Wind Energy Economics

The Influence of Gas and Carbon Prices

Rory Broderick

Trinity College Dublin

Dublin Economics Workshop June 16, 2011

System Focus for Study

- Ireland - All Island System in Year 2030
- Annual System Demand – 54000 GWh.
- Max. Demand 9600 MW
- Min. Demand 3500 MW
- Base load Generation Technologies

Outcome Metrics

- **LCOE** (Levelised Cost of Electricity)

  € / MWh(e)

  – Captures the LRAC of Electrical Energy

  – Used internationally in generation studies

- **MAC** (Marginal Abatement Cost) of CO2

  € / tonne CO2

  – Is a proxy for a Cost / Benefit ratio

  – Amount of CO2 abated is the benefit

Generation Cost Analysis
Levelised Cost Methodology

- Discounts Time Series of Expenditure (Incl Neg Extns)
- Discounts Time Series of Energy Output (Benefits)
- Quotient = Levelised Cost / Unit of Energy

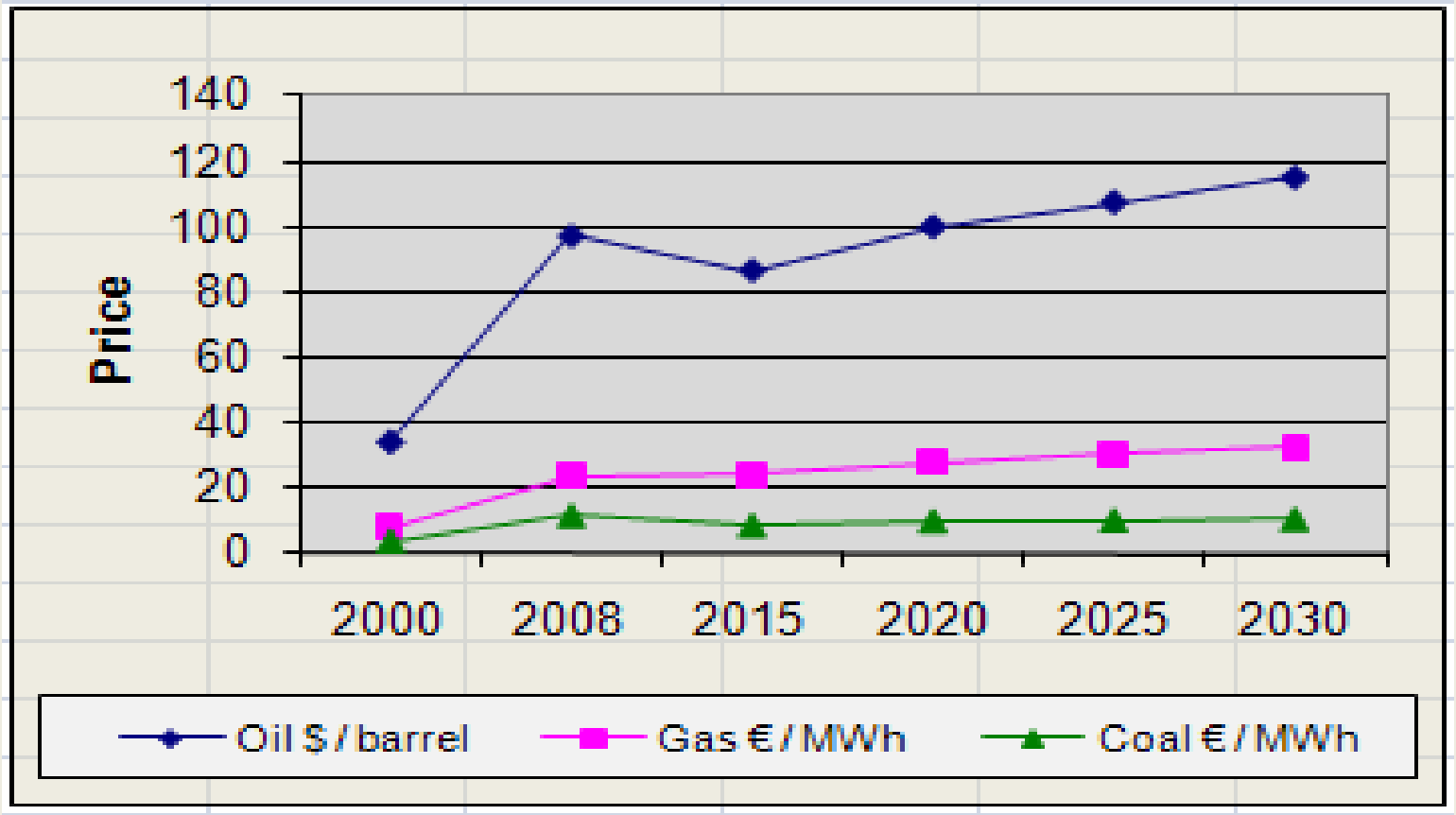
$$\Sigma_t (I_t + OM_t + F_t + NE_t + D_t)(1 + r)^{-t} / \Sigma E_t (1 + r)^{-t}$$

