IEA Wind Task 25 Storage Research

Ecar ENERGY

sei SUSTAINABLE ENERGY IRELAND

Risø DTU
National Laboratory for Sustainable Energy

Study Background

- IEA Task 25 : International task undertaken by 12 countries to carry out research and share information on the power system impacts of large scale wind
- National participant Ecar selected by SEI in 2007 to act on their behalf in IEA Task 25
- Ecar partnered with the National Laboratory for Sustainable Energy in Denmark – Risø DTU
- Aim was to carry out unit commitment based scheduling studies of a high wind 2020 power system in Ireland using the WILMAR scheduling tool

Storage Research Overview

- Use dedicated unit commitment software to examine the role and viability of large scale storage in a high wind 2020 power system
- Aim : To better understand the capabilities of storage in delivering benefit to society and the plant owners
- Three part study
  - Capital cost based storage screening study
  - Unit commitment scheduling analysis
  - Profitability analysis

2020 High Wind Power System

- All-Island power systems of Northern Ireland and the Republic of Ireland.
- 6000MW of wind = 34.4% of total energy provision
- 8300MW of non-renewable generation

Type of unit	No	Capacity (MW)	Fuel (€/GJ)
Base-loaded gas	12	4114	5.91
Mid-merit gas, Peaking	19	1646	6.46
Coal	5	1257	1.75
Peat	3	345	3.71
Base RE	1	306	2.78
Hydro	1	216	-
Pumped storage	4	292	-
Tidal	-	200	-
Wind power	-	6000	-

2020 High Wind Power System

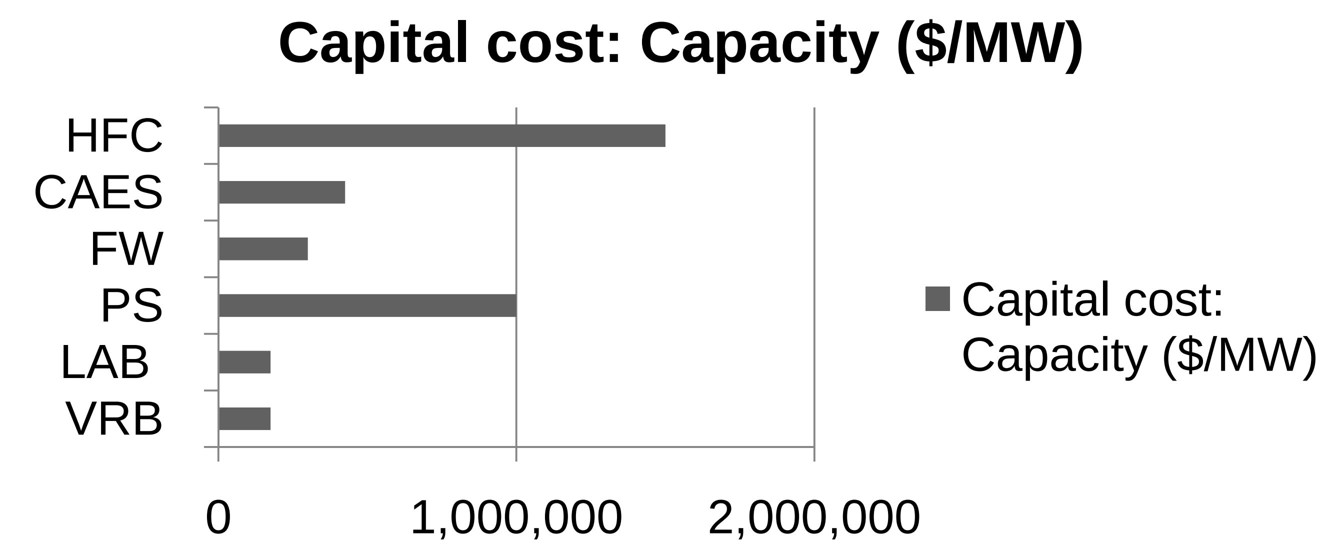
- Demand 3500 – 9600MW
- Carbon @ €30/t

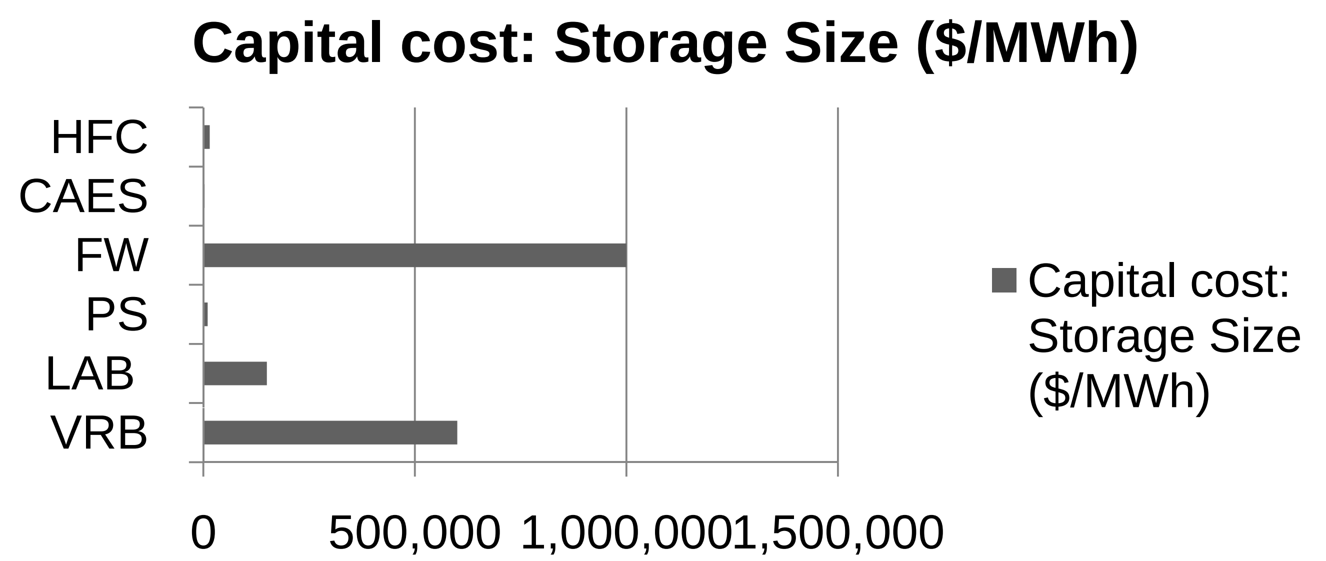
Type of unit	Start-up time
Mid-merit Gas and Peaking	<1
Peat	1-4
Base-loaded Gas	1-4
Coal	1-5

