Gas Quality
Scenario Development Work Stream

Sonia Brown

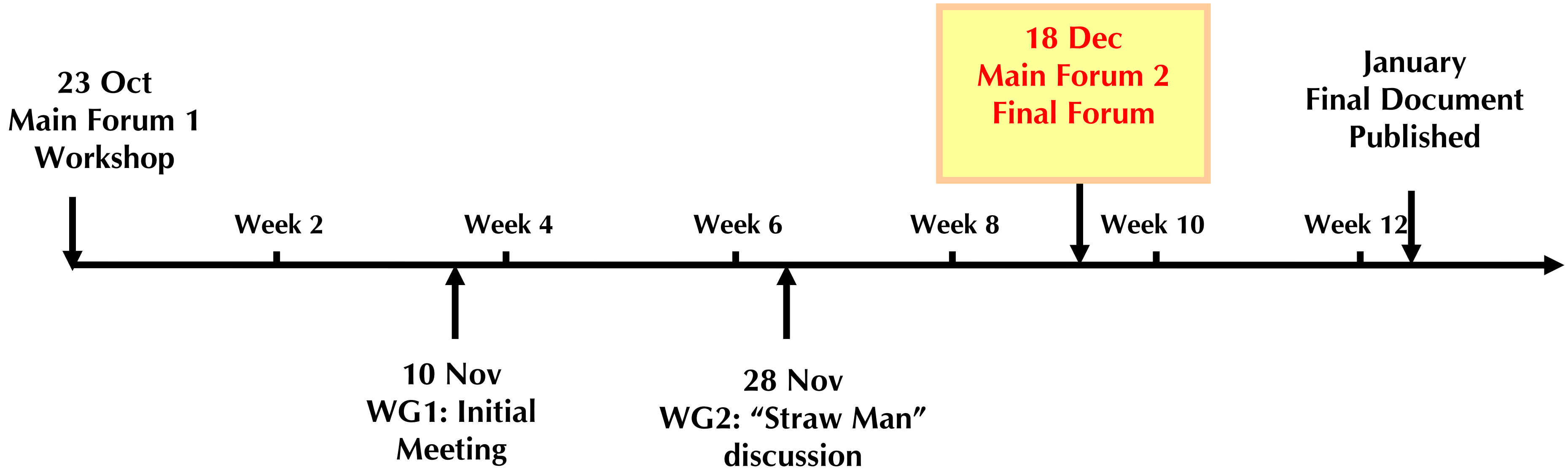
Director, Wholesale Markets

Welcome

- Ofgem workshop on gas quality in October
  - Considered GQ as an increasing constraint to supplies into GB
  - Smaller workgroup created to assess the constraint
- Scenario Development Working Group (WG)
  - Assessed range of gas supply and gas quality scenarios
  - 'Strawman': Ofgem/NG provided several options for initial consideration
  - Years 2009/10 and 2013/14 evaluated
  - Various entry points to NTS - Bacton given particular consideration

High level of uncertainty

Where we are…


23 Oct
Main Forum 1
Workshop
Week 2
Week 4
10 Nov
WG1: Initial
Meeting
Week 6
28 Nov
WG2: "Straw Man"
discussion
Week 8
18 Dec
Main Forum 2
Final Forum
Week 10
Week 12
January
Final Document
Published

Objectives for today

- ➢ Summary of TSOs views
- ➢ Focus on Bacton
- ➢ Discuss likelihood of the assessed scenarios
- ➢ Way forward

LNG Discussion

Uncertainty:

- Most LNG has a Wobbe Index well above the GS(M)R limit
- Most LNG will thus need to be processed to meet this limit
- Sourced from a wide range of countries
- Supply depends on price differentials

HOWEVER

LNG Import facilities are built with their own ballasting facilities

LNG Composition

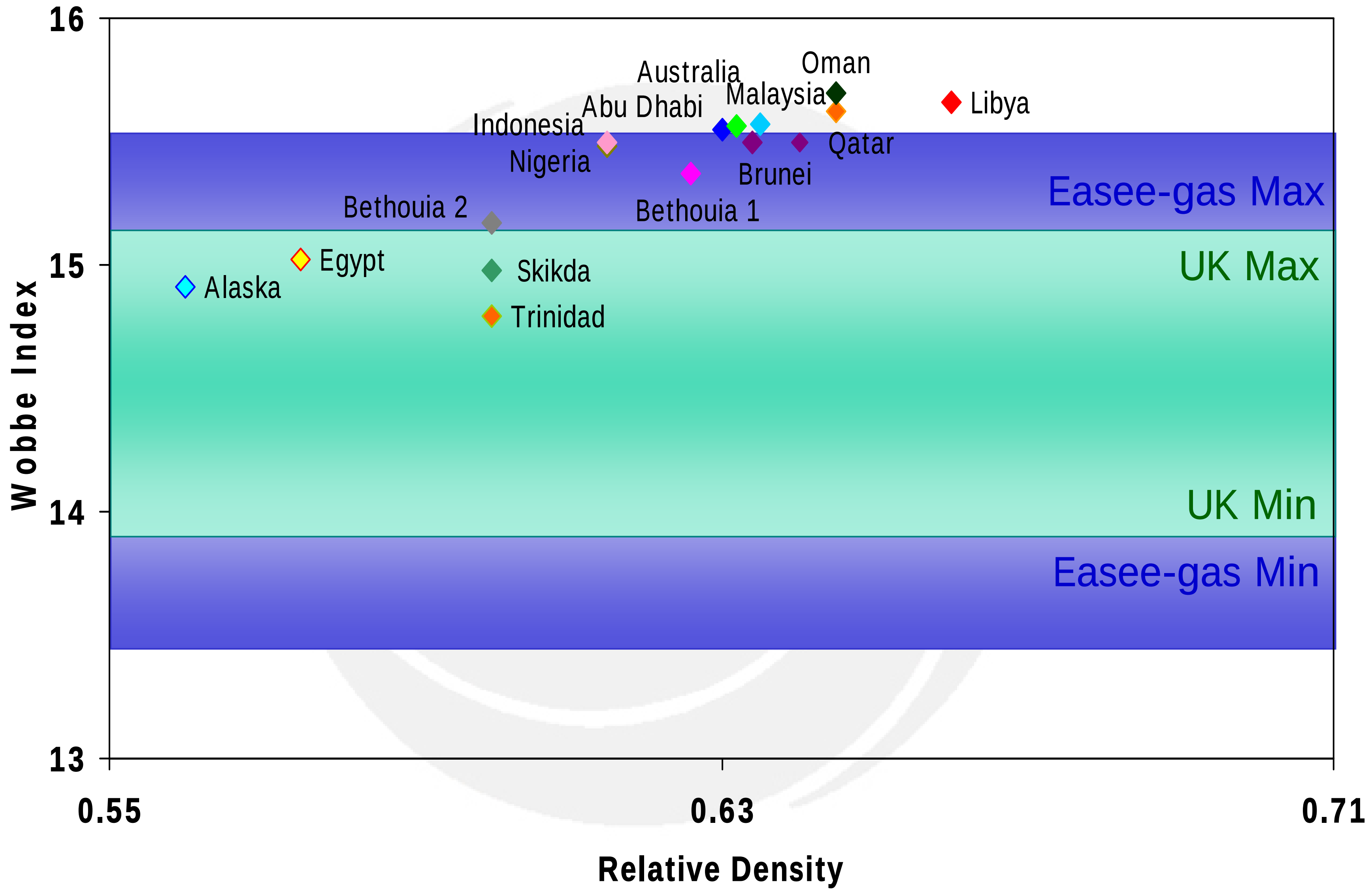
Promoting choice and value for all gas and electricity customers

Table 7 – LNG compositions (mol %)

Plant	Location	C1 Methane	C2 Ethane	C3 Propane	C4 Butane	N2 Nitrogen	Wobbe (MJ/m^3)
GL4Z	Algeria	87.16	8.78	2.1	0.7	1.26	52.26
GL1Z	Algeria	87.4	8.2	1.9	0.7	1.8	51.76
GL2Z	Algeria	91	7.63	0.52	0.03	0.82	51.57
GL1K	Algeria	91	6.7	0.6	0.2	1.5	51.07
Marsa El Braga	Libya	83.68	11.73	3.51	0.28	0.8	53.26
Nigeria LNG	Nigeria	87.9	5.5	4	2.5	0.1	53.88
NW Shelf	Australia	89	7.3	2.5	1	0.2	52.98
Brunei LNG	Brunei	89.4	6.3	2.8	1.3	0.2	53.05
PT Badak LNG	Indonesia	91.18	5.51	2.41	0.88	0.02	52.73
Arun LNG	Indonesia	88.48	8.36	1.56	1.56	0.04	53.21
MLNG	Malaysia	91.35	4.3	2.95	1.4	0	52.96
Atlantic LNG	Trinidad	95	4.6	0.38	0	0.02	51.57
Oman LNG	Oman	90	6.35	0.15	2.5	1	52.26
Qatar LNG	Qatar	No composition data provided					
RASGAS	Qatar	89.6	6.25	2.19	1.11	Not known	52.34 - 52.92
ADGAS	U.A.E	84	14	1	0.9	0.1	53.48
Kenai LNG	Alaska	99.8	0.1	0	0	0.1	51.7

