European Best Practice Guidelines for the Evaluation of CO_2 Capture Technologies

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Outline

- The European Benchmarking Task Force
- Results achieved
  - The Common Framework Definition Document (CFDD)
  - Test Cases for reference
  - Economic assessment
- Summary

The European Benchmarking Task Force

- Consistent and transparent comparison of CO_2 capture technologies is **important** and **difficult**
- A team was created with representatives from three FP7 projects – CAESAR, CESAR and DECARBit to
  - Elaborate a Common Framework Definition Document (CFDD)
  - Define and analyse set of test cases
- The results of the work were to be made public and easily accessible to the CCS community

1. The Common Framework Definition Document

- The purpose is **NOT** to recommend any values as the best or the right ones for future power plants
- The purpose **IS** to define a set of parameters to ensure that technical and economic comparison of novel cycles involving novel technologies is done in a consistent and fair way
- The choice of parameters is justified and the source acknowledged, for example IEA, DOE, EU, specialized publications, other projects, expert opinion and others are identified

1. The Common Framework DD

Operating & cost parameters of components based on novel technologies

- Ambient conditions
- Unit systems
- Fuel characteristics

Operating & cost parameters of standard components

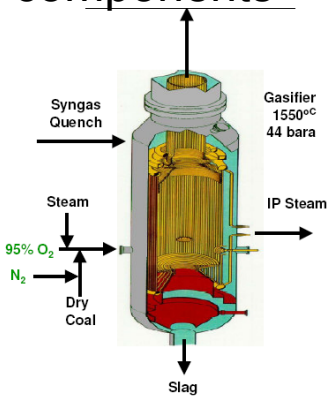
New air separation technologies

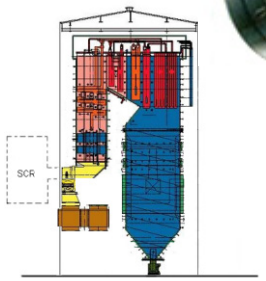
New CO_2 separation technologies

Cycle 1

Cycle 2

Cycle n





Consistent comparison of new technologies and cycles

2. The test cases

- Three cases without and with CO_2 capture
  - Integrated Gasification Combined Cycle
  - Natural Gas Combined Cycle
  - Ultra Super Critical Pulverized Coal
- The purpose is **NOT** to compare power generation technologies
- The purpose **IS** to propose references for comparisons of novel cycles within the same power generation technology – PF, IGCC, NGCC
- Contents of the report, for each case
  - Cycle description in detail
  - Heat and mass balance analysis
  - Operational characteristics
  - Operational performance
  - Comparison of results independently produced by two of the three projects

2. The test cases

- General assumptions
  - Plants operating at nominal base load
  - ‘New and clean’ conditions
- Assessment of the Specific Primary Energy Consumption for CO_2 Avoided – SPECCA:

$$SPECCA = \frac{HR - HR_{REF}}{E_{REF} - E} = \frac{3600 \cdot \left(\frac{1}{\eta} - \frac{1}{\eta_{REF}} \right)}{E_{REF} - E}$$

  - HR = heat rate of the plants
  - E = CO_2 emission rate of the plants
  - REF = reference plant without CO_2 capture

