CESI RICERCA

Third International Conference on Clean Coal Technologies for our Future - CCT 2007

Cagliari, 15-17 May 2007

Pre-feasibility Study of a Flexible Hydrogen-Electricity Co-production IGCC Coal-fed Plant with CO_2 Capture and Sequestration

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This work has been financed by the Ministry of Economic Development with the Research Fund for the Italian Electrical System under the Contract Agreement established with the Ministry Decree of March 23, 2006

SUMMARY

- Objectives and general criteria
- Plant configuration and flexibility
- Performance analysis
- Localisation
- Financial evaluation: assumptions and results
- Conclusions

Introduction / 1

- Objective: to assess the technical and economic feasibility of a coal-fed IGCC plant with CO_2 capture and sequestration
- Plant configuration allows to rapidly switch from only electric to electric-hydrogen co-production according to the kWh price in the electricity market
- Plant net electric power is about 70 MW, so it can be considered as a demo plant with industrial features, even if of small size
- Considering authorisation procedures, social acceptance problems and likely need of public funding support, the small size of the plant should make decisions easier

Introduction / 2

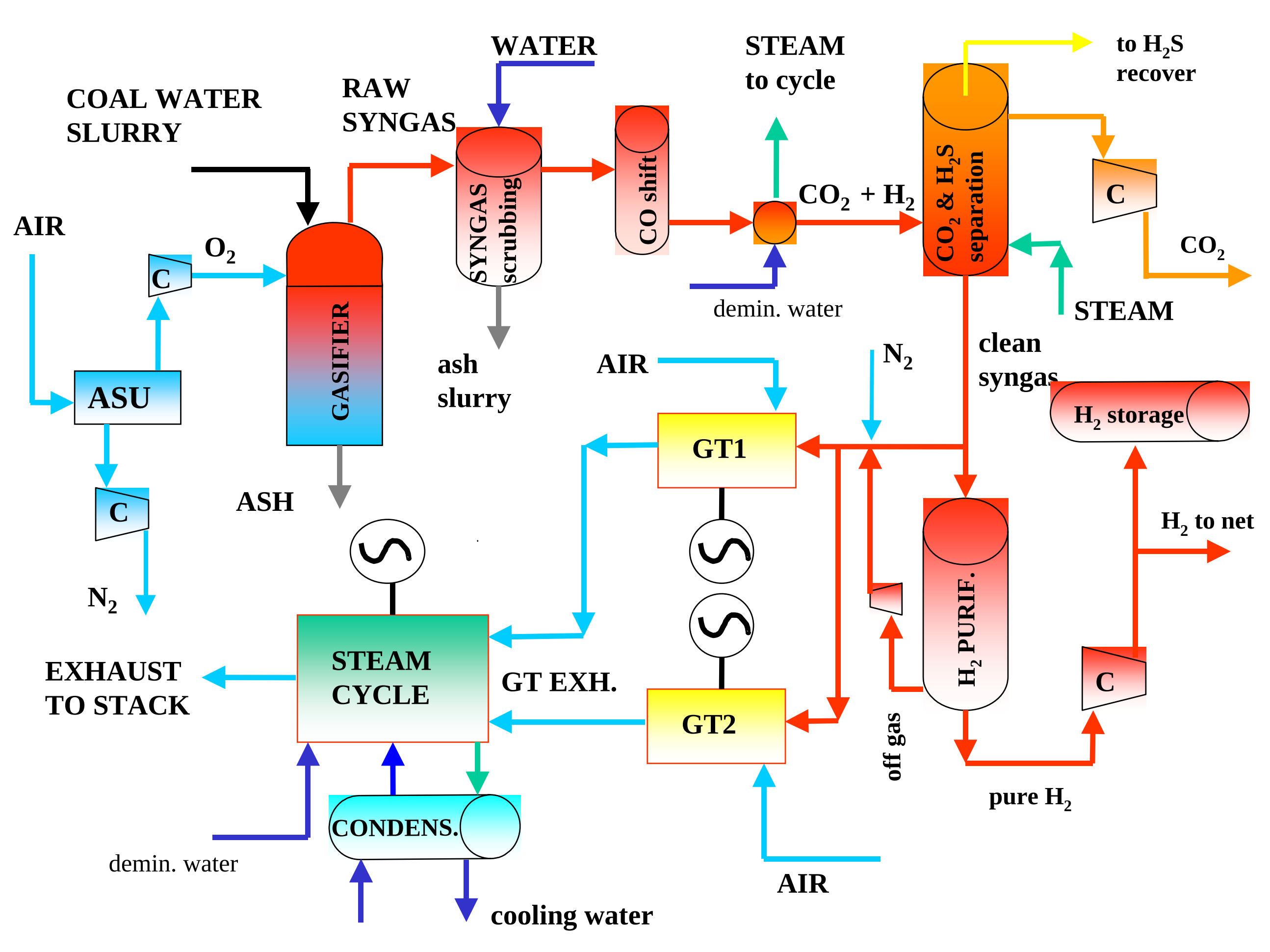
- Basic criterion is to only consider proven and commercially ready technologies, in order to favour IGCC reliability and reduce construction time, rather than to maximise the overall efficiency or minimise investment cost
- The considered site is in Portovesme industrial area within the Sulcis coal basin.
- The plant is assumed to be fed by 100% Sulcis coal
- Unminable coal seams at some tens of km from plant site are considered for geological storage of captured CO_2