Source: Importing Gas Into the UK – Gas Quality Issues – ILEX ENERGY

LNG Sources and Specifications

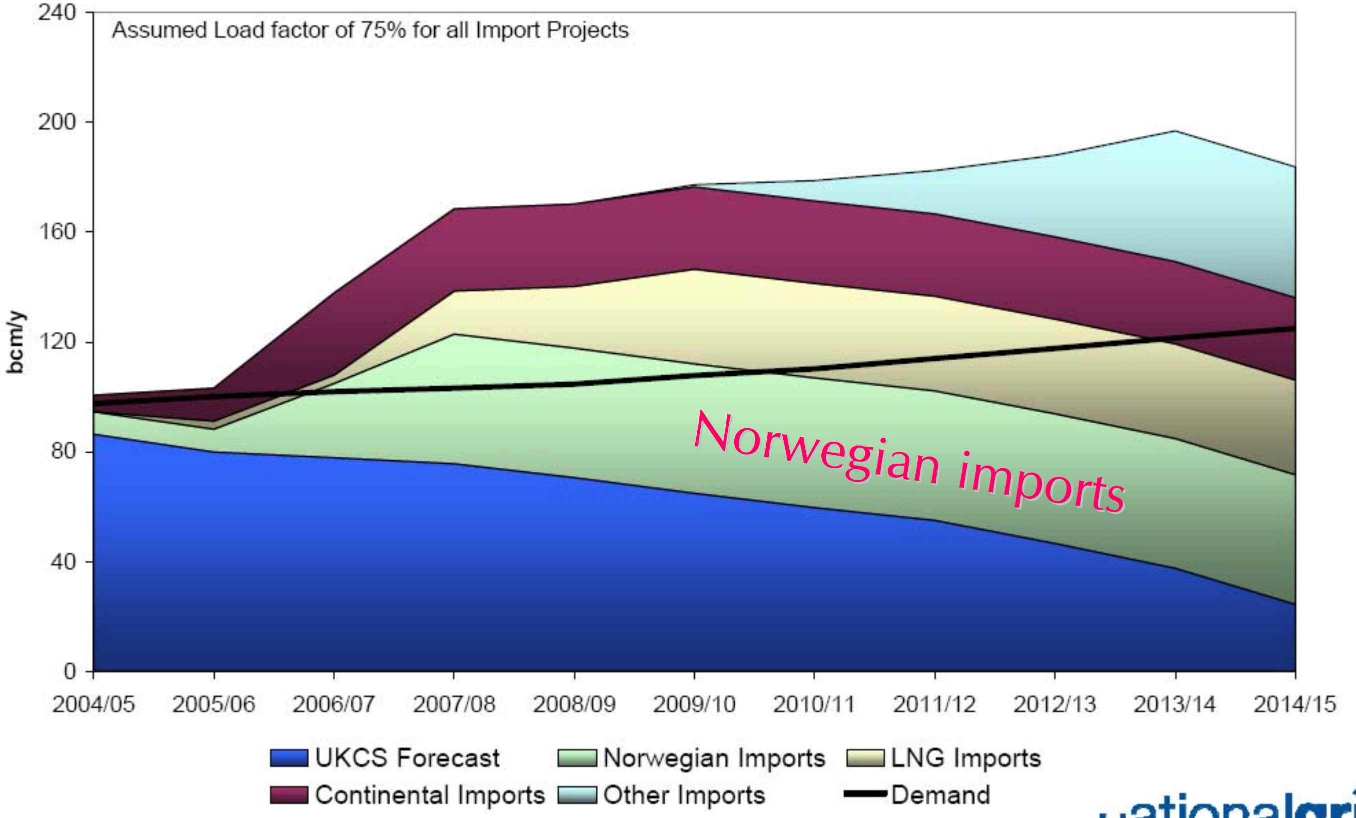


Norwegian Discussion

Summary of Norwegian Supplies

- Covers large proportion of UK demand going forwards
- Gas quality **IS** an issue
- Strong field blending interdependencies
- Great impact on UK prices if curtailment occurs

Norwegian gas important for future UK supplies



nationalgrid

Gas quality an issue for UK security of supply

Langeled

- Ormen Lange WI close to upper UK limit
- Relies on daily blending with Kollsnes and Sleipner gas
- Declining Sleipner production

Heimdal Area

- Strong field blending interdependencies (CO_2, WI, ICF)
- High CO_2 fields in area rely on blending with Oseberg for St. Fergus entry

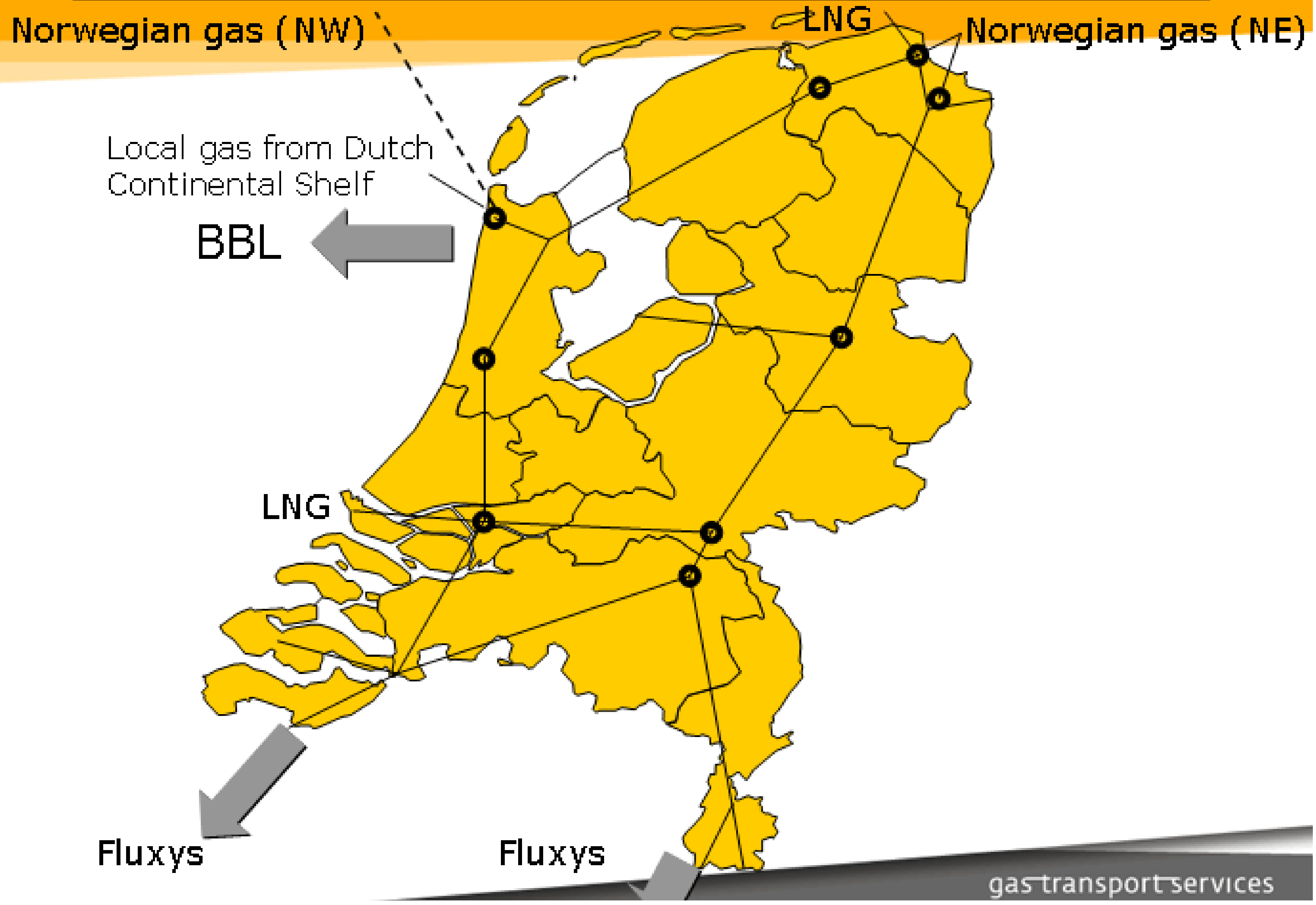
Ormen Lange & Oseberg

- Capable of covering 25 % of demand
- Great impact on UK prices if curtailment occurs
- Possible to route gas to continental Europe on long term

ofgem

Promoting choice and value for all gas and electricity customers

GTS grid hical gas after Open Season



Estimated Bacton flows 2009/10

Scenario	Flow BBL (mcm/d)	% in spec	% out of spec
Transit UK – Low	12	95	5
Equilibrium – Medium	24	95	5
Global LNG – High	36	95	5
Design limits - Extreme	48	90	10

Max flow Bacton: 110 mcm/d
Wobbe < 51 MJ/(s)m3 means in spec
Normally: gas from Dutch CS (in spec)
Otherwise: Norwegian gas (NE) (out of spec)

Assumptions

- Dutch CS supply forecasts according to GTS Business Plan 2006 (optimistic)
- No correction for structural loss of supply (optimistic)
- Probability of supply according to historical data (neutral)
- No correlation between Dutch CS supply and UK demand (pessimistic in case of high demand and optimistic in case of low demand)
- Uniform distribution of the Wobbe of the Dutch CS supply within quality envelope (pessimistic)

Estimated Bacton flows 2013/14 (1)

No Norwegian gas to NW of the Netherlands

Scenario	Flow BBL (mcm/d)	% in spec	% out of spec
Transit UK – Low	12	95	5
Equilibrium – Medium	24	95	5
Global LNG – High	36	90	10
Design limits - Extreme	48	75	25

Max flow Bacton: 110 mcm/d
Wobbe < 51 MJ/(s)m3 means in spec
Normally: gas from Dutch CS (in spec)
Otherwise: LNG or Norwegian gas (NE) (out of spec)

Estimated Bacton flows 2013/14 (2)

Norwegian gas via new off shore pipeline to NW of the Netherlands

Scenario	Flow BBL (mcm/d)	% in spec	% out of spec
Transit UK – Low	10	0	100
Equilibrium – Medium	20	1	99
Global LNG – High	30	2	98
Design limits - Extreme	40	5	95

Max flow Bacton: 110 mcm/d
Wobbe < 51 MJ/(s)m3 means in spec
Normally: Norwegian gas (NW) (out of spec)
Otherwise: gas from Dutch CS (in spec)
or LNG or Norwegian gas (NE) (out of spec)

ESTIMATED BACTON FLOWS THROUGH INTERCONNECTOR

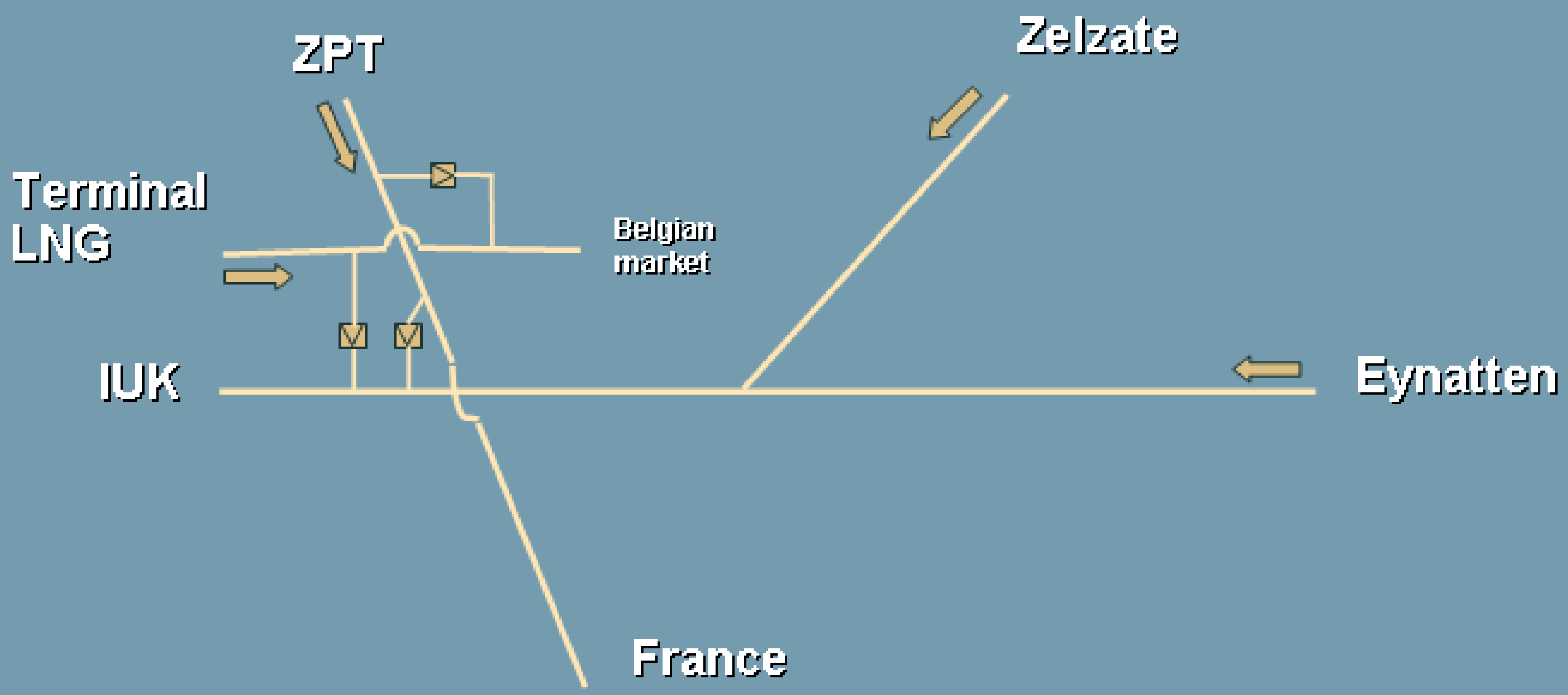
18t, December 2006

FLUXYS

TRANSIT GRID

FLUXYS

SIMPLIFIED NETWORK CONFIGURATION



Interconnector can be fed with gas coming from:

- Terminal LNG Zeebrugge
- Gas from Norway via Zeepipe Terminal (ZPT)
- Gas from The Netherlands via Zelzate (>2010)
- Gas from Russia/Germany via Eynatten

FLUXYS

ASSUMPTIONS

- Provided data are assuming that:
  - Planned project (both in Belgium & The Netherlands) are realised and on schedule
  - Interconnector's quality specs remain as existing today (Case 1)
  - Interconnector's quality specs are EASEEGAS compliant (Case 2)
  - Wobbe Index is defined at 25°C
  - Historical flows reflect future flows in term of quality (Fluxys cannot give any guarantee on it)
  - MIN, MAX & AVG values are calculated based on flows of last 3 years (except for Zelzate : data are provided by GTS)
  - Estimated flows are calculated based on network constraints and a max flow at IZT of 3.1 mcm/h. The given percentages are extreme scenarios
  - Limit scenarios are provided
  - Scenarios are based on technical flow capability and do not take into consideration any contractual constraints

FLUXYS

Historical WI (in MJ/m3(n))

	Minimum	Average	Maximum
Eynatten	50.344	52.600	53.859
Zelzate	53.500	UNKNOWN	56.916
ZPT	51.198	53.022	54.292
Terminal LNG	53.500	54.750	56.204

FLUXYS

Possible Scenarios 2010

CASE 1						
	IUK	EYNATTEN	ZELZATE	ZPT	TERM. LNG	Comments
Scenario 1	35%	35%	0%	0%	0,00%	ZPT gas out of spec
Scenario 2	38%	35%	0%	3%	0,00%	Very cold winter on continent. Max consumption in B & F. Max nomination Terminal
Scenario 3	50%	35%	0%	15%	0,00%	Cold winter on continent, limited nominations on terminal LNG
Scenario 4	70%	35%	0%	35%	0,00%	Low winter consumption. Max nomination terminal
Scenario 5	93%	35%	0%	58%	0,00%	Very very low consumption. Max nomination terminal

CASE 2						
	IUK	EYNATTEN	ZELZATE	ZPT	TERM. LNG	Comments
Scenario 1	100%	35%	7%	58%	0,00%	
Sceanrio 2	100%	35%	7%	0%	58,00%	
Scenario 3	100%	35%	29%	36%	0,00%	
Scenario 4	100%	35%	29%	0%	36,00%	

Possible Scenarios >2013

CASE 1						
	IUK	EYNATTEN	ZELZATE	ZPT	TERM. LNG	Comments
Scenario 1	45%	45%	0%	0%	0%	ZPT gas out of spec
Scenario 2	48%	45%	0%	3%	0%	Very cold winter on continent. Max consumption in B & F. Max nomination Terminal
Scenario 3	60%	45%	0%	15%	0%	Cold winter on continent, limited nominations on terminal LNG
Scenario 4	80%	45%	0%	35%	0%	Low winter consumption. Max nomination terminal
Scenario 5	100%	45%	0%	55%	0%	Very very low consumption. Max nomination terminal
CASE 2						
	IUK	EYNATTEN	ZELZATE	ZPT	TERM. LNG	
Scenario 1	100%	45%	0%	55%	0%	
Sceanrio 2	100%	45%	0%	0%	55%	
Scenario 3	100%	45%	48%	7%	0%	
Scenario 4	100%	45%	48%	0%	7%	

FLUXYS

National Grid

Bacton ballasting and blending for higher Wobbe imports

nationalgrid

Gas Quality Scenario Development

- This presentation concentrates on Wobbe reduction at Bacton for potential higher Wobbe gas imports through the Continental interconnectors at Bacton, namely BBL & IUK
- Other gas quality parameters for example low Wobbe associated with some UKCS fields are not addressed
- Imports of richer Norwegian gas at other terminals are also not addressed in this presentation

- This presentation reflects work in progress and is subject to further analysis

nationalgrid

Options for high Wobbe gas

- EASEE gas 54 MJ/m3
- GS(M)R max 51.4 MJ/m3

  [all reported Wobbe at standard conditions, normal are ~5.5% higher]

1. Terminal blending
   - Dependent on low Wobbe sources
   - Hence not necessarily a 'firm' service
2. Blending & limited ballasting
   - Again not necessarily a 'firm' service
3. Removal of higher hydrocarbons
   - Generally not economic for 'pipeline' gas
4. Full ballasting
   - Nitrogen ballasting
   - Possible but most unlikely CO2 addition

- **This presentation focuses on a nitrogen ballasting solution at Bacton and the possible role blending with lower Wobbe UKCS may provide**

nationalgrid

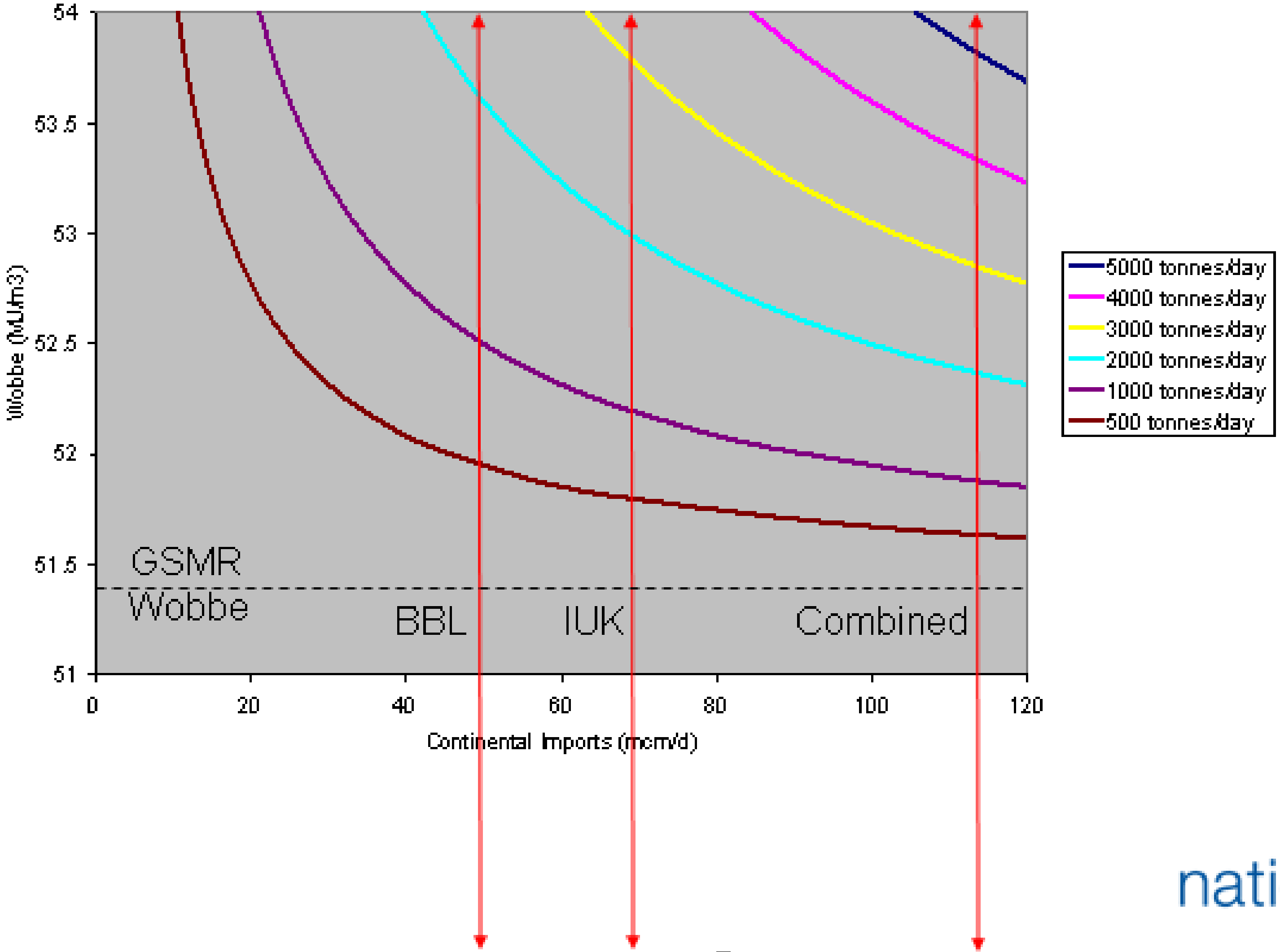
Estimation of N2 ballasting plant for Bacton