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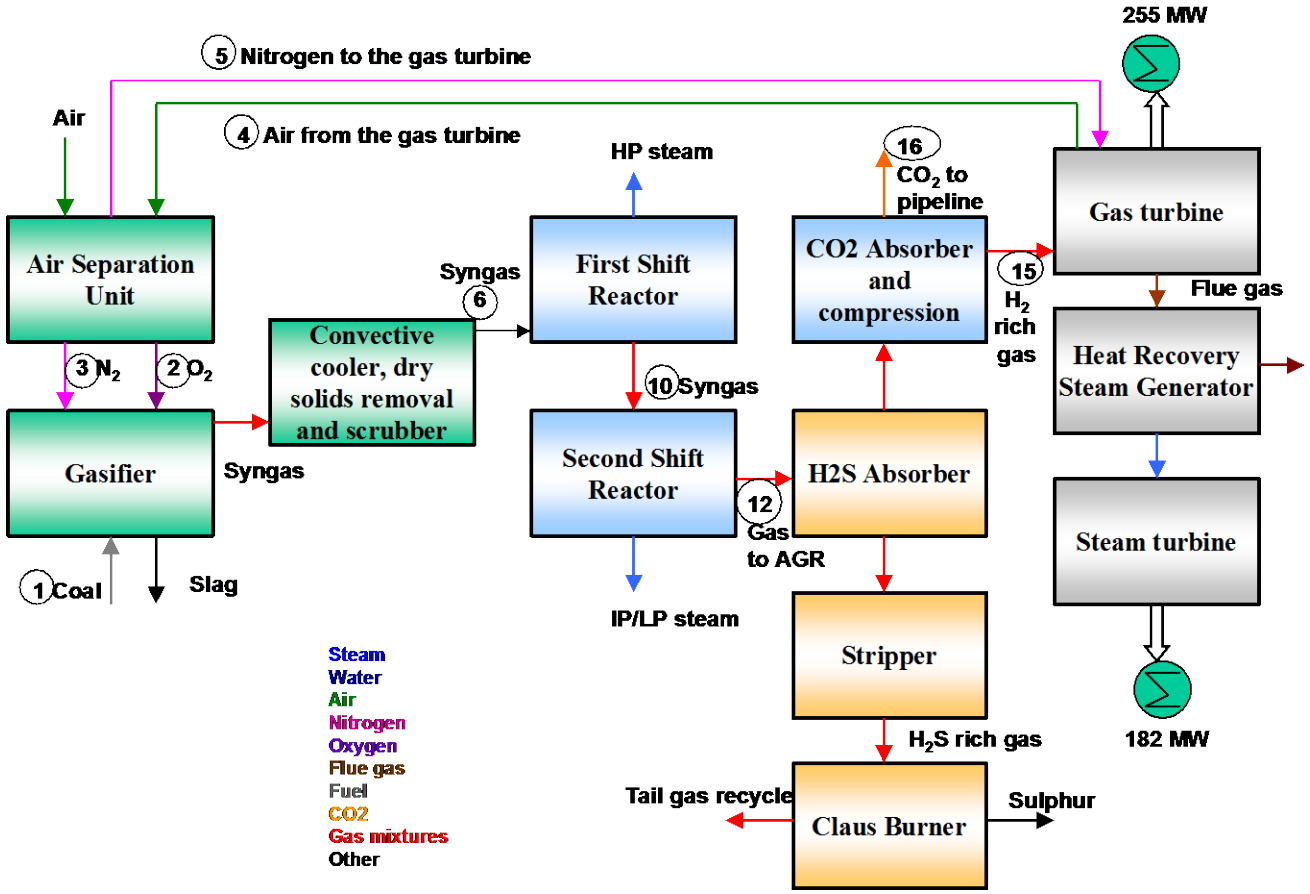
2. The test cases