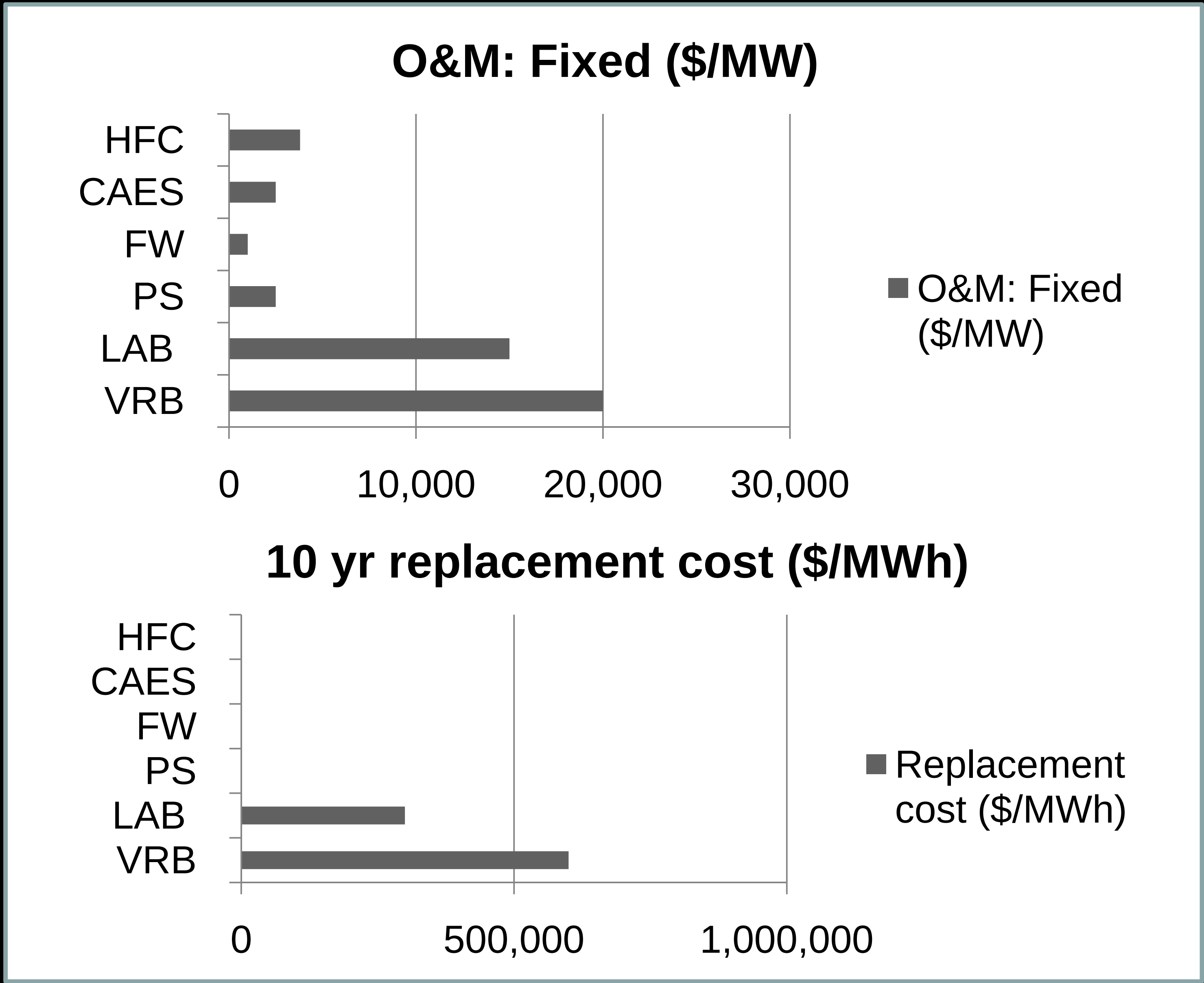
- Constraints on minimum online units
- Great Britain has 31 unit groups
- Great Britain wind = 12% of total demand
- 1000MW connection to Great Britain

Screening Study

- Aim: compare costs per MW , per MWh and arbitrage revenues to select a viable storage technology
- Revenues based on pool prices from an hourly scheduling simulation for the power system in the year 2020
- Storage Technologies
  - Vanadium Redox Battery (VRB)
  - Lead Acid Battery (LAB)
  - Pumped Hydro Storage (PS)
  - Fly Wheel (FW)
  - Compressed Air Energy Storage (CAES)
  - Hydrogen Fuel Cells (HFC)