Plant configuration / 1

- Low pressure cryogenic air separation unit (ASU) non integrated to power island, supplying 95% pure O_2 to gasifier and N_2 to GT for fuel dilution.
- Gasification island: GE -Texaco technology (coal slurry fed and syngas quenching). This technology is widely used in Italian refineries and allows to reduce capital cost compared to other technologies.
- Syngas cooling and two stages sour shift
- AGR unit based on Selexol™ solvent (90% of CO_2 capture): moderate capital and operation costs compared to ammines, high reliability
- SRU unit by conventional Claus-Scott process. Significant recovery of solid S due to high 6% S-content in Sulcis coal is economically justified, steam is produced by oxidation of H_2S to SO_2.

Plant configuration / 2

- CO_2 compression (to 100 bar) and drying unit for sending the gas by pipeline to the injection field (40 km estimated length)
- PSA unit for hydrogen separation and purification (99,98% purity), operated in co-production mode. Off-gas from PSA is mixed to residual syngas from AGR and fed to GT. An in site hydrogen storage (reservoir capacity: 2000 m^3 at 200 bar) is sized for 12 hours of equivalent production.
- Power island is made of two identical 25 MW TG (Siemens ST-600), each followed by an HRSG, and by one, 46 MW steam turbine.
- Sea water is used for the steam condenser cooling and make up water by reverse osmosis desalination unit is also provided.