- Potentially very high combined BBL & IUK flowrates (115 mcm/d)
- Wobbe at EASEE gas spec 2.6 MJ/m3 higher than GSMR
- Assuming no blending is possible, N2 requirement is proportional to Δ Wobbe above 51.4 MJ/m3 and flow
- Hence considerable potential N2 ballasting requirement of 5000+ tonnes/day

nt f…

nationalgrid

N2 ballasting requirement for Continental imports at Bacton



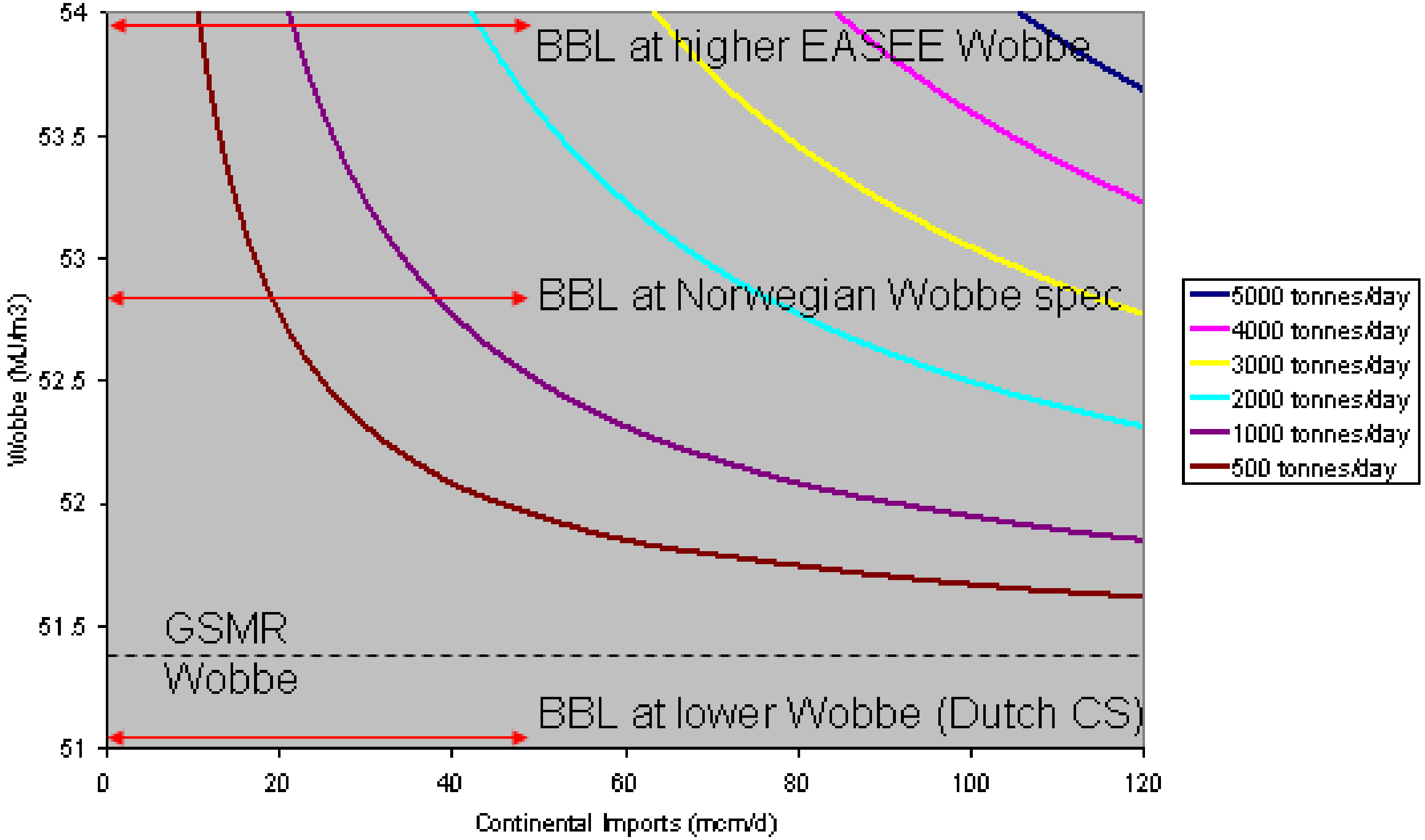
nationalgrid

Estimation of N2 ballasting plant for BBL

- GTS suggest that for BBL, higher Wobbe will only become a major issue if new Troll pipeline from Norway lands in Netherlands, impact of planned LNG and imported Norwegian tends to be discounted for most conditions
  - Max flow ~48 mcm/d
  - Higher flows have a higher probability for out of spec gas
  - Wobbe for new Troll could be 52.8 MJ/m3 (max) unless Norwegian contracts also change towards EASEE gas
  - →Max N2 required for BBL = 1220 tonnes/day
  - (2270 tonnes/day at EASEE gas spec)

nationalgrid

N2 ballasting requirement for BBL imports at Bacton



nationalgrid

Estimation of N2 ballasting plant for IUK (1)

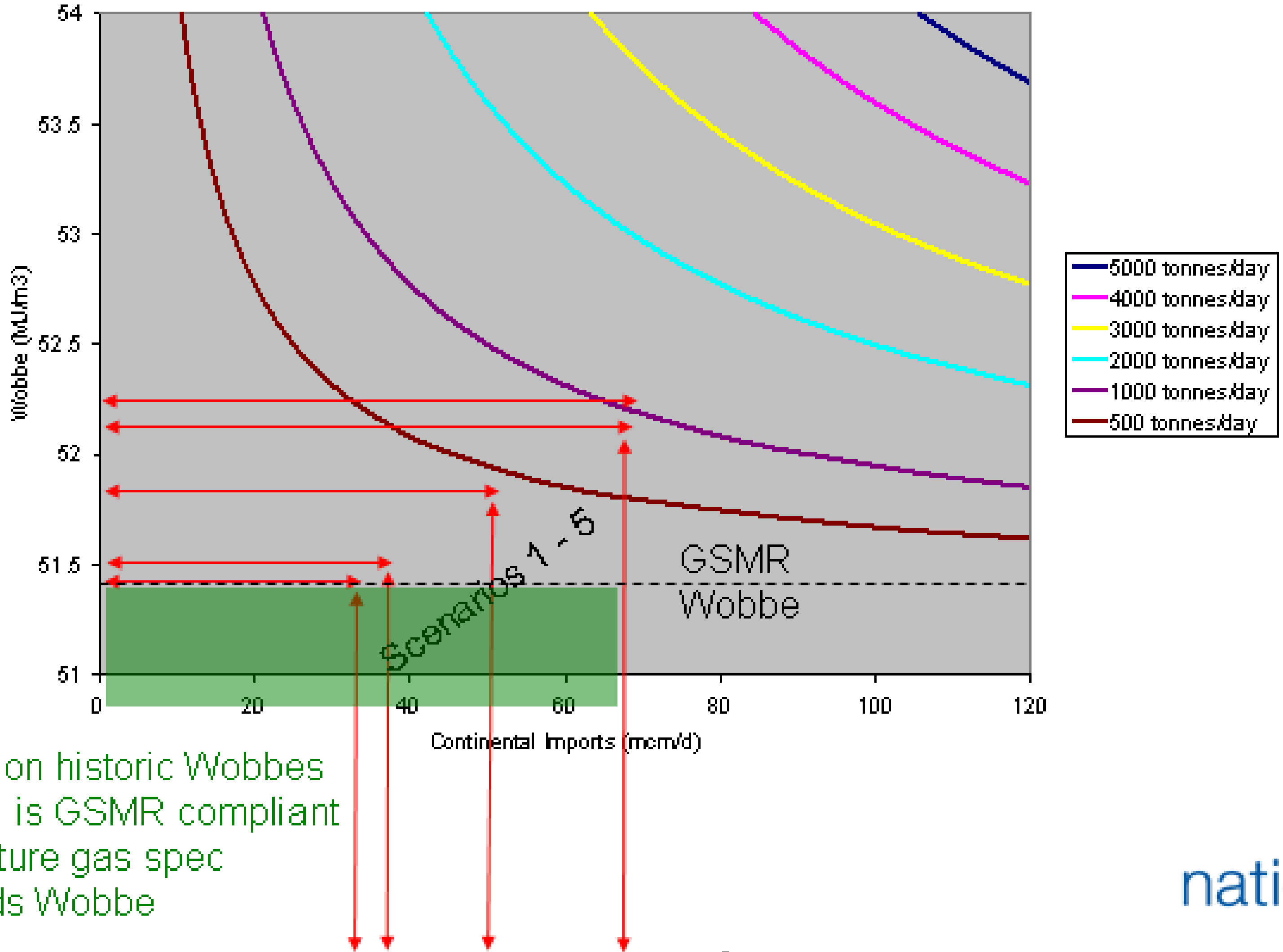
- Fluxys identify 4 sources of gas for IUK at various flow levels for IUK
  - 35% Eynatten (Russian gas through Germany)
  - 0 – 29% Zelzate (Netherlands)
  - 0 – 58% Zeepipe (Norway)
  - 0 – 58% Zeebrugge LNG

		Historic		
Wobbe	**Min**	**Average**	**Max**	**Future?**
Eynatten	47.72	49.86	51.05	51.40
Zelzate	50.71	52.33	53.95	54.00
ZPT	48.53	50.26	51.46	52.80
ZLNG	50.71	51.90	53.27	54.00

- An additional gas quality range has been added to assess **future** gas trends
- Fluxys have provided 2 cases (Existing gas quality and EASEE gas) and a range of IUK flow scenarios
- For Case 1 at existing gas quality specs, gas is GSMR compliant
- For Case 1 only at possible future gas quality specs does, gas exceeds GSMR

nationalgrid

N2 ballasting requirement for IUK imports at Bacton (Case 1)



Based on historic Wobbes
Case 1 is GSMR compliant
only future gas spec
exceeds Wobbe

nationalgrid

Estimation of N2 ballasting plant for IUK (2)

- For Case 2 at EASEE gas specs, higher IUK flows are possible for all scenarios (~70 mcm/d), but gas quality becomes an issue:

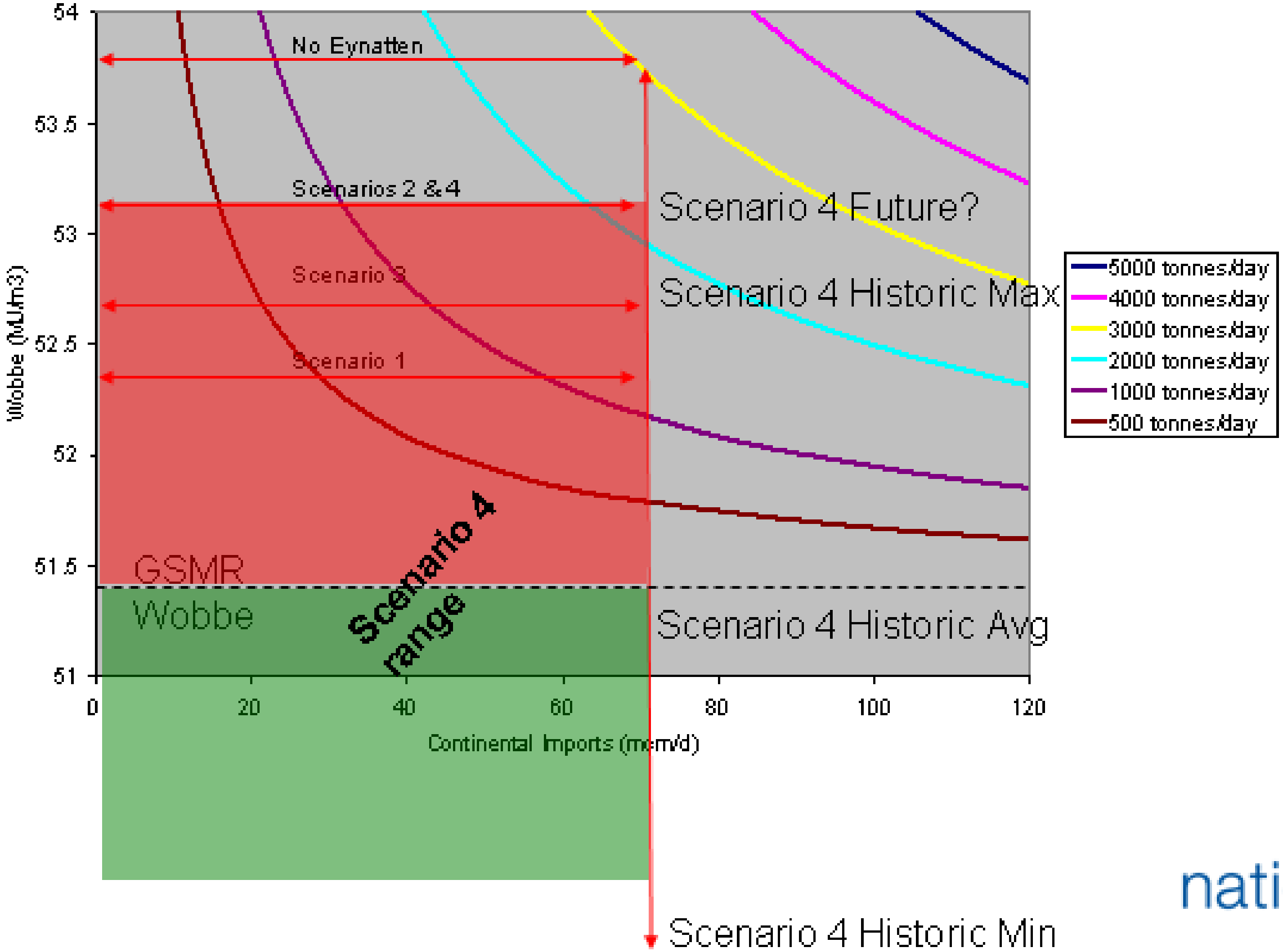
Historic	MJ/m3	Scenario 1	Scenario 2	Scenario 3	Scenario 4	No Eynatten
	Min	48.40	49.66	48.88	49.66	50.43
	Average	50.26	51.21	50.72	51.31	51.81
	Max	51.49	52.54	52.04	52.69	53.23
	Future?	52.39	53.09	52.66	53.09	53.84