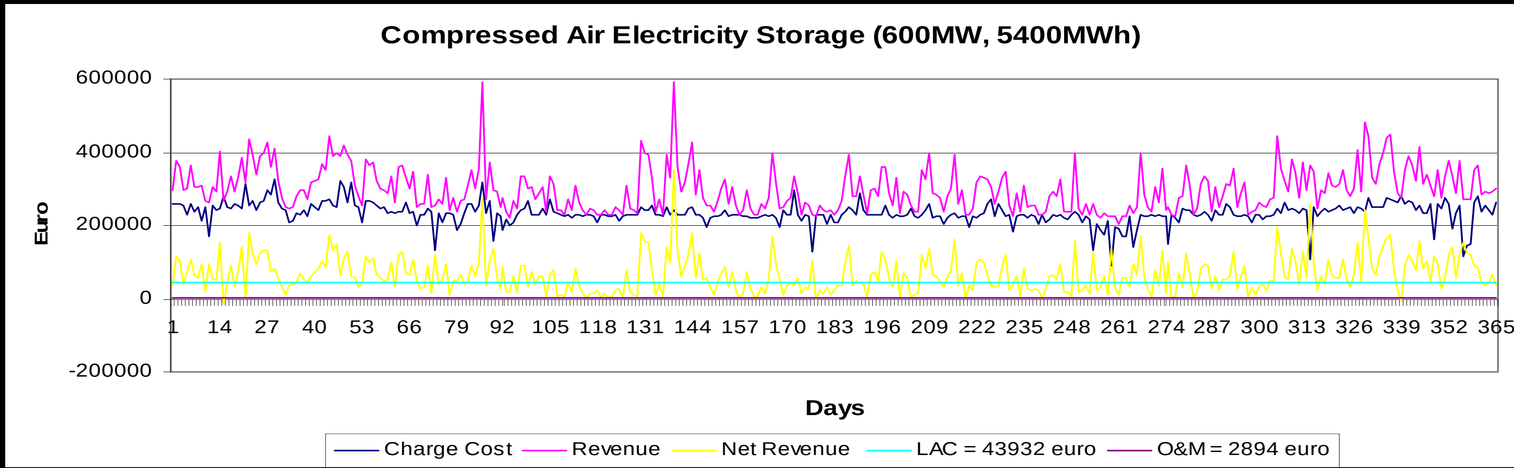

Capital cost: Capacity ($/MW)
HFC
CAES
FW
PS
LAB
VRB
0
1,000,000
2,000,000
Capital cost: Capacity ($/MW)


Capital cost: Storage Size ($/MWh)
HFC
CAES
FW
PS
LAB
VRB
0
500,000
1,000,000
1,500,000
Capital cost: Storage Size ($/MWh)

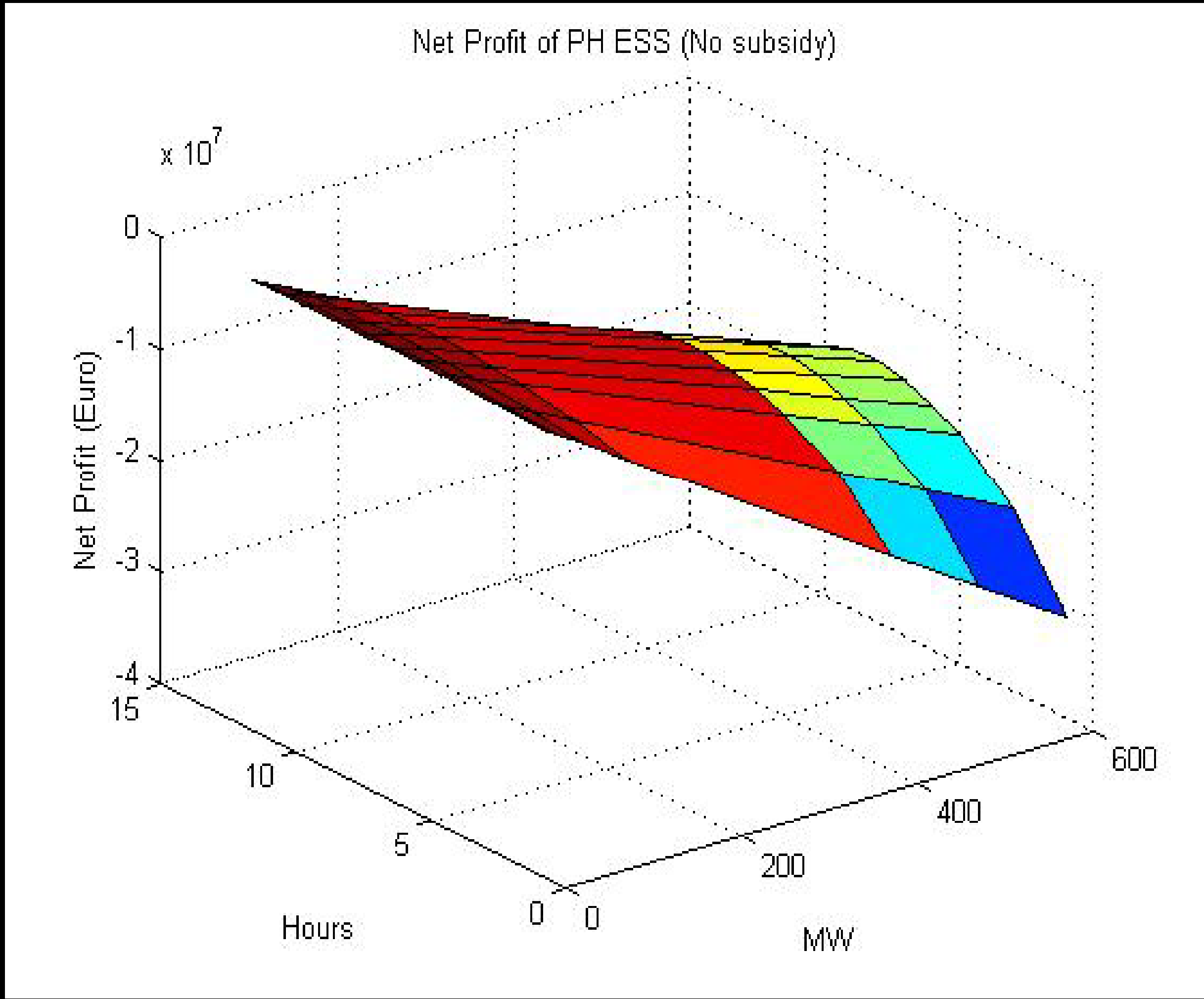

O&M: Fixed ($/MW)
HFC
CAES
FW
PS
LAB
VRB
0
10,000
20,000
30,000
O&M: Fixed ($/MW)
10 yr replacement cost ($/MWh)
HFC
CAES
FW
PS
LAB
VRB
0
500,000
1,000,000
Replacement cost ($/MWh)

Screening Study

- Assume daily cycling with capacity from 100-600MW and storage from 1-12hours
- Revenues based on pool prices from an hourly scheduling simulation for the power system in the year 2020
- Identical efficiency, payment period and interest rate assumed for all storage.