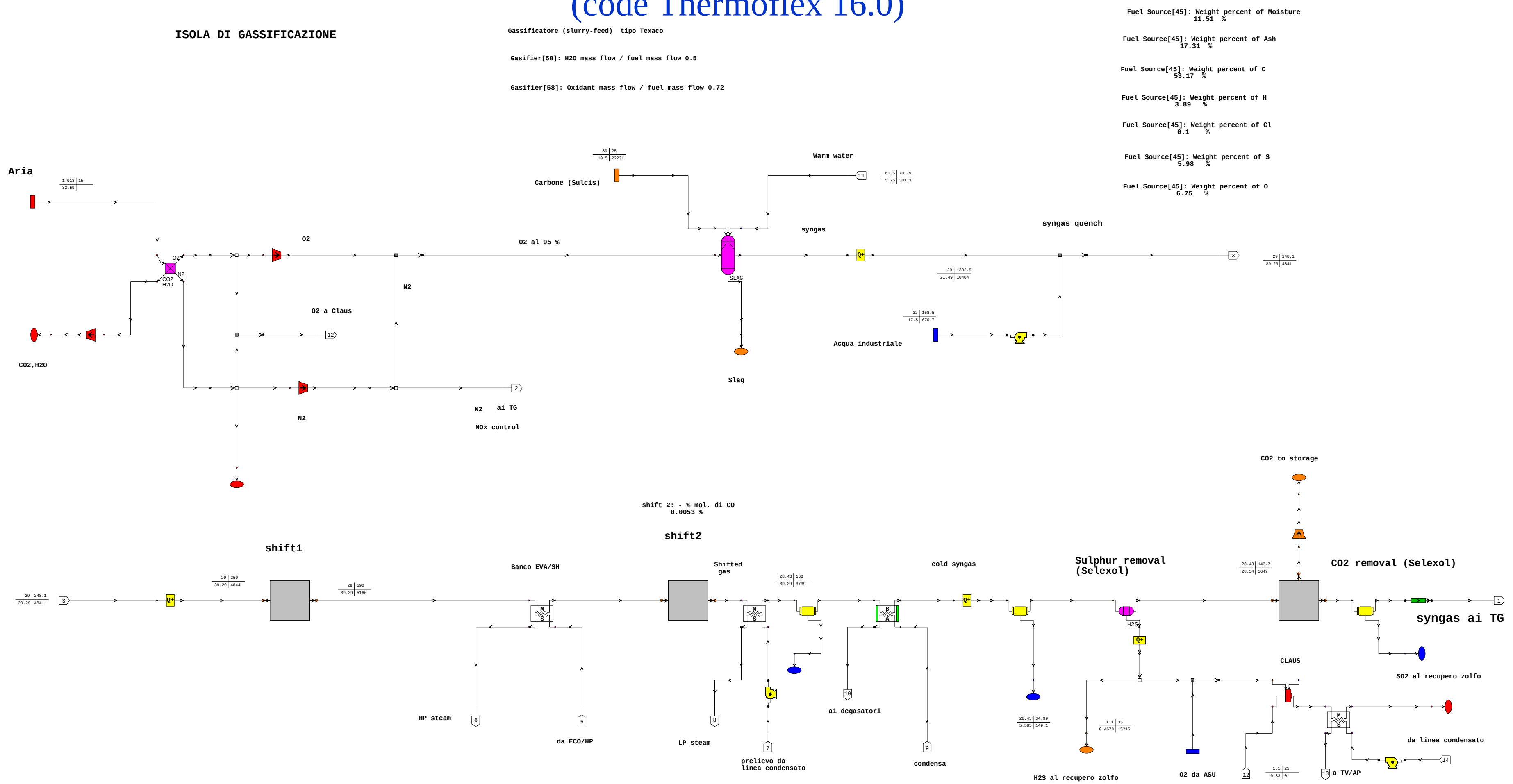
Schematic plant configuration

Flexible operation approach and modelling

- General approach: gasifier at 100% capacity, variable electric power.
- Frequent load changes of the gasifier are avoided
- A modular power island configuration is necessary: twin GT's and HGRS allow to reduce the output from 100 % to 25%
- Modular configuration increase plant availability, too
- Steady-state modelling has been performed by Thermoflex™ (16.0) code, considering the 3 different operating conditions:
- only electric production (two GT at 100% load; set up 100%-100%);
- medium hydrogen co-production (one GT off, one GT on at 100% load; set up 0%-100%);
- high hydrogen co-production (one GT off, one GT on at 50% load; set up 0%-50%).

