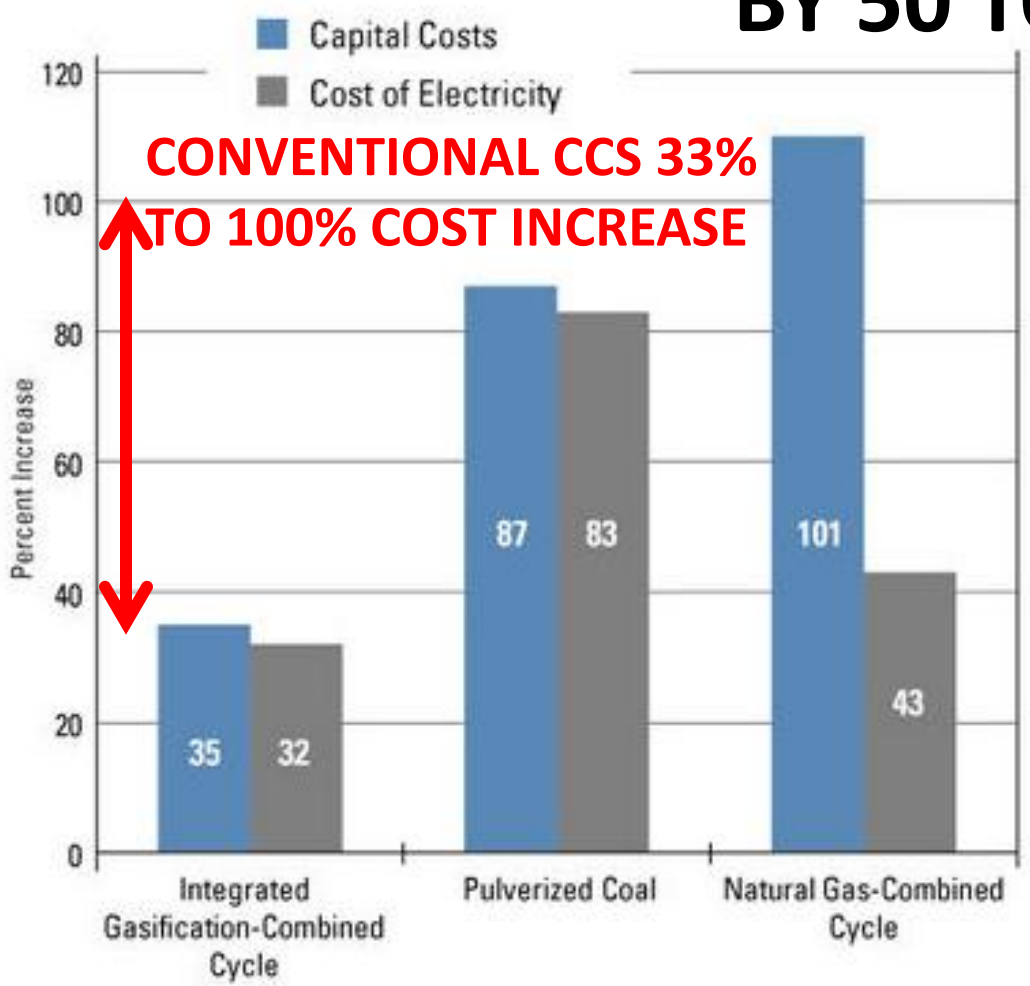
DECARBONISED SNG: BGL CO-GASIFICATION OF WASTES, BIOMASS AND COAL WITH CCS DELIVERS LOW COST 'CLEAN' ENERGY, REDUCES COST OF CCS BY 50 TO 75%



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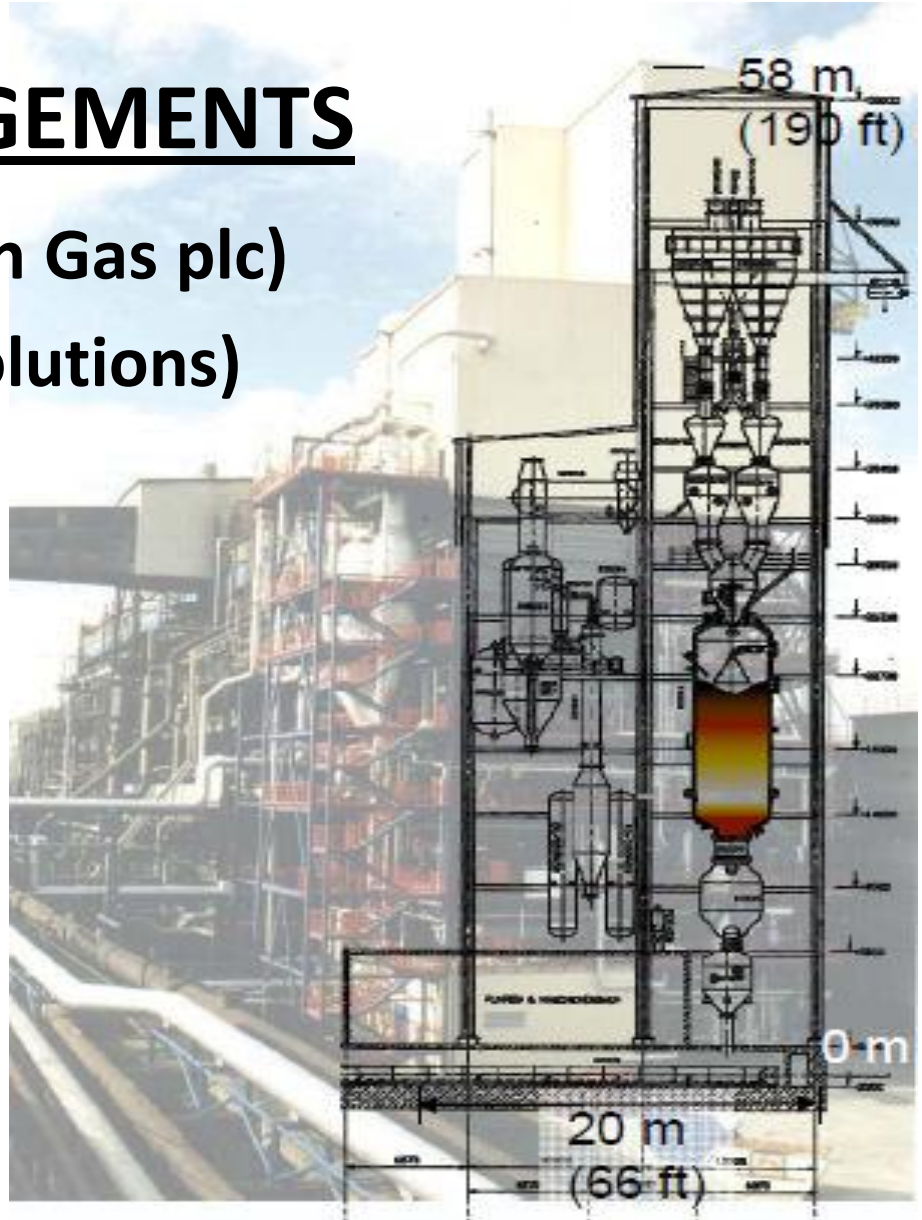
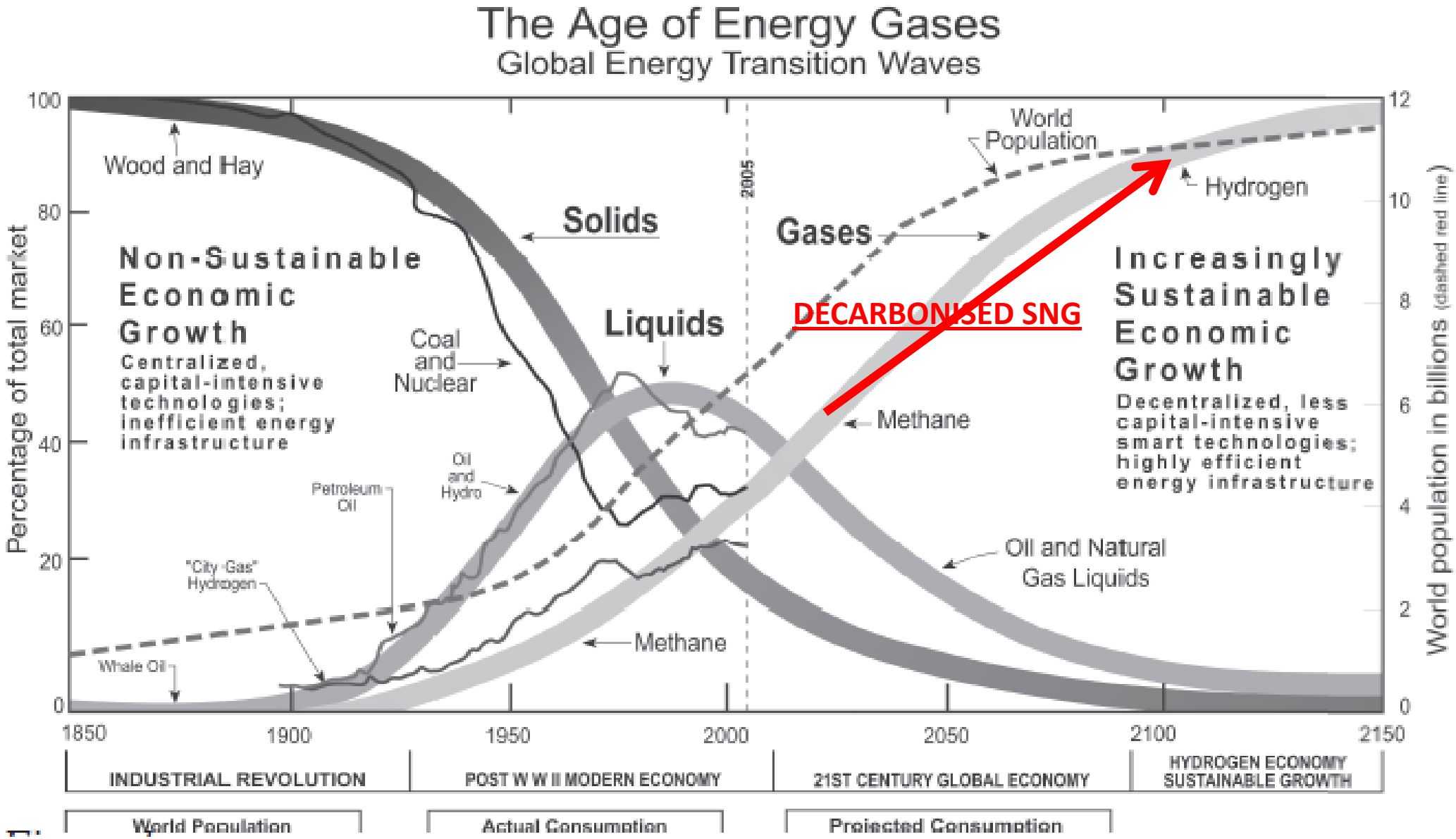
ACKNOWLEDGEMENTS

- GL Noble Denton Ltd (ex-British Gas plc)
- Jacobs Engineering (ex-Aker Solutions)
- GE Energy Inc
- Timmins CCS Ltd
- Waste Recycling Group Ltd
- Kier Group plc
- Envirotherm GmbH
- Tectronics Ltd
- CNG Services Ltd
- Greenhill LLP
- Claverton Energy Group



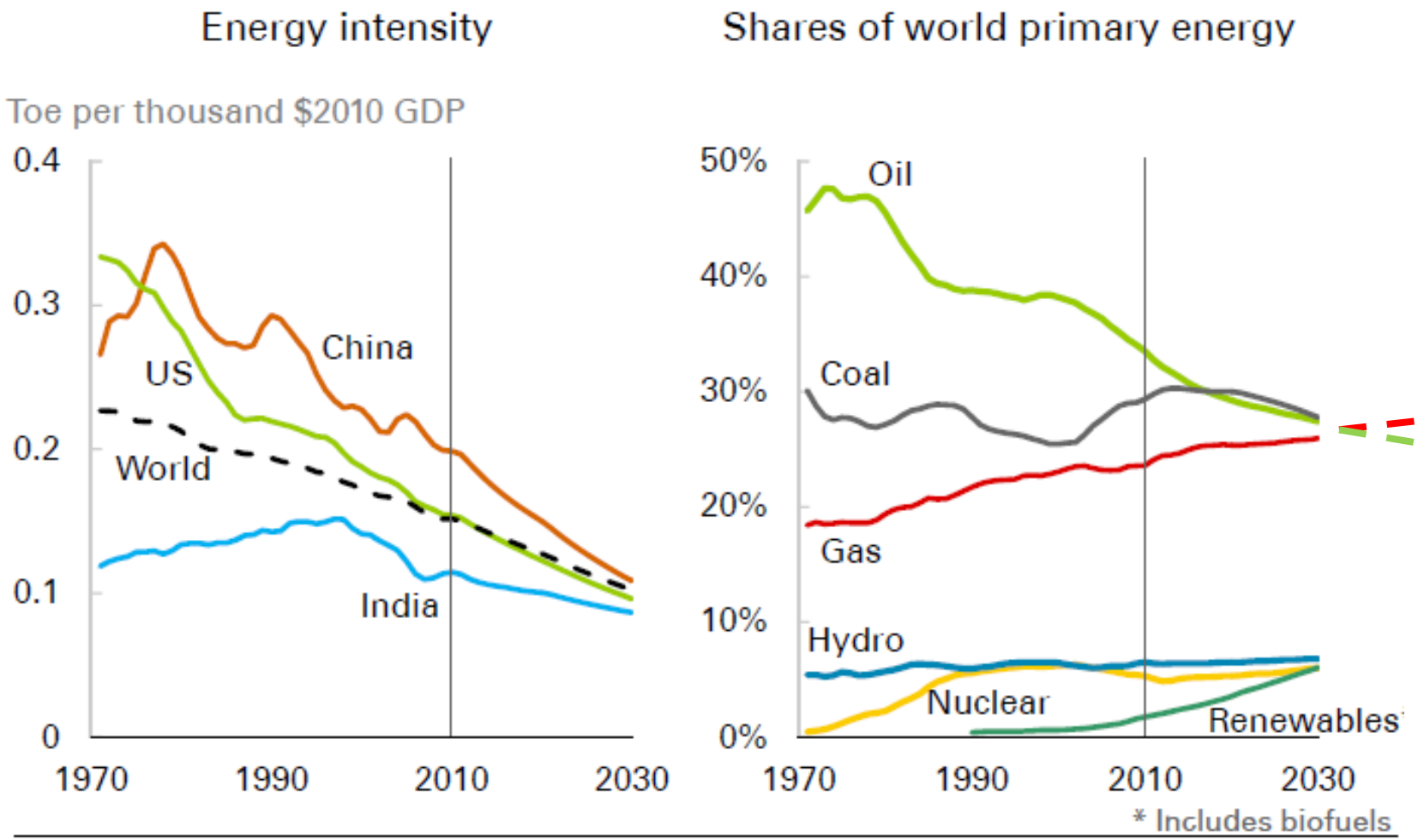
British Gas Lurgi multi-fuel gasifier at SVZ Schwarze Pumpe

DECARBONISED SNG: LOW CARBON ENERGY VECTOR COMPLIMENTS BOTH FOSSIL METHANE AND SUSTAINABLE HYDROGEN



WILL GAS OVERTAKE OIL AFTER 2030?

Convergence of energy intensity and fuel shares…



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SNG PLANTS: LARGE HIGH CONCENTRATION POINT SOURCES OF CO_2

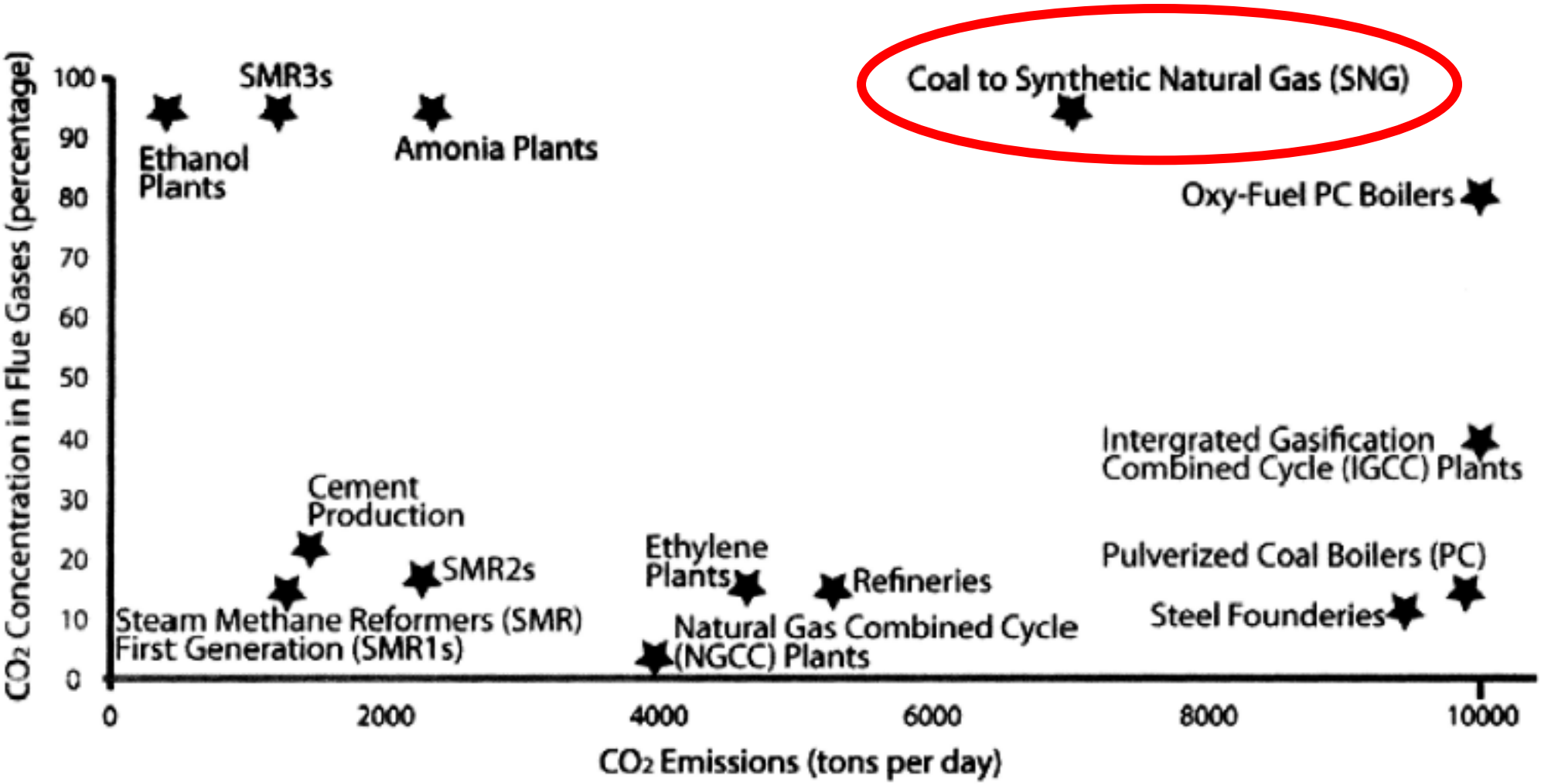


Figure 4 - CO_2 Point Sources: Amount vs. Concentration

MANY NATURAL GAS PROCESSING PLANTS ARE LIKE SNG PLANTS – INHERENTLY CARBON CAPTURE READY

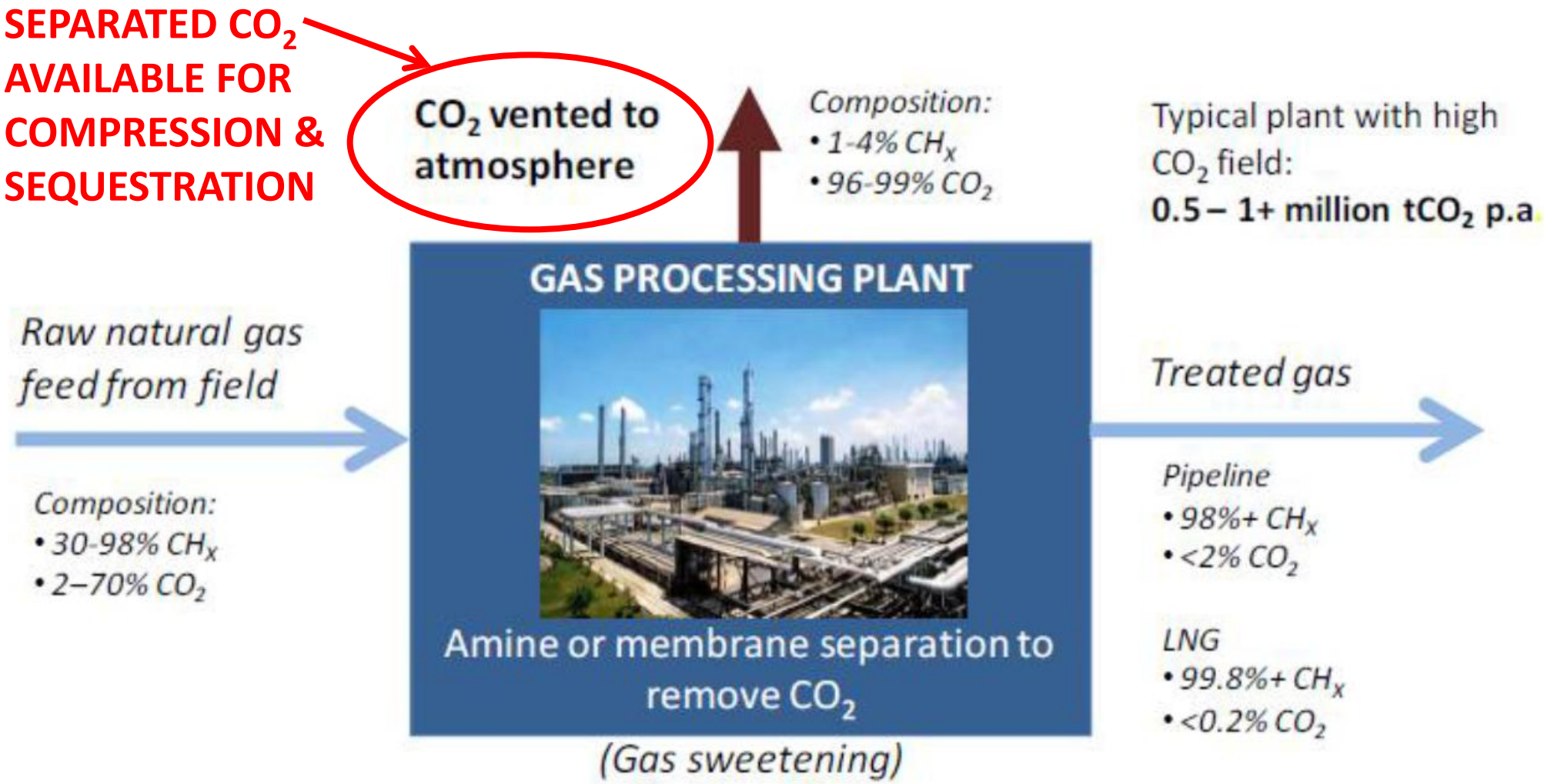
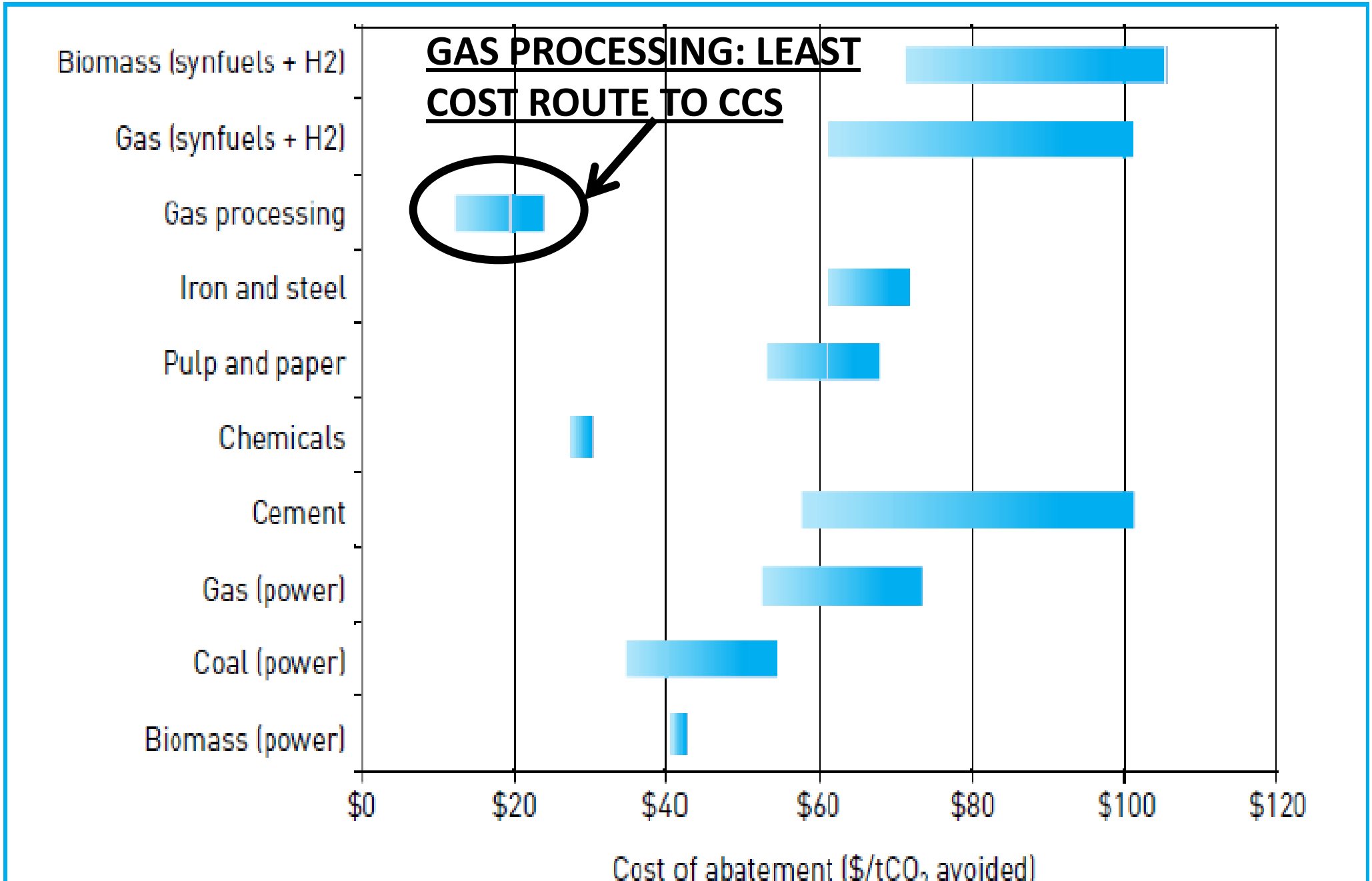