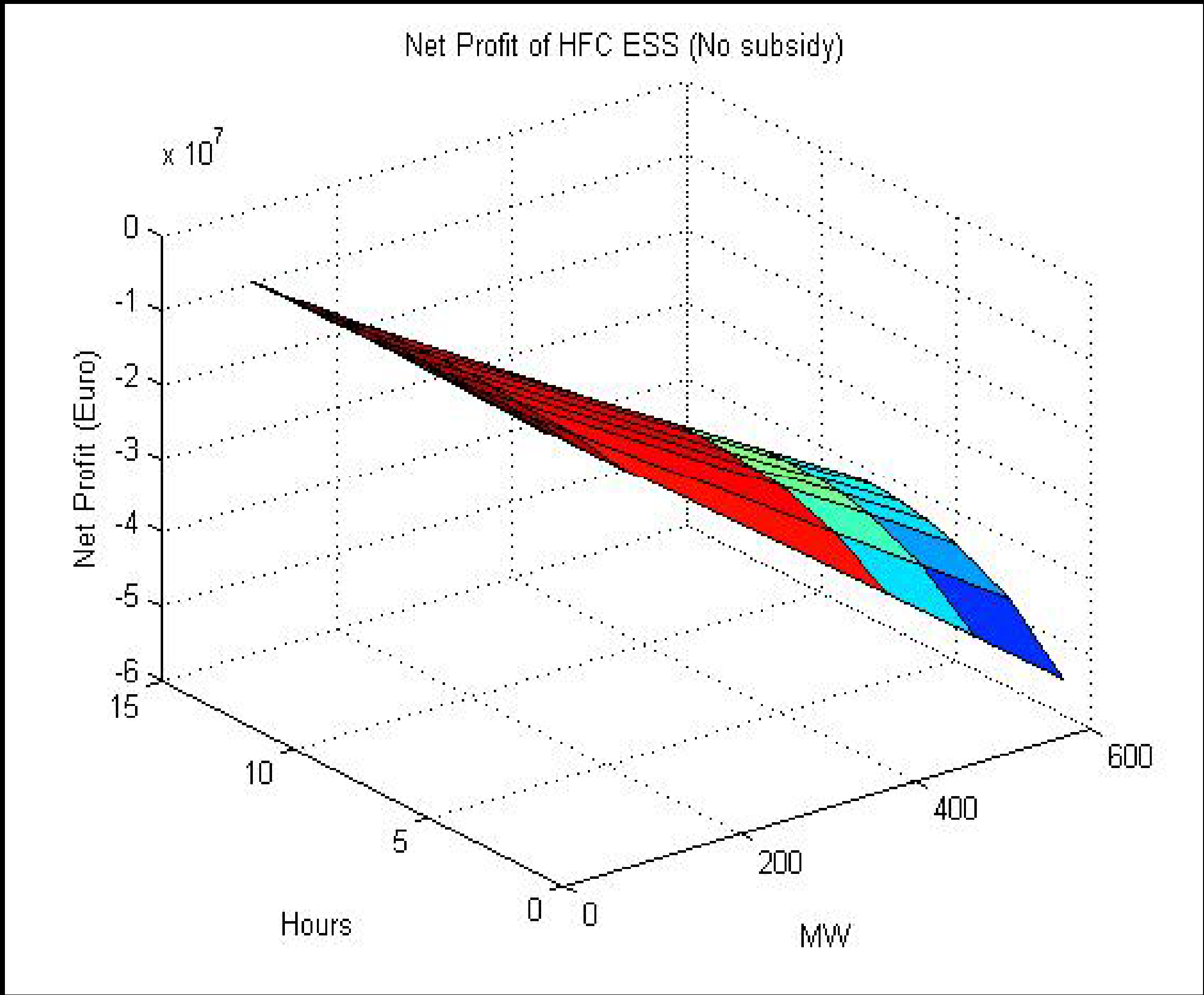


Screening Study Results



Consulting, Analysis, Research, Training & Advice

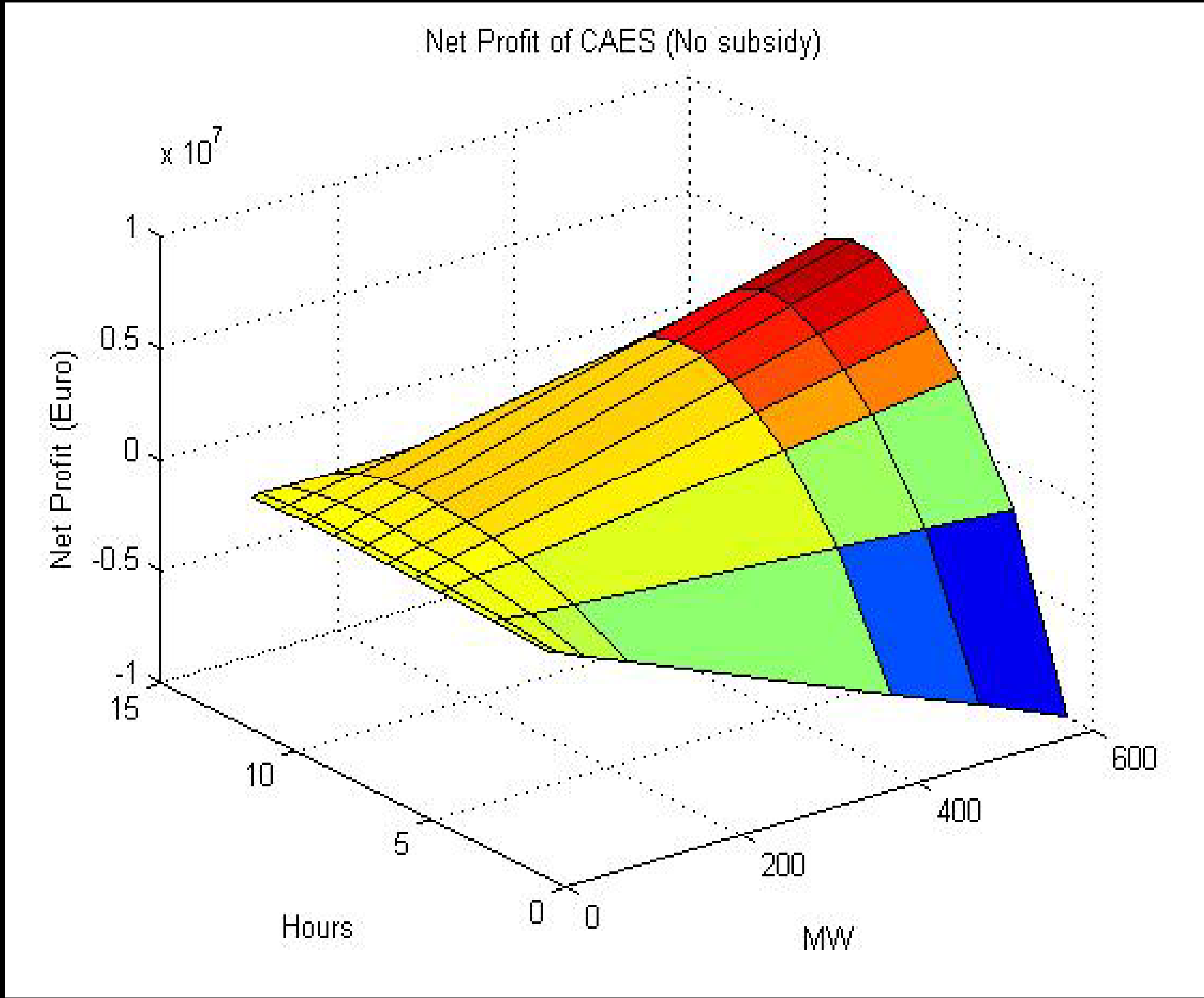
Screening Study Results



Ecar ENERGY

Consulting, Analysis, Research, Training & Advice

Screening Study Results



Consulting, Analysis, Research, Training & Advice

Scheduling Model Analysis

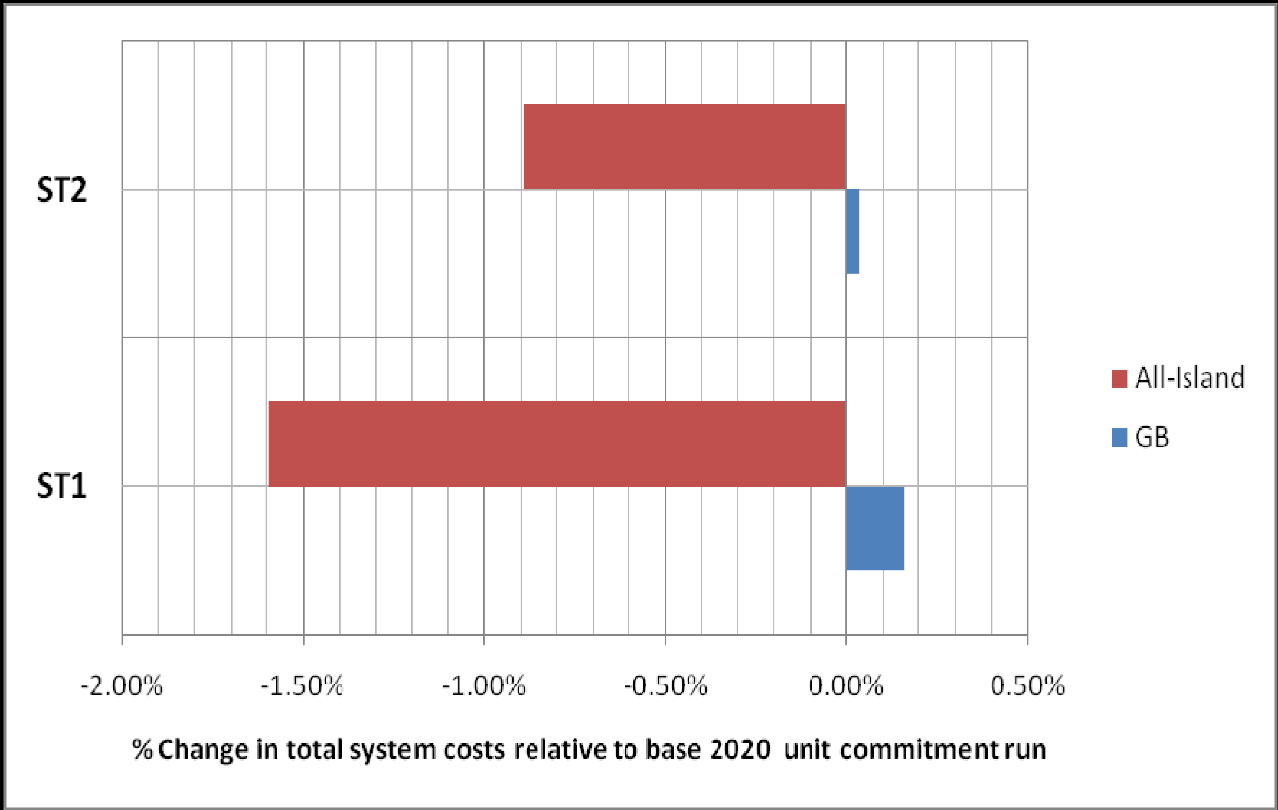
- Aim : Model the selected storage technology in a high wind generation scheduling model
  - Impact of storage on total system costs
  - Impact on other generation
  - Impact on emissions
  - Impact on prices
- Two CAES plants were modelled in the scheduling model with operational and intertemporal constraints included
  - ST1: 1200MW, 3000MWh
  - ST2: 300MW, 3000MWh
  - Efficiency of 78% assumed

Impact on Total System Costs

- Scheduling model operates similar to wholesale market eg SEM
- System cost reduction is the only objective, storage like all other generation is a means to archive the objective
- Using storage should help with cost reduction
  - Increase production of cheap base load plant
  - Decrease production of expensive peaking plant
- Only if cost of moving the energy is better than any other alternative
  - E.g. Storing wind energy may appear to make sense but not burning fuel may be a cheaper solution !