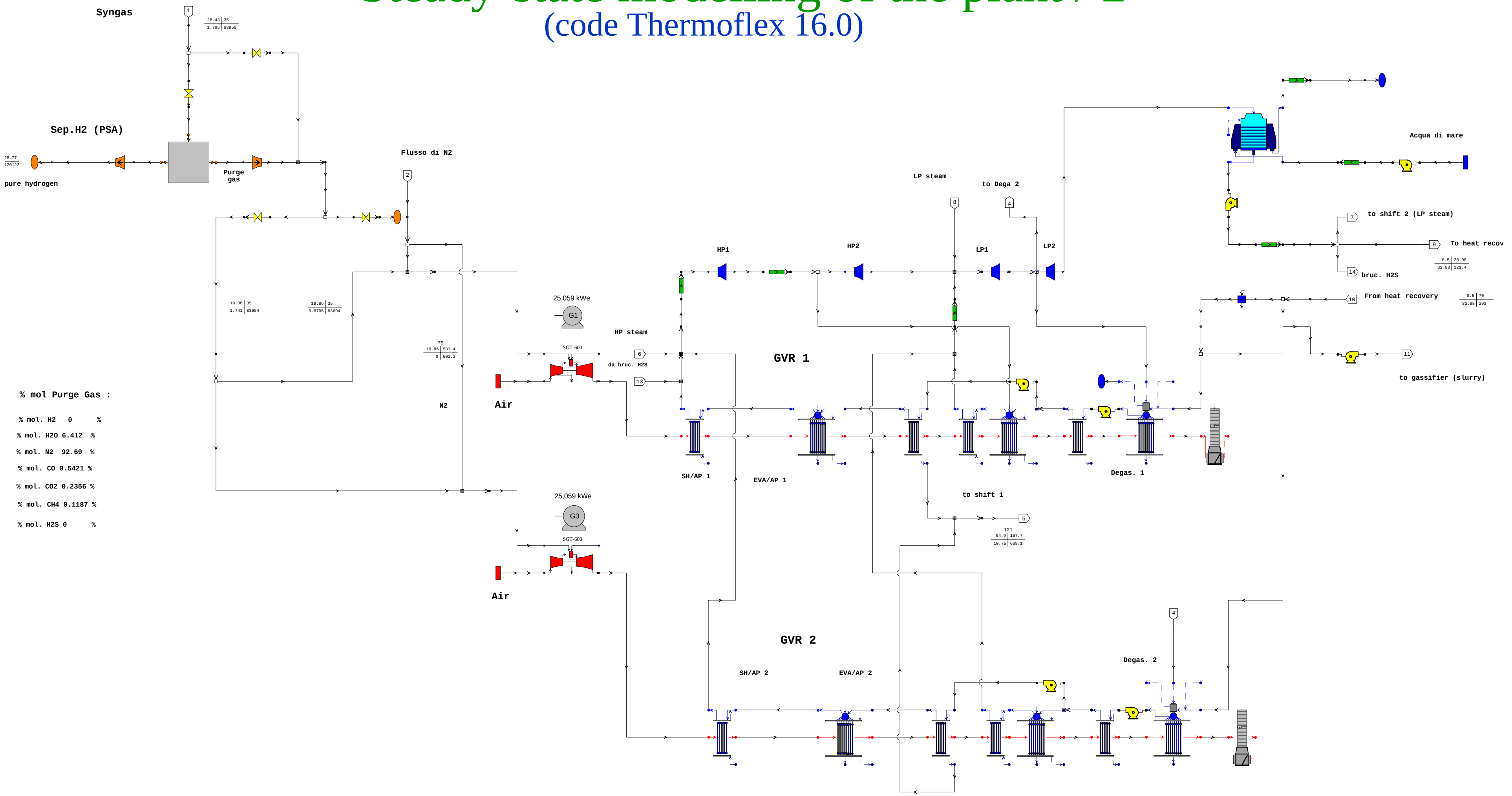
Steady-state modelling of the plant / 1

(code Thermoflex 16.0)



Steady-state modelling of the plant / 2

(code Thermoflex 16.0)



