00	£0.00	£0.00	£0.00	-£35.00	£0.00
Nuclear	Nuclear	70%	60%	50%	0.00	£0.00	£6.50	£6.50	£0.00	£10.40
Nuclear New	Nuclear	80%	75%	70%	0.00	£0.00	£6.50	£6.50	£0.00	£10.40
Biomass	Renewables	80%	75%	70%	0.00	£0.00	£25.00	£25.00	£15.00	£40.00
CHP	Gas	80%	75%	70%	0.22	£5.72	£21.99	£27.71	£16.63	£44.34
CHP New	Gas	80%	75%	70%	0.22	£5.72	£21.99	£27.71	£16.63	£44.34
CCGT CCS	Gas	80%	75%	70%	0.00	£0.00	£39.99	£39.99	£23.99	£63.98
Clean Coal CCS	Coal	80%	75%	70%	0.00	£0.00	£37.63	£37.63	£22.58	£60.20
CCGT New	Gas	80%	75%	70%	0.34	£8.88	£34.13	£43.01	£25.80	£68.81
Gas - Other	Gas	80%	75%	70%	0.34	£8.88	£34.13	£43.01	£25.80	£68.81
CCGT	Gas	80%	75%	70%	0.36	£9.36	£35.99	£45.35	£27.21	£72.56
Intercon Europe Imp	Intercon Europe	95%	95%	95%	0.00			£0.00	£0.00	£0.00
Intercon Europe Float	Intercon Europe	95%	95%	95%	0.00	£9.36	£35.99	£44.22	£26.53	£70.75
Intercon Europe Exp	Intercon Europe	95%	95%	95%	0.00	£9.36	£35.99	£46.49	£27.89	£74.38
Coal - LCPD In	Coal	80%	75%	70%	0.93	£24.07	£31.98	£56.05	£33.63	£89.68
Coal - LCPD Out	Coal	80%	75%	70%	0.93	£24.07	£31.98	£56.05	£33.63	£89.68
Coal - Non LCPD	Coal	80%	75%	70%	0.93	£24.07	£31.98	£56.05	£33.63	£89.68
Intercon Ireland Imp	Intercon Ireland	95%	95%	95%	0.00			£0.00	£0.00	£0.00
Intercon Ireland Float	Intercon Ireland	95%	95%	95%	0.00	£24.07	£31.98	£54.65	£32.79	£87.44
Intercon Ireland Exp	Intercon Ireland	95%	95%	95%	0.00	£24.07	£31.98	£57.45	£34.47	£91.92
Pumped Storage Pump	Pumped Storage	95%	80%	70%	0.00			£0.00	£0.00	£0.00
Pumped Storage Gen	Pumped Storage	95%	80%	70%	0.00			£56.61	£33.97	£90.58
Pumped Storage Float	Pumped Storage	95%	80%	70%	0.00			£39.63	£23.78	£63.41
Oil	Peaking	90%	80%	70%	0.72	£18.72	£111.42	£130.14	£78.08	£208.22
OCGT	Peaking	100%	100%	100%	0.84	£21.84	£149.33	£171.17	£102.70	£273.88
User defined	User defined	100%	100%	100%	0.84	£21.84	£149.33	£171.17	£102.70	£273.88
Curtail	Curtail	100%	100%	100%	0.00			£4,000.00	£4,000.00	£4,000.00

Network background selected

Gone Green | Select network scenario to use

Generation and demand background

	2011/12	2012/13	2013/14	2014/15	2015/16
Total Gene	82871	85302	82288	86244	86438
Demand	56181	55981	56781	56881	57081

Station	Fuel Type	Flop Zone	Flop Major	Annual Generatio	2011/12	2012/13	2013/14	2014/15	2015/16
A_CCGT	CCGT	A	A	2123	2,123	2,123	2,123	2,123	2,123
A_OCGT	OCGT		A	144	249	249	249	249	144
A_Oil	Oil		A	0	1,140	1,140	1,140	1,140	0
B_CCGT	CCGT	B	B	420	420	420	420	420	420
B_CCGT New	CCGT New		B	900	900	900	900	900	900
B_CHP	CHP		B	158	158	158	158	158	158