Figure 1: CCS abatement cost range – 2010-50 by sector (USD/tCO_2 avoided)[16]

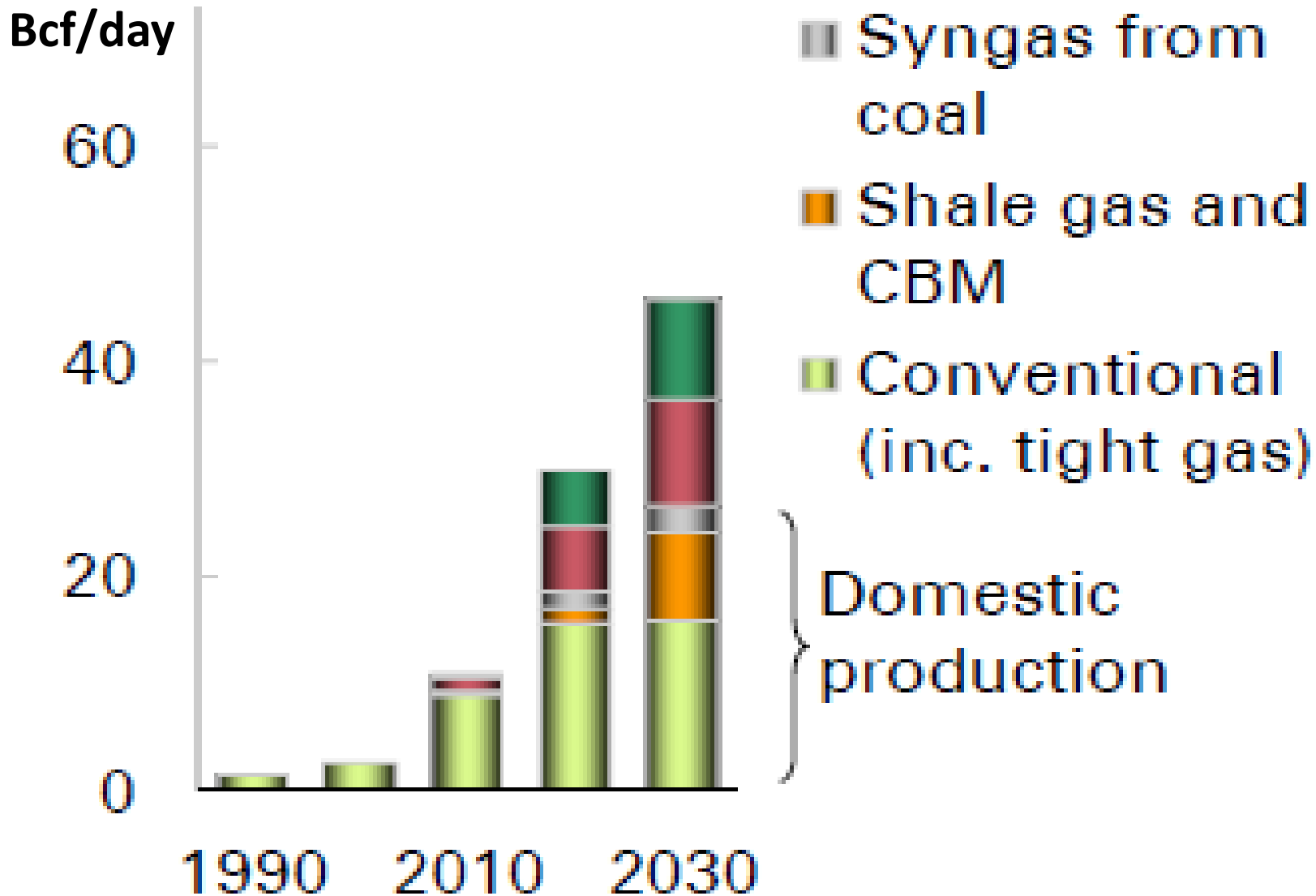


2030 CHINESE GAS SUPPLY GROWS TO 475bn m^3 pa
GAS GROWTH 7.6% pa. 2.5 x GDP GROWTH 3.0% pa

- Natural gas is projected to be the fastest growing fossil fuel globally (2.1% p.a.). The non-OECD accounts for 80% of global gas demand growth, averaging 2.9% p.a. growth to 2030. Demand grows fastest in non-OECD Asia (4.6% p.a.) and the Middle East (3.7% p.a.).
- Gas grows rapidly in China (7.6% p.a.) to a level of gas use in 2030 (46 Bcf/d) equal to that of the European Union in 2010. China contributes 23% to the global demand increase. The share of gas in China's primary energy consumption expands from 4.0% to 9.5%.
- On the supply side the main regional contributors to growth are the Middle East (26% of global growth) and FSU (19%). Significant incremental supply (11-12% of global growth each) is also expected from Australia, China, and the US.
- LNG represents a growing share of gas supply. Global LNG supply is projected to grow 4.5% p.a. to 2030, more than twice as fast as total global gas production (2.1% p.a.) and faster than inter-regional pipeline trade (3.0% p.a.). LNG contributes 25% of global supply growth 2010-30, compared to 19% for 1990-2010.

© BP 2012

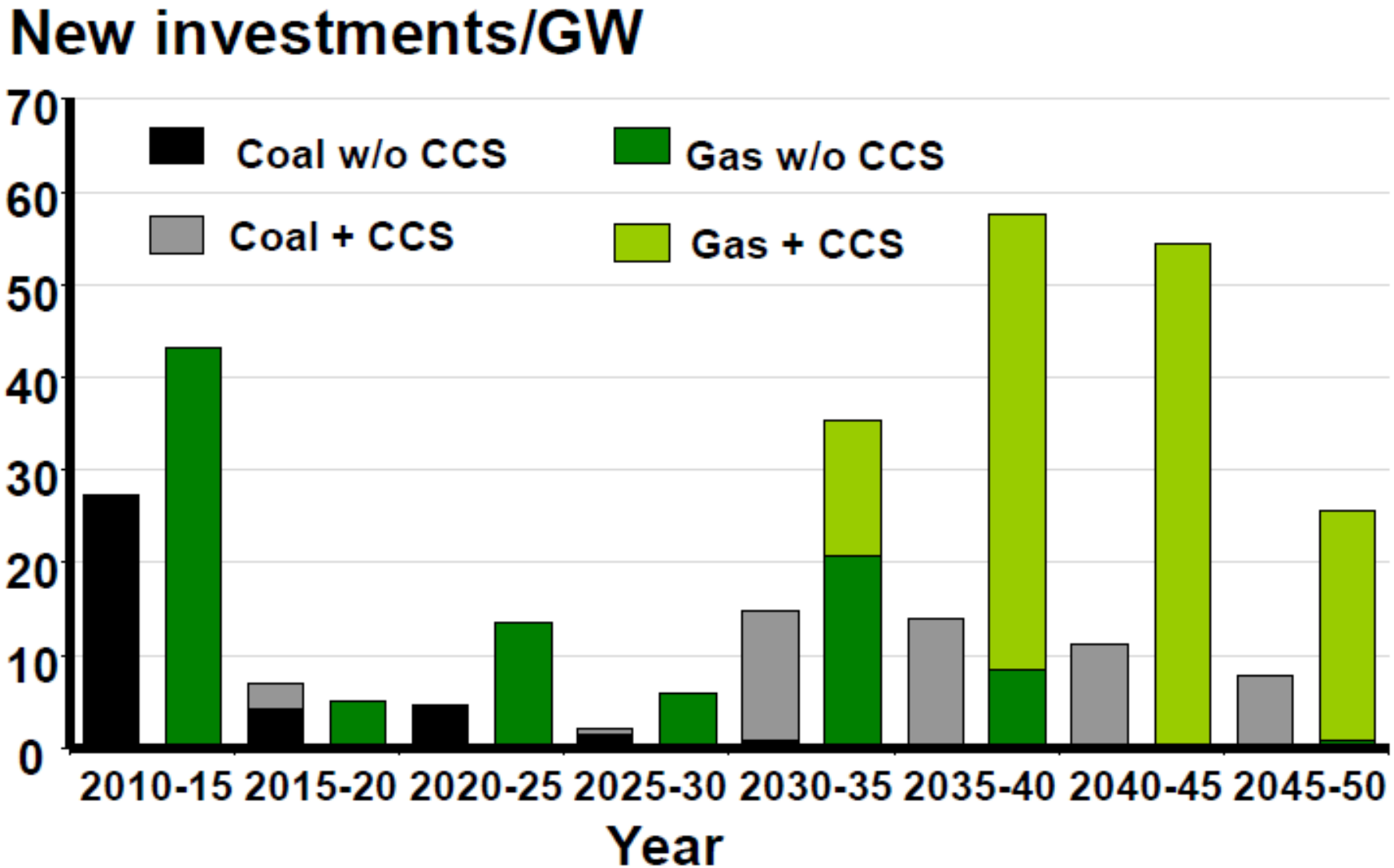
6% pa CHINESE DOMESTIC GAS PRODUCTION GROWTH: 2010 92 bn m^3 pa. 2030 275 bn m^3 pa



CHINESE COAL TO SNG 2012: 32 PLANTS PLANNED OR IN DEVELOPMENT. TOTAL CAPACITY 111 bn m^3 pa

	Location	Company	Capacities(bn Nm3/a SNG)	Status
1	Ordos, Inner Mongolia	Huineng Coal Chemical	2	Construction
2	Ordos, Inner Mongolia	Shenhua Group	2	Development
3	Ordos, Inner Mongolia	CNOOC	8	Development
4	Chifeng, Inner Mongolia	Datang/ Beijing Gas/ Tianjin Jinneng	4	Construction
5	Datong, Shanxi	CNOOC, Datong Coal Mining	4	Development
6	Manasi, Xinjiang	Gezhouba Xinjiang Investment	2	Planned
7	Yili, Xinjiang	CPIC, Xinwen Mining	6	Development
8	Yili, Xinjiang	CPIC	6	Development
9	Yili, Xinjiang	Yili Xintian Coal Chemical	2	Construction
10	Yili, Xinjiang	Lu'an Group	4	Planned
11	Yili, Xinjiang	Yongmei/ Chongqing Doyen	4	Planned
12	Yili, Xinjiang	China National Coal	4	Development
13	Yili, Xinjiang	Xinjiang Guotou Baodi	2	Development
14	Yili, Xinjiang	China Guodian Corporation	4	Construction
15	Yili, Xinjiang	Qinghua Group	1.3	Construction
16	Changji, Xinjiang	Shendong Tianlong Group	1.3	Development
17	Changji, Xinjiang	China Huaneng Group	4	Construction
18	Changji, Xinjiang	Henan Coal Chemical Group	4	Development
19	Changji, Xinjiang	China National Coal Group	4	Development
20	Changji, Xinjiang	China Huadian Corporation	6	Development
21	Changji, Xinjiang	Kailuan Group	4	Development
22	Changji, Xinjiang	Changji Shengxin Industry	1.6	Development
23	Changji, Xinjiang	Tebian Electric Apparatus Stock	4	Development
24	Changji, Xinjiang	Xinjiang Huahong Mining	2	Development
25	Changji, Xinjiang	Yankuang Group	4	Development
26	Aletai, Xinjiang	Xinjiang Guanghui Group	4	Development
27	Tacheng, Xinjiang	Xuzhou Coal Mining Group	4	Construction
28	Hami, Xinjiang	Tsinghua Ziguang	0.8	Development
29	Huainan, Anhui	Anhui Province Energy Group, SDIC	2	Development
30	Fuxin, Liaoning	Datang Energy Chemicals	4	Construction
31	Zhangye, Gansu	Jiuquan Iron&Steel Group	4	Development
32	Bijie, Guizhou	Sinopec	4	Development

IEA/EU PREDICTS 240GW OF NEW 'CLEAN GAS' GENERATION BETWEEN 2010 AND 2050 AND 50GW OF NEW 'CLEAN COAL'. 175 bn m^3 pa OF GAS @ 60% EFFICIENCY, 60% LOAD FACTOR



EU PREDICTS 50 TO 150 GW OF GAS FIRED GENERATION WITH CCS BY 2030. MARKET LEADERS: UK,SPAIN & ITALY

Figure 6 Potential for gas CCS in 2030 – High gas, pragmatic scenario

Under this scenario, Spain and the UK would have more than 10 GW of gas plant with practical potential for CCS in 2030.

Transport and storage of CO_2 would be a significant limiting factor for Italy, reducing its practical potential to zero. France and Germany would also see reduced practical capacity as a result.

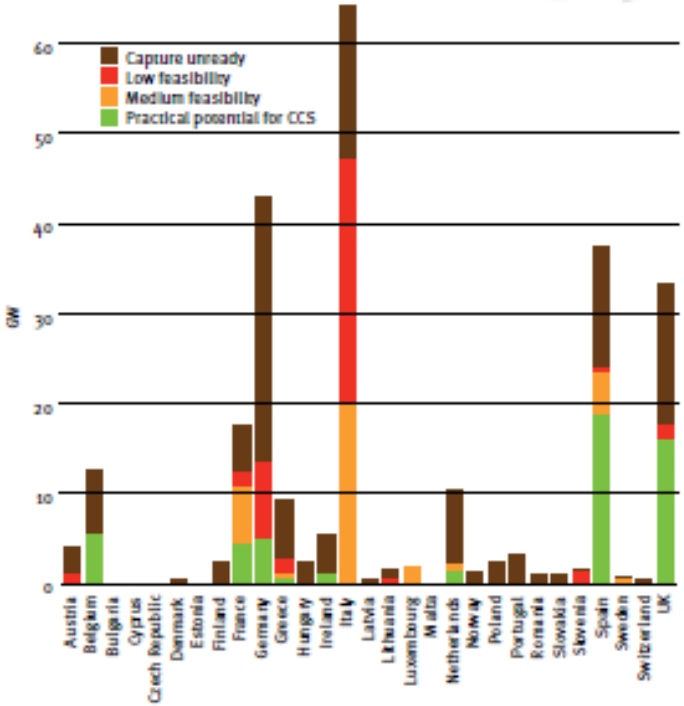
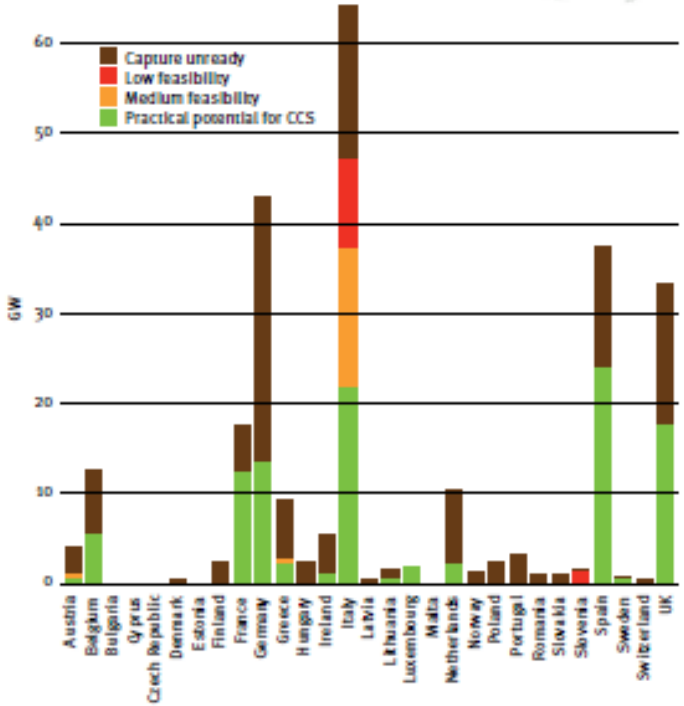


Figure 7 Potential for gas CCS in 2030 – High gas, push scenario

Under this scenario, France, Germany, Italy, Spain and the UK would have more than 10 GW of gas plant with high practical potential for CCS in 2030.

Transport and storage of CO_2 is mainly a limiting factor for Italy.

Most countries continue to have a significant part of the gas fleet failing to meet capture readiness requirements (eg due to plant age).



INCREASING DECARBONISED SNG EFFICIENCY WTH CCS: REDUCES COSTS AND EMISSIONS, AND INCREASES PROFITS

ESTIMATED NET EFFICIENCIES FOR SNG PLANTS:

- **1986 BRITISH GAS CPS STUDY: 76%. CCR. (HICOM)**
- **2007 DOE/NETL/WORLEY PARSONS: 60.4%. CCR.**
- **2007 ADVANTICA/BG GROUP: 73%. CCR (HICOM).**
- **2011 DOE/NETL/WORLEY PARSONS: 61.5%. CCS.**
- **2012 POSCO LIVE PROJECT: approx. 60%. CCR.**
- **2012 DECARBONISED SNG WITH TIMMINS CCS: approx 76 to 77%. CCS (HICOM)**
- **CHINESE NATIONAL DEVELOPMENT AND REFORM COMMISSION CONSIDERS RAISING SNG MINIMUM ENERGY EFFICIENCY REQUIREMENT FROM 52% TO 56%.**

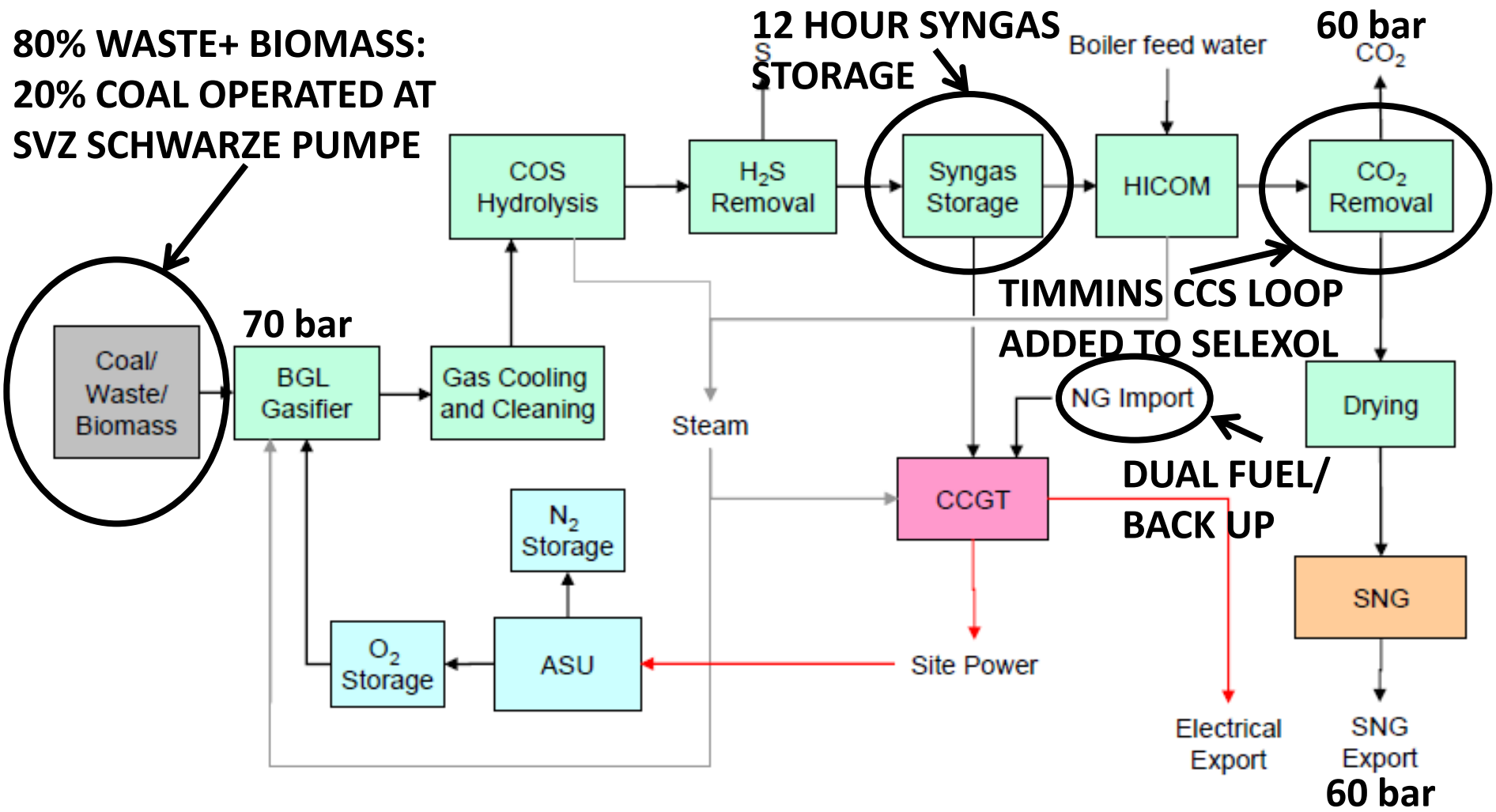
Note: Reliable publicly accessible efficiency and emissions data for SNG plants very difficult to find.

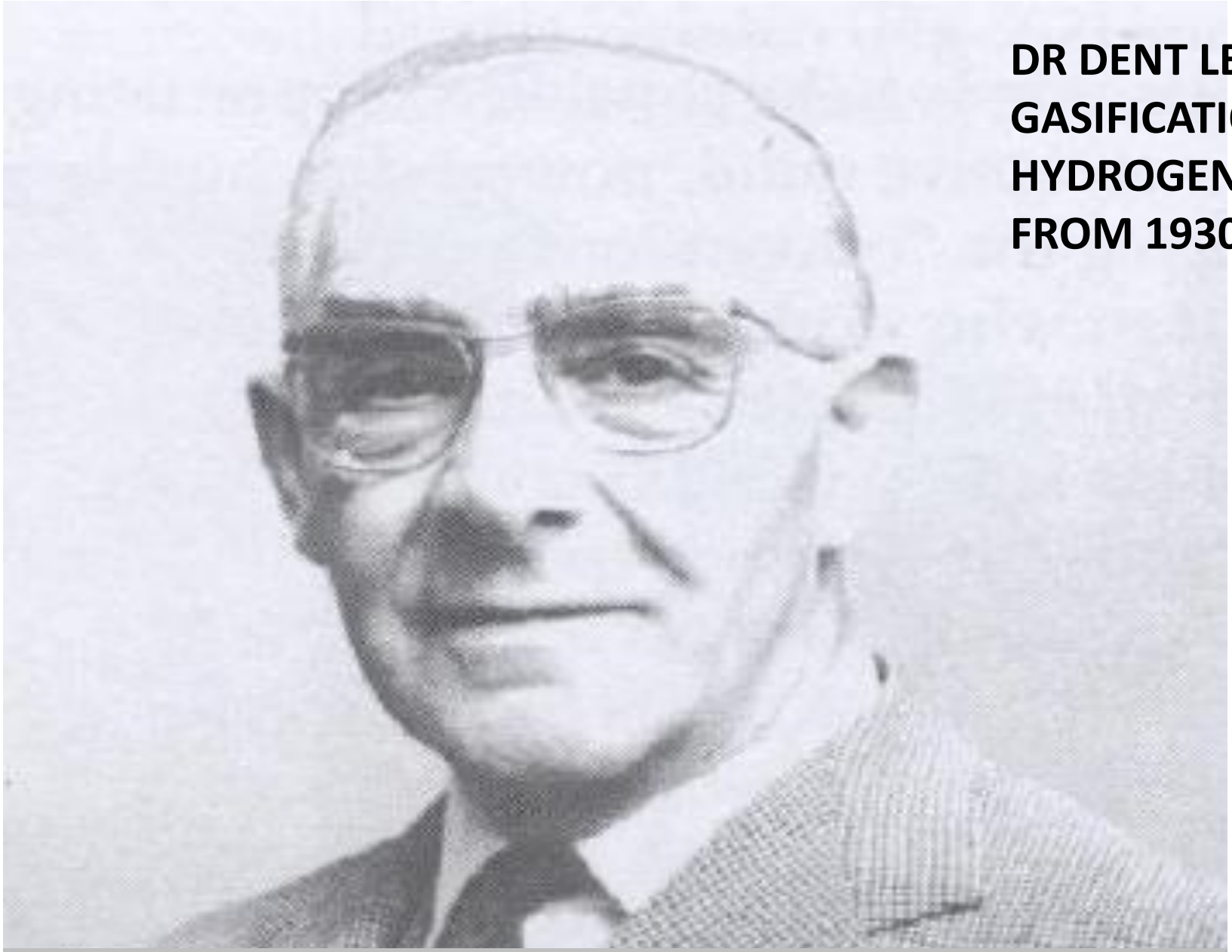
VISION: CLEAN LOW COST ENERGY

ZERO EMISSIONS = PROFITS

- Co-gasify partly biogenic wastes, biomass and coal. Produce low carbon SNG and electricity with near zero pollution.
- Sequestering biogenic Carbon offsets fossil Carbon emissions.
- Proven BGL multi-fuel co-gasification to SNG at 75+% efficiency.
- Decarbonising SNG saves 50-80% of cost of CCS on coal or gas.
- Decarbonised SNG fires existing dispatchable CCGT's.
- Existing gas grid provides energy store.
- Receive enhanced RHI/ROC's for 'advanced gasification'.
- Receive waste gate fees to avoid Landfill Tax.
- Enhanced revenue from renewables and waste exceeds revenue from sales of electricity and gas.