- Integrated Gasification Combined Cycle with capture

DECARBit and CAESAR



2. The test cases

- Integrated Gasification Combined Cycle with capture

DECARBit and CAESAR

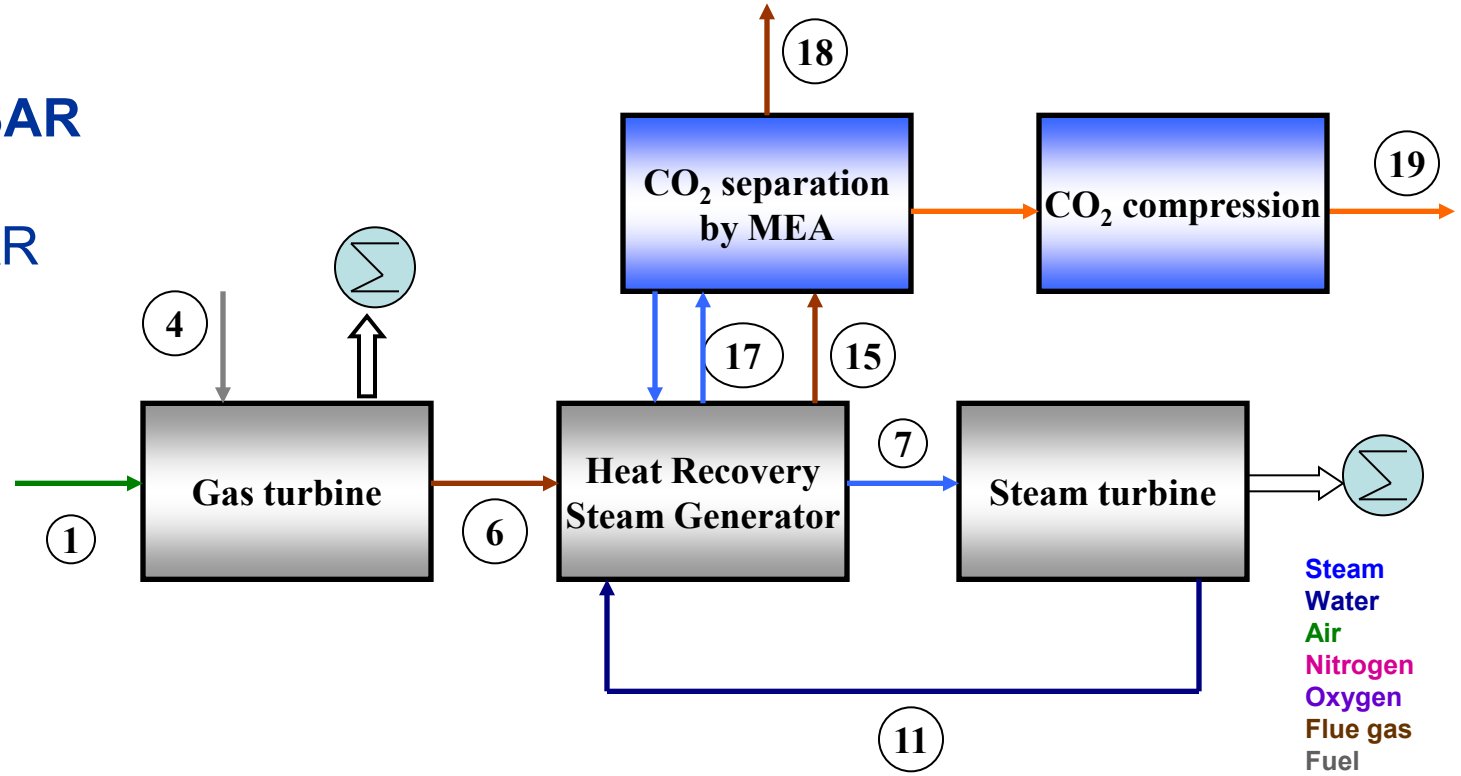
Comparison of some characteristics and performance

	DECARBit MWe	CAESAR MWe
GT output	282.87	304.97
ST output	168.46	175.95
Gross elec. power output	457.17	491.09
Total aux. power consumption	104.43	107.61
Net electric power out.	352.74	383.48
Efficiency	36.66	36.40
Specific emissions kg/MWh	85.28	97.54
SPECCA	3.30	3.67