Overview / Results Multiyear / Calc MultiYear / Input Network / **Input Gone Green**

Navigating the model –
Input network assumptions

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Results | Workings | Inputs | All

Network capacities and connectivity

Network Connectivity

The table on the right defines the connectivity between zones and boundaries. A 1 (or -1) means the surplus [or deficit] of generation over demand in the zone will determine the flow on the boundary. A 0 or blank indicates that the boundary is not affected by the zone. A boundary can be linked to multiple zones and the total flow across the boundary will be the sum of the generation less demand in all the zones affecting the boundary. For example it shows that generation minus demand in zone T determines the flows across boundary B4

The table below right shows the base network capability (ie the boundary ratings before transmission reinforcements are added).

The table beneath lists the planned wider network reinforcements, their impact on the boundary capabilities, the year of commissioning by scenario and the NG spend. The network scenario is selectable on the scenario definition sheet. Individual reinforcements can be "switched off" by toggling the <User Override> field to false.

			Constraint		
			North to South Sco	tland to Engl	Upper North
Zone	Name	Transfer MW	B4	B6	B7a
A	London				
B	S Coast				
C	Estuary				
D	S Central				
E	SW				
F	SW Peninsula				
G	W Central				
H	South Wales				
J	East Mids				
K	Trent				
L	West Mids				
M	North Wales				
N	NW				
P	Yorks				
Q	North East				1
R	Cumbria				1
S	S Scot (SPTL)			1	1
T	N Scot (SHETL)		1	1	1
U	Norwich, Sizewell & Bramford				
V	Wylfa & Dinorwig				
Use of capacity (MW)					

Existing network capacity

			Constraint		
			B4	B6	B7a
Base Cap (MW)		Winter	2,205	3,300	5,400
	90%	Spr/Aut	1,985	2,970	4,860
	80%	Summer	1,764	2,640	4,320