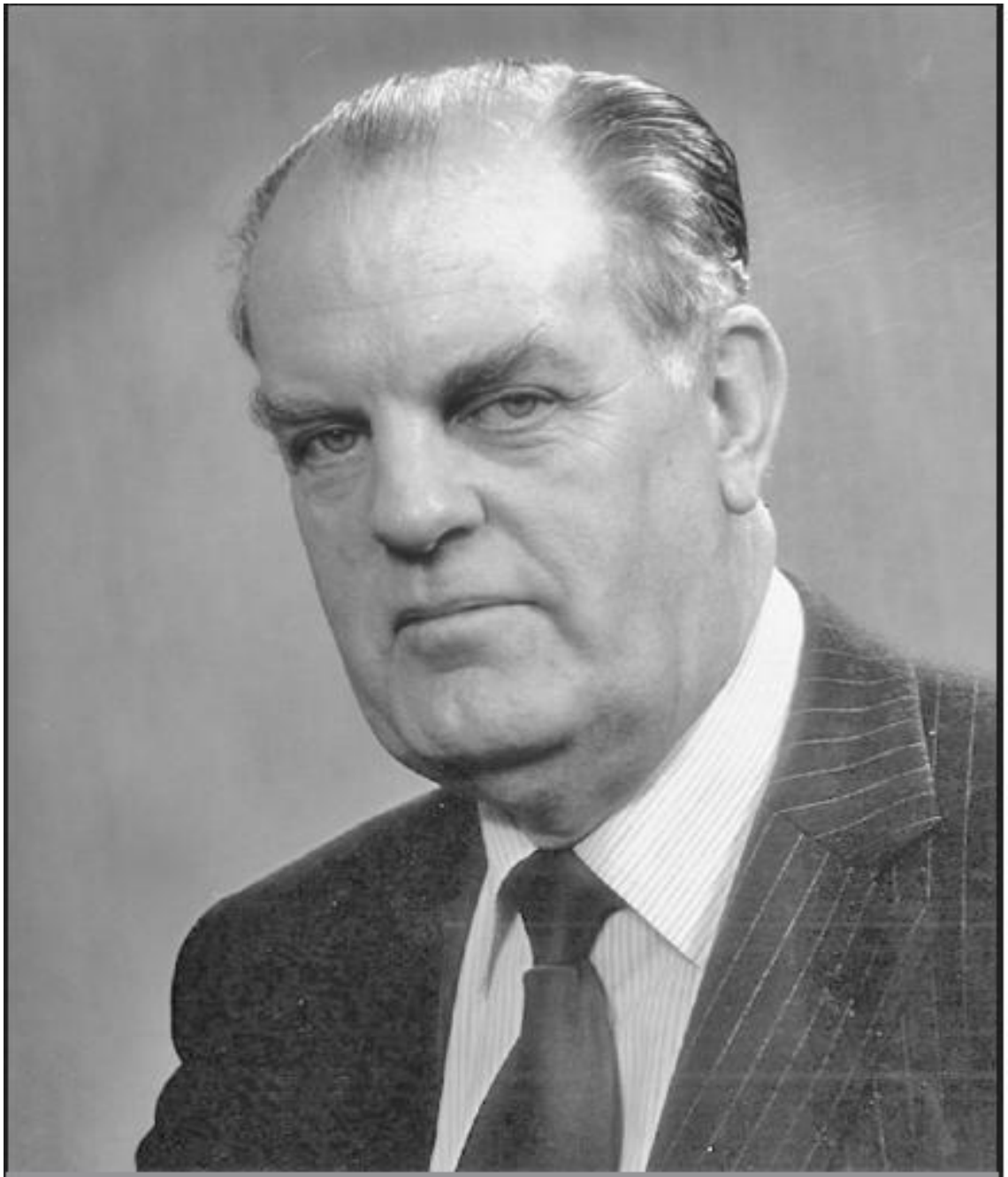
DECARBONISED SNG AND ELECTRICITY CO-PRODUCTION USING PROVEN BRITISH GAS HIGH PRESSURE COAL TO SNG AND IGCC TECHNOLOGY WITH MINOR VARIATIONS





DR DENT LED BRITISH GASIFICATION AND HYDROGENATION R & D FROM 1930's TO 1960's

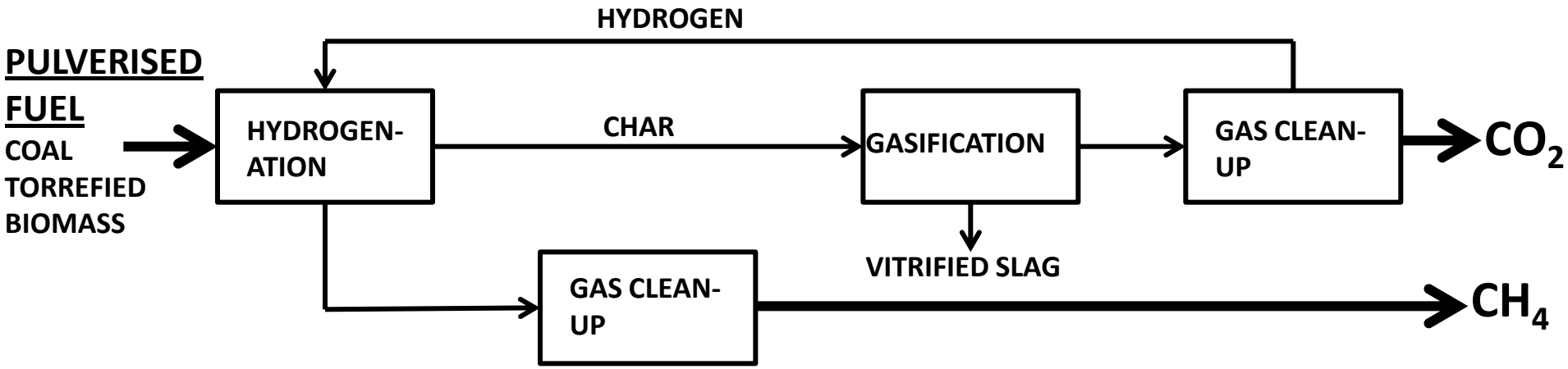
DR. F. J. DENT OBE FRS 1905 - 1973



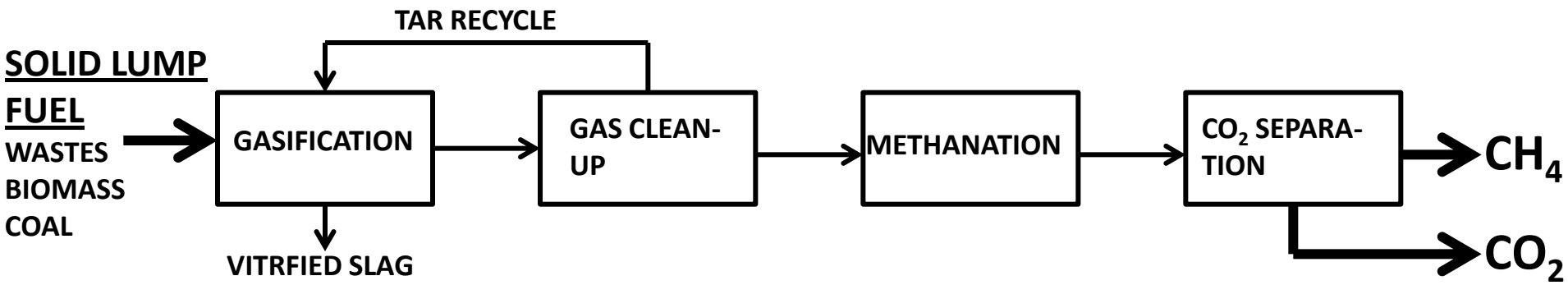
Sir Denis Rooke OM, CBE, FRS, FREng, 1924–2008

SIR DENIS ROOKE LED THE CONVERSION OF THE GAS GRID FROM TOWN GAS TO NATURAL GAS AND SNG FROM 1960's TO 1990's

COMPARISON BETWEEN BRITISH GAS HYDROGENATION AND METHANATION TECHNOLOGY DEVELOPMENTS

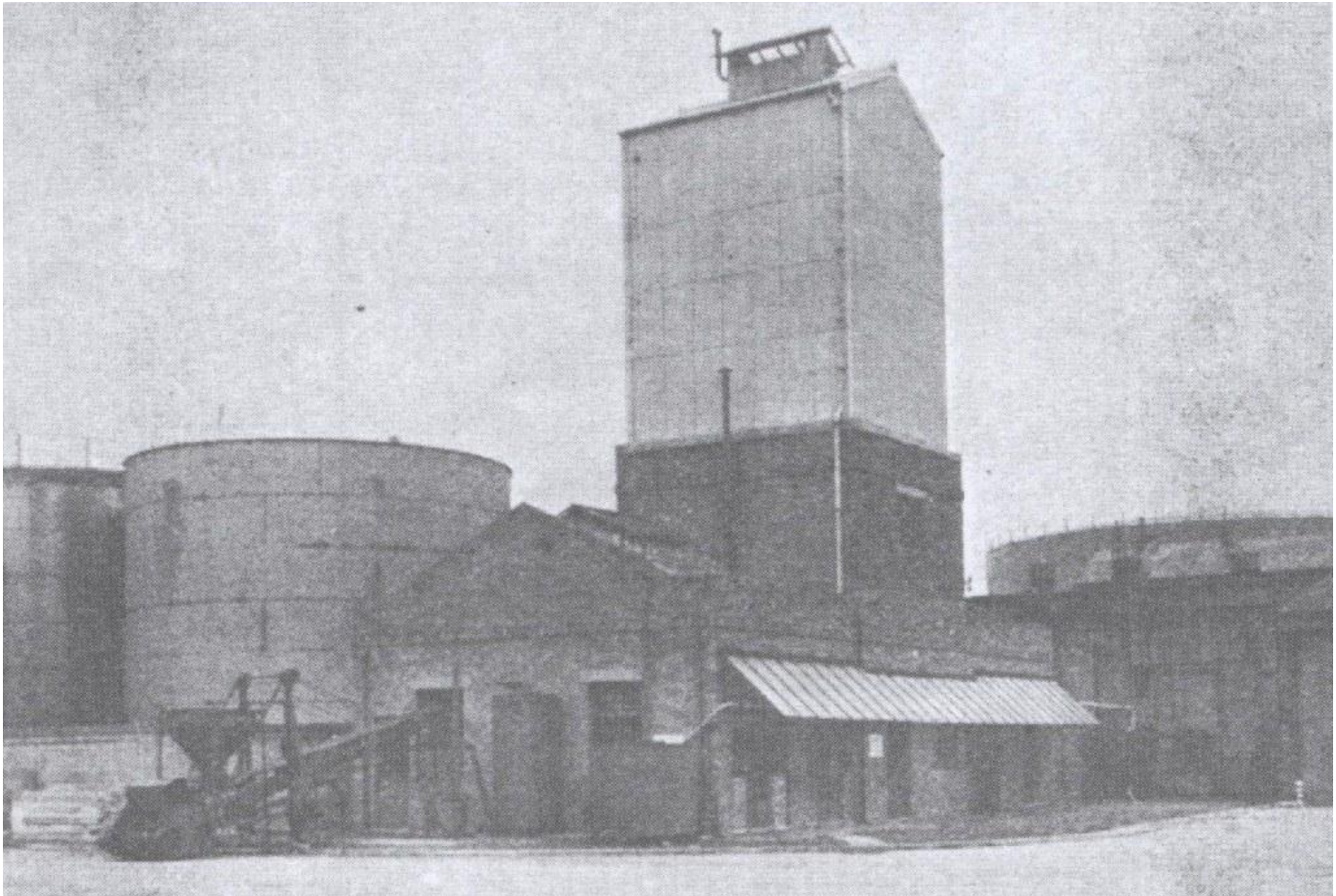


HYDROGENATION: 78% EFFICIENCY PILOT SCALE LOWER CAPEX

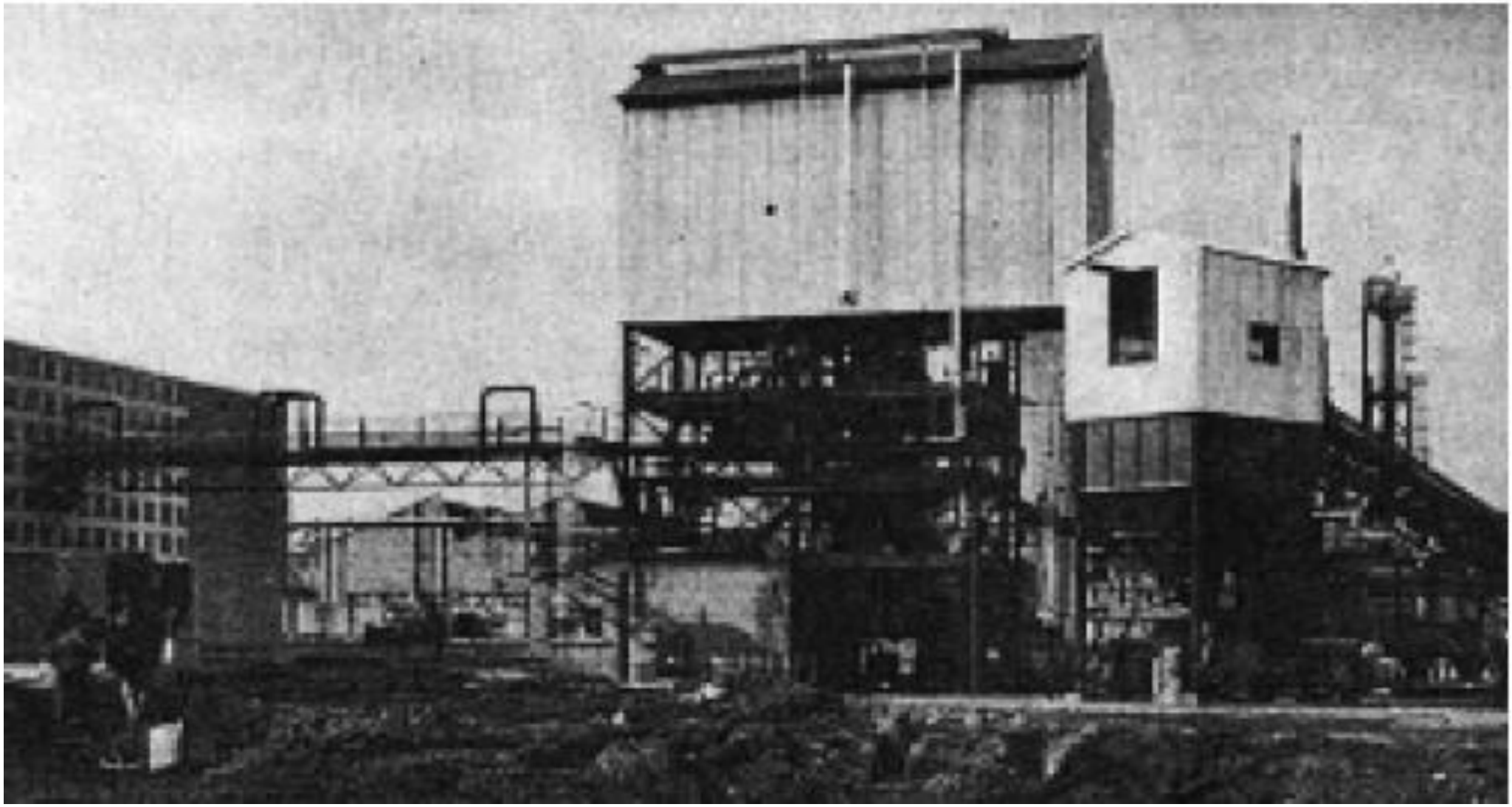


METHANATION: 76% EFFICIENCY COMMERCIAL SCALE HIGHER CAPEX

COAL HYDROGENATION PLANT GAS RESEARCH BOARD POOLE



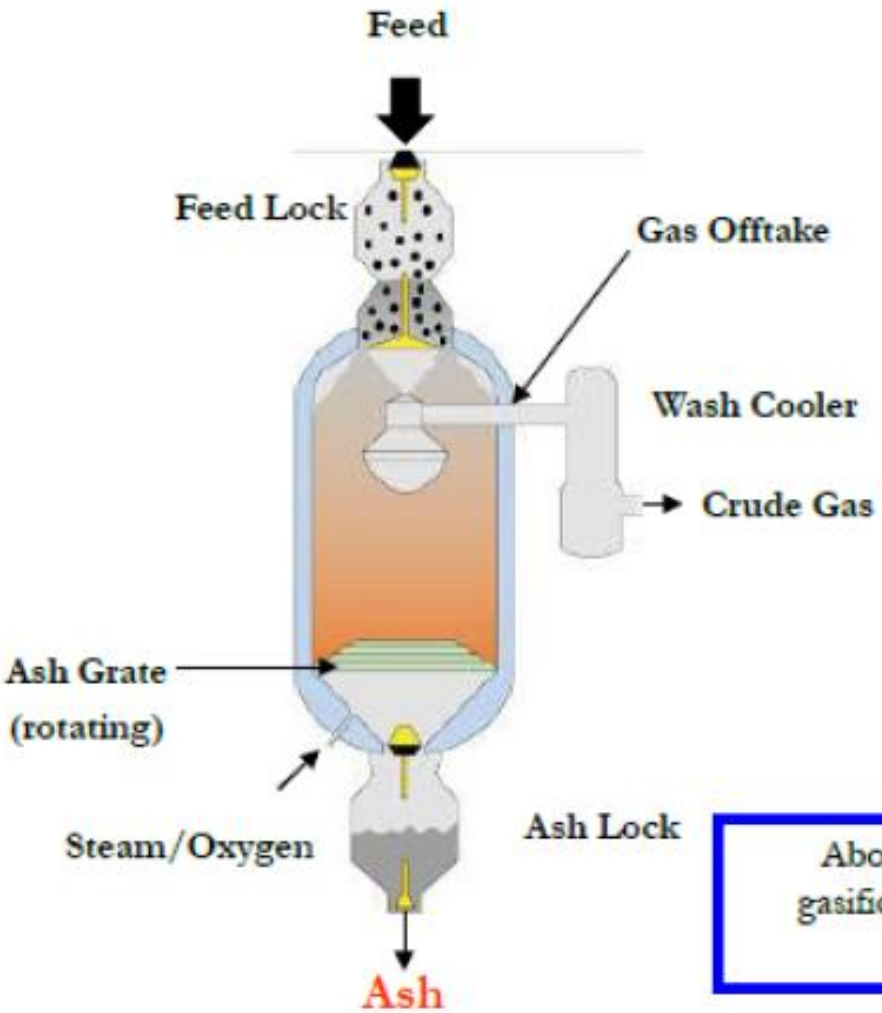
BGL SLAGGING GASIFIER AT MIDLANDS RESEARCH STATION



BGL SLAGGING GASIFIER BASED ON PROVEN LURGI DRY ASH GASIFIER. HIGH EFFICIENCY DUE TO LOW STEAM & OXYGEN USE

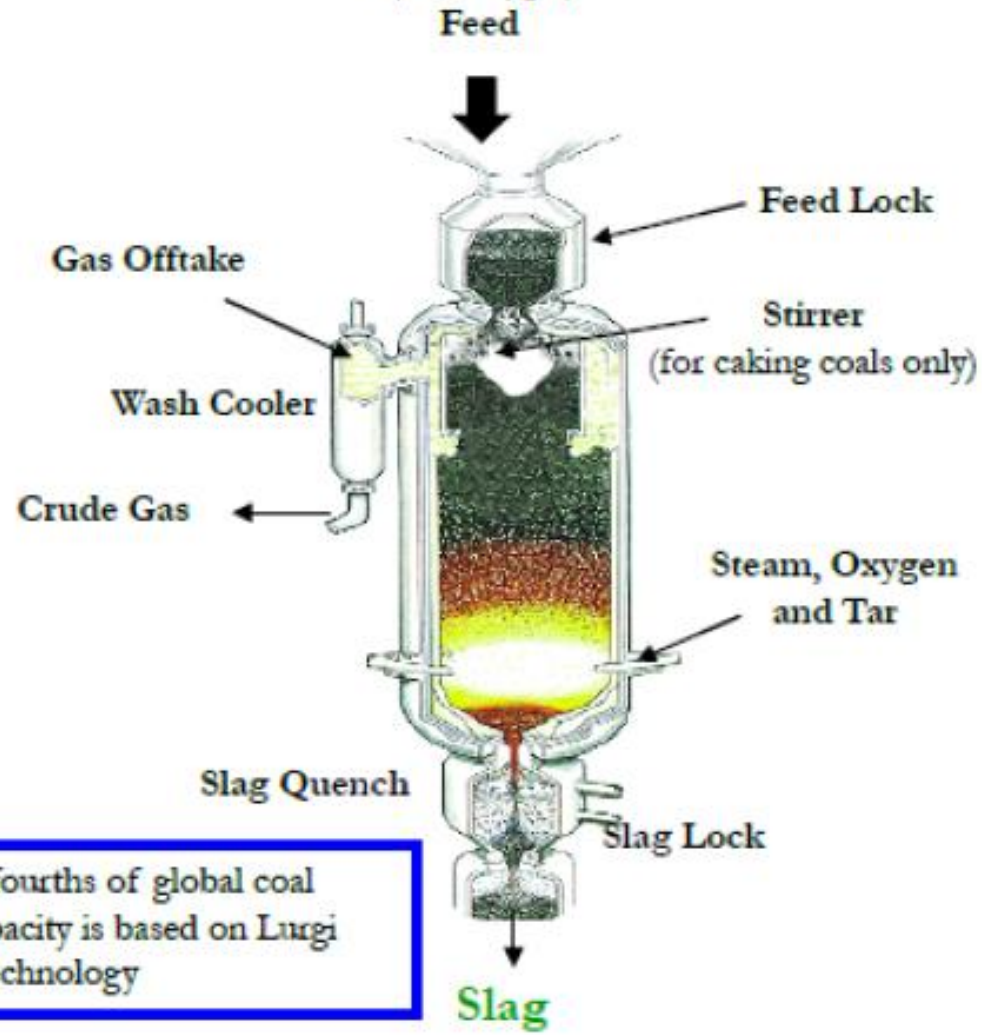
Lurgi - Pressure Gasifier

(North Dakota/Sasol type)