2. The test cases

- Natural Gas Combined Cycle with capture

CAESAR
and
CESAR



2. The test cases

- Natural Gas Combined Cycle with capture

CAESAR and CESAR

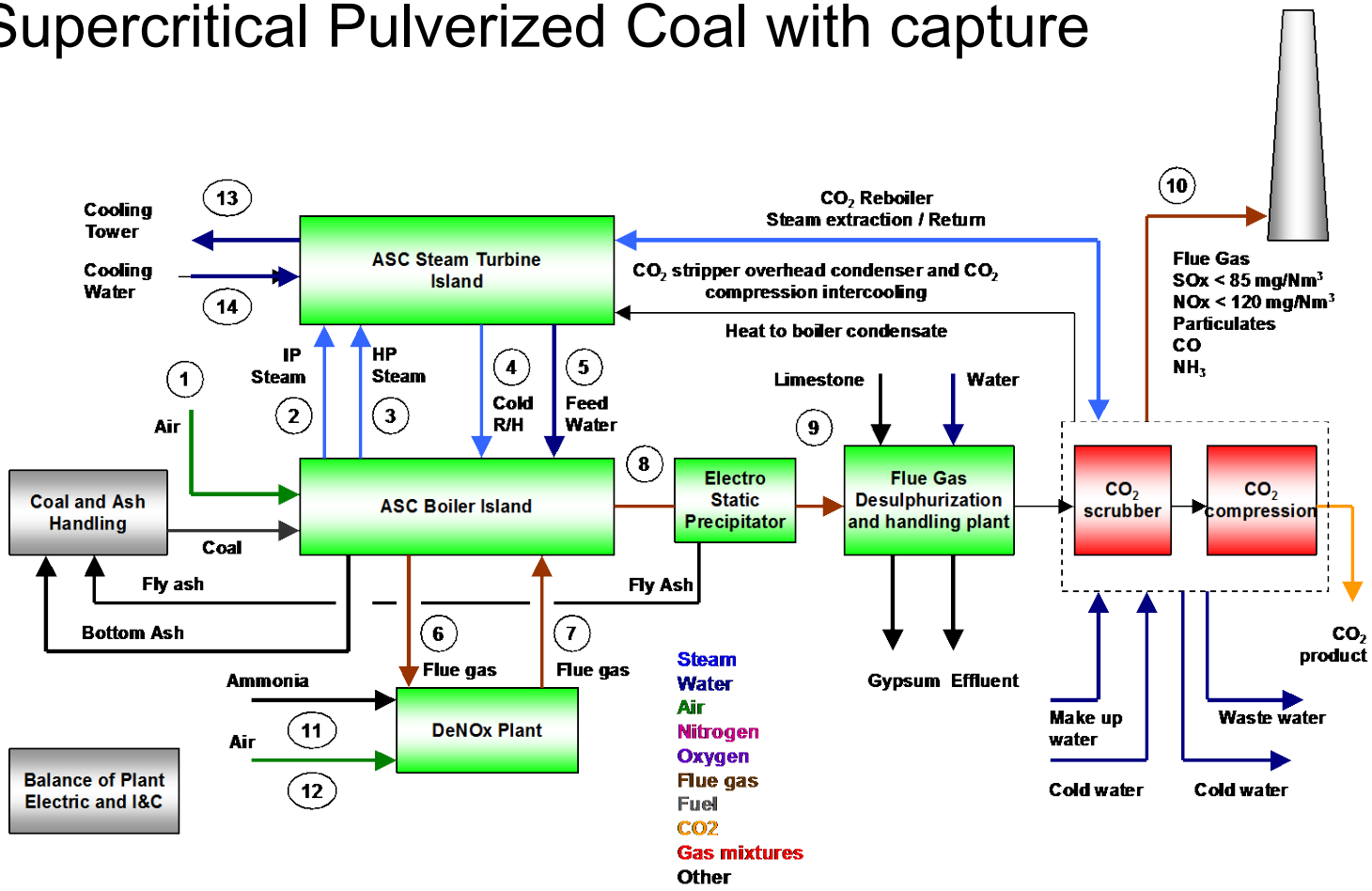
Comparison of some characteristics and performance

	CAESAR	CESAR
Number of Gas Turbines	2	1
GT power output MWe	272.10	289.20
ST power output MWe	215.70	99.10
Gross elec. power output MWe	754.90	388.30
Total aux. power cons. MWe	45.20	31.50
Net electric power out. MWe	709.70	356.80
Efficiency	49.90	49.30
Specific emissions kg/MWh	36.20	41.90
SPECCA MJ/kgCO_2	3.30	3.61

2. The test cases

- Ultra Supercritical Pulverized Coal with capture

CESAR
and
CAESAR



2. The test cases

- Ultra Supercritical Pulverized Coal with capture

CESAR and CAESAR

Comparison of some characteristics and performance calculated by two projects

	CESAR MWe	CAESAR MWe
ST gross power output	684.20	686.90
Total aux. power consumption	135.00	124.50
Net electric power output	549.20	562.40
Efficiency with capture	33.40	33.50
CO2 emitted kg/MWh	104.70	104.00
SPECCA MJ/kgCO_2	4.35	4.16

3. Economic assessment

- *Parameters and assumptions* -

- Long term future economic developments are hard to predict, so 2008 was chosen as the reference year (start of the three projects)
- Average Chemical Engineering Plant Cost Index (CEPCI) of 576% is assumed for 2008 (100% for 1958)
- Power plant economic lifetime = 25 years
  - 40 years also considered for coal power plants, as in ENCAP, CASTOR and CESAR
  - 15 years also considered for natural gas power plants
- Construction time
  - 4 years for coal and lignite
  - 3 years for natural gas