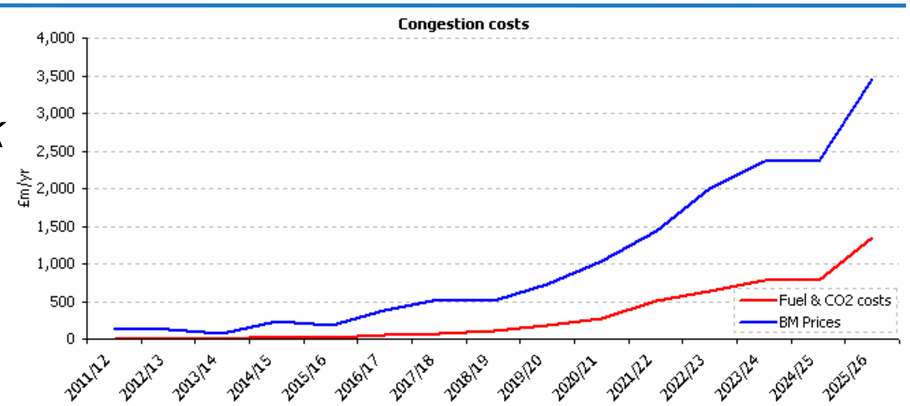
New schems creating additional capacity

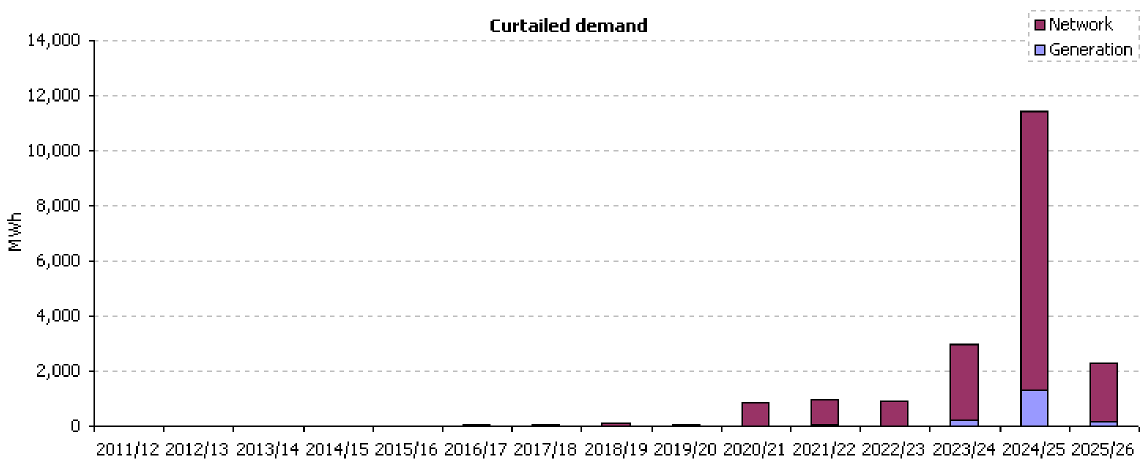
									Constraint		
Slow Prog	Gone Green	Accel Growth	User Override	Active	OHL km	£m	Reinf package	Blank	B4	B6	B7a
2014	2014	2014		TRUE			Beauly-Denny overhead line		950		
2016	2016	2016		TRUE			400kV Ring Kintore Reactive Compensation		750		
2016	2016	2016		TRUE			Denny-Kincardine 400kV		800		
2015	2015	2015		TRUE		730	Western HVDC Link			2,090	1,800
2015	2014	2014		TRUE		125	Anglo-Scottish Series & Shunt Compensation			1,100	
2024	2018	2017		TRUE		480	Eastern HVDC Link		1,430	1,430	1,000
2014	2014	2014		TRUE		30	Penwortham QBs				400
2023	2019	2019		TRUE	47	610	New Hinckley Point - Seabank OHL and assoc works				
2017	2015	2013		TRUE		90	Reconductoring circuits in East Anglia				
2021	2017	2015		TRUE	28	255	New OHL & reconductoring work in East Anglia				
3000	2024	2021		TRUE		40	QBs in East Anglia				
2014	2014	2013		TRUE		180	Establish 2nd Pentir-Traw 400kv circuit				
2014	2016	2020		TRUE		100	Series compensation and reconductoring work in North Wales				
2023	2022	2020		TRUE		810	Wylfa-Pembroke 2GW HVDC link				
2014	2014	2014		TRUE		5	Daines 225MVAR MSC DNs				
2020	2020	2020		TRUE		10	Sundon and Ratcliffe 225MVAR MSCs				
2020	2020	2020		TRUE		460	North London Reinforcements & St John's Wood - Hackney cable				
2019	2019	2019		TRUE		50	Turn in Sundon - Cowley circuit at East Claydon				
2019	2019	2019		TRUE		85	North East London uprate to 400kV				
2014	2014	2014		TRUE		30	East London reinforcements				
2016	2016	2016		TRUE		70	East London reconductoring				
2016	2016	2016		TRUE		20	Kingsnorth-Cobham reconductoring				
2015	2015	2015		TRUE		75	South London reconductoring				
2015	2015	2015		TRUE		35	Essex reconductoring				

Overview | Results Multiyear | Calc MultiYear | **Input Network** | Input Gone Green

Running a scenario –
No network reinforcement

- Constraint costs rise(!)
  (Compared to a total NG network investment spend of £4.6b)