Impact on Total System Costs

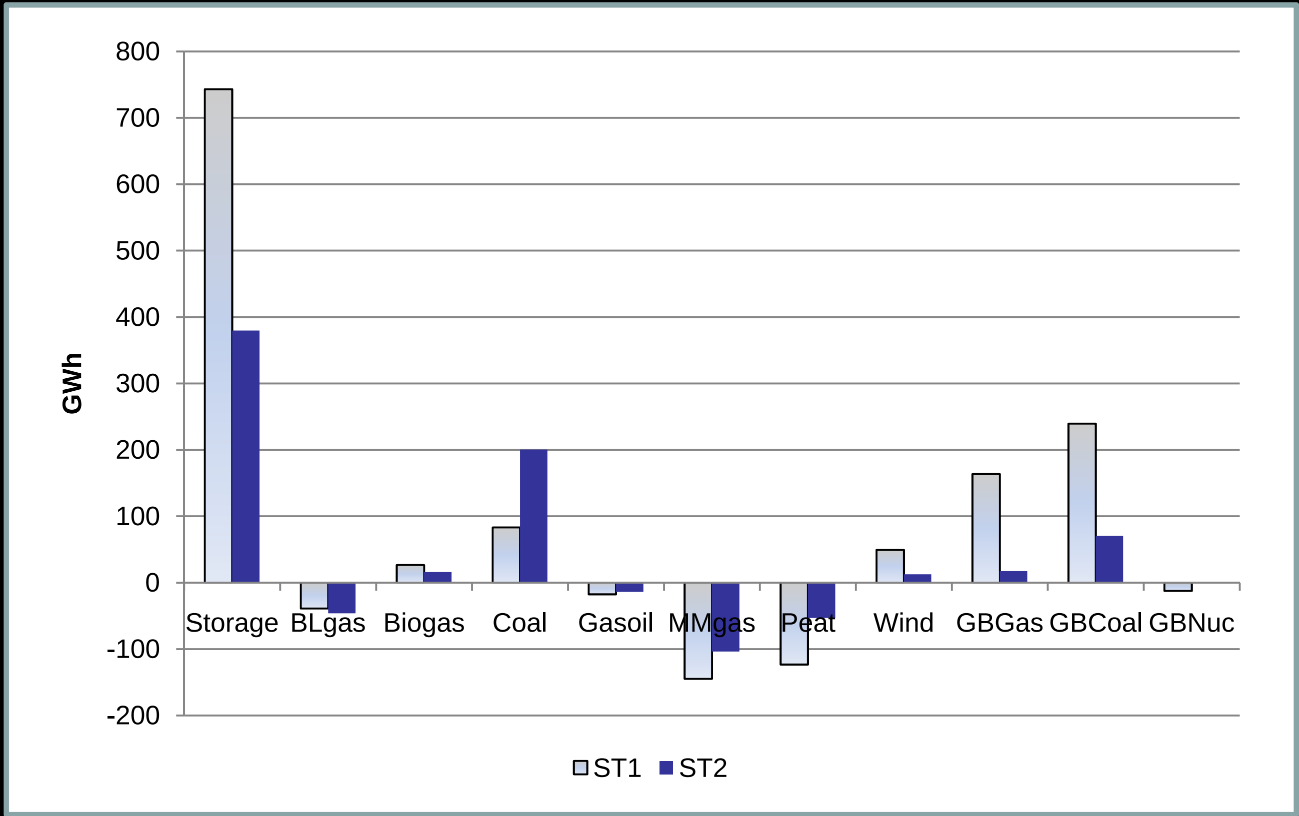
- Comparison made with no-storage and ST1, ST2 yearly scheduling simulations



Consulting, Analysis, Research, Training & Advice

Impact on Other Generation

- Larger ST1 plant makes use of baseload GB plant, ST1 facility too small to increase use of same plant