Yields the long run average cost of electricity generated over the life of the generator Levelised Cost of Electricity **LCOE**

3 Big Issues

- Future Fossil Fuel Prices in 2030
  - Gas
  - Coal
- Social Cost of CO2 (Shadow Price)
- Discount Rate

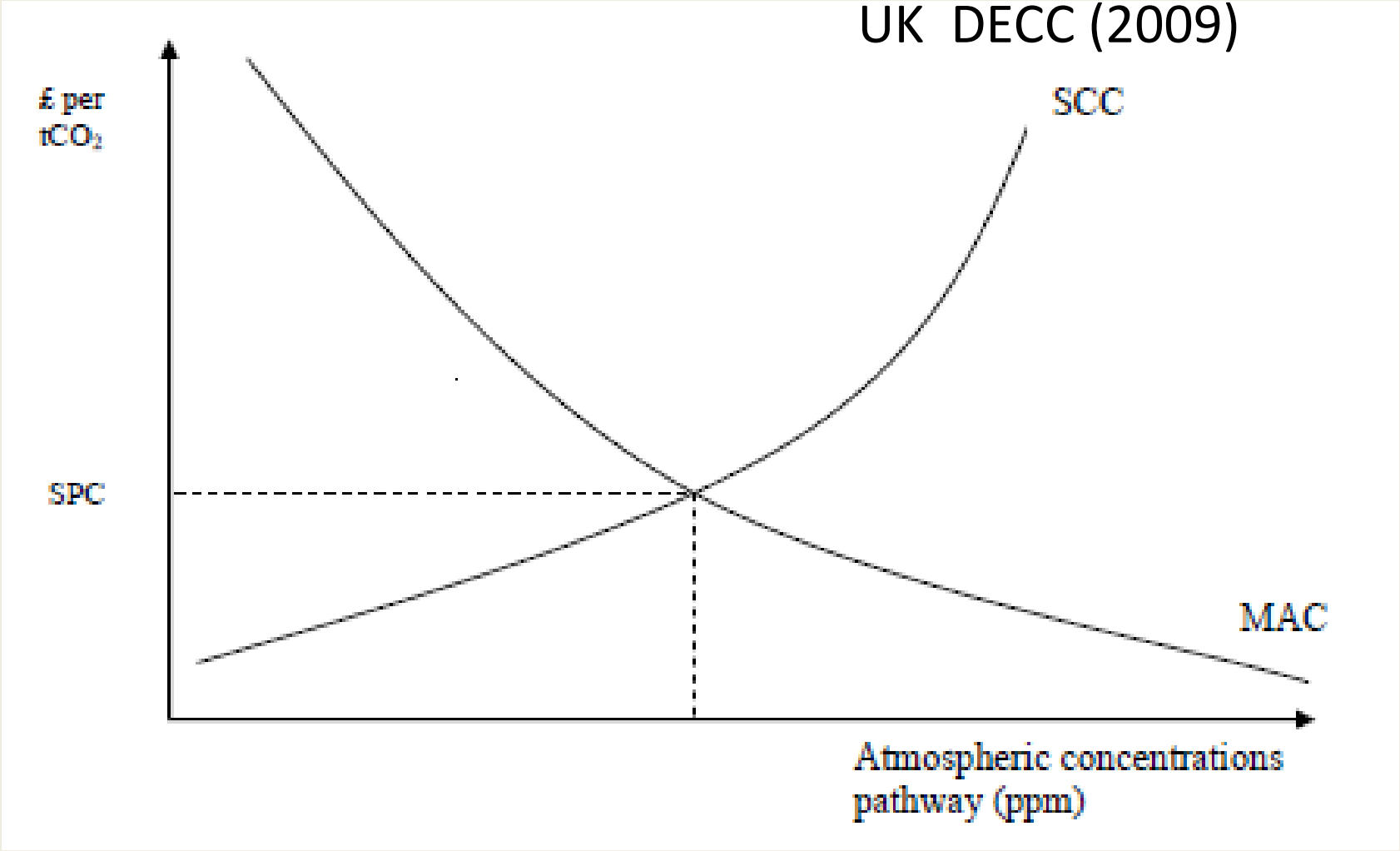
IEA Fuel Price Assumptions



IEA World Energy Outlook 2009

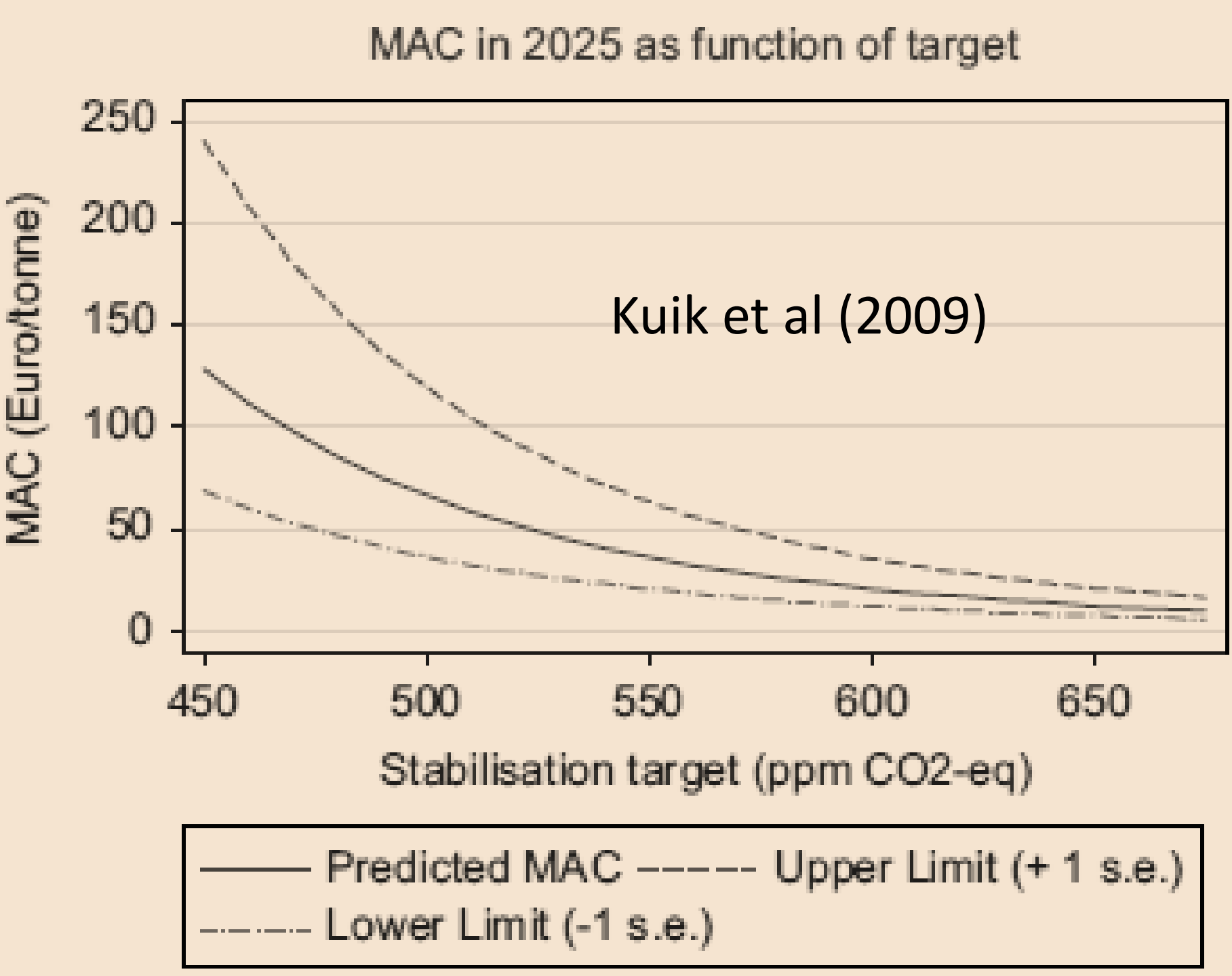
Shadow Price of Carbon – Theory

UK DECC (2009)