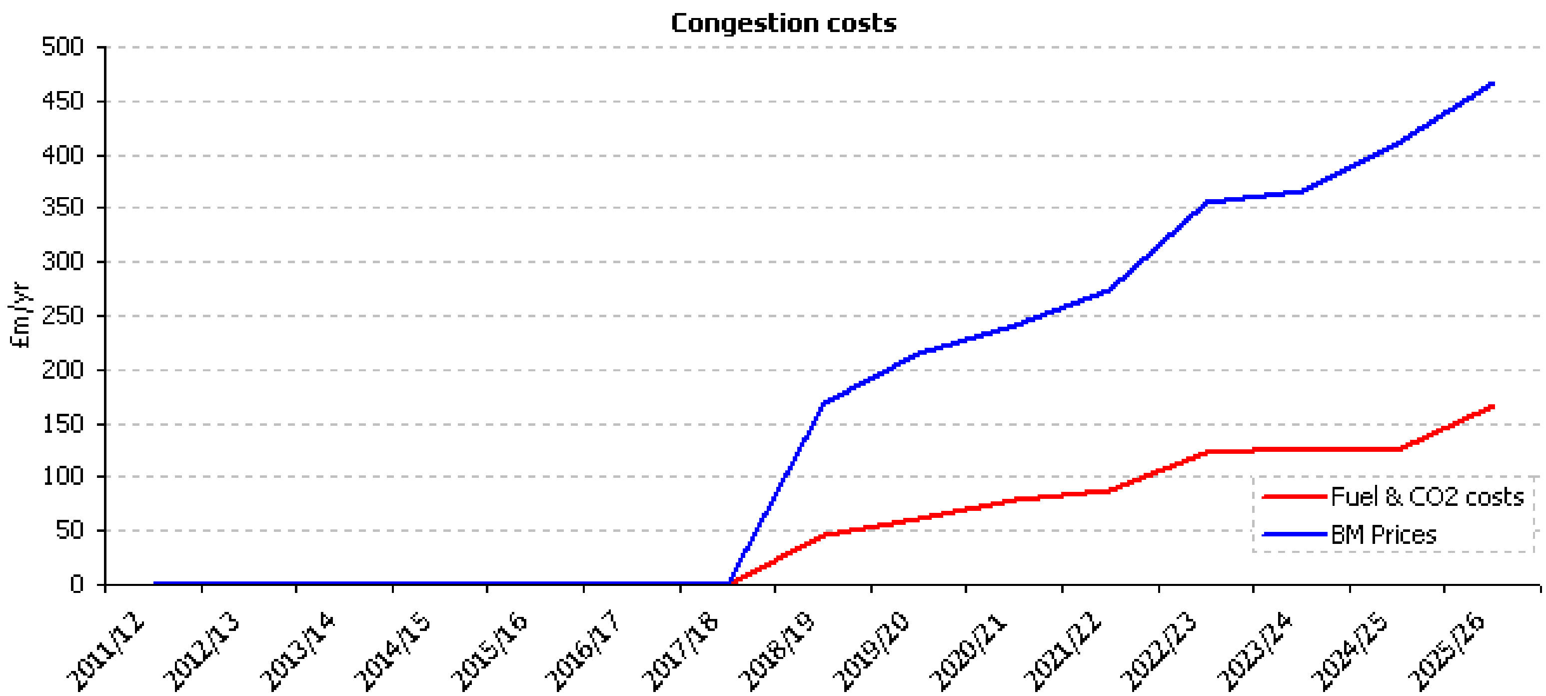




- Unsupplied demand
  (Compared to a maximum of 1.2GWh in the reinforced case)

Running a scenario – Eastern HVDC

- Eastern HVDC constraint costs saving
  (Compared to a NG network investment spend of £480m)