Ecar ENERGY

Consulting, Analysis, Research, Training & Advice

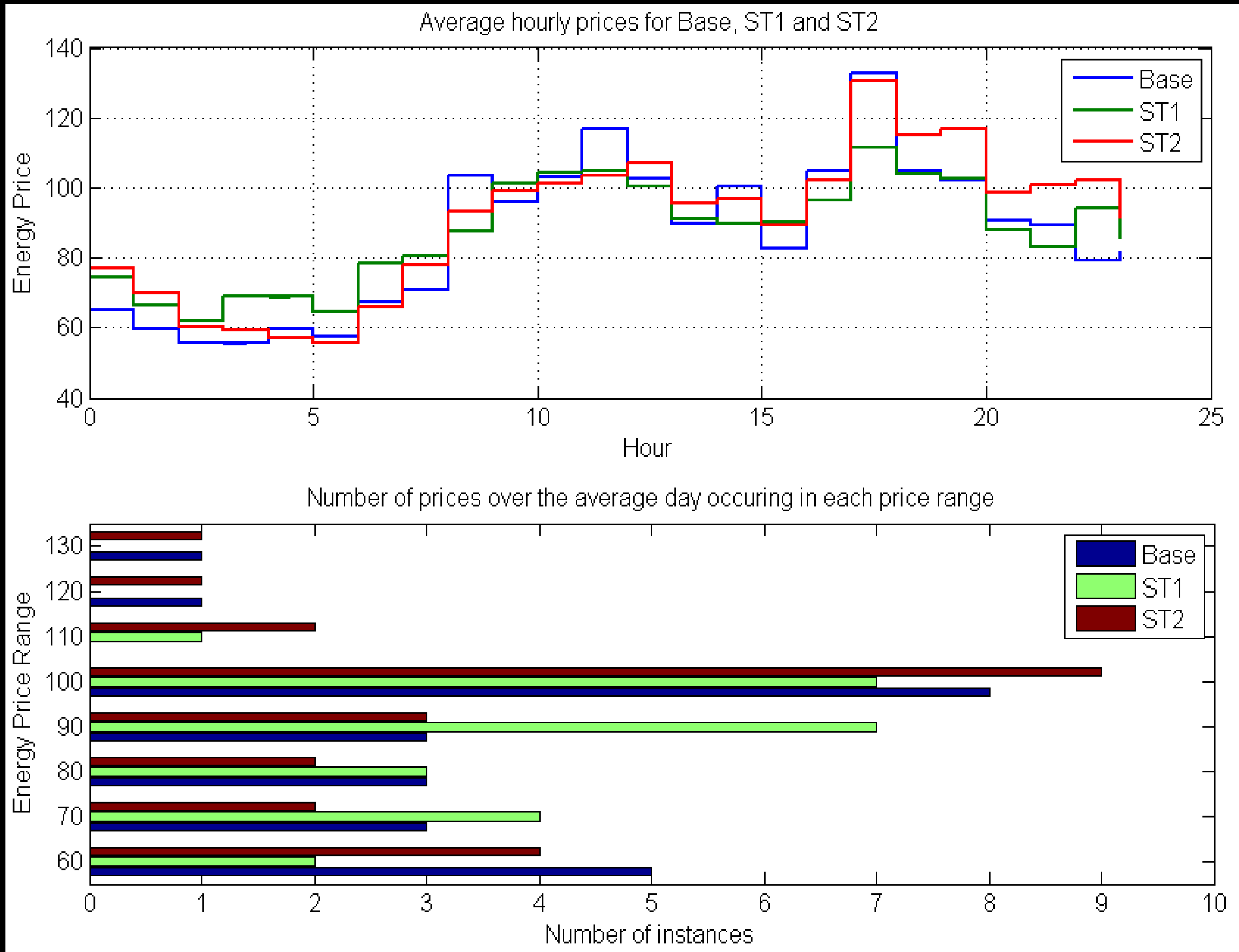
Impact on Emissions

- Impact on emissions driven by change in generation usage

Region	Base Case (Mt/year)	ST 1 (Mt/year)	ST 2 (Mt/year)
Ireland	15.5	15.34	15.52
GB	190.4	190.62	190.43
Total	205.9	205.96	205.95

- The increased use of base load GB plant increases GB emissions in ST1 while reducing All-Island emissions
- ST2 causes increased use of All-Island base load increasing All-Island emissions
- In both cases the cost reductions achievable with storage are at the expense of a slight increase in emissions , (carbon at €30/t)

Impact on Prices



Impact on Prices

- The scheduling of storage decreases the price spread

	Base Case (€/MWh)	ST 1 (€/MWh)	ST 2 (€/MWh)
Standard deviation of prices	21.3	14.5	20.5
Storage load factor		5.4%	12.6%

- The larger ST1 facility has a significant flattening effect on prices and an associated reduction in load factor compared to ST2
- Energy revenues are very dependant on load factor

Profitability of Storage

- Appropriately sized storage brings societal benefits
- Could a new CAES facility “wash its face” in the 2020 power system examined here on energy arbitrage alone ?
- Caveats of this analysis :
  - Use the ST1 and ST2 plants only
  - Capital costs of CAES are a big unknown
  - Very basic financing assumed
  - Other revenues not considered

Costs of Storage

	Schoenung and Hassenzahl (2003)	Ridge Energy Storage (2005)	Lund et al. (2009)
Power related cost	425 $/kW	504 $/kW	
Energy (cavern) related cost	35 $/kWh	101 $/kWh	
Balance of plant	50 $/kW	28 $/kW	
Fixed O&M per annum	2.50 $/kW	14 $/kW	
Compressor Variable Cost			2.3 €/MWh
Turbine Variable Cost			2.7 €/MWh
Variable O&M Cost		1.50 $/MWh	
Assumed Efficiency	73%	80%	69%
Heat Rate	3800 – 4400 Btu/kWh	4500 Btu/kWh	

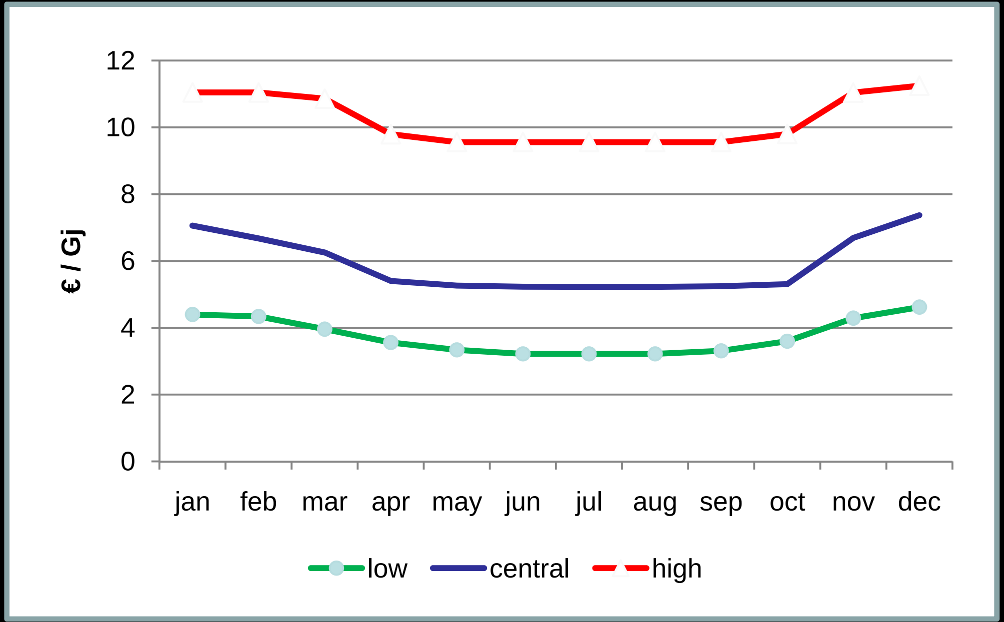
Costs of Storage

- Low central and high cost cases were considered

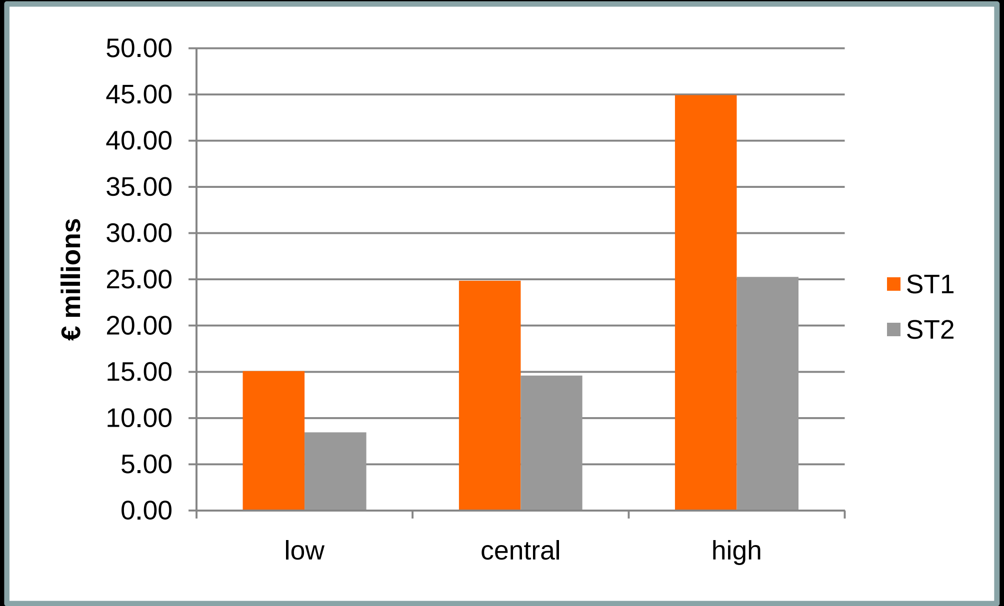
ST1 : 1200 MW turbine, 3000MWh (M€)	Power related cost	Energy (cavern) related cost	Balance of plant cost	Total Capital costs	Annualised @ 8% for 20 years	Fixed O&M cost
Low	402.0	84.0	26.4	512.4	52.2	2.4
Central	439.2	162.0	37.2	638.4	65.0	7.8
High	476.4	240.0	46.8	763.2	77.7	13.2