3. Economic assessment

- *Method* -

- Estimations are made of
  - Capital costs
  - Fixed and variable operation and maintenance costs
  - Fuel costs
- Capital investment cost is calculated with
  - Bottom-up approach – using parameters derived from the heat and mass balance calculations
  - Top-down approach – based on equipment supplier estimates of entire Engineering, Procurement and Construction Costs

3. Economic assessment

- *Evaluation criteria* -

- Economic viability measured through
  - CO_2 avoidance cost
  - Breakeven Electricity Selling Price (BESP)
    - capital investment costs
    - fixed O&M costs (e.g. Labour)
    - variable O&M costs (consumables)
    - fuel costs
- A sensitivity analysis is made with respect to main assumptions (e.g. specific investment costs, fuels, etc.)

3. Economic assessment

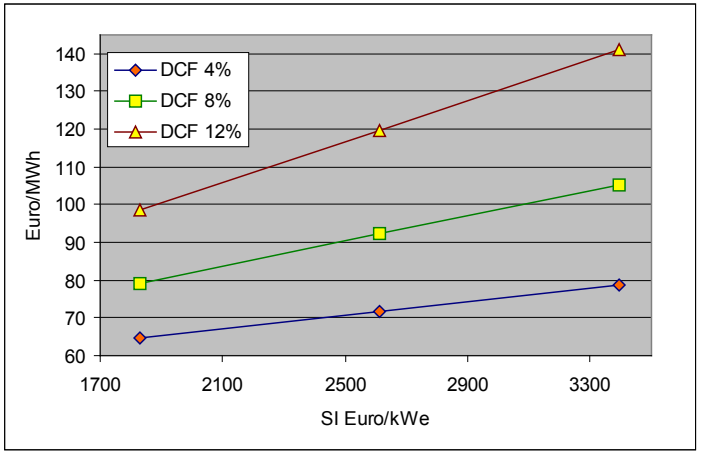
- *Test cases* -

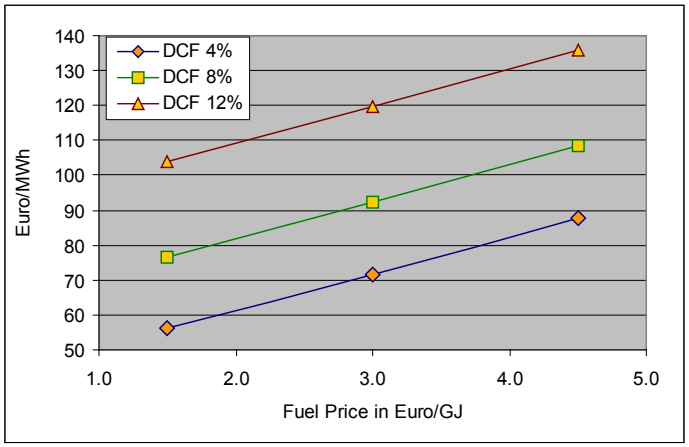
- Advanced super-critical pulverized coal
  - Top down approach
    - Engineering, Procurement and Construction costs quote requested to power plant and turbine suppliers for the entire power plant in 2008, with uncertainty of + - 30%
    - Suppliers also requested to estimate fixed and variable operating costs
    - For the CO_2 capture plant, quotes for the main equipment were requested from several vendors, for calculated equipment sizes
    - Installation costs estimated as percentages of the equipment costs