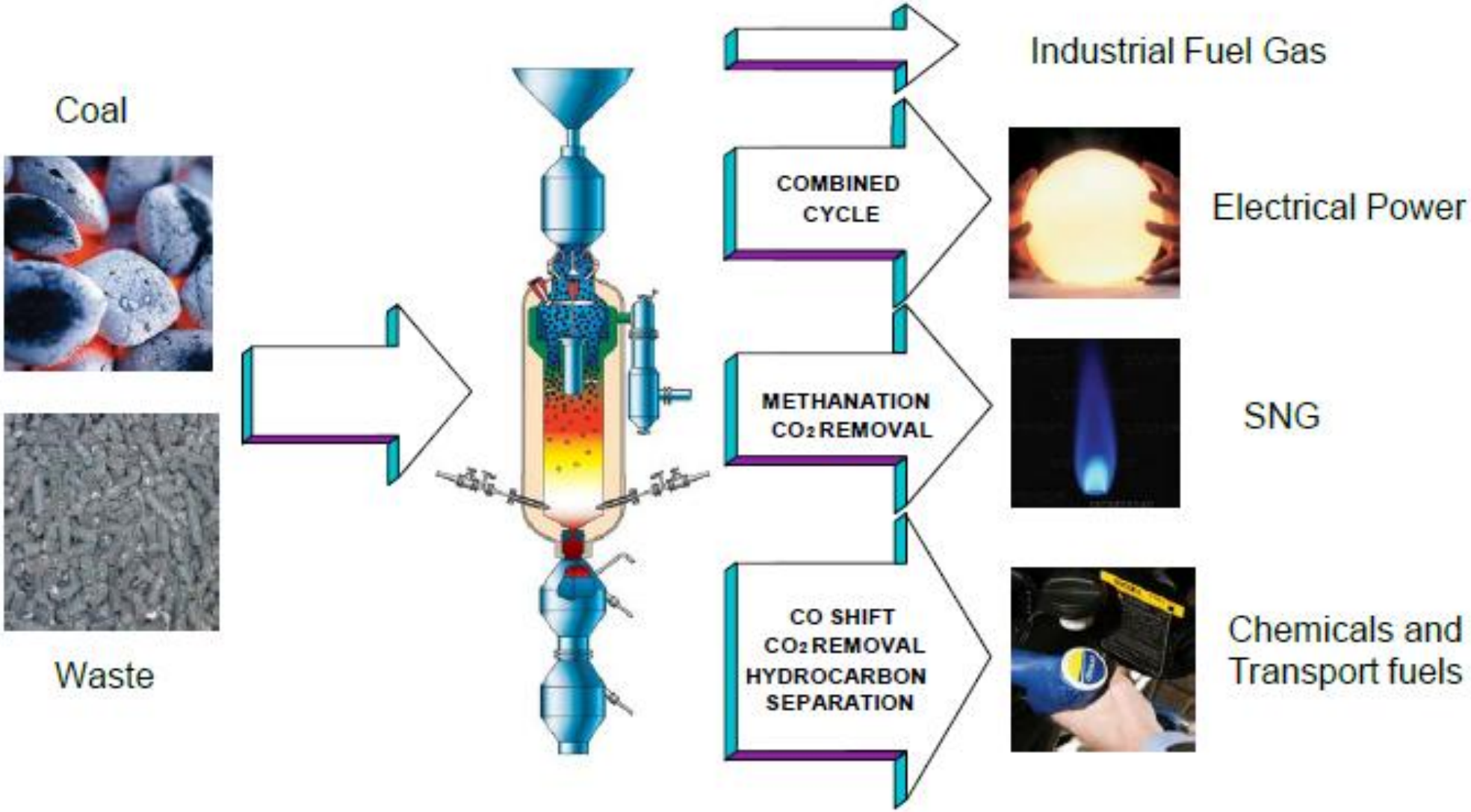
BGL Gasifier

(SVZ type)

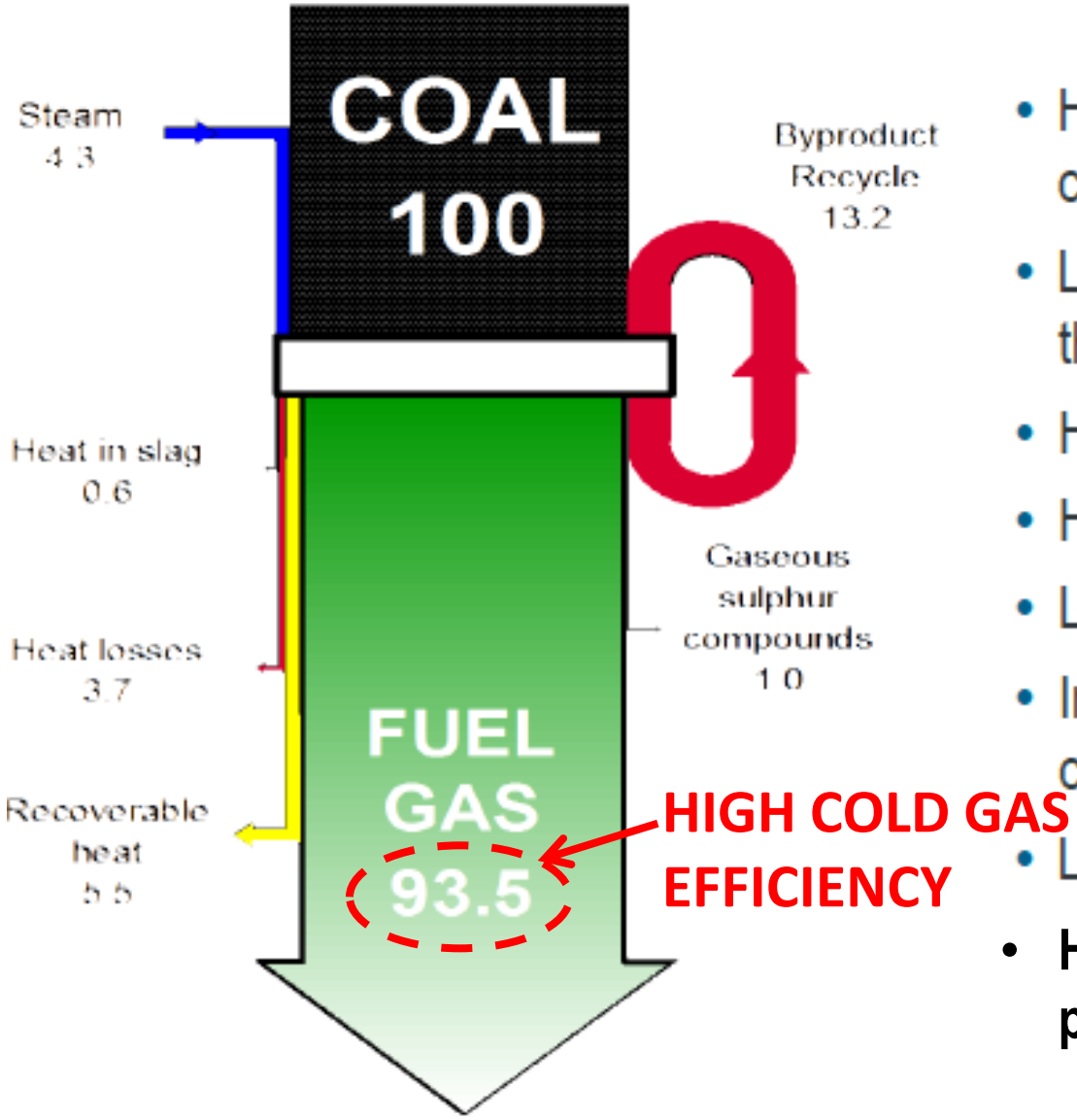


About three fourths of global coal gasification capacity is based on Lurgi technology

BGL GASIFICATION: FLEXIBLE TECHNOLOGY



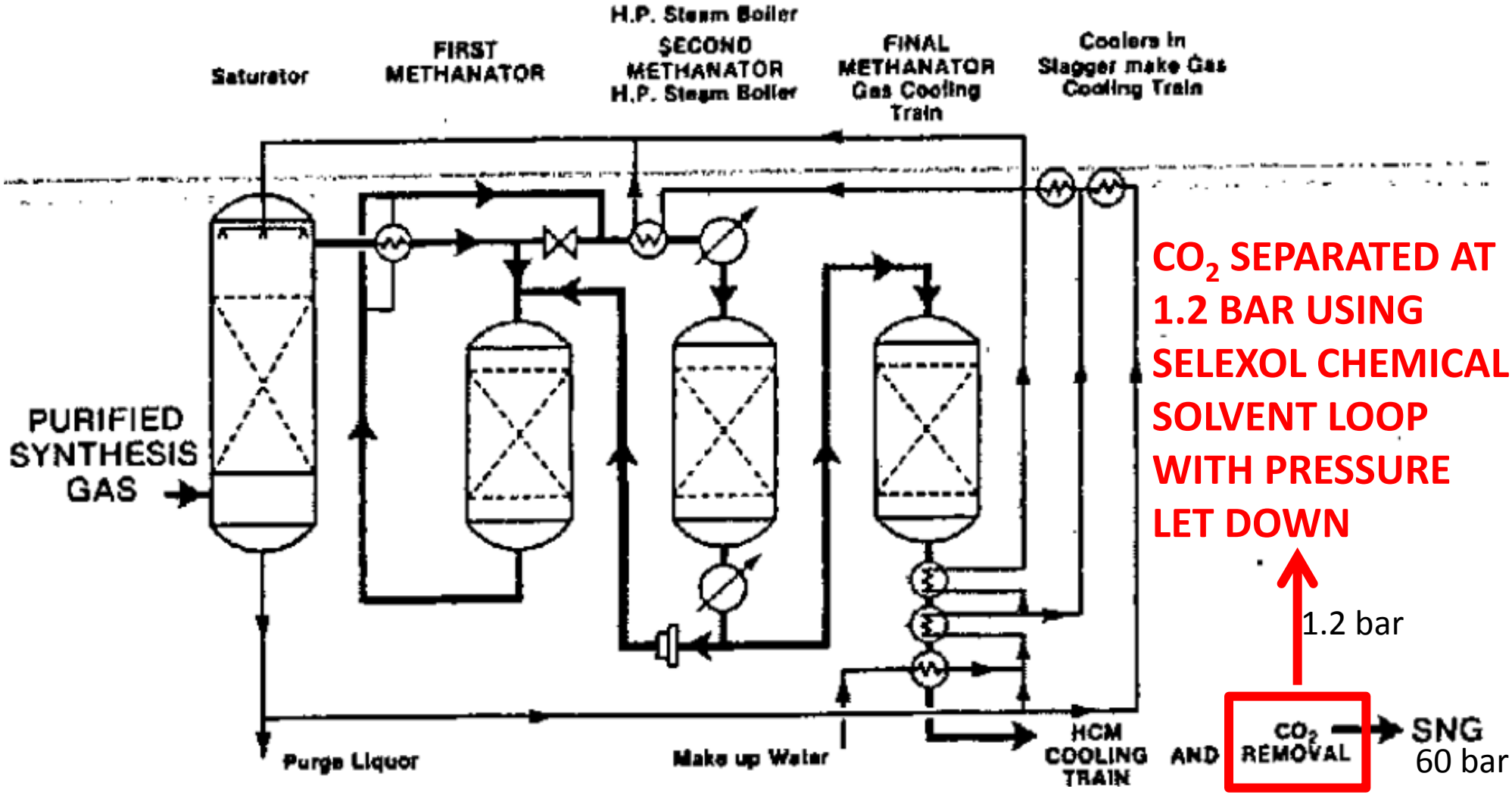
BGL: WORLD'S HIGHEST COLD GAS EFFICIENCY SOLID MULTI-FUEL CO-GASIFIER



- Heat recovery from product gas by contact with coal bed
- Low oxygen consumption – 50-60% of that for entrained flow gasifiers
- High cold gas efficiency
- High carbon conversion
- Low gasifier outlet temperature
- Inexpensive and well proven conventional gas cooling train
- Low CO_2 content in Syngas
- **High Methane output suitable for SNG production**

BRITISH GAS HICOM HIGH EFFICIENCY COMBINED SHIFT AND CATALYTIC METHANATION PROCESS

Combining 'shift' and 'methanation' reactions reduces the quantity of steam to be injected into, and subsequently removed from, the process. Exothermic methanation reaction is cooled by recycling SNG from second stage methanator to first stage methanator.



BRITISH GAS COAL TO SNG EFFICIENCY APPROX. 76% NET AT 70 BAR PRESSURE

EXTRACT FROM 1986 BRITISH GAS - SNG CPS STUDY 6 ES-12: Section 3.0 Gasmaking Efficiency (HHV basis)

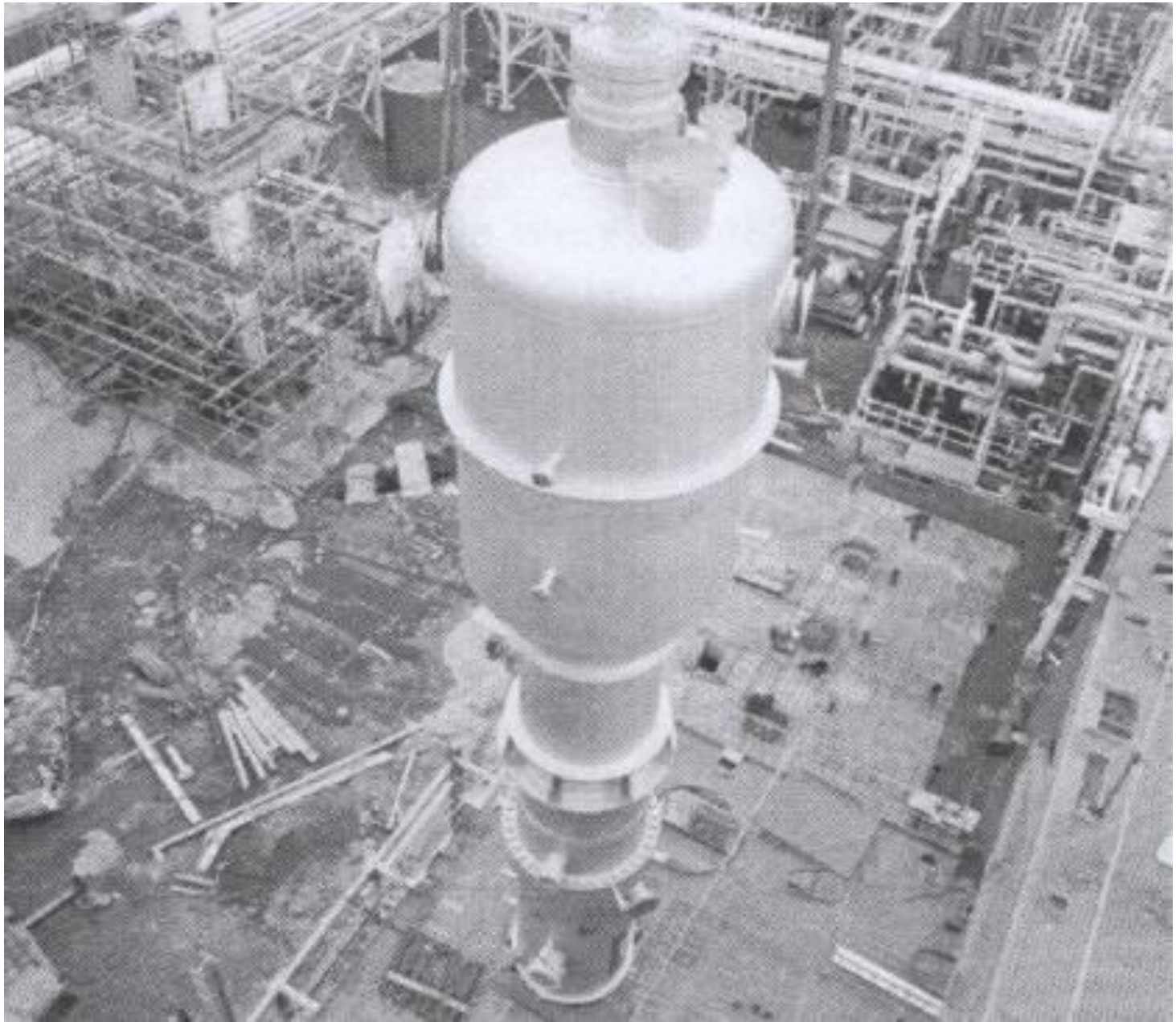
	Low pressure	Medium Pressure	High Pressure
Gasification pressure (bar a)	32	56	80
SNG/Coal efficiency (%)	75.26	75.66	76.15
SNG/Coal + power import efficiency (%)	74.60	75.39	75.94

%

Increasing gasification pressure increases overall process energy and cost efficiency:

- **Increases overall thermodynamic efficiency of 'heat engine'.**
- **Increases energy intensity and throughput rate of gasification reaction.**
- **Improves gasifier throughput and operational stability.**
- **Increases Methane production in gasifier.**
- **Reduces production of tars and heavy hydrocarbons**
- **Reduces volume of pressure vessels and pipework.**
- **Increases gas solubility in solvent loop gas clean-up processes.**
- **Increases catalytic Methanation conversion efficiency.**
- **Reduces SNG and CO_2 re-pressurisation energy losses.**

WESTFIELD 70 BAR HIGH PRESSURE GASIFICATION PLANT



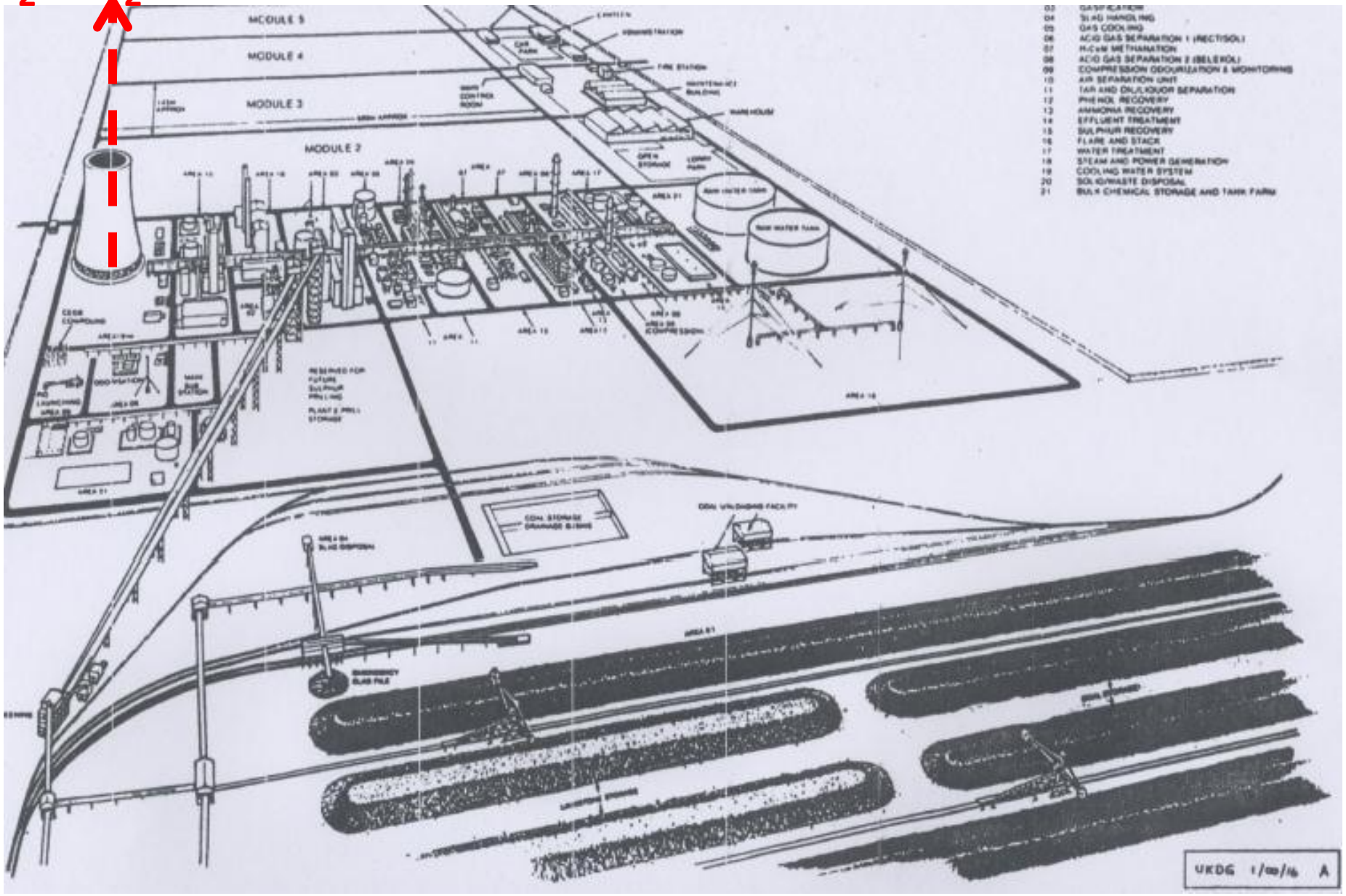
WESTFIELD DEVELOPMENT CENTRE

BRITISH GAS CORPORATION 30 YEAR PLAN

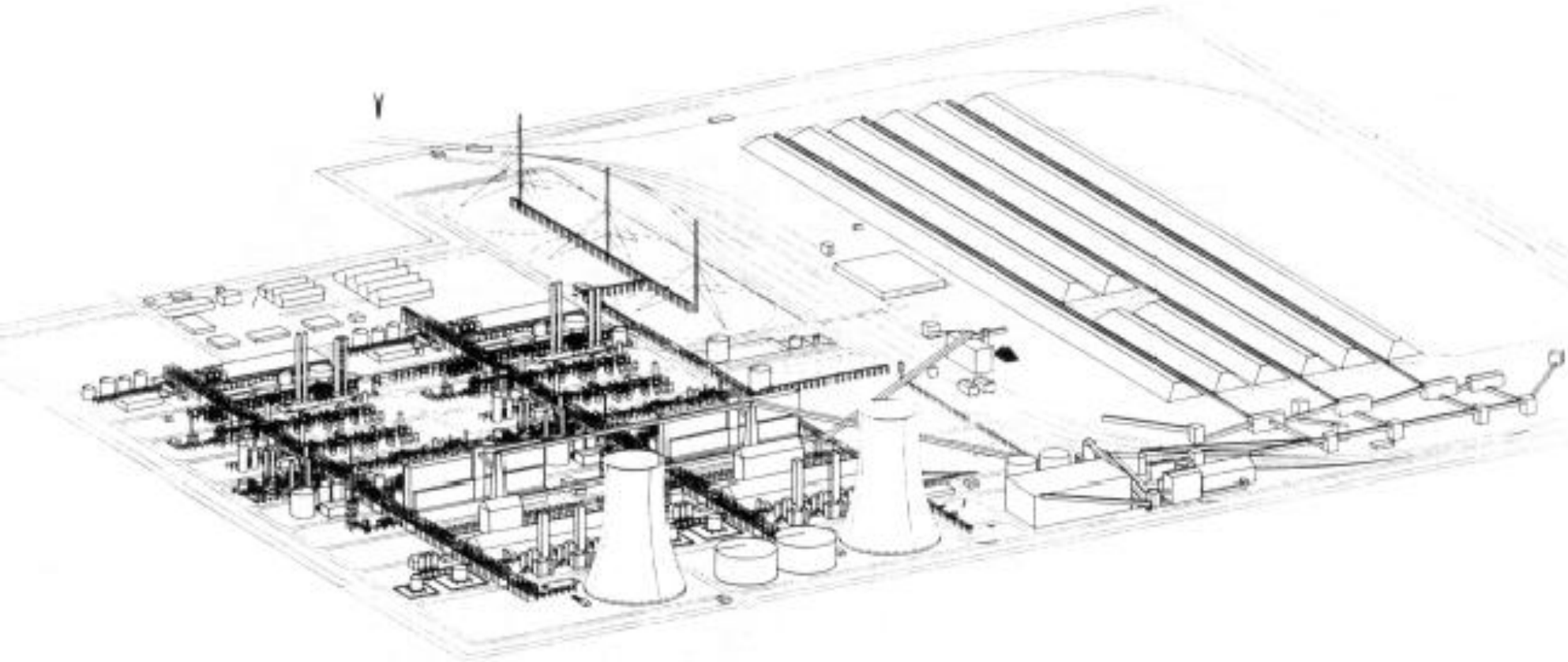
- New Scientist 10th Dec.1981: Article on process plant safety mentions British Gas' plans to build 20+ 250m ft^3/day SNG plants at disused Town Gas production sites.
- British Gas report Jan. 1985: "The expectation that natural gas production will fall steeply in the early 1990's…ensure that SNG can be introduced as a major supply option…one projection suggests the introduction of SNG could be by 2010-2020…a commercial SNG plant will comprise 5 units and produce 250m ft^3/day…coal requirement of 5mtpa…10 plants of this capacity would…produce half of the present natural gas consumption...planning to execute a design study for a commercial scale plant." (Study completed Oct. 1989)

BRITISH GAS MODULAR 5x1mtpa SNG PLANT 1989

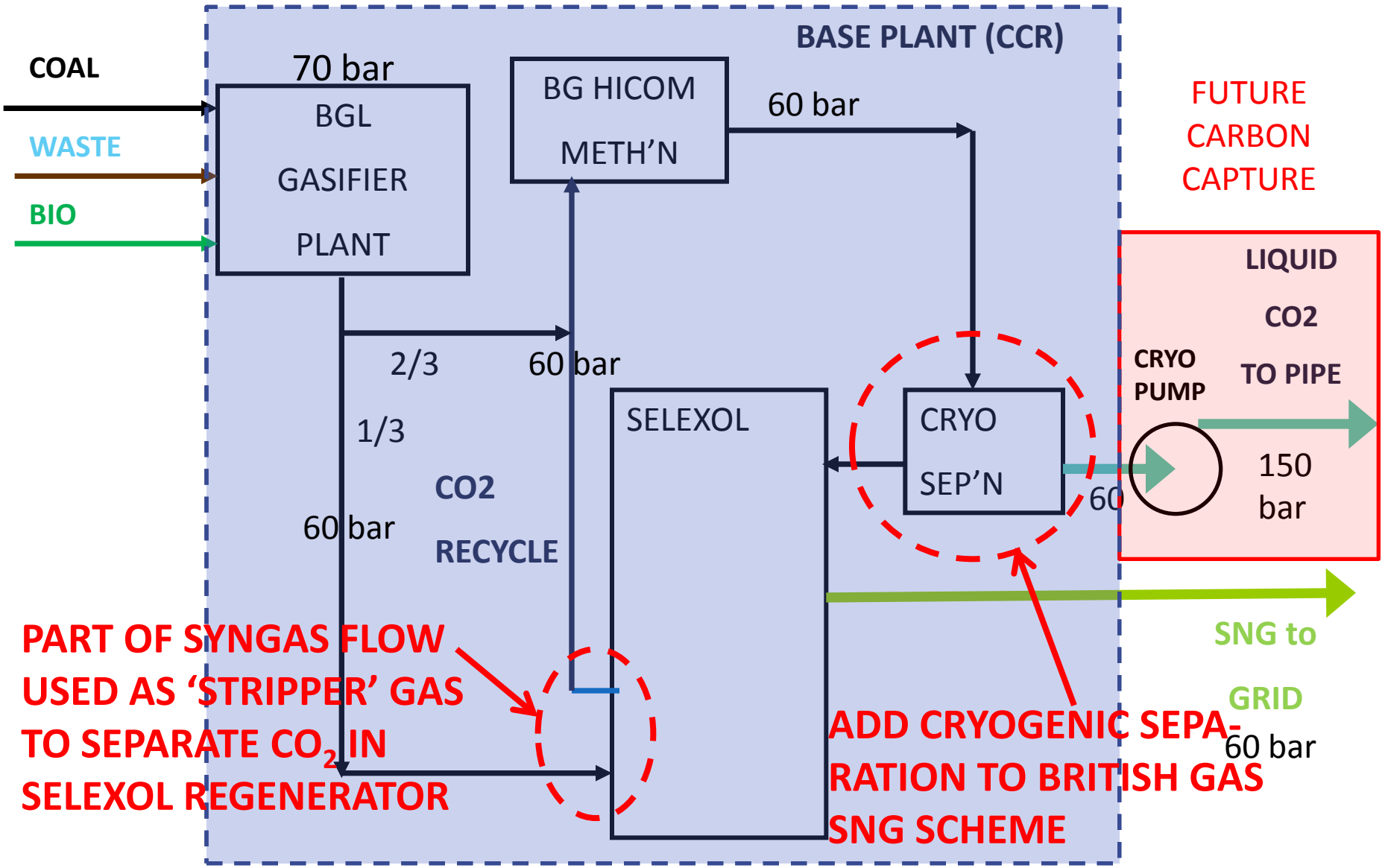
$CO_2 + N_2$ DISCHARGED TO ATMOSPHERE AT 1.2 bar



BRITISH GAS ALTERNATIVE 2 X 2.5mtpa MODULAR COAL TO SNG PLANT 1989



TIMMINS CCS ADDED TO BGL + HICOM/SELEXOL. COST/ENERGY FOR CRYOGENIC SEPARATION OFF-SET BY REDUCING LET DOWN AND RE-PRESSURISATION LOSSES IN SELEXOL CO_2 SEPARATION. PLANT OPERATES AT 60 bar PROCESS PRESSURE.