- For historic average conditions only the scenario which assumes no Eynatten gas are gas quality services required
- For historic max and future max, high Wobbe approaching EASEE gas spec results
- N2 ballasting requirements for IUK are also highly flow dependent:

70 mcm/d	N2 tonnes/day	Scenario 1	Scenario 2	Scenario 3	Scenario 4	No Eynatten
	Min	0	0	0	0	0
	Average	0	0	0	0	520
	Max	117	1453	813	1642	2332
	Future?	1264	2148	1599	2148	3107

nationalgrid

N2 ballasting requirement for IUK imports at Bacton (Case 2)



nationalgrid

Summary needs of N2 ballasting plant at Bacton

- BBL – limited requirements unless new Troll pipeline is landed at Balgazand
  - At design flow (~48 mcm/d) 1220 tonnes/day N2
  - Up to 2270 tonnes/day if EASEE gas spec is applied to Norwegian imports

- IUK – limited or no requirements if existing gas specifications remain, but possible lower IUK flows
- With change to EASEE gas specs, higher IUK flows are possible (~70 mcm/d)
- N2 ballasting then becomes determined by gas sourcing strategy, IUK flow and Belgium regulatory developments
  - N2 ballasting range 0 – 3000+ tonnes/day

- **Combined N2 ballasting range 0 – 5000+ tonnes/day**

nationalgrid

Estimation of Bacton UKCS flows & Wobbe

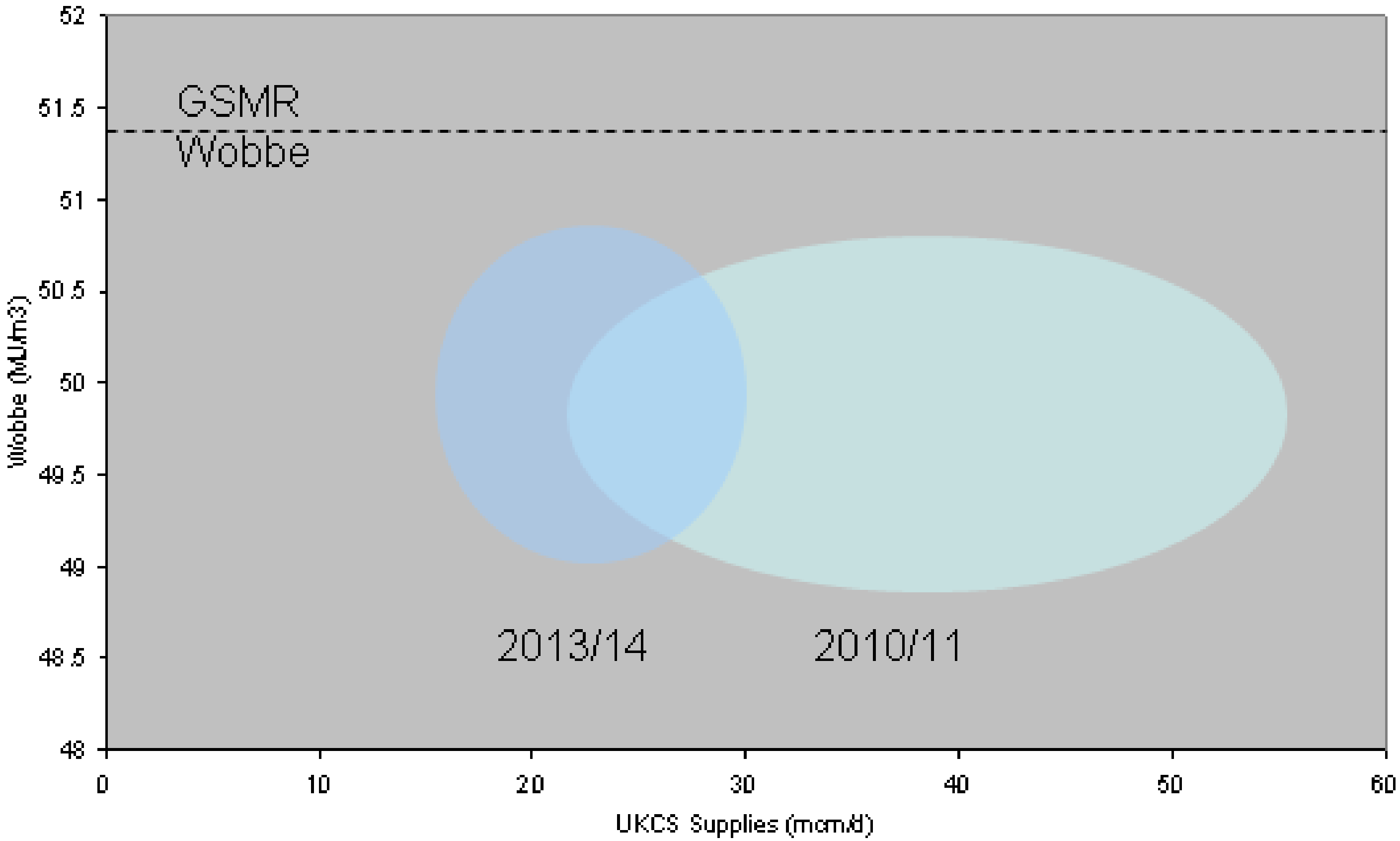
- Bacton UKCS flows based on National Grid's 2006 Base Case supply forecasts
- No allowance in flows for field outages
- Gas quality ranges based around sub-terminal compositions

	Flow (mcm/d)		Wobbe (MJ/m3)	
	2010/11	2013/14	2010/11	2013/14
Max	56	30	50.8	50.9
Average	35	23	49.7	49.6
Min	24	16	48.8	49.1

- UKCS supplies may provide opportunities for blending, but this is subject to uncertainties associated with flow and Wobbe

nationalgrid

Typical flow & Wobbe envelopes for UKCS supplies at Bacton



The envelopes are representative rather than specific of the ranges of both flow and Wobbe

nationalgrid

Consideration of blending & ballasting scenarios at Bacton

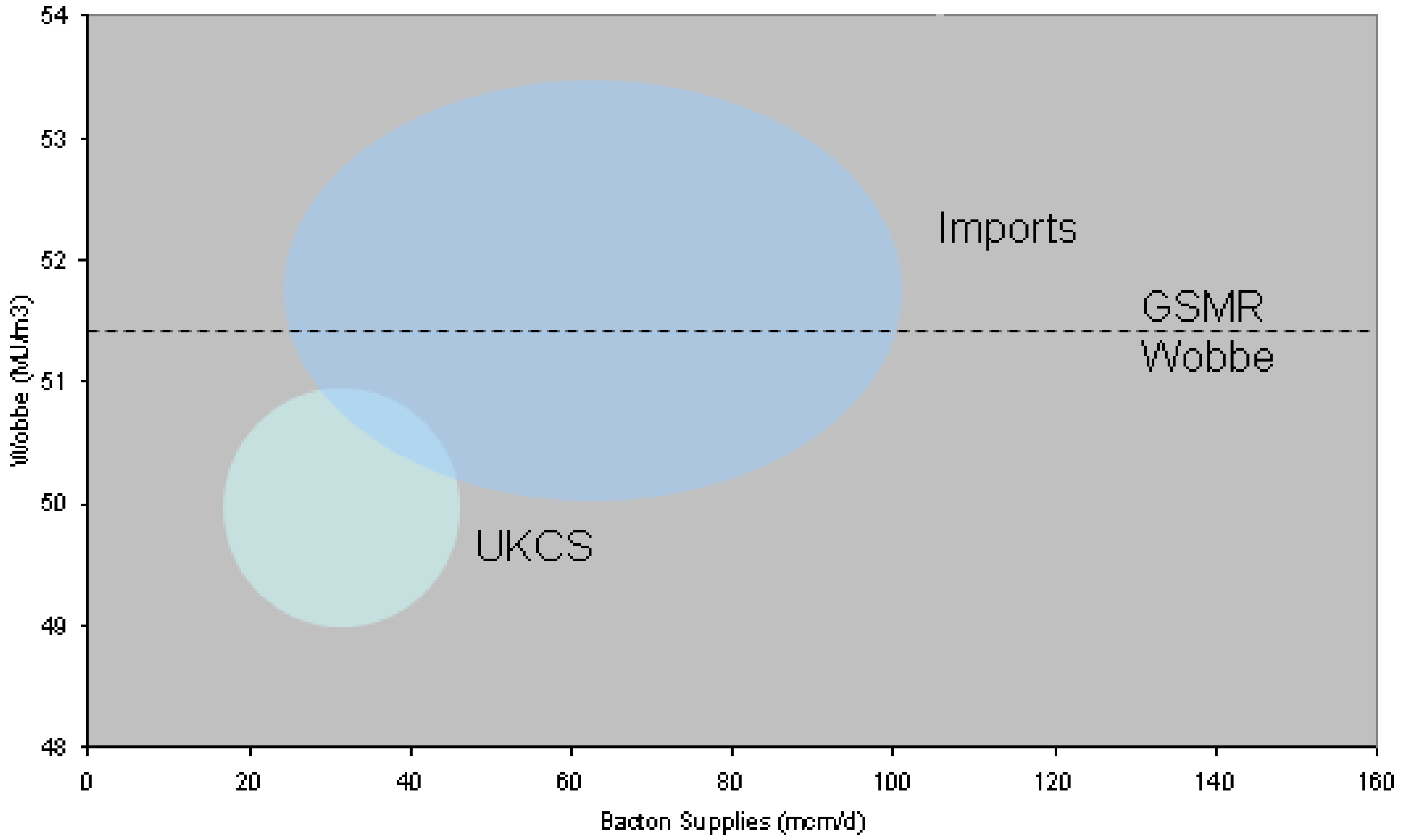
- Consider a matrix of UKCS supplies and imports
- Consider variations of both flow and Wobbe