3. Economic assessment

- *Advanced super-critical pulverized coal* -

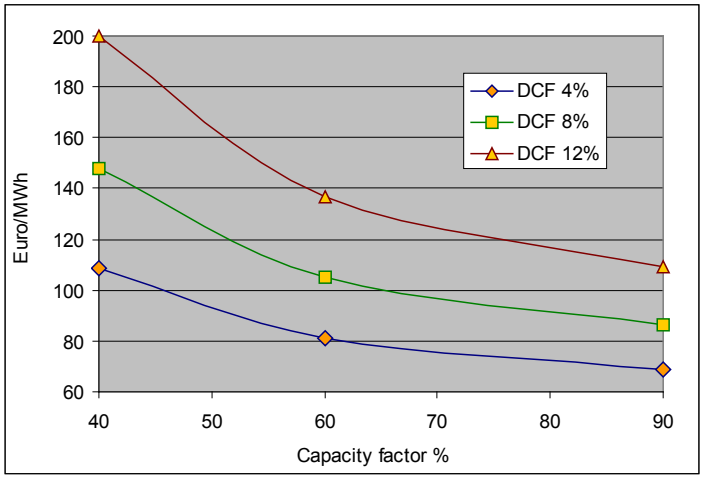
BESP versus specific investment

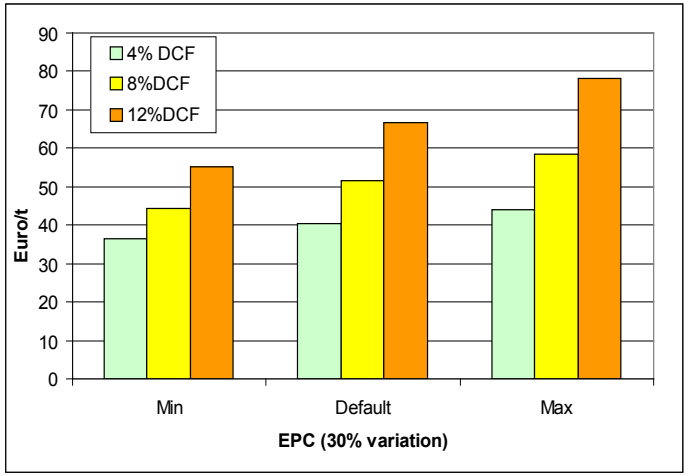




BESP versus fuel price

BESP versus capacity factor





CO_2 avoidance cost versus Specific investment variation

3. Economic assessment

- *Test cases* -

- Integrated gasification combined cycle
  - Bottom up approach - equipment and installation costs estimated for:

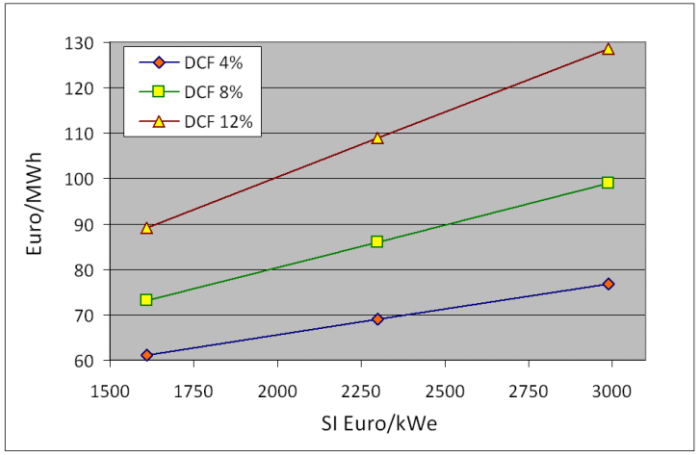
Coal handling
Gasifier
Gas turbine
Steam turbine
Heat recovery steam generator
Low temperature heat recovery
Cooling
Air separation unit

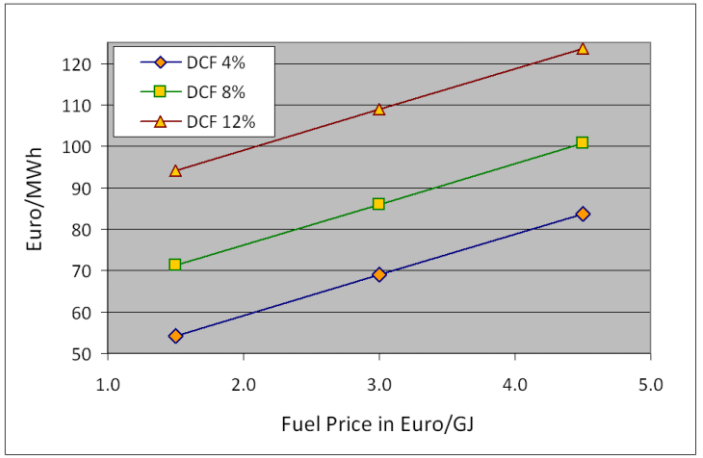
Ash handling
Acid gas removal
Gas cleaning
Water treatment
Water gas shift reactor
Claus burner
Selexol plant
CO_2 compression unit