1989 CPS HIGH TEMPERATURE HICOM CATALYST USED AT GREAT PLAINS LIGNITE TO ELECTRICITY, SNG, CCS/EOR AND FERTILISER

3 BRAND NEW BGL's IN CHINA

DTI 2002-2003: ROLE OF WASTE, BIOMASS AND COAL CO-GASIFICATION

"Combines the use of a reliable coal supply with gate fee wastes and biomass qualifying for renewables certificates and greenhouse gas benefits." (DTI Spring 2003)

"Coal can be thought of as a 'flywheel'…a means to scale economies…with tangible environmental benefits, including fossil fuel resource conservation and reduced CO_2 emissions." (DTI 2002)

"BGL gasifier is better suited to….fuels of widely differing mechanical properties….widely believed to be the clear leader in the larger scale gasification of variable property feedstocks." (DTI 2003)

"The BGL slagging gasifier has been demonstrated and is now commercially available for the manufacture of SNG". (Coal Research Forum 1996)

REFERENCE PROJECT: SVZ SCHWARZE PUMPE

- Commercial production of power, methanol and heat from waste
- Commercial scale 3.6m gasifier developed from Westfield experience
- Start-up in 2000
- Successful co-gasification of briquetted lignite and waste feedstocks

- **Full environmental certificate 1998**
- **Certified non-leaching vitrified slag**
- **20% coal:80% waste/biomass 2003**
- **UK EA Best Available Technology 2005**
- **UNEP approved to destroy POP's 2006**
- **In India awaiting re-use 2012**

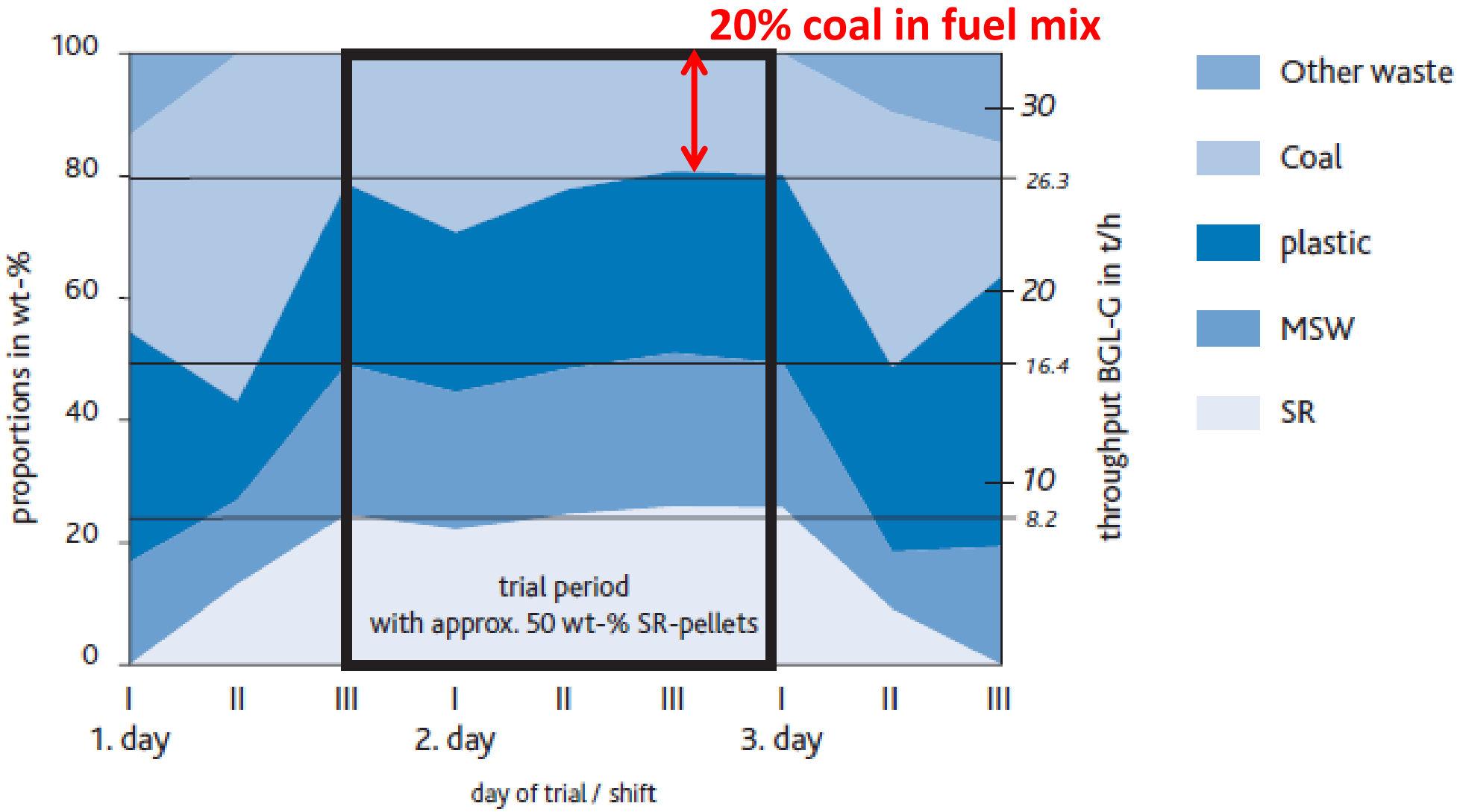
WASTE/COAL MIXES CO-GASIFIED AT SVZ

Data provided by Allied Syngas Corporation

Exhibit III-2 Waste / Coal Mixtures Demonstrated in Commercial BGL Gasifier at SVZ[8]

	max./min. Range	Demonstrated Operation Range			
RDF-Pellets	5 - 50	20	25	40	40
Agglomerated Plastic Waste	5 - 50	30	45	45	20
Compacted Shredder Light Fraction	0 - 10	-	-	-	-
Briquetted Industrial Sludge Briquetted Sewage Sludge	5 – 25	25	10	5	15
Shredded Wood Waste	0 - 15	-	-	-	-
Hard Coal/Lignite	20 - 25	19/6	12.5/7.5	12.5/7.5	19/6

TECPOL 80% MIXED WASTES:20% COAL CO-GASIFICATION TESTS AT SVZ 2003



39% MIXED WASTES: 36.6% BIOMASS: 24.4% COAL/TDF FUEL USED FOR COST BENEFIT AND EMISSIONS ANALYSES

FUEL INPUTS (v.14)	(Fuel mix by ARDay/WRG Ltd. Chemical analysis by GL Noble Denton Ltd)					% total	% Carbon	% biogen-	Total %	
	Tonne pa	cv MJ/kg	£/tonne	£/GJ	£m pa	mass	dry mass	ic Carbon	biogenic (	
Coal	115,000	30	65	1.8	7.475	18.70%	83.92%	0	0	
MSW	75,000	10	-100	-10	-7.5	12.20%	57.80%	65%	4.58%	
C and I waste	25,000	14	-75	-5.77	-1.875	4.06%	64.20%	65%	1.69%	
RDF/SRF 50/50	100,000	18	-12.5	-0.833	-1.25	16.26%	64.70%	65%	6.84%	(67% mass raw waste
Contaminated/woody biomass/straw	225,000	16	30	2.175	6.75	36.58%	50.00%	100%	18.29%	(<25% moisture)
Tyre Derived Fuel	35,000	36.5	-25	-0.694	-0.875	5.69%	84.70%	0	0	
Hazardous bio/sewage /solvents/inks/slu	40,000	20	-100	-4.545	-4	6.50%	60.97%	50%	1.98%	(MBM/geno/clinical)
Total	**615,000**	**19.56**	**-2.073**	**-0.106**	**-1.275**	**100%**	63.58%		**52.5%**	
Add Hazardous APC residue disposal	60,000	0	-100	N/A	-6					(ex limestone saving
Total	**675,000**	**17.82**	**-10.78**	**-0.605**	**-7.275**					

Notes: Total waste input inc. APC residues = 235ktpa + 100ktpa x 1.5 RDF = 385 ktpa. Total raw material input = 725 ktpa

Biomass 36.6%; wastes 39% (assumed 65% biogenic, ex TDF), and coal + TDF 24.4% by mass. Biogenic Carbon content 52.5% by mass.

APC residues assumed zero energy content. May have small energy content if activated Carbon used in APC.

ULTIMATE FUEL ANALYSIS	
Carbon	63.14%
Hydrogen	6.27%
Oxygen	28.33%
Nitrogen	1.0%
Sulphur	0.68%
Chlorine	0.6%
Total	100%

TOTAL BIOGENIC CARBON PROPORTION APPROX 52.5% BY MASS

DECARBONISED (CARBON NEUTRAL) SNG

BIOENERGY CARBON CAPTURE & SEQUESTRATION (BECCS):

Sequestering biogenic Carbon neutral CO_2 removes Carbon emissions from the atmosphere and offsets fossil Carbon emissions.

ZERO EMISSIONS:

50% biogenic fuel + 50% Carbon removal

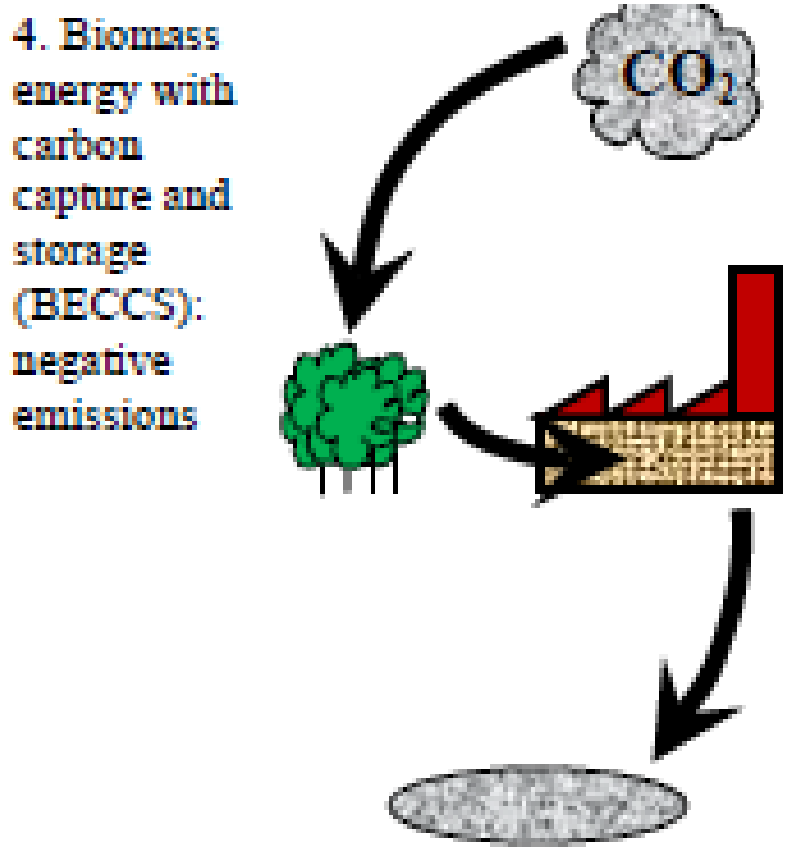
= zero net fossil Carbon emissions.

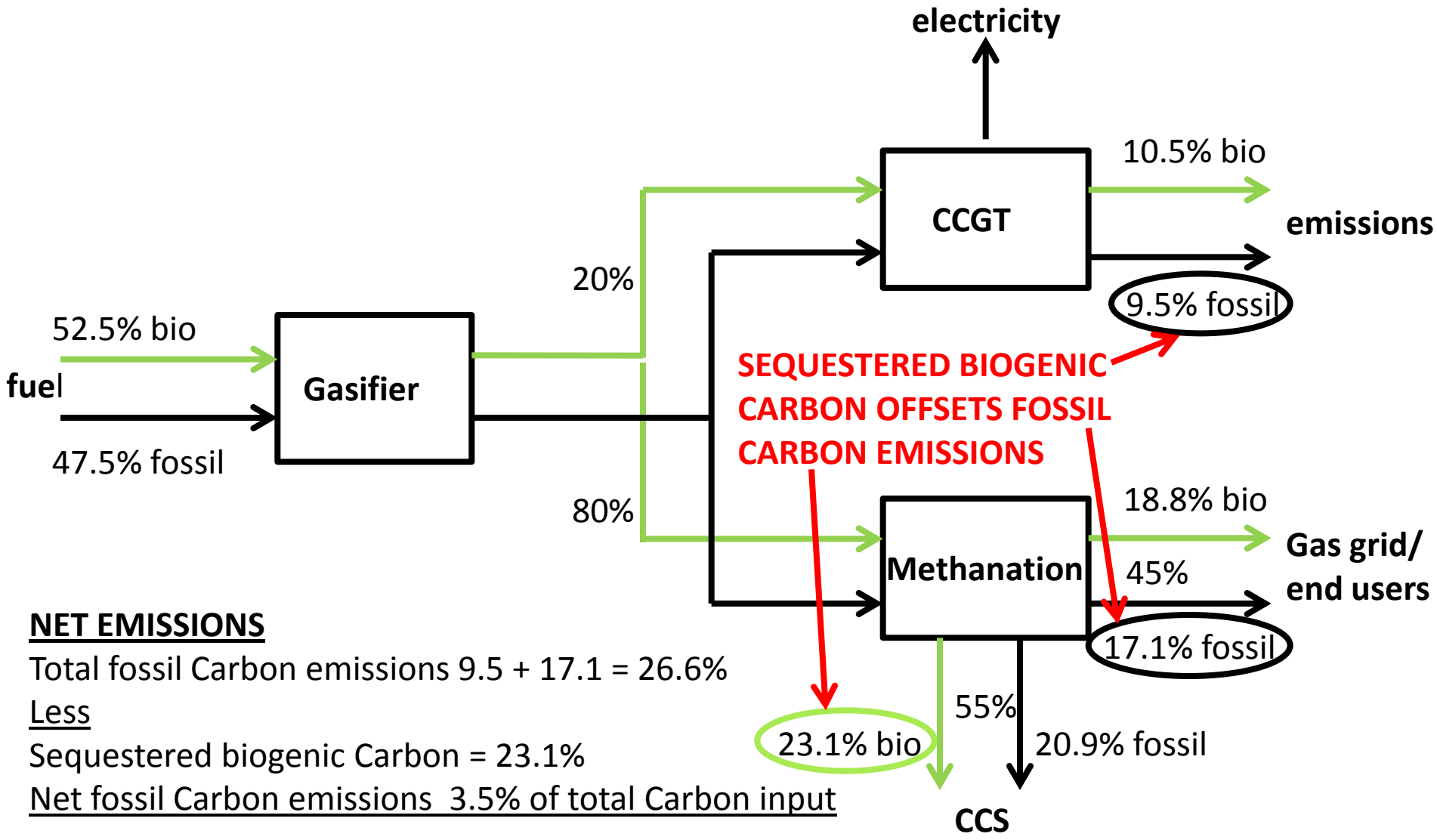
PRACTICAL SOLUTION:

52.5% biogenic fuel + 44% C removal,

emissions equivalent to 100% coal

+ 96.5% C removal.





NET EMISSIONS

Total fossil Carbon emissions 9.5 + 17.1 = 26.6%

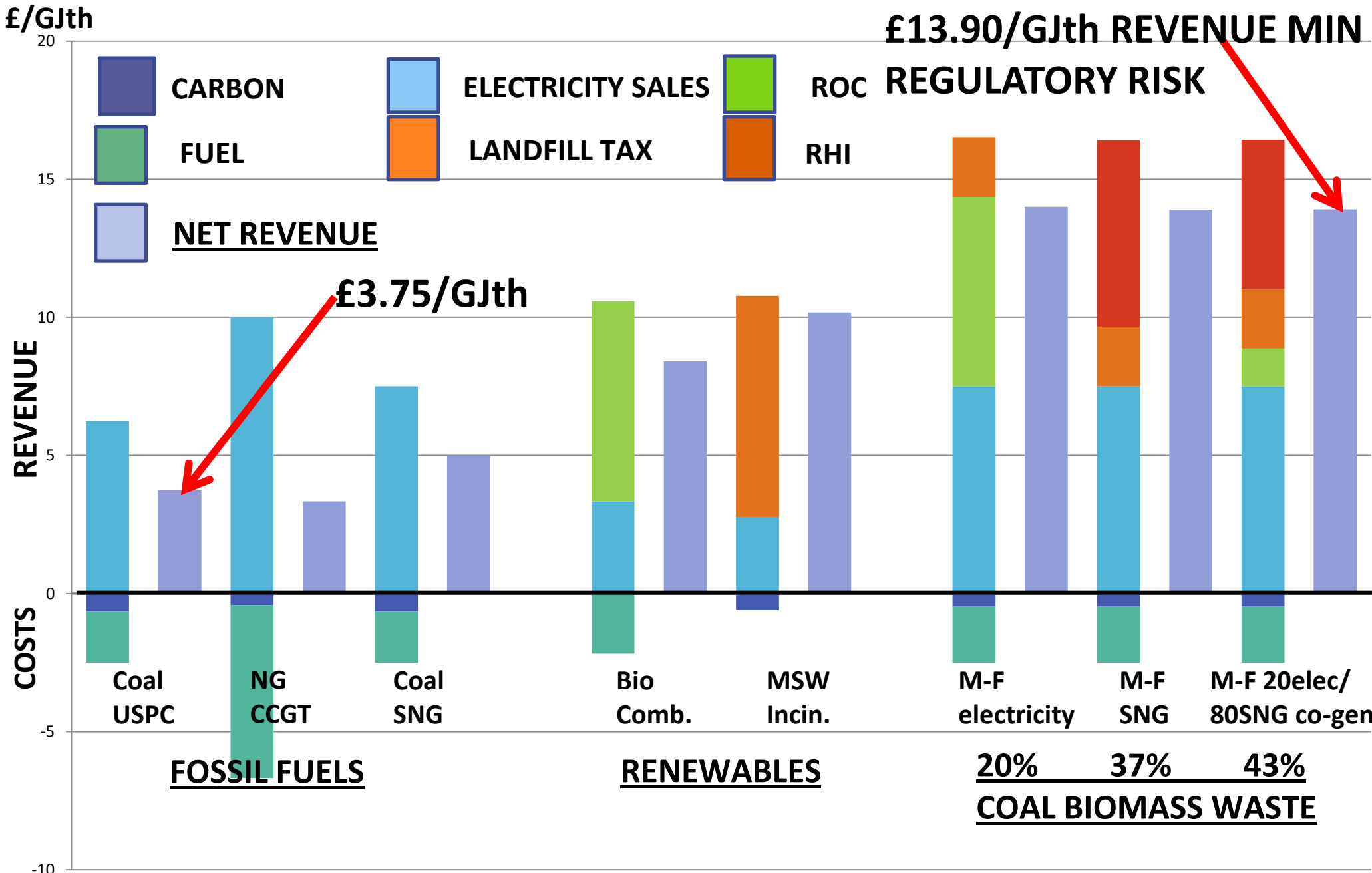
Less

Sequestered biogenic Carbon = 23.1%

Net fossil Carbon emissions 3.5% of total Carbon input

DECARBONISED SNG CARBON BALANCE

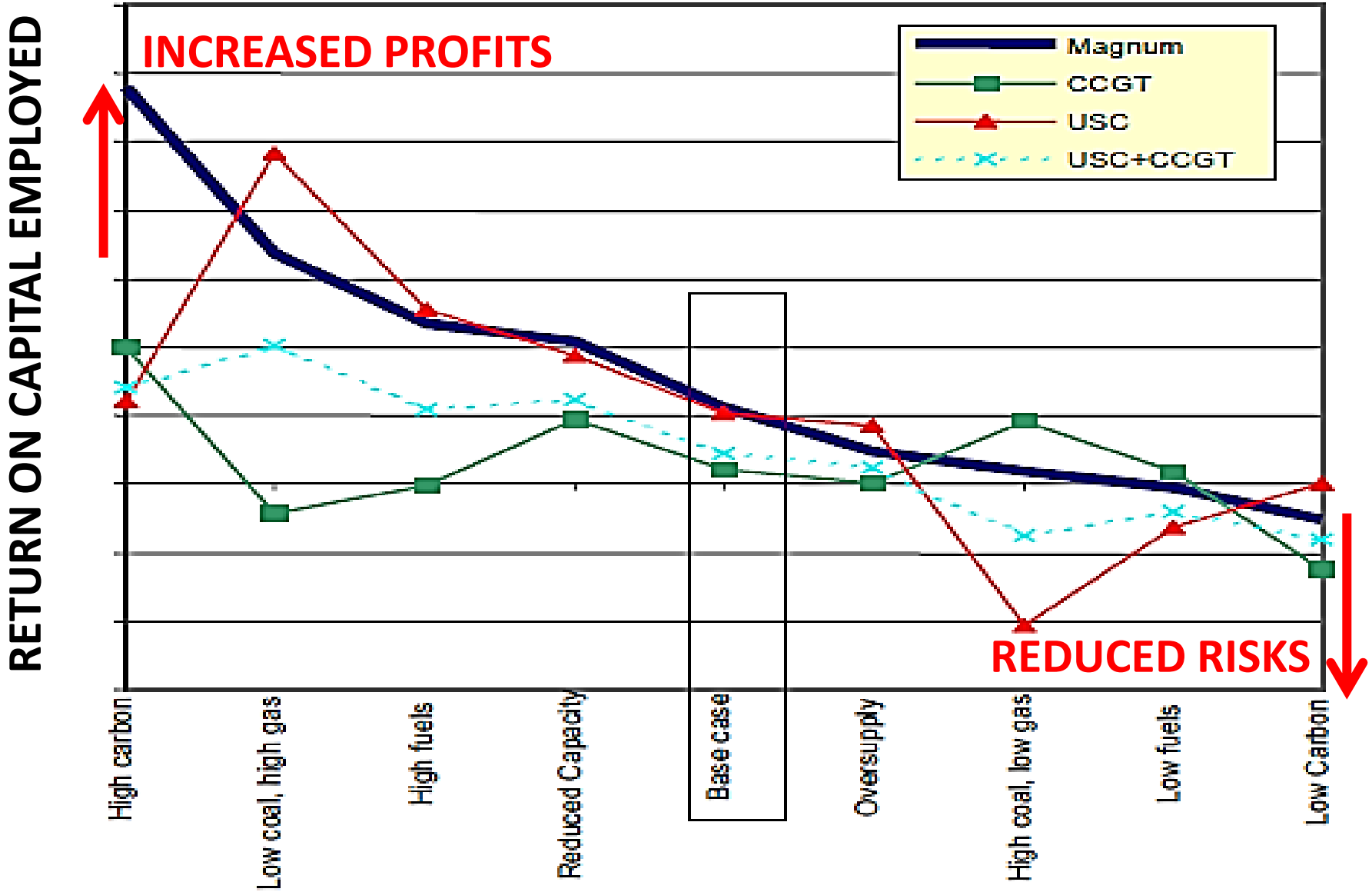
DECARBONISED SNG ENHANCES 'CLEAN DARK SPREAD' BY 370%