	Wobbe (MJ/m3)		Flow (mcm/d)	
	UKCS	Imports	UKCS	Imports
Low	49.0	50.0	15	25
Average	50.0	52.5	30	50
High	51.0	53.5	45	100

- Hence 81 permutations
- Whilst some of the permutations could be considered extreme (low UKCS flows and high imports) they do reflect the likely range of supply possibilities
- Resultant Wobbe above 51.4 need further ballasting to meet GSMR

nationalgrid

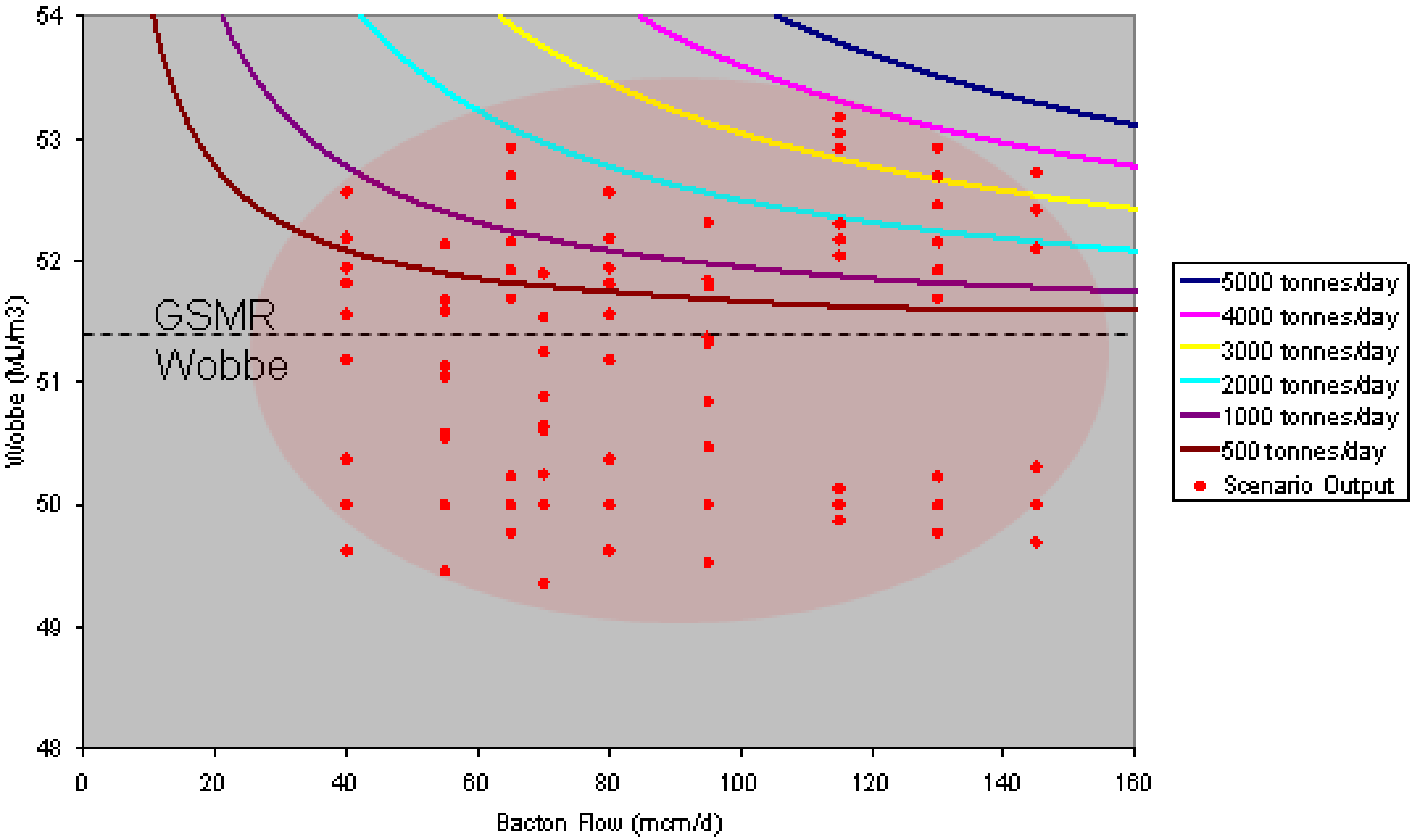
Flow & Wobbe envelopes for UKCS supplies & imports at Bacton for scenario analysis



The envelopes are representative rather than specific of the ranges of both flow and Wobbe

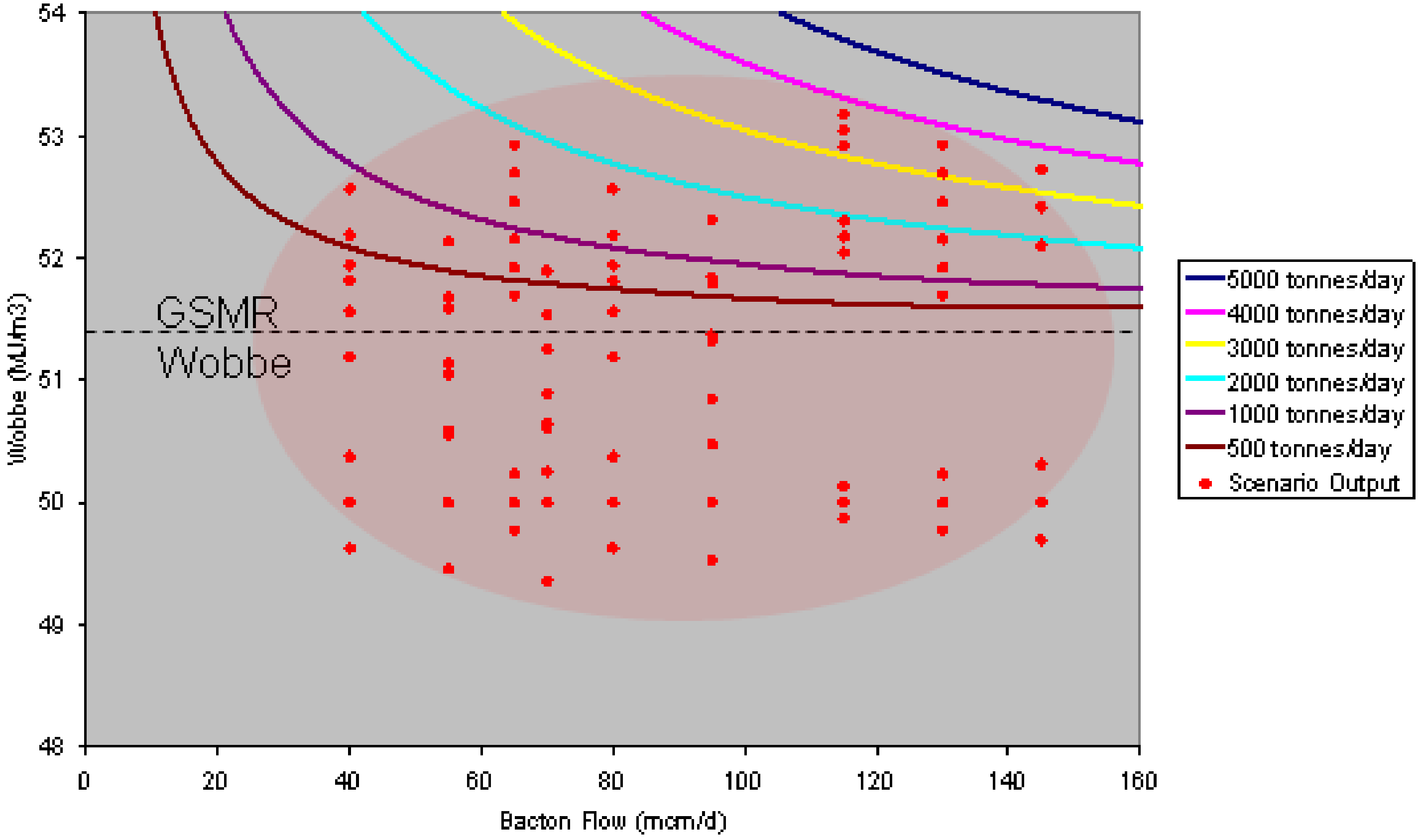
nationalgrid

Scenario analysis for UKCS supplies & imports at Bacton



nationalgrid

Scenario analysis for UKCS supplies & imports at Bacton



nationalgrid

National Grid

Gas Quality Services:
Nitrogen ballasting for high Wobbe

Work in progress

nationalgrid

Gas Quality Service Options

ptions

- There are 3 main possible service offerings:
  - Blending; mixing of incoming gas streams to create a homogenous gas quality on exit
  - Ballasting; the addition of nitrogen to lower Wobbe
  - Enrichment; the addition of propane to increase Wobbe

- Each service could potentially be offered as a standalone service
- Alternatively it might be possible to combine some or all of these offerings to manage the full EASEE gas Wobbe range and to the optimum the use of the available gas streams

nationalgrid

Key Characteristics of Options (Bacton example)

Option	Blending	Ballasting	Enrichment
Type of service	H-Wobbe: Interruptible L-Wobbe: Interruptible	H-Wobbe: Firm	L-Wobbe: Firm
Key technical aspects	Control system Upstream GQ signals Blending loops (space requirement) as limited scope for fortuitous blending.	Control system Upstream GQ signals Process plant (space required) Large power requirement Unique - not been done before with this size and on an existing site	Control system Upstream GQ signals Propane sourcing / storage (space required)
Safety case / planning considerations	Material change to safety case	Material change to safety case Site change of use Environmental Impact Assessment	Material change to safety case Site change of use - COMAH Environmental Impact Assessment
Costs	To be developed, but material.	Capex up to £200m(+) See following slides.	To be developed
Upstream considerations	Unless a firm service is offered, it is unlikely that the interconnectors would change their entry specification. Therefore only benefit in this case would be related to low Wobbe UKCS supplies.	Challenge of scaling the plant and ensuring sufficient resilience to provide a firm service, which in turn results in a change to the high Wobbe range of the interconnectors.	Largely proven technology, should lead to change in interconnector low Wobbe range.
Summary	Blending unlikely to result in significant increases in accessible gas. However does provide an opportunity for optimisation in an overall ballasting / enrichment process - but unless a change in the firmness of the service is acceptable, only Opex costs will be reduced. At Bacton limited scope for fortuitous blending.	Provides the greatest opportunity to access additional gas volumes. However, significant risks in terms of scale and complexity. Also concerns about resilience of the plant.	Provides access to limited additional volumes of gas. To change the classification of the site to COMAH is a major issue, that needs to be further explored.