ST2 : 300 MW turbine, 3000MWh (M€)	Power related cost	Energy (cavern) related cost	Balance of plant cost	Total Capital costs	Annualised @ 8% for 20 years	Fixed O&M cost
Low	100.5	84.0	6.6	191.1	19.5	0.6
Central	109.8	162.0	9.3	281.1	28.6	2.0
High	119.1	240.0	11.7	370.8	37.8	3.3

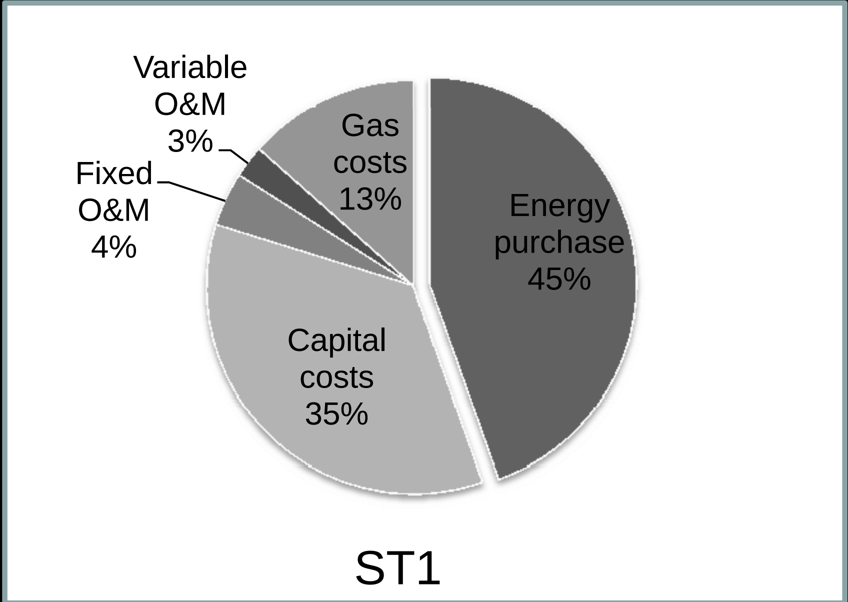
Gas Cost

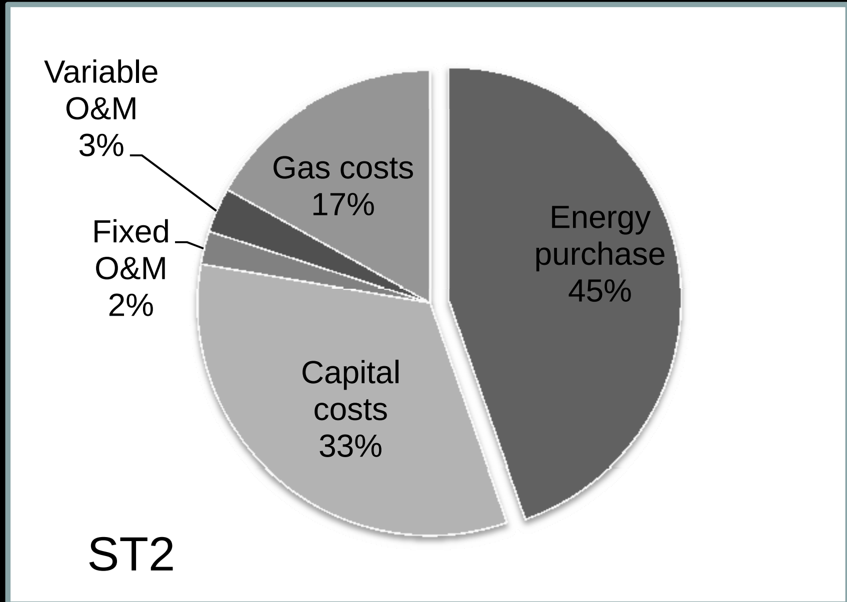


Gas & Carbon Cost



Cost Breakdown





Profitability

Annual Costs in € millions for ST1	Cost Scenario		
	Low	Central	High
Energy purchase costs	82.3	82.3	82.3
Total Capital costs	52.2	65	72
Fixed costs	2.4	7.8	13.2
Variable costs	2.4	4.7	9.5
Gas and carbon	15.0	24.8	45
Total cost	154.3	184.6	222
Total Energy Revenues	96	96	96

Annual Costs in € millions for ST2	Cost Scenario		
	Low	Central	High
Energy purchase costs	38.61	38.61	38.61
Total Capital costs	19.5	28.6	37.8
Fixed costs	0.60	2.0	3.3
Variable costs	1.3	2.7	5.4
Gas and carbon	8.5	14.6	25.3
Total cost	68.5	86.5	110.4
Total Energy Revenues	66	66	66

Conclusions

- If centrally based scheduling of energy in a power system is assumed then in the system examined here
  - Storage isn't special
  - Storage with capacity of < 3% peak demand < 10hrs storage brings benefits to the system and the owners
- Modelling carried out here is a floor on possible benefits
- Increased benefits may accrue to
  - System operators
    - Variability management, reserve, ancillary services
  - Owners
    - Uplift, capacity payments, ancillary payments, portfolio management