CO2 Price for Policy Appraisal

- **Irish Govt**.(June 2009) recommends a CO2 price of €39/t for the period 2015 and onwards.
- **UK Govt**. (July 2009) adopts a new long term target based carbon pricing policy in line with projected **marginal abatement costs (MAC).** For 2030, a central price of £70/t has been adopted .
- My study adopts €80/t. CO2 as the Shadow P.


MAC in 2025 as function of target
MAC (Euro/tonne)
250
200
150
100
50
0
450
500
550
600
650
Stabilisation target (ppm CO2-eq)
Kuik et al (2009)
Predicted MAC
Upper Limit (+ 1 s.e.)
Lower Limit (-1 s.e.)

Scenarios Compared

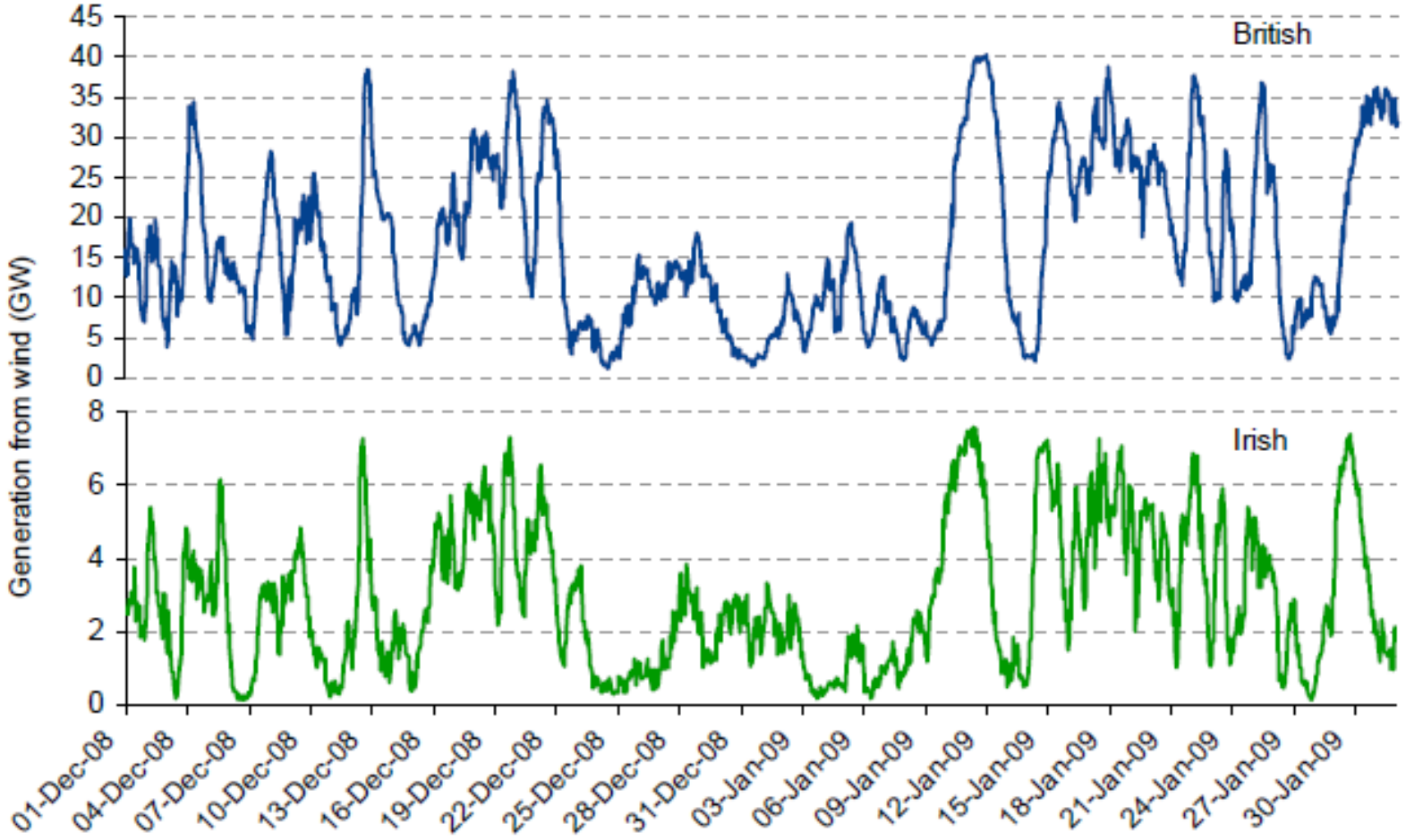
Peak System Demand : 9600 MW

Installed Onshore Wind Capacity	Percent of Peak System Load
2000 MW	21%
4000 MW	42%
6000 MW	63%
Base Ref. Case is Combined Cycle Gas Turbine (CCGT)	

Export of Irish Wind Power to GB

- **Theoretically attractive**
  - Allow export of excess Irish wind power.
  - Reduces curtailment of Irish wind energy output
- **Practical / Commercial Problems**
  - GB power market = Mainly **bilateral** contracts
  - Severe **lack of liquidity** in "day ahead" GB market
  - **Correlation** of Irish/GB load demands high (0.89)
  - **Difficult Sell (**wind power variable/unpredictable)
  - GB has revised upwards it's own **long term wind target**
- **Conclusion**: Export of Wind Power Problematic

Figure 2 – Example wind generation profiles for 2030 with wind of 2008/09



Source: POYRY Consulting

Wind - A Free Power Source ?

- Almost zero variable cost but **High Capital Cost**
- **Capricious**
  - Variable Output (mean output < 1/3 rated)
  - Undependable: Cannot be relied on with certainty to meet loads.
  - Must be curtailed if output > what system can absorb.
- **Location** : Most appropriate sites remote from load demands
- **Freq. Response**: Inadequate (response to system disturbance)

Impacts of above on Power Systems

- **Reliability Reserve:** system needs extra conventional capacity
- **Balancing Costs:** More spinning reserve , More cycling .
- **Network :** Must be reinforced / extended for remote power sources

These impose extra costs on system but nevertheless wind can be a valuable source of low carbon electrical energy in Ireland