nationalgrid

Aerial view of Bacton

nationalgrid

Ballasting

- This presentation concentrates on Wobbe reduction through ballasting
- It specifically looks at treatment of potential rich gas imports through the Continental interconnectors at Bacton, namely BBL & IUK
- This presentation reflects work in progress and is subject to further analysis

nationalgrid

Options for nitrogen ballasting

- Offsite generation
  - N2 piped in (need local air separation plant)
  - N2 brought in through road tankers
- Onsite generation
  - N2 from an air separation plant - ASU (cryogenic distillation – hence high power requirements)
  - N2 is produced as GAN (gaseous nitrogen) & LIN (liquified nitrogen)
  - LIN is more expensive than GAN but can be stored to provide a back-up facility, provide operational flexibility, optimise design and if required be topped up through road tankers

nationalgrid

Nitrogen ballasting requirements

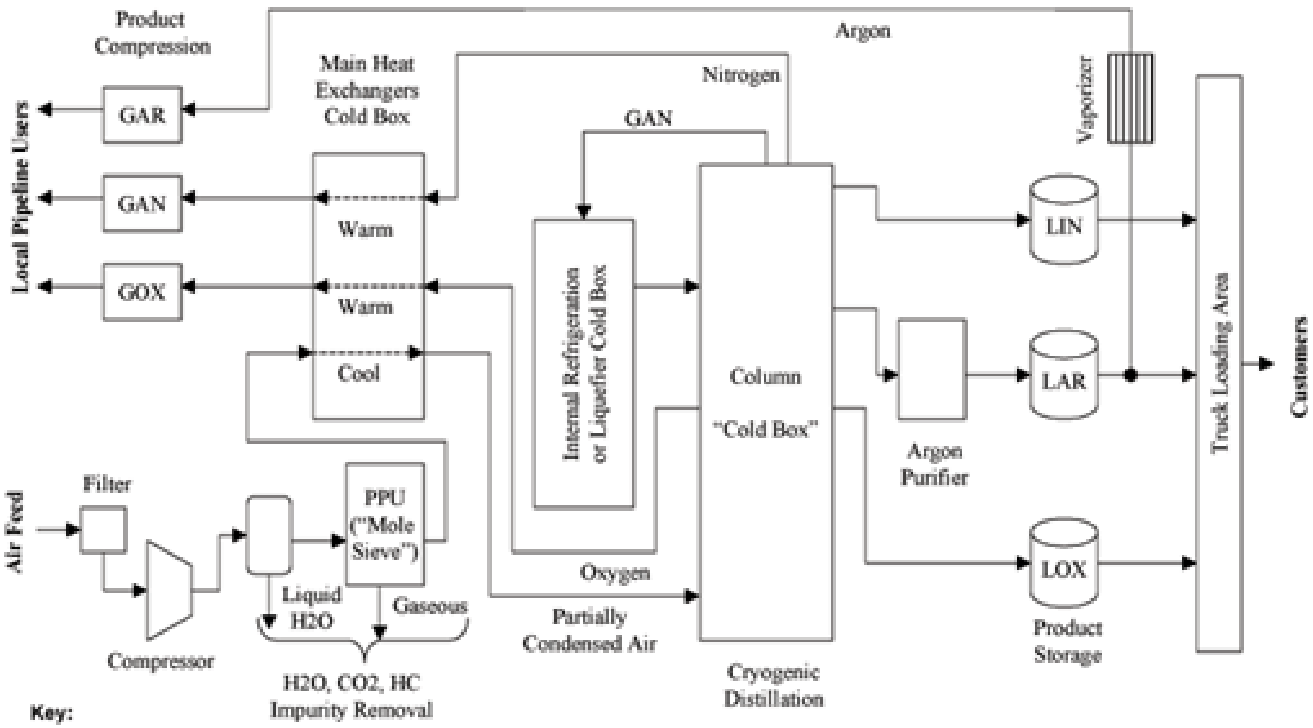
- 1000 tonne of N_2 reduces Wobbe ~1 MJ/m3 for 55 mcm natural gas

- Use of stored LIN through road tankers is only appropriate as a limited back-up facility, due to quantity of N_2 required
- Frequent tanker deliveries of N_2 would also be expensive with N_2 costs reported at £100-200/tonne

- Hence the need for an ASU as built for Grain 1, under construction for LNG imports at both Milford Haven plants and planned for Grain 2
- Teesport LNG plan to use locally piped N_2

nationalgrid

Air Separation Units (ASU)



Key:

Gaseous	Product	Liquid
GAN	Nitrogen	LIN
GAR	Argon	LAR
GOX	Oxygen	LOX
CO2	Carbon Dioxide	-
H2O	Water	H2O
HC	Hydrocarbons	-

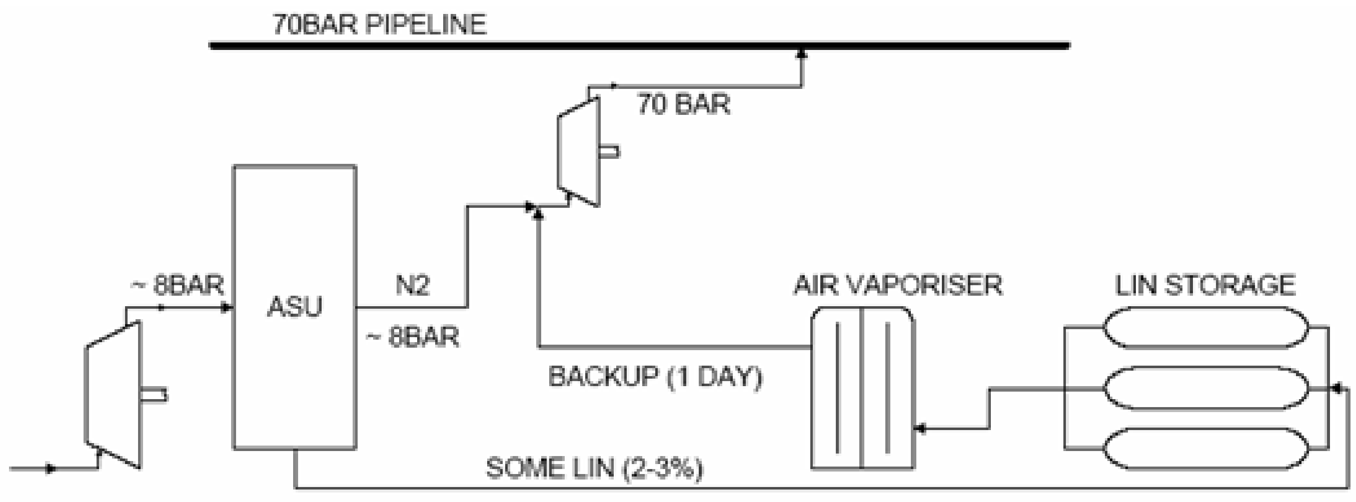
Generic Air Separation Unit (ASU)

- Shows inter-relationship of major components
- Specific plants will vary

nationalgrid

ASU for N2 only

- Design can be simplified from conventional ASU as only N2 is required
- Primary product is GAN but LIN is also produced for back-up purposes
- LIN also enables opportunity for considerable design flexibility / optimisation
- High power requirement, compression required for air feed, refrigeration and GAN injection up to pipeline pressure



nationalgrid

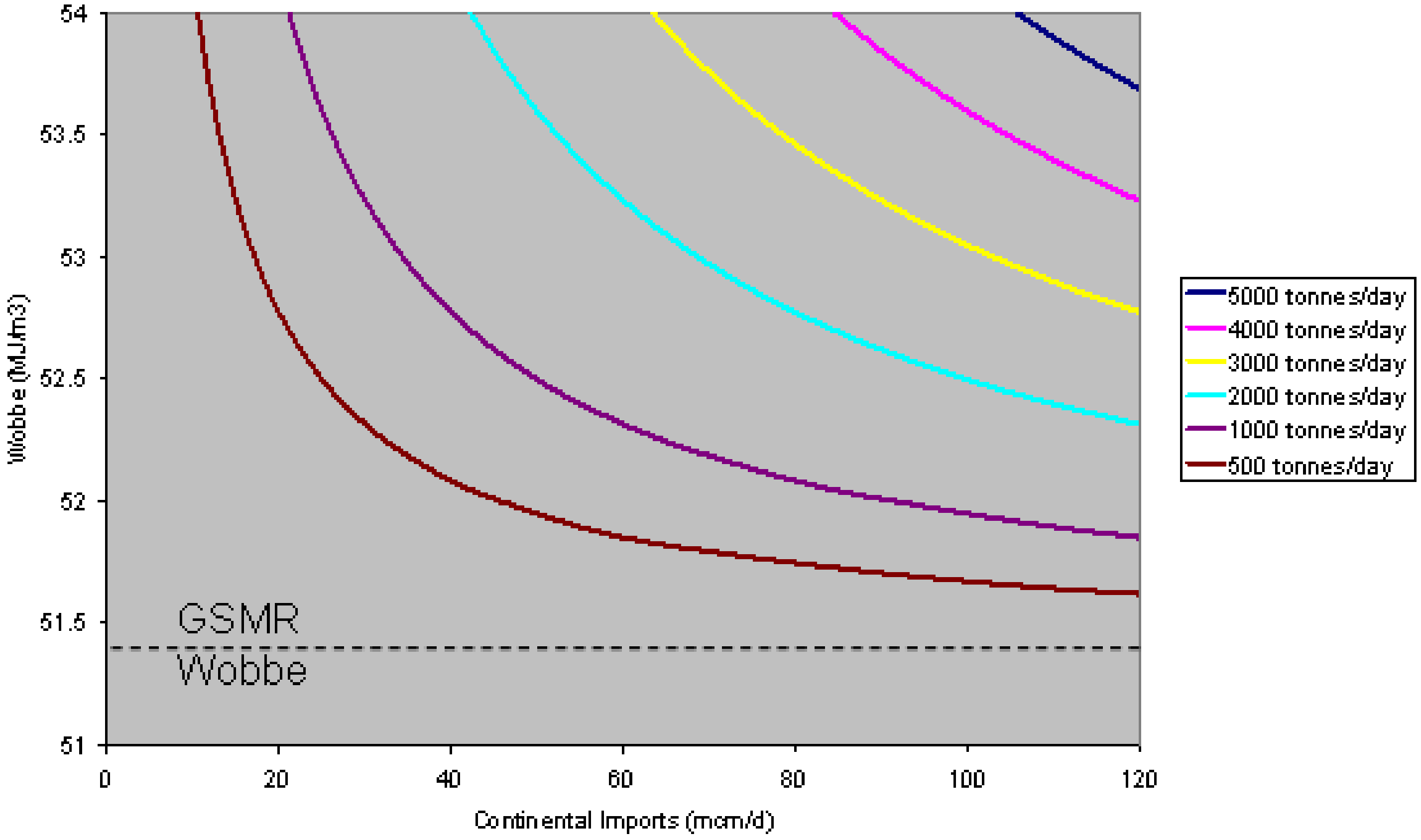
Estimation of N2 ballasting plant for Bacton