FUEL SWITCHING REDUCES RISK, ENHANCES PROFITS

Nuon coal, gas and biomass multi-fuel IGCC

Solid business case Magnum vs. alternatives



SYNGAS STORAGE ENHANCES DISPATCHIBILITY & PROFITS

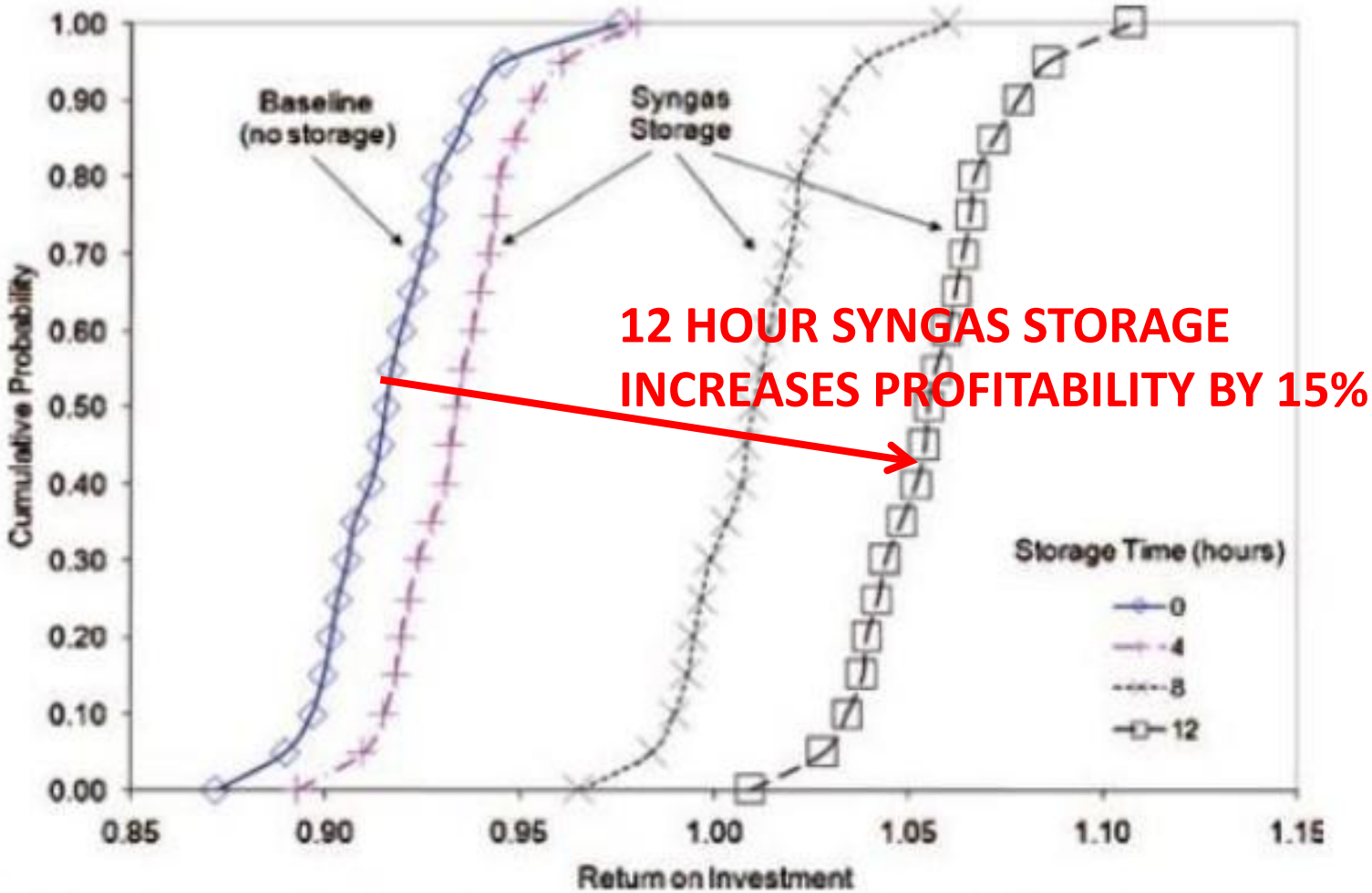


FIGURE 3. ROI for syngas storage scenario using a 1+0 IGCC facility with 80% availability, Cinergy node, 100% debt financing at 8% interest rate, economic and plant life of 30 years (amortization factor 0.0888), 2007 EIA AEO coal price forecast with accuracy factor, and 63 bar storage pressure.

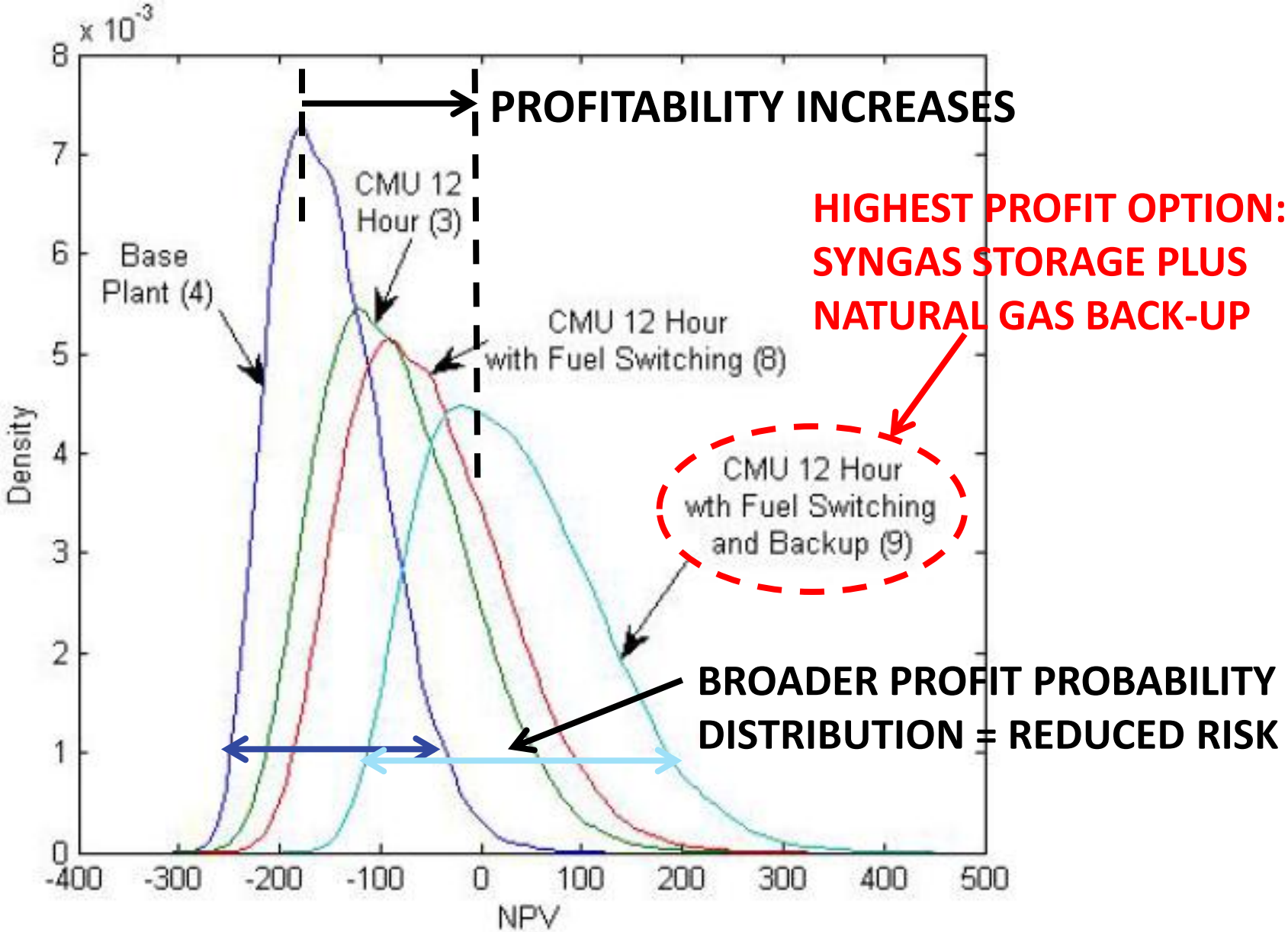
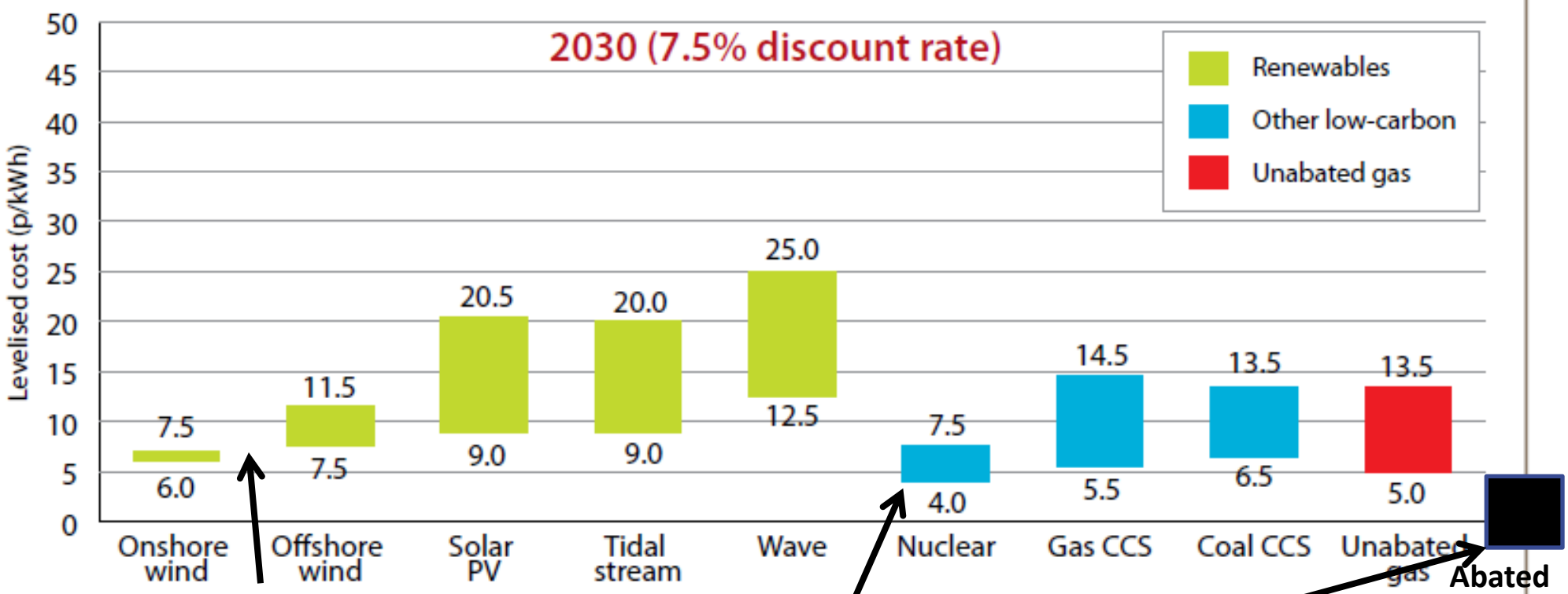


Figure 6. Effect of Fuel-Switching Capability on NPV of Plant Base Prices Scenario, Natural Gas as Alternate Fuel

ABATED TECHNOLOGY COSTS: DISPATCHABLE DECARBONISED SNG @ 4.5p/kWh - 6.0p/kWh ROC's = -1.5p/kWh

Figure 2: Estimated cost ranges for low-carbon power technologies at 7.5% discount rate (2030)



DISPATCHABLE DECARBONISED SNG BALANCES INTERMITTENT WIND AND BASE LOAD NUCLEAR AT LEAST WHOLE SYSTEM COST

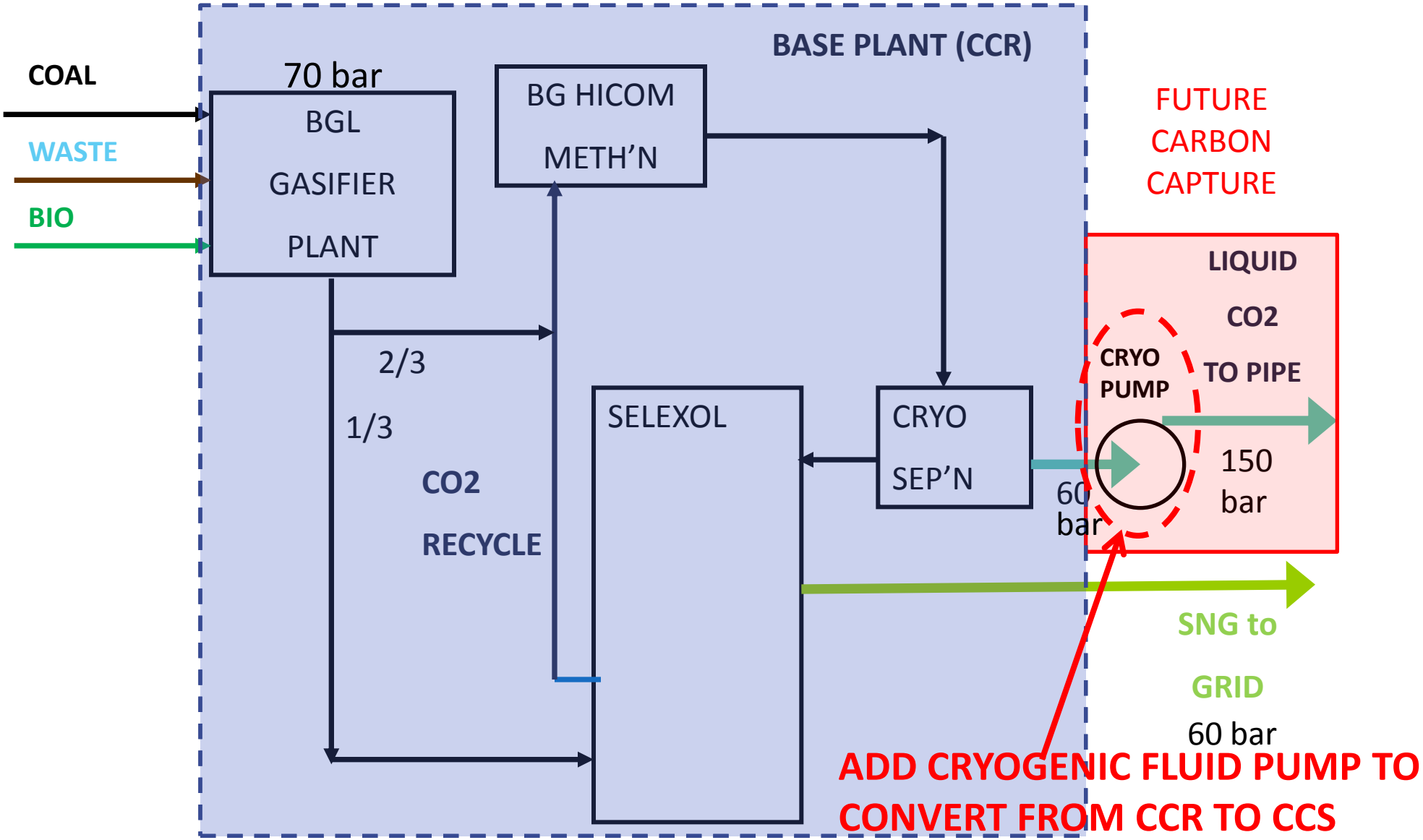
Source: CCC calculations,

Note(s): As Figure 1, with

WHY IS DECARBONISED SNG + CCS SO CHEAP?

- Use existing electricity and gas grid and CCGT's
- Use abundant negative cost partly biogenic fuel: waste.
- 50+% biogenic proportion x double ROC's and/or RHI.
- Low Carbon cost penalty due to partly biogenic fuel, high energy efficiency and low cost CCS.
- 75+% efficiency to SNG.
- Maximise plant load factor.
- SNG plant Carbon Capture Ready. Produces CO_2 by-product.
- Low SNG compression cost at 70 bar plant pressure.
- CO_2 transport and storage costs 50% of coal or gas.
- Timmins CCS produces 60 bar fluid CO_2. Marginal abatement cost of Carbon at plant gate: £17.50/tonne.

Timmins CCS: Carbon Capture Ready multi-fuel SNG. Adding liquid CO_2 pump costs £17.5/tonne C abated < Carbon floor.



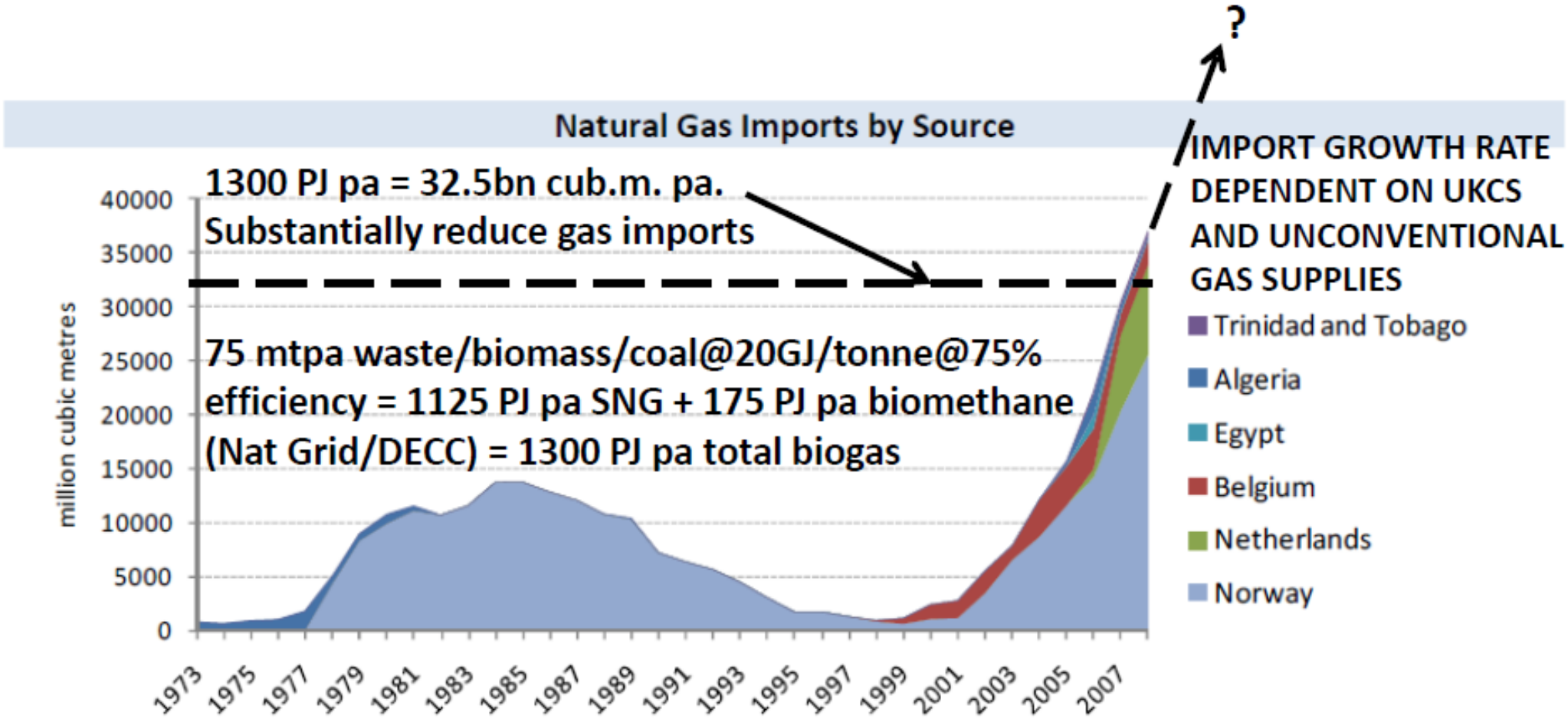
SUMMARY OF FEASIBILITY STUDY

- Slagging gasifier to SNG produces NEAR ZERO HARMFUL POLLUTANTS and CO_2. Heavy metals encapsulated in vitrified aggregate. Near zero particulates, NOx and SOx. Sulphur recycled.
- REVIEW FOR CHRIS HUHNE APRIL 2011: UK produces 250 to 275 mtpa of solid fuels: 25 mtpa of coal and high Carbon content wastes; 115 mtpa of mixed wastes, and 125 mtpa of non-food biomass/wastes.
- Co-gasifying 15 mtpa coal:28 mtpa biomass:32 mtpa waste will supply 30% of current UK gas demand; or 33% of 2030 electricity demand.
- Costs: Electricity £45/MWh less £60/MWh ROC's. SNG 40p to 45p/therm less 100p/therm RHI.
- Decarbonised SNG with CCS PROFITABLE TO-DAY
- Timmins CCS process on SNG reduces plant gate cost of 150 bar supercritical CO_2 to £17.5/tonne (TSB CATS funding for IGCC case)

DECARBONISED SNG: POLICY OBJECTIVES

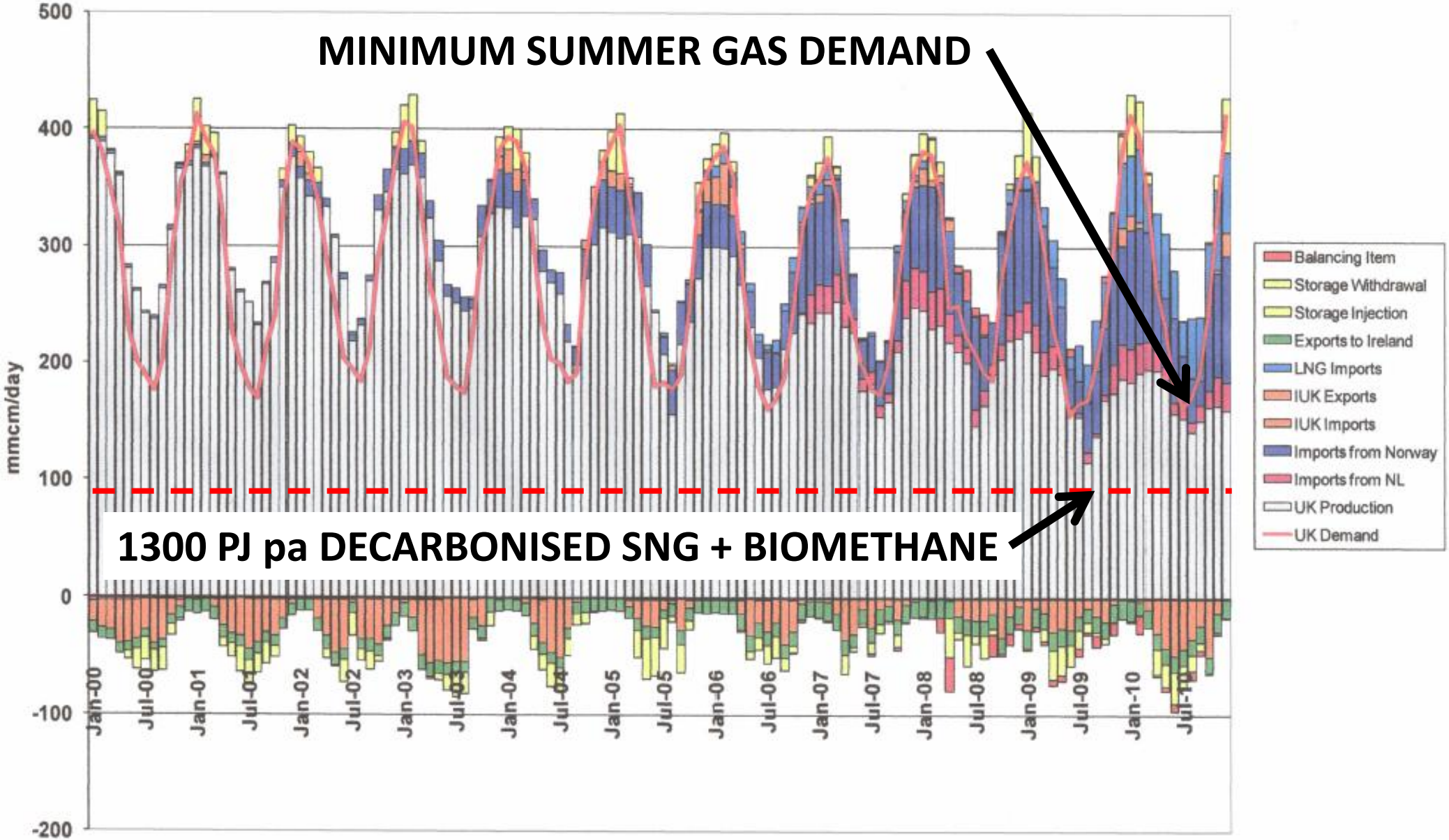
- **AFFORDABLE. Deliver low Carbon energy at lower cost than incumbent fossil fuel technologies using existing energy infrastructure.**
- **SECURE. Use indigenous sustainable resources. Maximise use of residual wastes.**
- **SUSTAINABLE. Whole system emissions intensity <50 gCO_2/kWh.**
- **SYSTEM INTEGRATION. Dispatchable, storable, renewable energy supports demand response, wind, nuclear, coal and CCS. Maximise load factors.**