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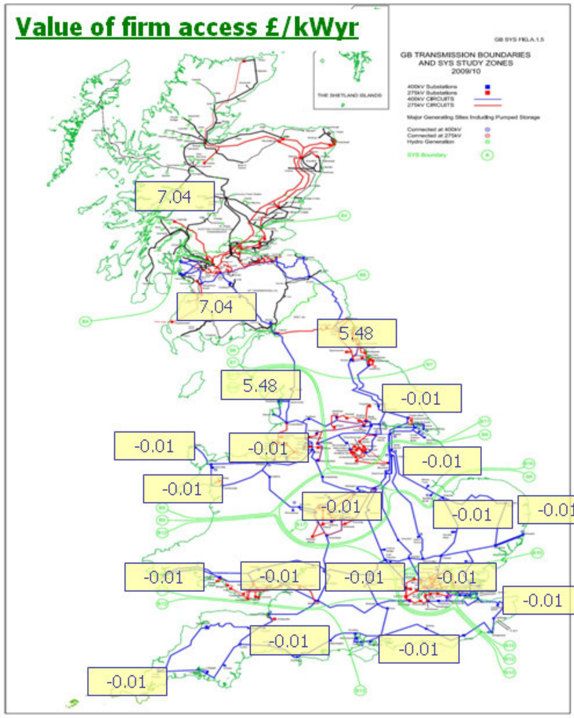
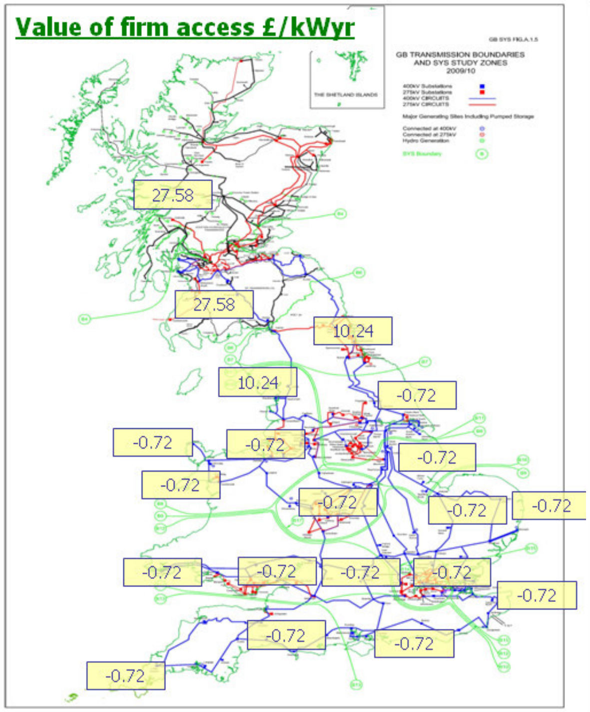
Transmission value

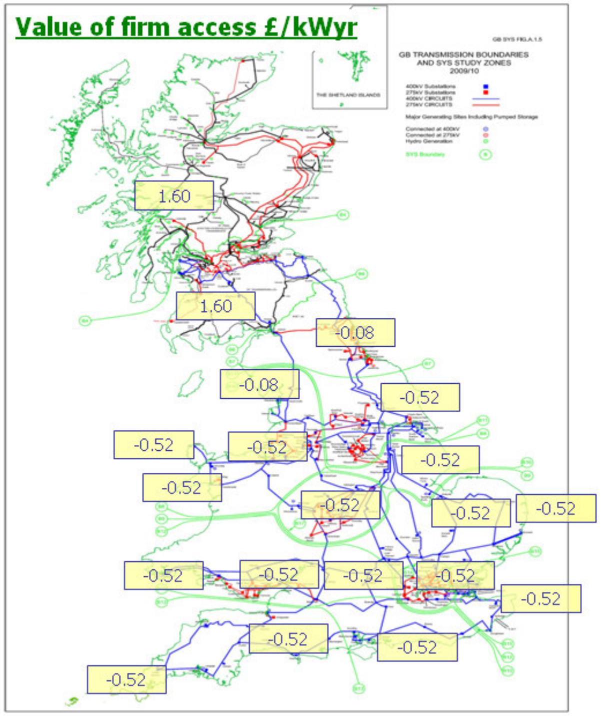
- Onshore Wind *(2020 – Full network)*



- Onshore Wind *(No bootstraps)*



- New CCGT *(No bootstraps)*



Help

- If you need help running ESI or using any of its facilities please contact
  - William Kirk-Wilson on 01926-655424 or email: william.kirkwilson@uk.ngrid.com
- If you wish to discus potential developments to the economic modelling implemented in ESI please contact
  - Lewis Dale on 01926-655837 or email: Lewis.Dale@uk.ngrid.com
- If you need details on National Grid's RIIO-T1 consultation process please contact
  - Graham Frankland on 07796-993718 Graham.Frankland1@uk.ngrid.com