3. Economic assessment

- *Integrated gasification combined cycle* -

BESP versus specific investment





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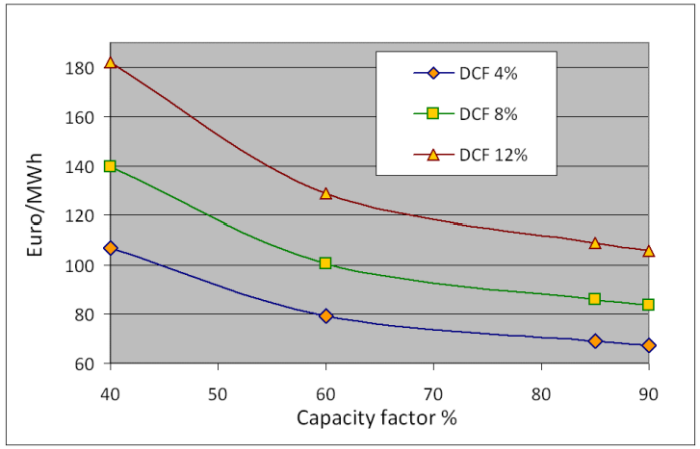

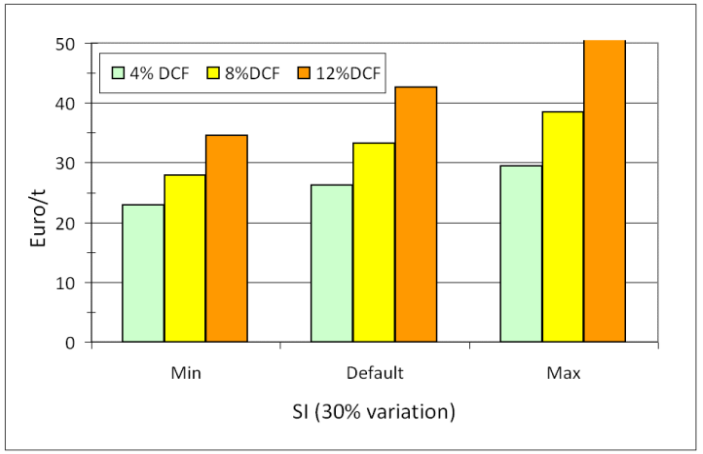

CO_2 avoidance cost versus Specific investment variation

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3. Economic assessment

- *Test cases* -

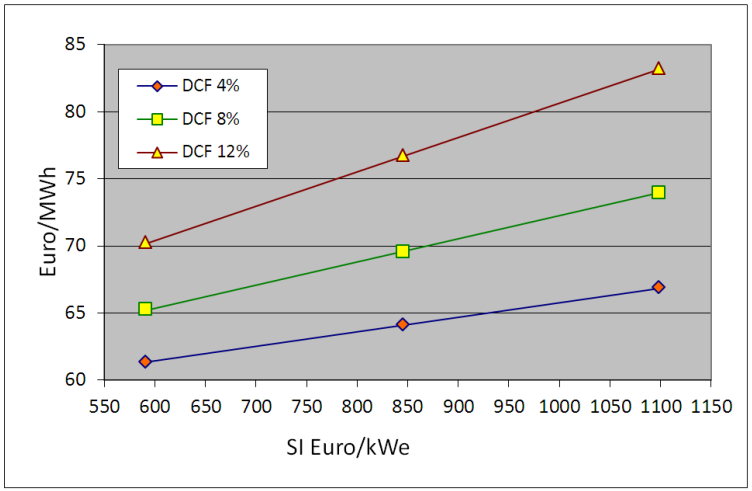
- Natural gas combined cycle
  - Bottom up approach - equipment and installation costs estimated for:

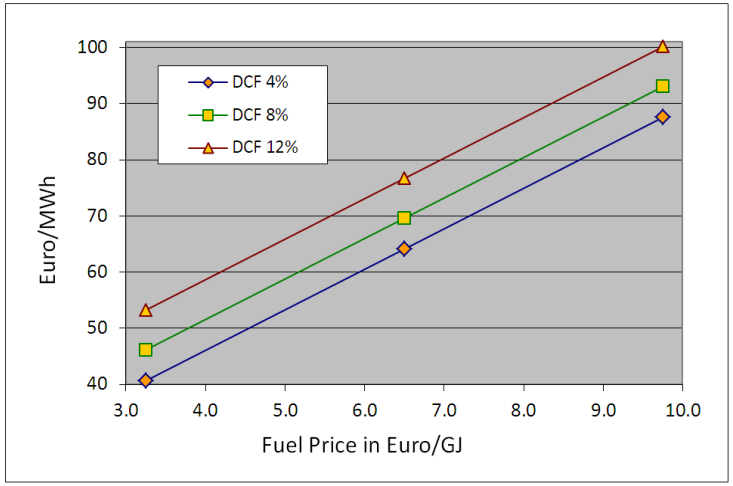
    Gas turbine
    GT generator and auxiliaries
    Steam turbine
    ST generator and auxiliaries
    Feedwater and miscellaneous
    BOP systems
    MEA CO_2 separation system
    CO_2 compression unit

3. Economic assessment

- *Natural gas combined cycle* -

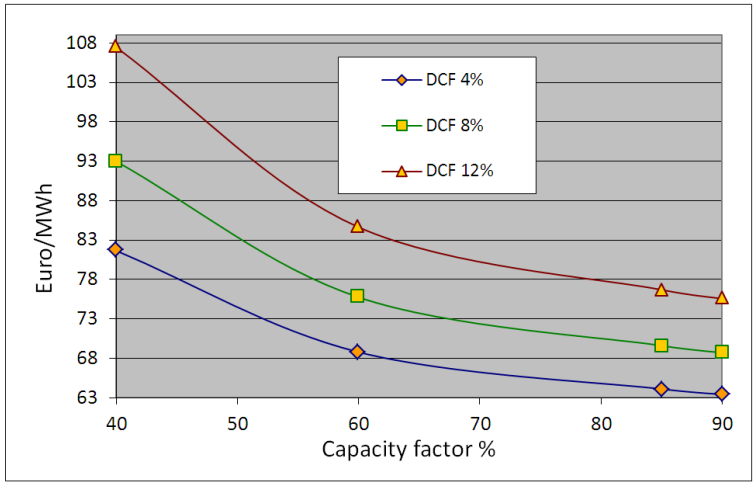
BESP versus specific investment

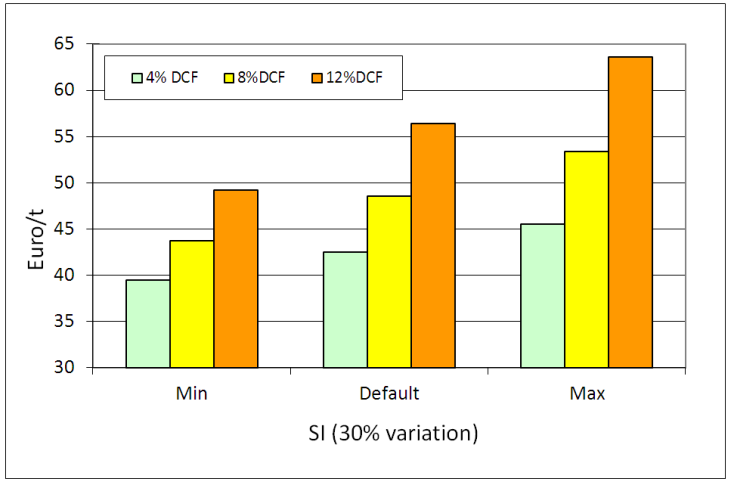




BESP versus fuel price

BESP versus capacity factor





CO_2 avoidance cost versus Specific investment variation

Summary

- What was achieved
  - Common Framework Definition Document

    Standard parameters and assumptions to be adopted for consistent techno-economic evaluations of Carbon Capture technologies
  - Test cases and preliminary benchmarking results from the three projects – technical part
  - Test cases and preliminary benchmarking results from the three projects – economic part
- Possible future developments with new EU projects but also with North America and Australia, where a similar interest exists at this moment.

Thanks for your attention!!

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