REDUCED GAS IMPORT DEPENDENCE AND SUPPLY DIVERSIFICATION

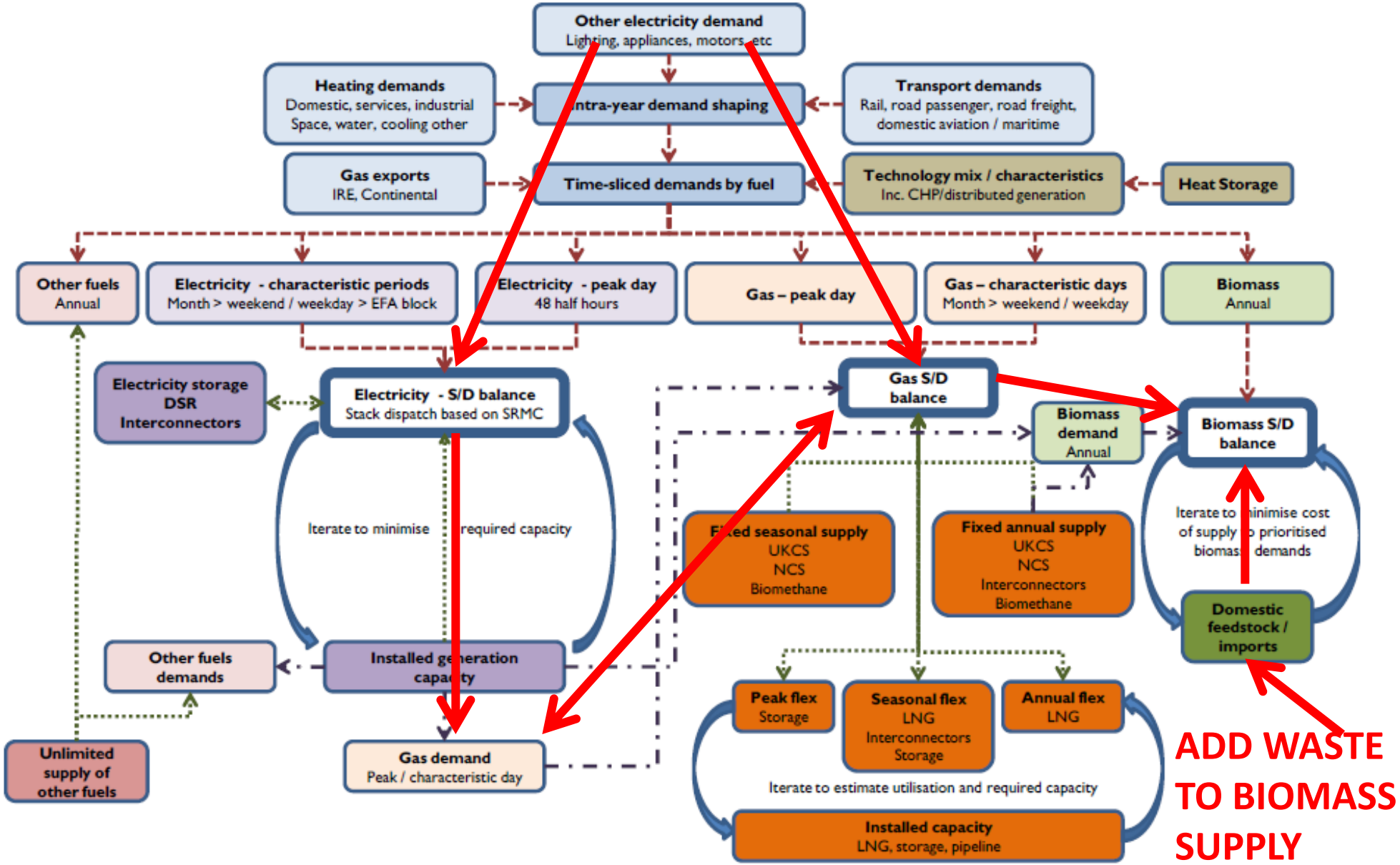


Source: Natural Gas Information, IEA

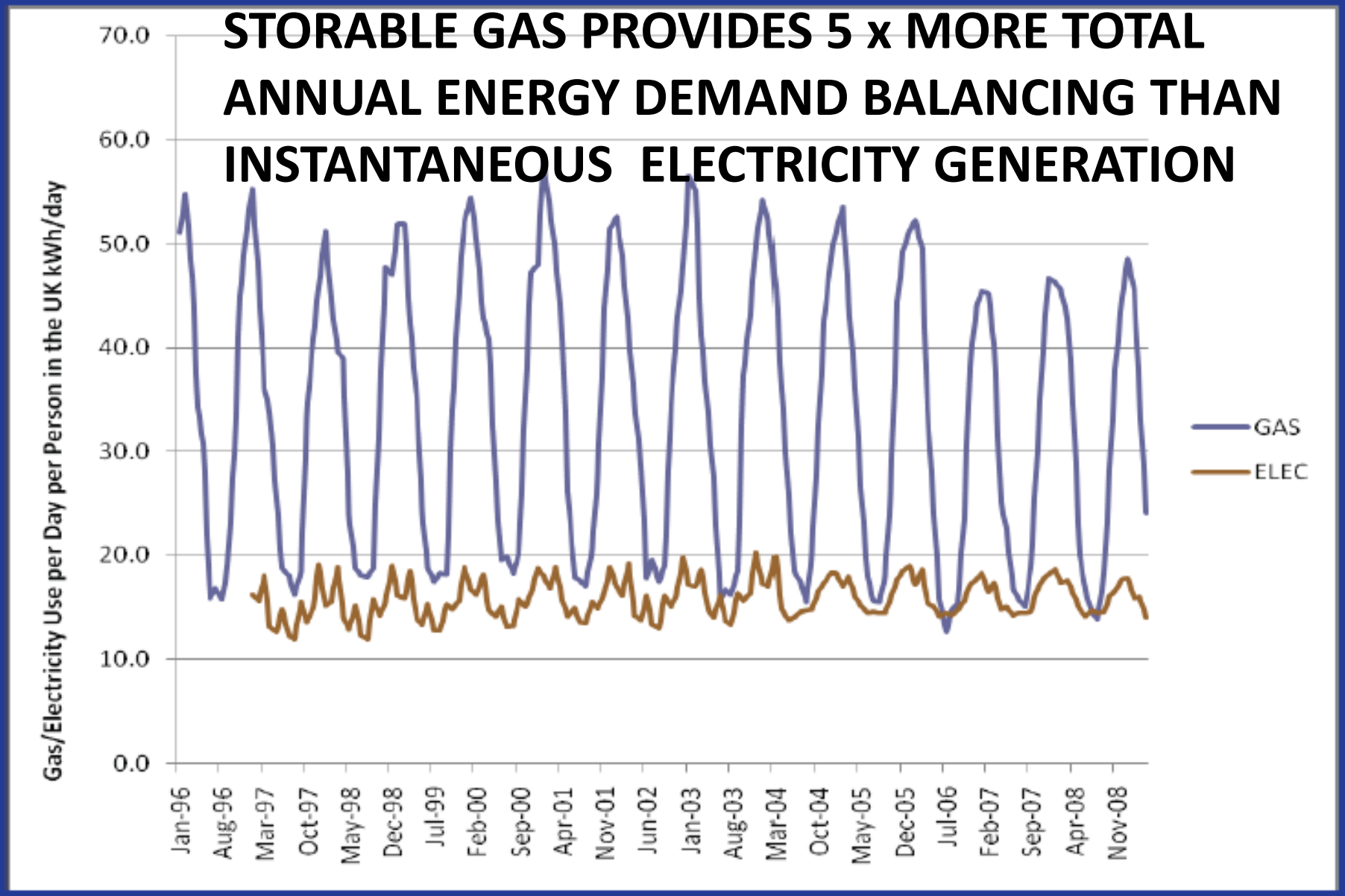
LOW CARBON GAS SUPPLY VERSUS UK GAS SUPPLY/DEMAND CYCLE

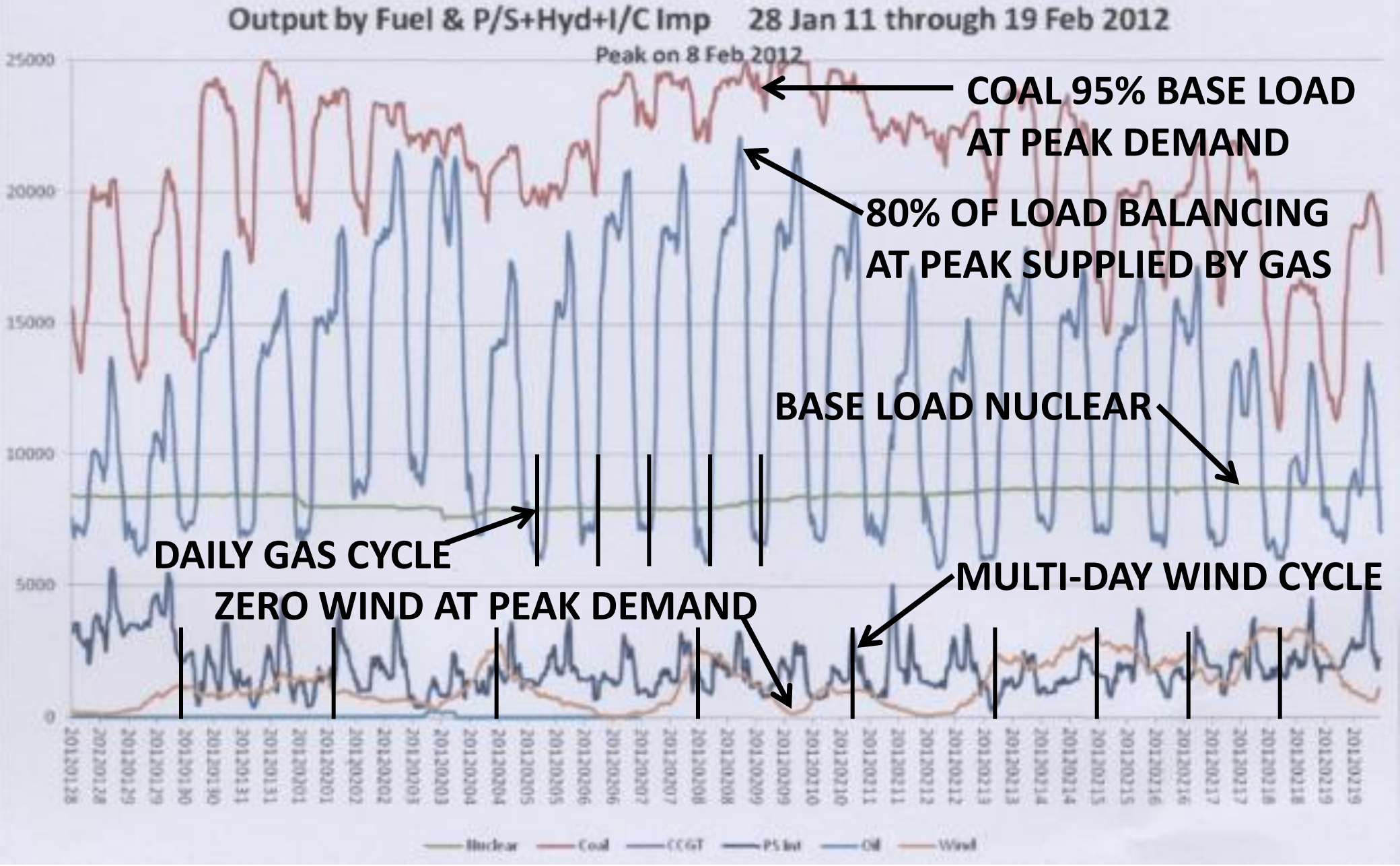


ENA/REDPOINT INTER-CONNECTED ELECTRICITY, GAS AND BIOMASS MARKET MODEL



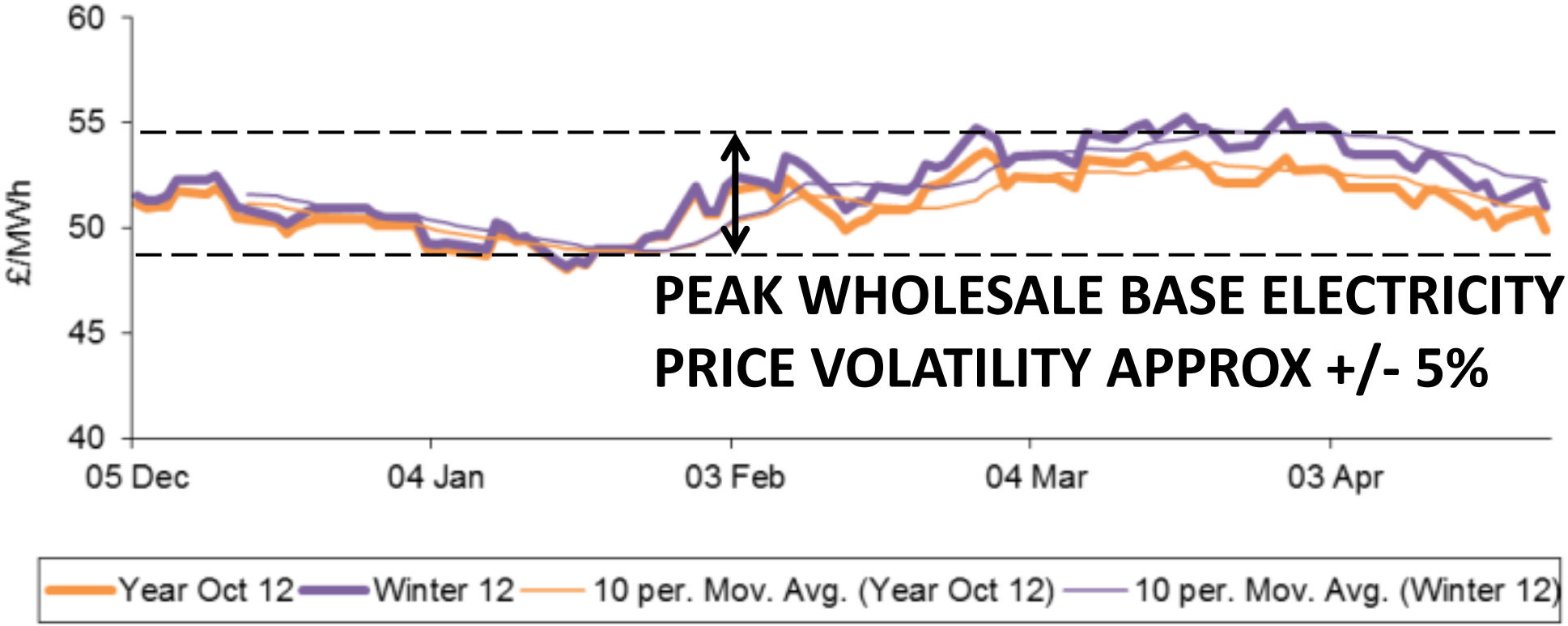
* gas peak 3 times electricity peak
* 340 TWh Grid + 700 TWh gas in 2011





WINTER 2012 DAILY ELECTRICITY DEMAND BALANCING

WELL FUNCTIONING MARKET: ELECTRICITY AND GAS FUTURES ABSORB PEAK DEMAND VOLATILITY



WINTER 2012 PEAK GAS DEMAND FUTURES

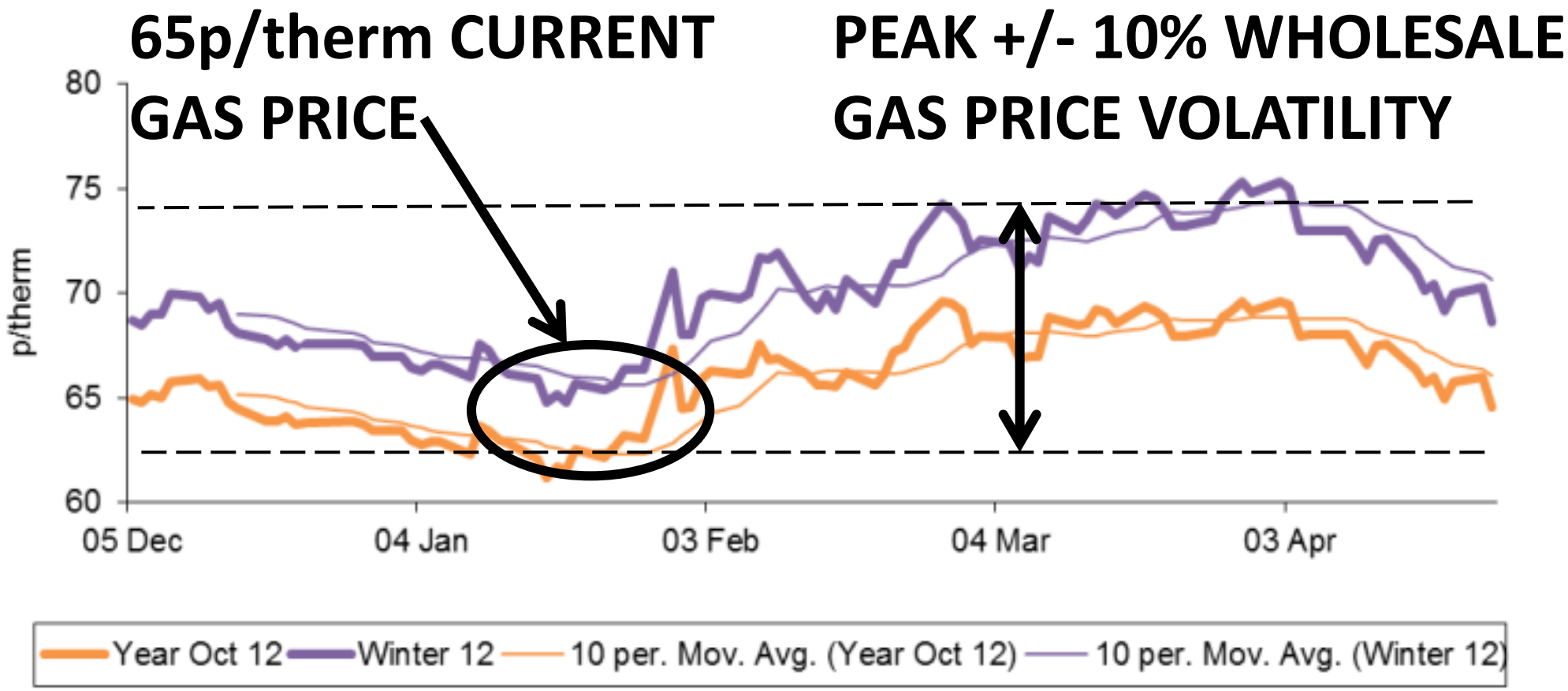
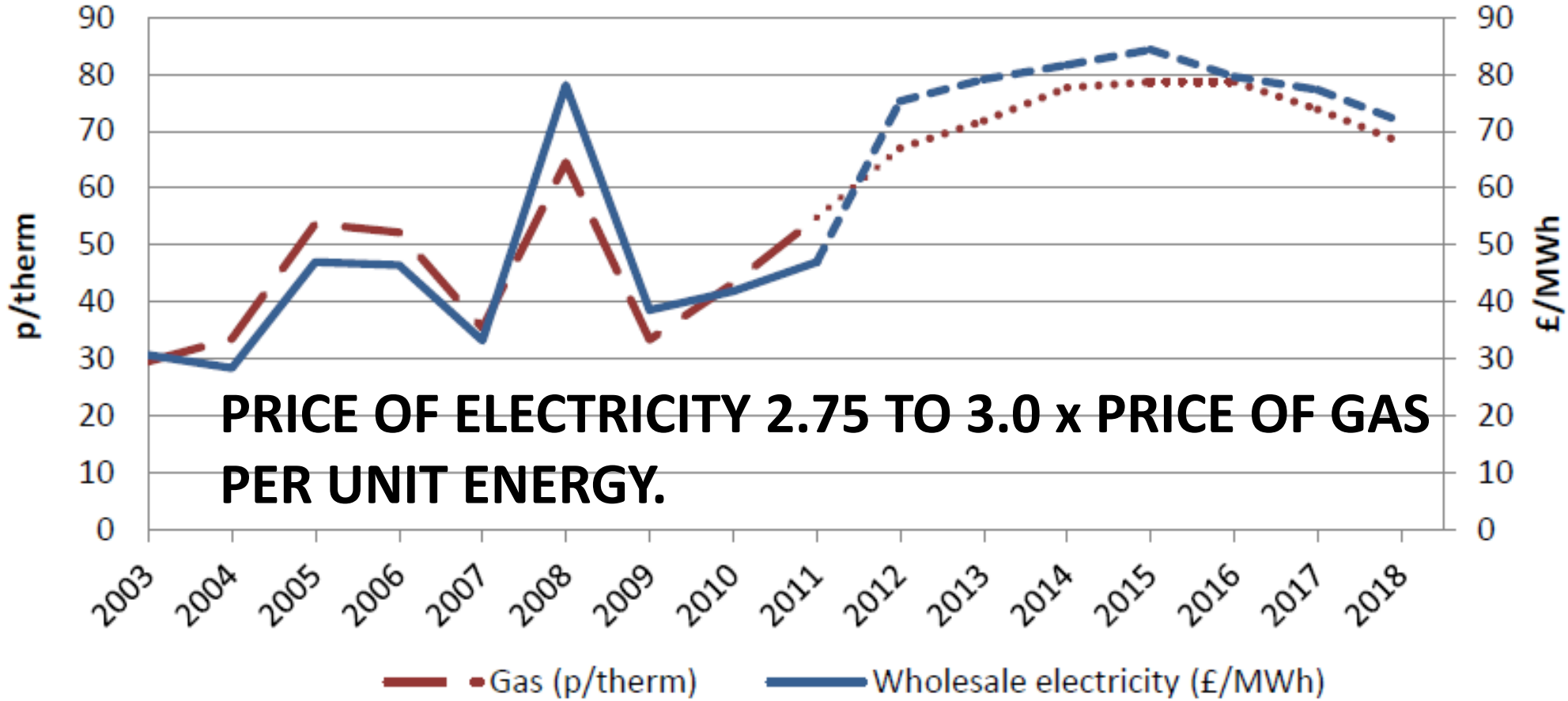


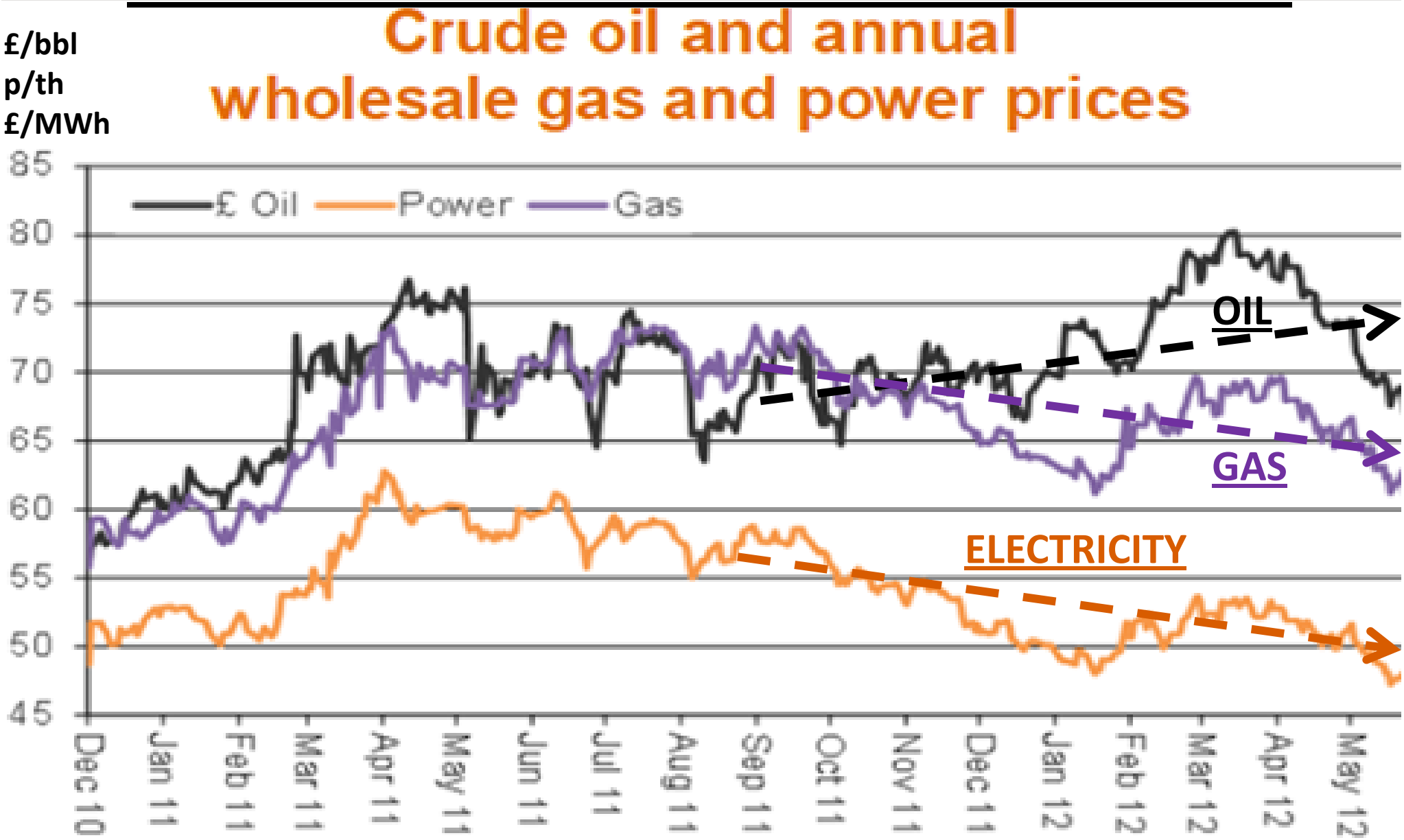
Chart 1: Historic and projected electricity and gas prices



PRICE OF ELECTRICITY 2.75 TO 3.0 x PRICE OF GAS PER UNIT ENERGY.