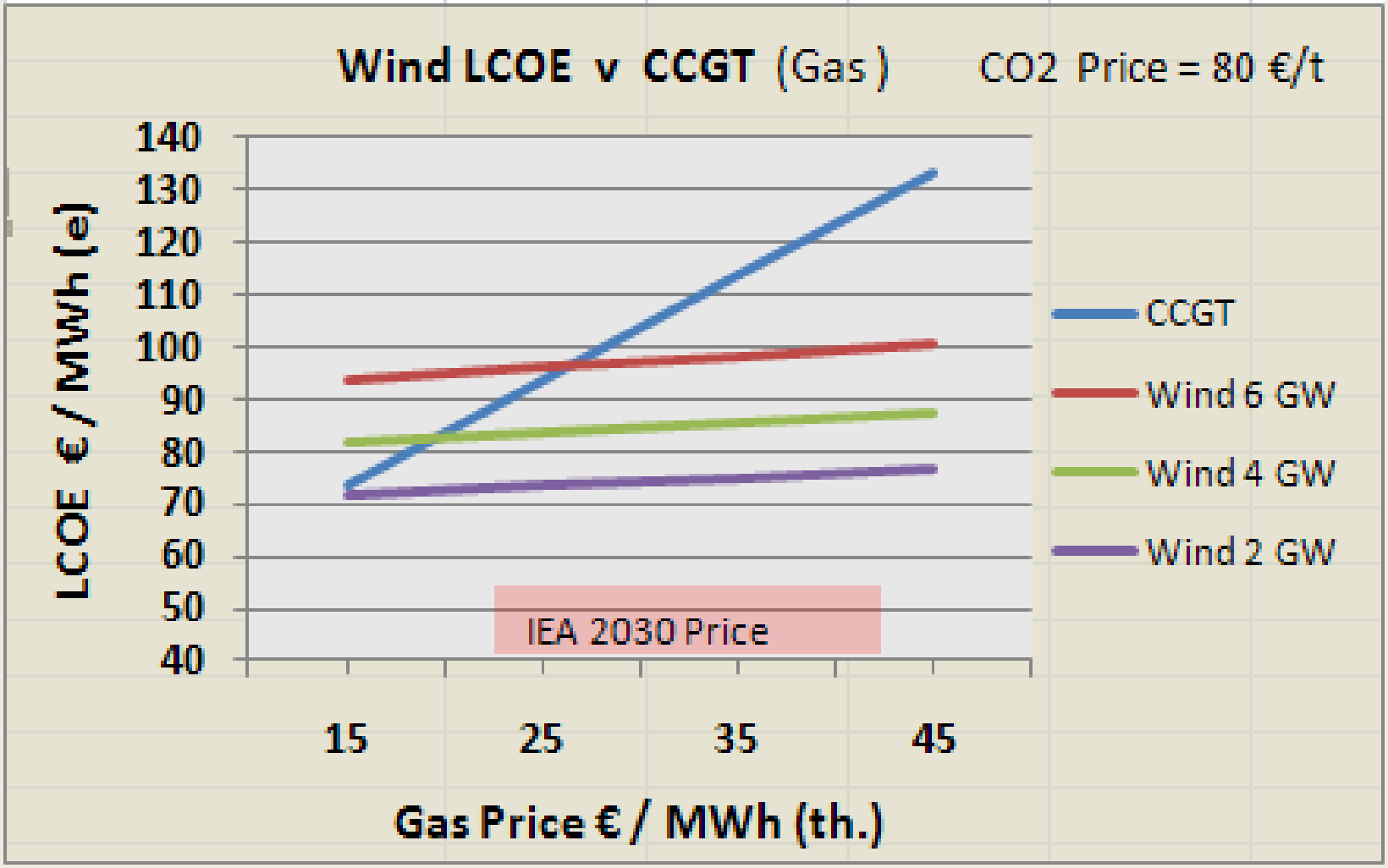
Wind LCOE - Inputs

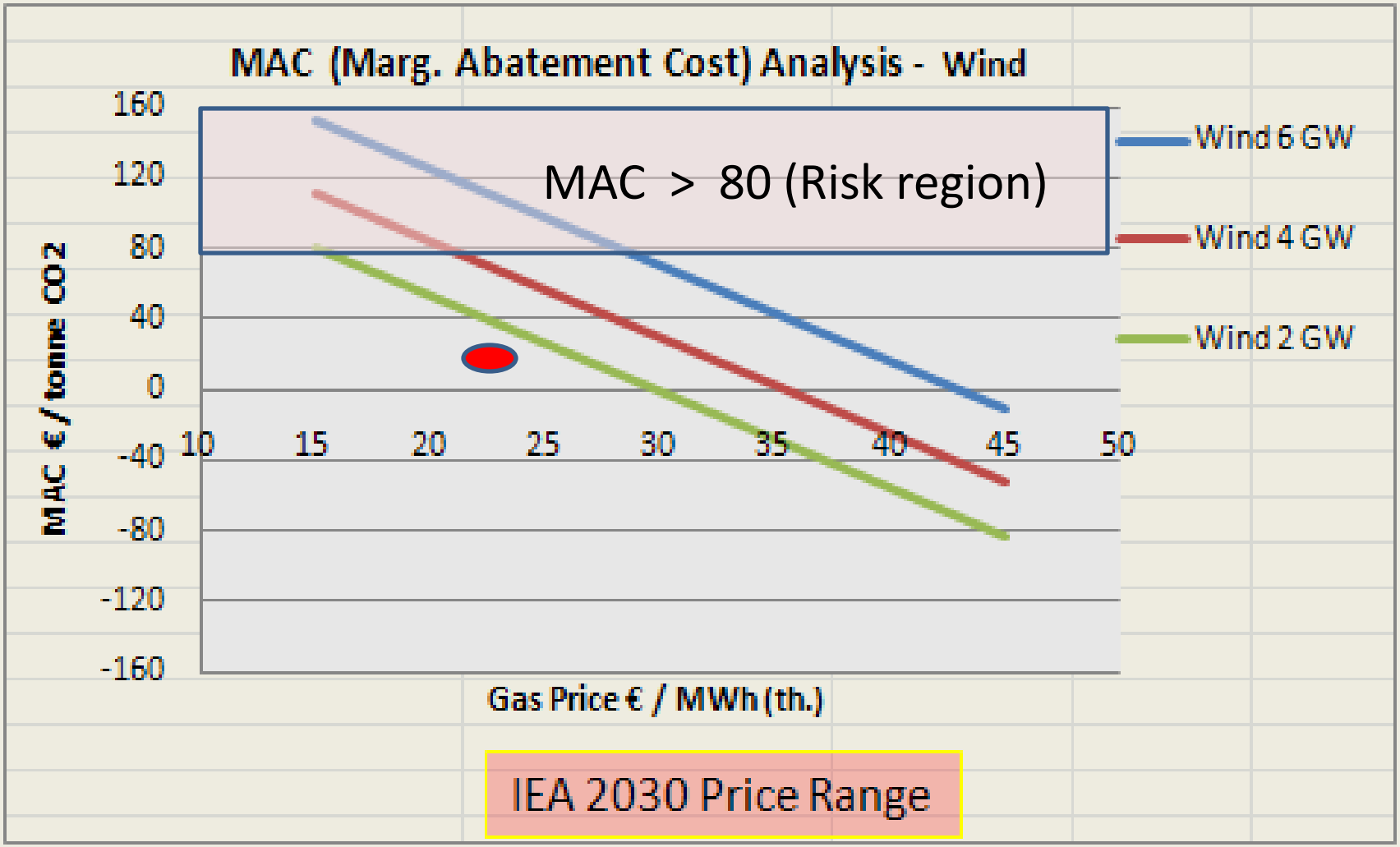
Cap. Investment €/kW	1400		
Discount Rate	6.8%		
Build Time	2 yrs.		
Op. Life	20 yrs.		
Fixed Ann. Cost €/kW	35		
Installed Wind Capacity	2 GW	4 GW	6 GW
Wind Cap. Factor %	31%	30%	29%
Wind Cap. Credit %	26%	18%	15%
Wind Curtailment %	0 %	2 %	11 %

Results – Wind LCOE (2030)

Costs in € / MWh Wind Energy Output			
Installed Wind Capacity	2 GW	4 GW	6 GW
Unadjusted Energy Cost	**62.4**	**65.8**	**75.0**
Cost of Reliability Reserves	3.5	5.9	7.5
Extra Balancing Cost *	7.9	9.3	10.9
Network Reinforcement	1.1	4.3	4.9
Total Adjusted Wind LCOE	**74.9**	**85.4**	**98.3**
Wind Energy Percent in SEM	10%	19%	25%

* Gas @ 35 €/MWh & CO2 @ 80 €/t


Wind LCOE v CCGT (Gas)
CO2 Price = 80 €/t
LCOE € / MWh (e)
140
130
120
110
100
90
80
70
60
50
40
IEA 2030 Price
CCGT
Wind 6 GW
Wind 4 GW
Wind 2 GW
15
25
35
45
Gas Price € / MWh (th.)


MAC (Marg. Abatement Cost) Analysis - Wind
MAC > 80 (Risk region)
Wind 6 GW
Wind 4 GW
Wind 2 GW
MAC € / tonne CO2
160
120
80
40
0
-40
-80
-120
-160
10
15
20
25
30
35
40
45
50
Gas Price € / MWh (th.)
IEA 2030 Price Range

Summary

- LCOE & MAC are suitable economic metrics for appraisal of future generation options
- Future gas price a key determinant for choices
- Wind Power Generation (WPG)
  - Export of wind power problematic
  - WPG imposes extra costs on Irish system
  - But moderate WPG (4GW = 19% pen. in 2030) attractive even with low future gas prices.
  - Provides a balanced response to the projected risks/rewards

Policy Implications

- Internalise extra system cost imposed by WPG
- Immediate further WPG investment not justified by present gas and carbon prices
- Alignment of Irish/GB wholesale elec. markets important
- Economic optimisation of WPG level not compatible with emission targets.
- Other significant low carbon generation sources needed – Nuclear? CCS?