- Potentially very high combined BBL & IUK flowrates (115 mcm/d)
- Wobbe at EASEE gas spec 2.6 MJ/m3 higher than GSMR
- Hence considerable potential N2 ballasting requirement of 5430 tonnes/day

- **Assuming no blending is possible, N2 requirement is proportional to Δ Wobbe above 51.4 and flow**

nationalgrid

N2 ballasting requirement for Continental imports at Bacton



nationalgrid

Preliminary cost analysis of N2 ballasting plant

- **Bacton requirements at design limits could be in excess of 5000 tonnes/day**
- The following analysis is based on the costing of a 1000 tonnes/day N2 ballasting plant [a range of costs for 0 – 5000 tonnes/day is also shown]
- Production is primarily GAN with LIN storage for 3000 tonnes [0 – 15000 tonnes]
- Estimated power requirements 12.2 MWe [0 – 61 MWe]
- Estimated Capex £40 million [£0 – 200 million] (£3.44 m/year at 7% over 25 years) [£0 – 17.2 million]
- Opex dominated by power consumption, at 70% Load Factor (LF) = £4.5 m/year [£0 – 22.5 million]
- Opportunity for considerable design flexibility / optimisation with trade offs between GAN / LIN / LIN storage etc

nationalgrid

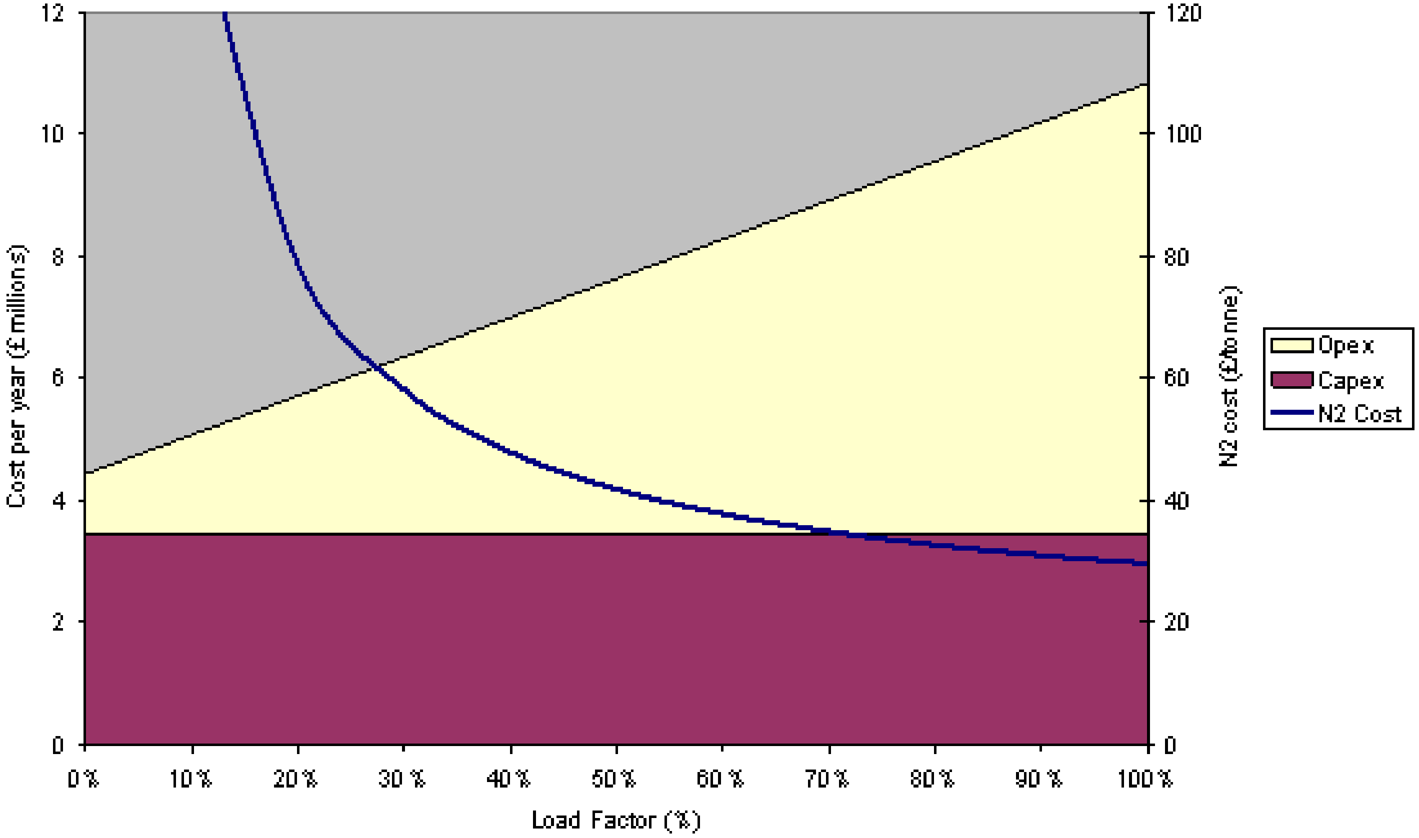
N2 costs are highly dependent on Load Factor

- 1000 tonne/day N2 ballasting, Opex based on power & £1 m/year for other costs
- Table below shows N2 costs at typically £35/tonne, higher at lower LFs
- Power component represents up to 2/3rds of cost
- Lower costs for N2 reported elsewhere but may not reflect full needs

LF	Capex	Opex	Total	Tonnes	£/tonne
0%	3.44	1.00	4.44	0	
10%	3.44	1.64	5.08	36500	139.18
20%	3.44	2.28	5.72	73000	78.36
30%	3.44	2.92	6.36	109500	58.08
40%	3.44	3.56	7.00	146000	47.95
50%	3.44	4.20	7.64	182500	41.86
60%	3.44	4.84	8.28	219000	37.81
70%	3.44	5.48	8.92	255500	34.91
80%	3.44	6.12	9.56	292000	32.74
90%	3.44	6.76	10.20	328500	31.05
100%	3.44	7.40	10.84	365000	29.70

nationalgrid

Estimated annual costs for 1000 tonne/day N2 ballasting plant



nationalgrid

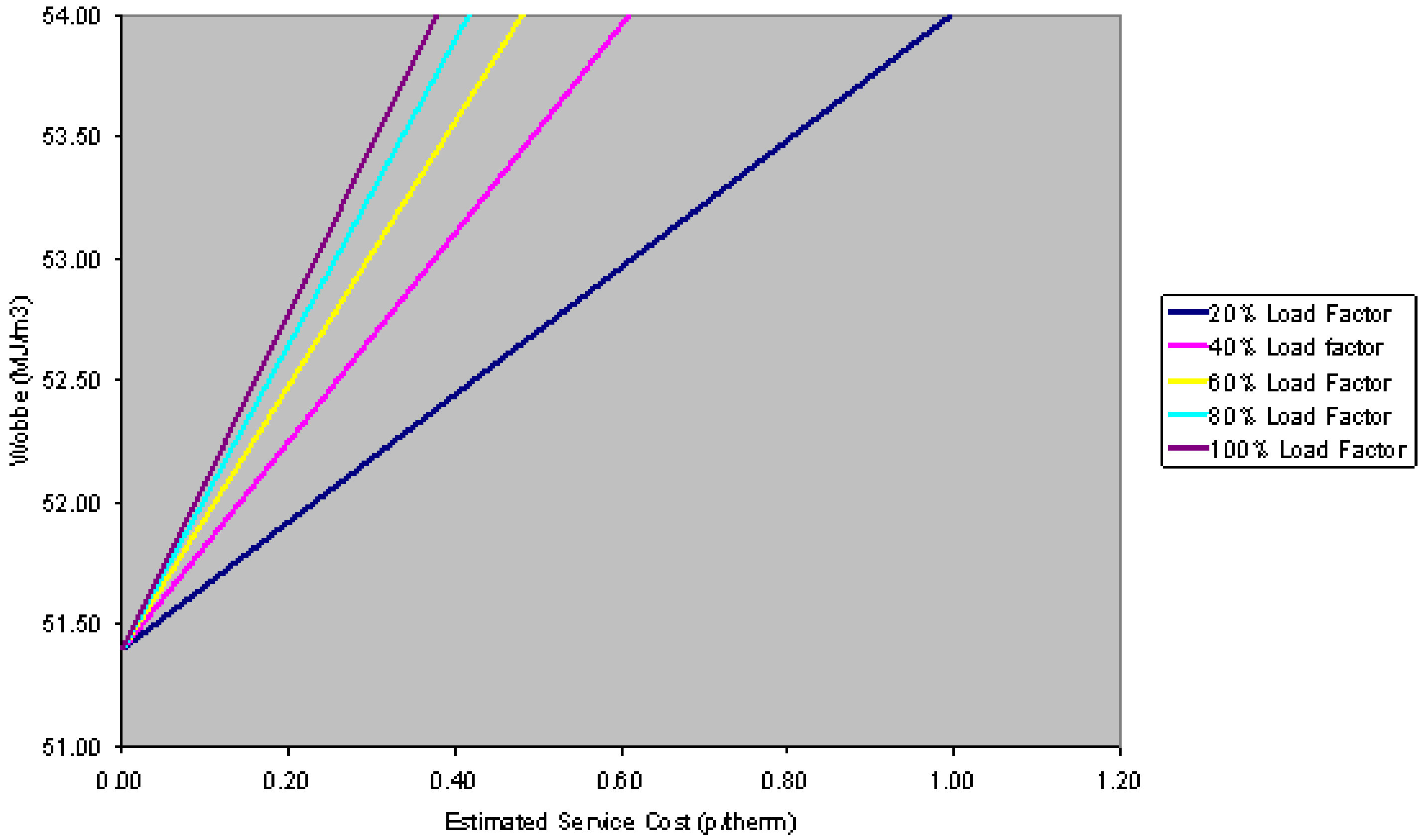
Cost (pence per therm) of a N2 ballasting service

- Costs are dependent on Load Factor and Wobbe reduction
- Costs as low as 0.15 p/therm are possible at high LF

	Pence / therm Wobbe reduction (MJ/m3)		
LF	1	2	2.6
0%			
10%	0.68	1.36	1.77
20%	0.38	0.77	1.00
30%	0.28	0.57	0.74
40%	0.23	0.47	0.61
50%	0.20	0.41	0.53
60%	0.19	0.37	0.48
70%	0.17	0.34	0.44
80%	0.16	0.32	0.42
90%	0.15	0.30	0.40
100%	0.15	0.29	0.38

nationalgrid

Estimated service cost for 1000 tonne/day N2 ballasting plant



nationalgrid