Source: Annual averages. 2010 prices. Historical gas prices: Bloomberg. Historical electricity prices: London Energy Broker's Association. Gas and electricity projections (central): DECC 2011

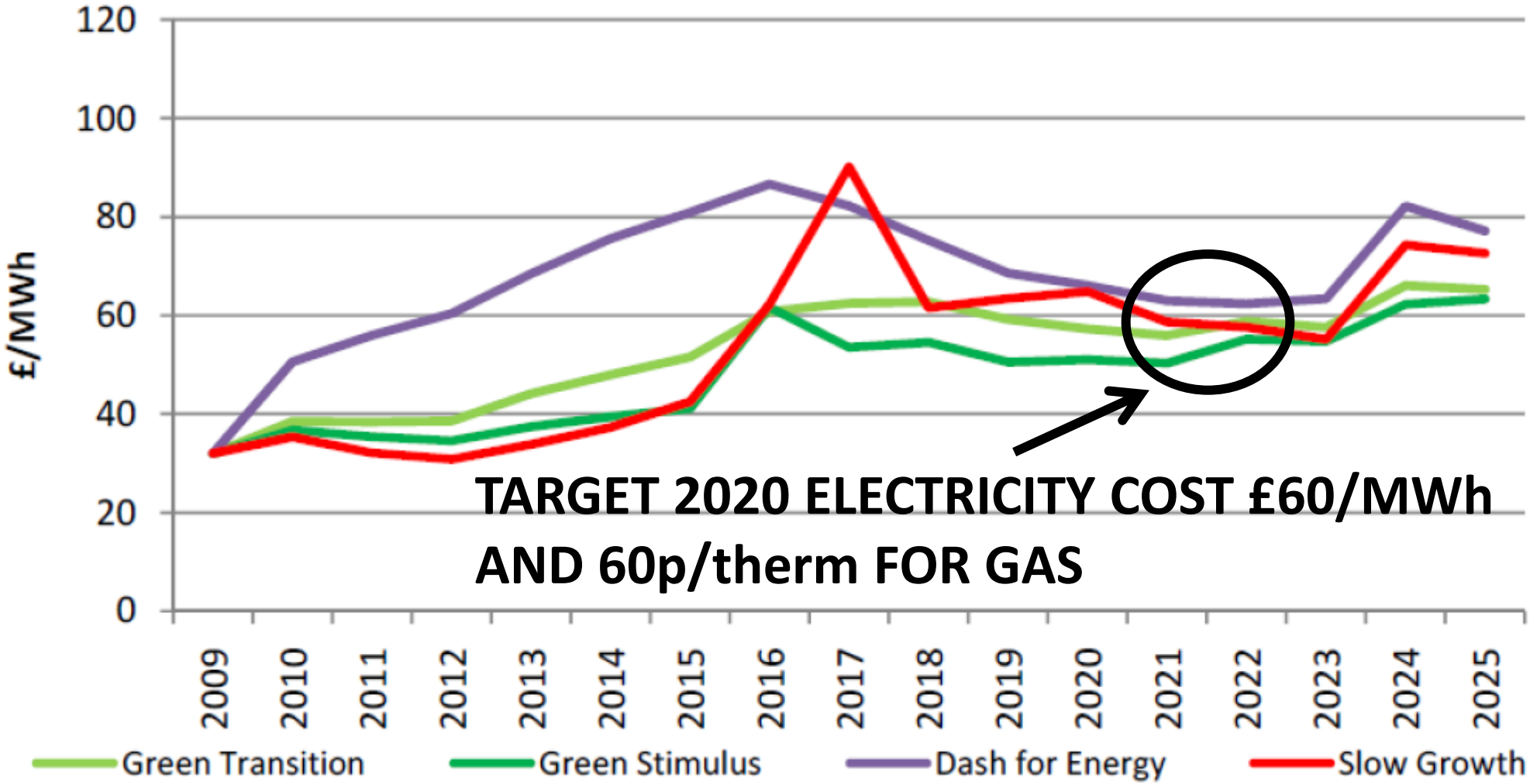
WILL UK GAS AND ELECTRICITY PRICES CONTINUE TO DIVERGE FROM OIL PRICE AS LAST 18 MONTHS?



GAS OR ELECTRICITY?

- Gasification produces 100% SNG; 100% electricity, or mix of SNG and electricity.
- Typical 75% efficiency to SNG, 45% efficiency to electricity. 1.66 x more energy output per unit energy input for SNG than electricity.
- BUT price per unit energy 2.75 to 3.0 x higher for electricity than SNG.
- All things being equal, electricity is always 66% more profitable than SNG.
- 1GJ of 52.5% biogenic fuel converted at 45% efficiency produces £7.50 of peak electricity + £6.85 ROC = £14.35 revenue (2012 buy out value + 50% recycled 'fines' at 2018 1.8 ROC banding for advanced gasification)
- 1GJ of 52.5% biogenic fuel converted at 75% efficiency produces £4.69 of SNG + £10.06 RHI = £14.75 revenue (2011-2031 fixed RHI for biomethane)
- ROC and RHI banding and values effectively produce 'level playing field'.
- What happens when RHI ends in 2031? Propose long-term flexible CfD for decarbonised gas, otherwise SNG plants may all convert to electricity.

OFGEM PROJECT DISCOVERY ELECTRICITY PRICE TRAJECTORIES

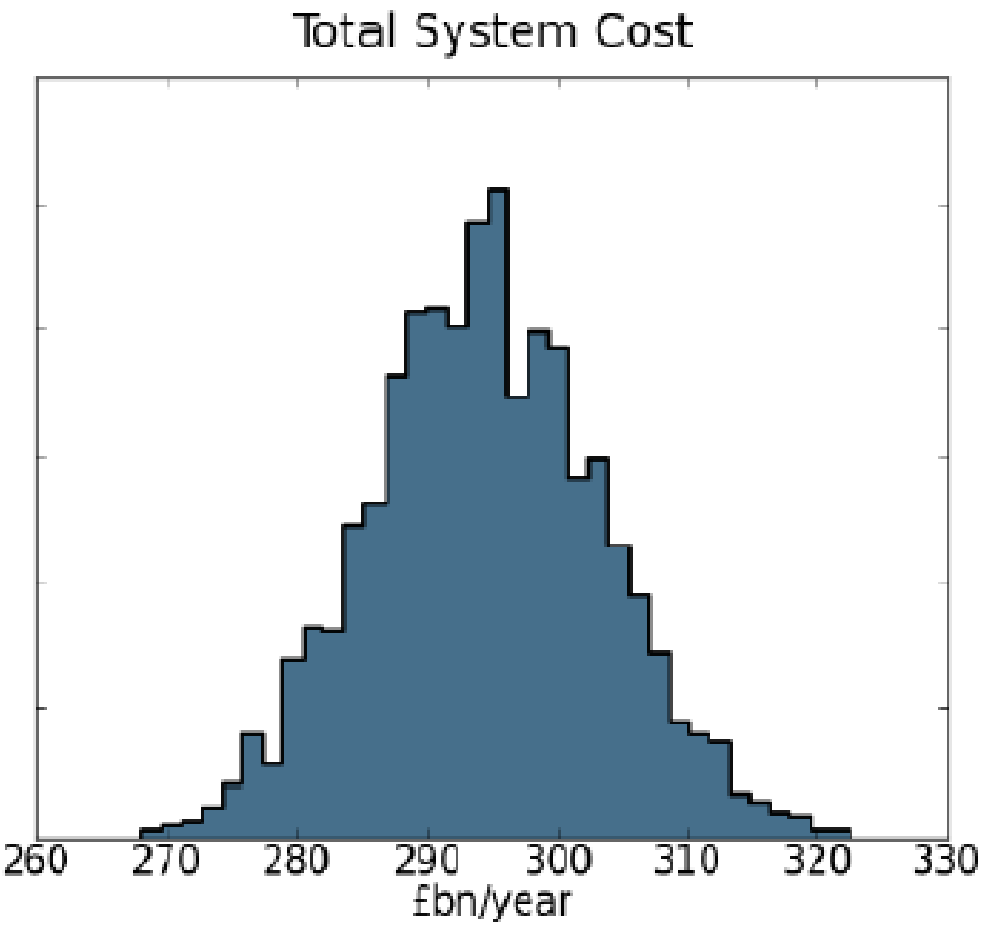


2050 abatement cost is <1% GDP

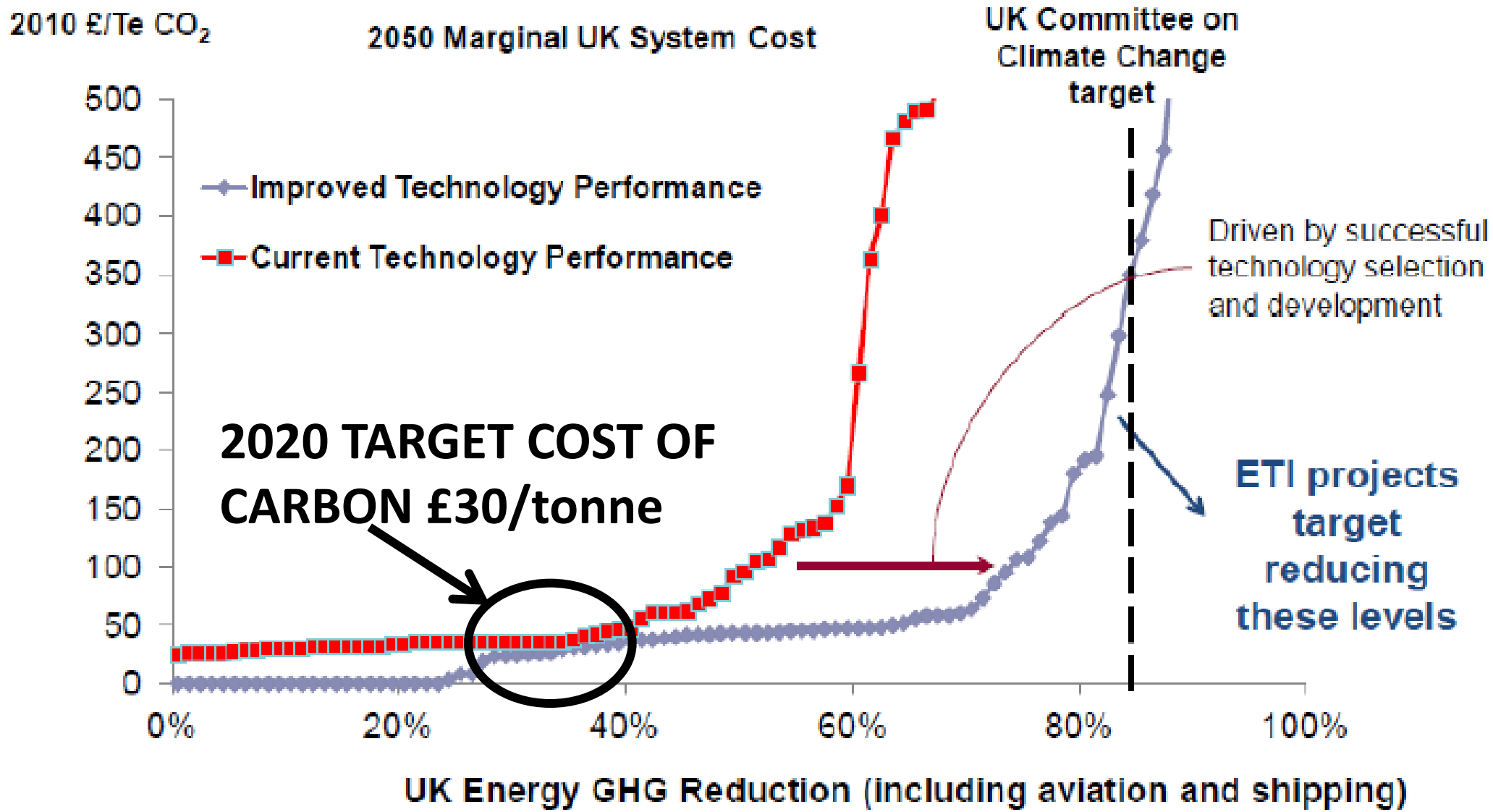
Biomass and CCS are key levers, nuclear is part of the 'base platform'

£2010(Mean)/year	
Total system cost	£294bn
Abatement cost	£26bn (0.7% GDP)
Average cost	£51/tCO2
Marginal cost	£360/tCO2
No biomass	+£44bn
No CCS	+£42bn
No nuclear	+£4bn
No tech devt*	+£106bn

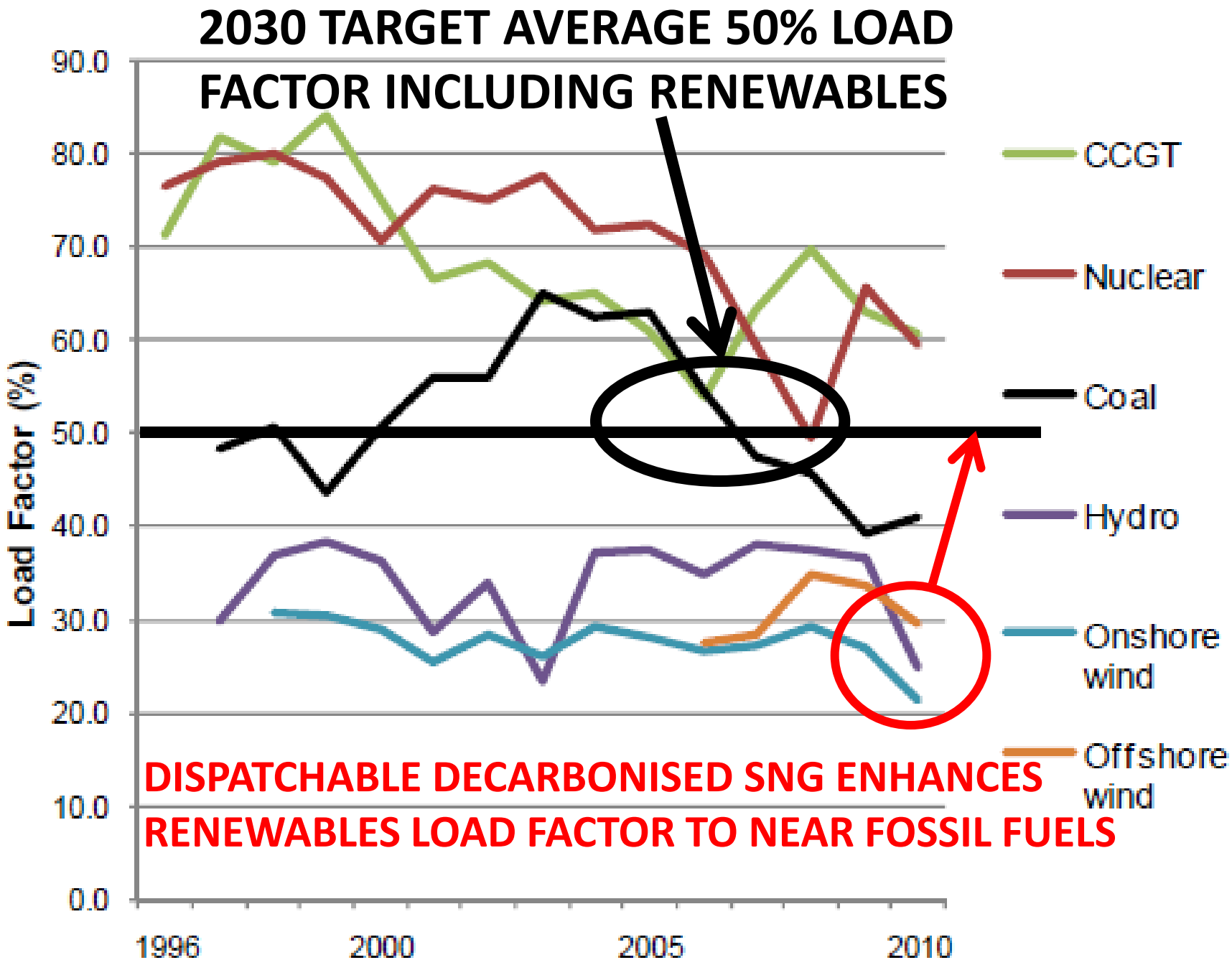
*Assumes current technology cost/performance



Combined avoided NPV cost ~£3.5tr 2010 to 2050


2010 £/Te CO_2
2050 Marginal UK System Cost
UK Committee on Climate Change target
500
450
400
350
300
250
200
150
100
50
0
Improved Technology Performance
Current Technology Performance
Driven by successful technology selection and development
2020 TARGET COST OF CARBON £30/tonne
ETI projects target reducing these levels
0%
20%
40%
60%
80%
100%
UK Energy GHG Reduction (including aviation and shipping)

Load factors by technology type, 1996 to 2010



2030 GRID: 50% RENEWABLES, 50% AVERAGE LOAD FACTOR, EMISSIONS < 50gCO_2/kWh

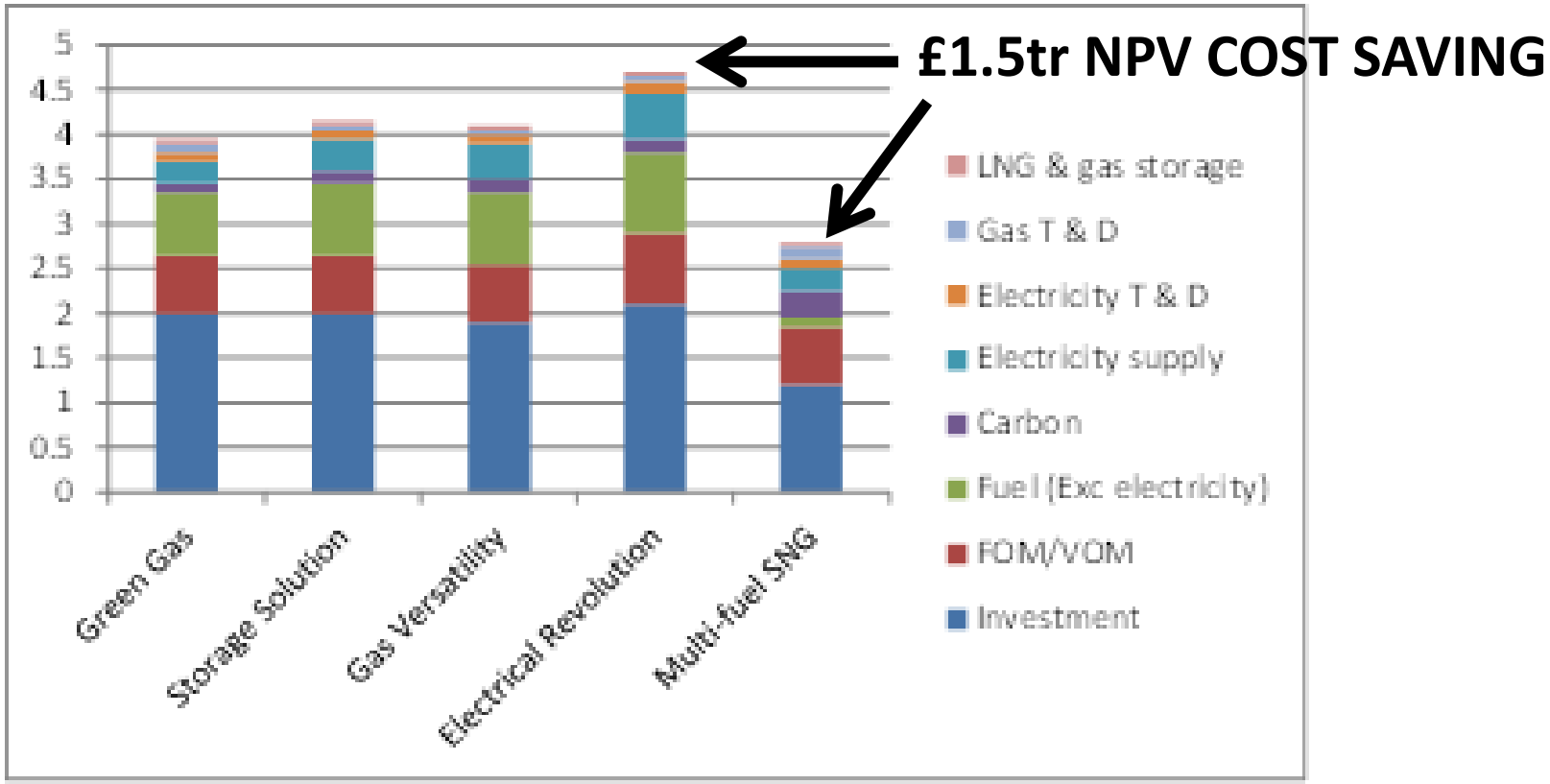
REDUCING THE 'OVERNIGHT' CAPITAL COST OF DECARBONISING THE UK ELECTRICITY GRID 2025 TO 2050

GRID SCENARIO 2025 TO 2050 BASED ON NATIONAL GRID PLC/ENA 'GREEN GAS' AND 'STORAGE SOLUTION' SCENARIOS. EXISTING TECHNOLOGIES. MODERATI DEMAND MANAGEMENT, ENHANCED GRID INTER-CONNECTORS AND ENERGY STORAGE REDUCE SUPPLY/DEMAND FLUCTUATIONS, DEMAND RESPONSE REDUCED. TOTAL RENEWABLE AND BIOMASS ENERGY CONTENT APPROXIMATELY 50% OF TOTAL ELECTRICITY SUPPLY. FULL CCS ROLL-OUT.

	Connecte load	Base load	Peak min wind/sun	Peak max wind/sun	Average supply	Load factor	% total supply	Carbon intensity	Renewable Proportion
Nuclear	15	12.5 GW	12.5 GW	12.5 GW	12.5 GW	83%	16.66%	0	0%
Intermittent renewables	55	15	7	37	18.5	34%	24.66%	0	100%
Multi-fuel IGCC (CCS on SNG product only)	15	12.5	14	11.5	13	86%	17.33%	65	52.5%
SNG fuelled existing CCGT's	30	6.5	28	1.5	10.5	35%	14%	65	52.5%
Bio-Methane fuelled existing CCGT's	2.5	1	2.5	1	1.5	60%	2%	0	100%
Coal with 90% post combustion CCS	15	10	14	11.5	11.5	77%	15.33%	90	0%
Embedded micro-generation/demand management	17.5	7.5	7	10	7.5	43%	10%	0	100%
TOTALS	**150 GW**	**65 GW**	**85 GW**	**85 GW**	**75 GW**	**50%**	100%	**34 gCO_2 /kWh**	**51.10%**
Add Reserve generation to back up macro demand management, inter-connectors and energy storage.									
Low merit gas (Capacity payment)	10 GW	0	5 GW	5 GW	1 GW	7%	1.33%	410	
TOTALS	**160 GW**	**65GW**	**90 GW**	**90 GW**	**76 GW**	**48%**		**39.5 gCO_2 /kWh**	**50%**

MEETS TARGETS!

UK NPV energy cost 2010 to 2050 (£tr base data from ENA/Redpoint report)



PROPOSED WAY FORWARD

1. SNG + CCS flow sheet optimisation. GL funding (pro bono). Validate fuel mix and efficiency assumptions.
2. OCCS cost reduction task force. CCSA?
3. Pre-FEED and optimum plant size CAPEX study. TSB + ANO funding? Validate CAPEX assumptions.
4. Fuel supply chain study. DECC biofuels/OCCS funding? Cranfield + E4Tech?
5. 2030 policy support to decarbonise gas grid. GMR?
6. FEED and pilot plant. Industry/Government funding