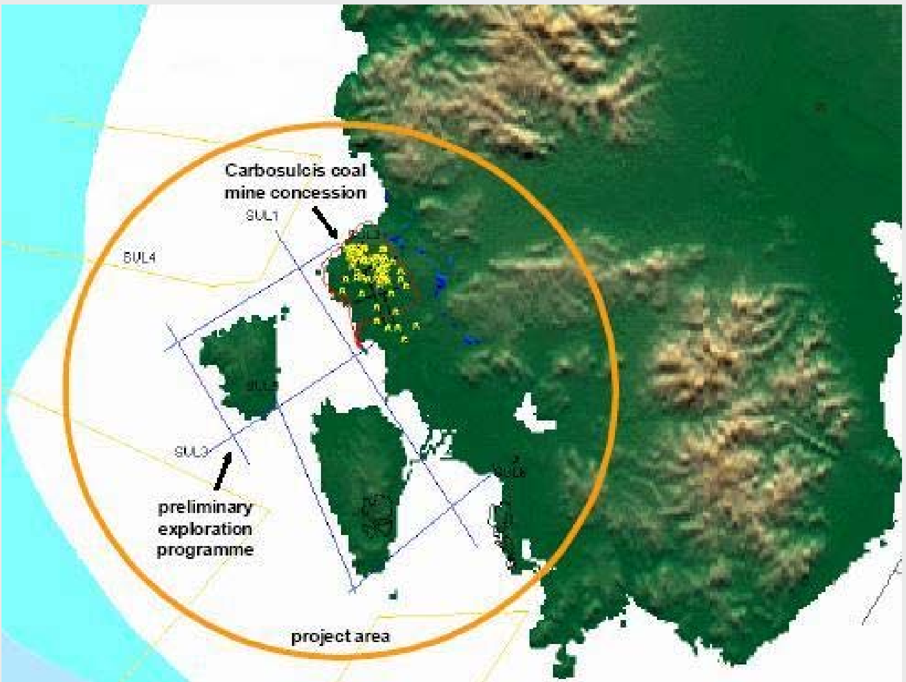
Main results of plant simulation

Plant set up	100%-100%	0%- 100%	0%- 50%	units
Gasification island				
Coal feed to gasifier	10.35	10.35	10.35	kg/s
Produced syngas total flow rate	21.24	21.24	21.24	kg/s
Power island				
GT1 syngas flow rate	1.078	1.505	1.270	kg/s
GT1 load	100	100	50	%
GT1 exhaust temperature	544	545	467	°C
GT1 electric power	25.18	25.37	13.04	MW_e
GT2 syngas flow rate	1.078	n.a.	n.a.	kg/s
GT2 load	100	n.a.	n.a.	%
GT2 exhaust temperature	544	n.a.	n.a.	°C
GT2 electric power	25.18	n.a.	n.a.	MW_e
ST electric power	46.01	28.85	22.93	MW_e
Gross overall electric power	96.36	54.22	35.98	MW_e
Auxiliaries consumption				
Plant auxiliaries consumption	26.63	27.88	28.83	MW_e
CO_2 drying and compression (10 MPa)	2.77	2.77	2.77	MW_e
H_2 compression (20 MPa)	0.04	2.16	3.07	MW_e
Plant parameters				
Coal thermal input (LHV)	230.1	230.1	230.1	MW_{th}
Co-produced H_2 flow rate	0.01	0.58	0.83	kg/s
Co-produced H_2 energy content	1.4	69.64	99.65	MW
Net electric power	69.72	26.33	7.15	MW_e
Plant total produced power[(1)]	71.13	95.97	106.79	MW
Plant total electric efficiency	30.3	11.5	3.1	%
Plant total energetic efficiency[(2)]	30.9	41.7	46.4	%
Captured CO_2 flow rate	19.8	19.8	19.8	kg/s

[(1)] electric power + co-produced H_2 energy content

LHV (H_2) = 120067 kJ/kg

[(2)] total produced power / coal thermal input (LHV)



Sulcis area for ECBM Project

Possible site in Portovesme (CA) industrial zone: plant area 13 ha.

General plant layout

Economic pre-feasibility: investment evaluation

(DOE metodology 1999 - “Market Based Advanced Coal Power Systems”)

Assumptions:

- 2,5 years construction time
- 6,2 % total interest on OC paid during construction (IDC)
- 9 €/m^2 land cost
- Energy threshold price: 50 €/MWh (based on Italian Electric Market 2006 data)
- Minimum period of continuos co-production: 5 h or 8 h
- 80% utilisation factor

Production configurations

Investment costs:

- Overnight cost (OC) 156,4 M€
- Total plant investment (TPI) 171,9 M€
- Specific investment 2240 €/kW

Production modes:

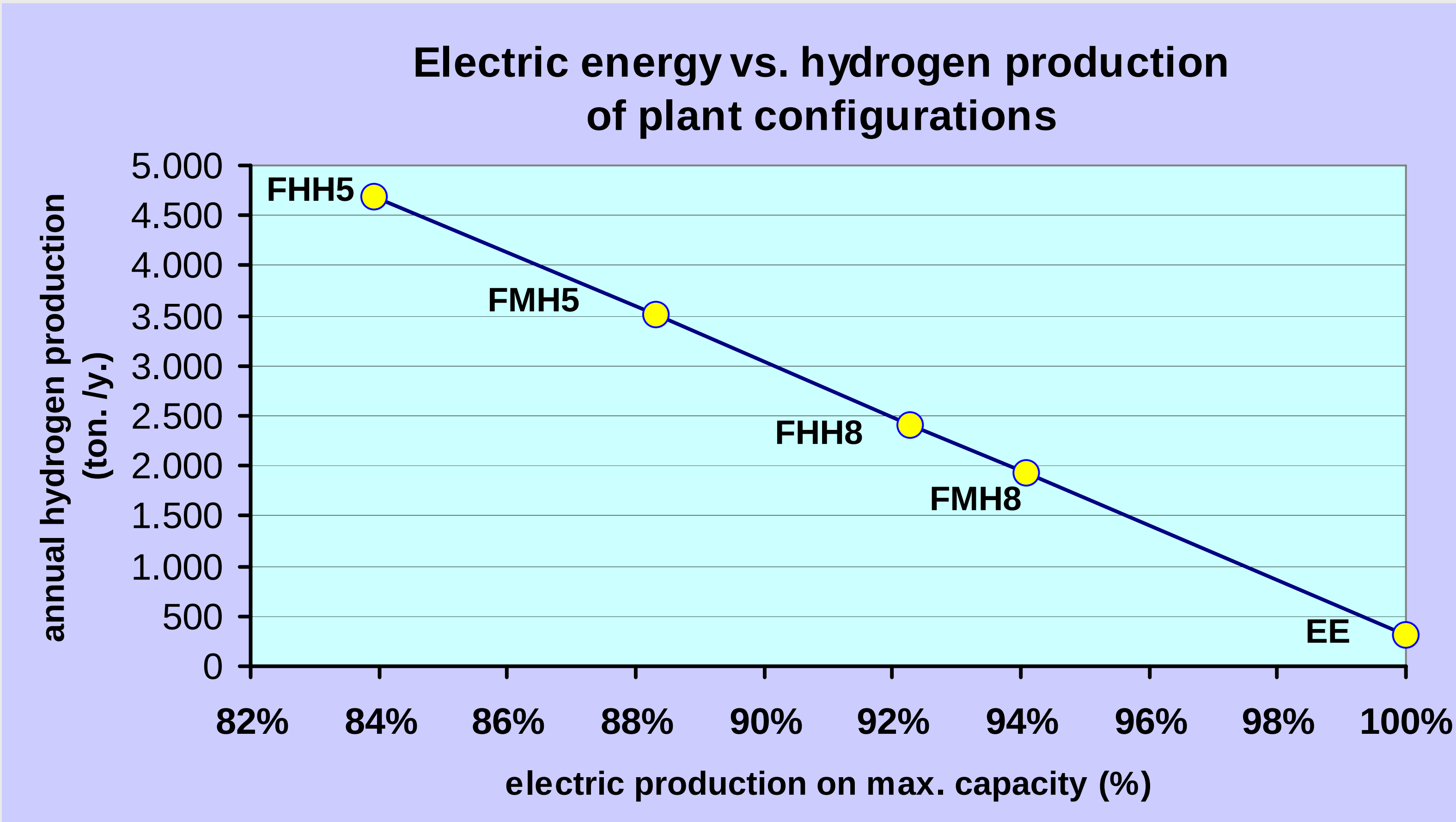
- only electric EE over 24h/day (baseline case)
- medium H_2 co-production FMH

(100%-100% load TG when price > 50 €/MWh , 0%-100% when < 50 €/MWh)

- high H_2 co-production FHH

(100%-100% load TG when price > 50 €/MWh , 0%-50% when < 50 €/MWh)

Production configurations



Production costs

Operation costs

• coal 100% from Sulcis (LHV = 20830 kJ/kg), ash-cake disposal cost included (into mines)	55 €/ton
• 45 people working staff at cost of	50000 €/y
• overhead on direct labour cost	25%
• average plant maintenance on OC (5% for power island)	2,6%
• insurance and local taxes	1%
• CO_2 transport in pipeline (40 km away) and geological storage	6,1 €/ton

Financial charge

• plant life	25 y
• equity - ROE	20% - 15%
• debt - annual cost	80% - 4,4%
• tax rate	37,25%
• funding period	20 y
• depreciation period	9 y

Production incomes

Electric energy

• calculated from hourly real prices in 2006 Italian Electric Market for Sardinia zone

Hydrogen

• gross market price (Italian market) 1,45 €/kg

Sulphur

• recovered S selling price 19 €/ton

CO_2 emission credits

• ***for electric production***

avoided CO_2 = difference between allowances from Italian Allowance Plan (according to European Trading System for "new entry" -after 2007- solid fuel plants) and actual emissions

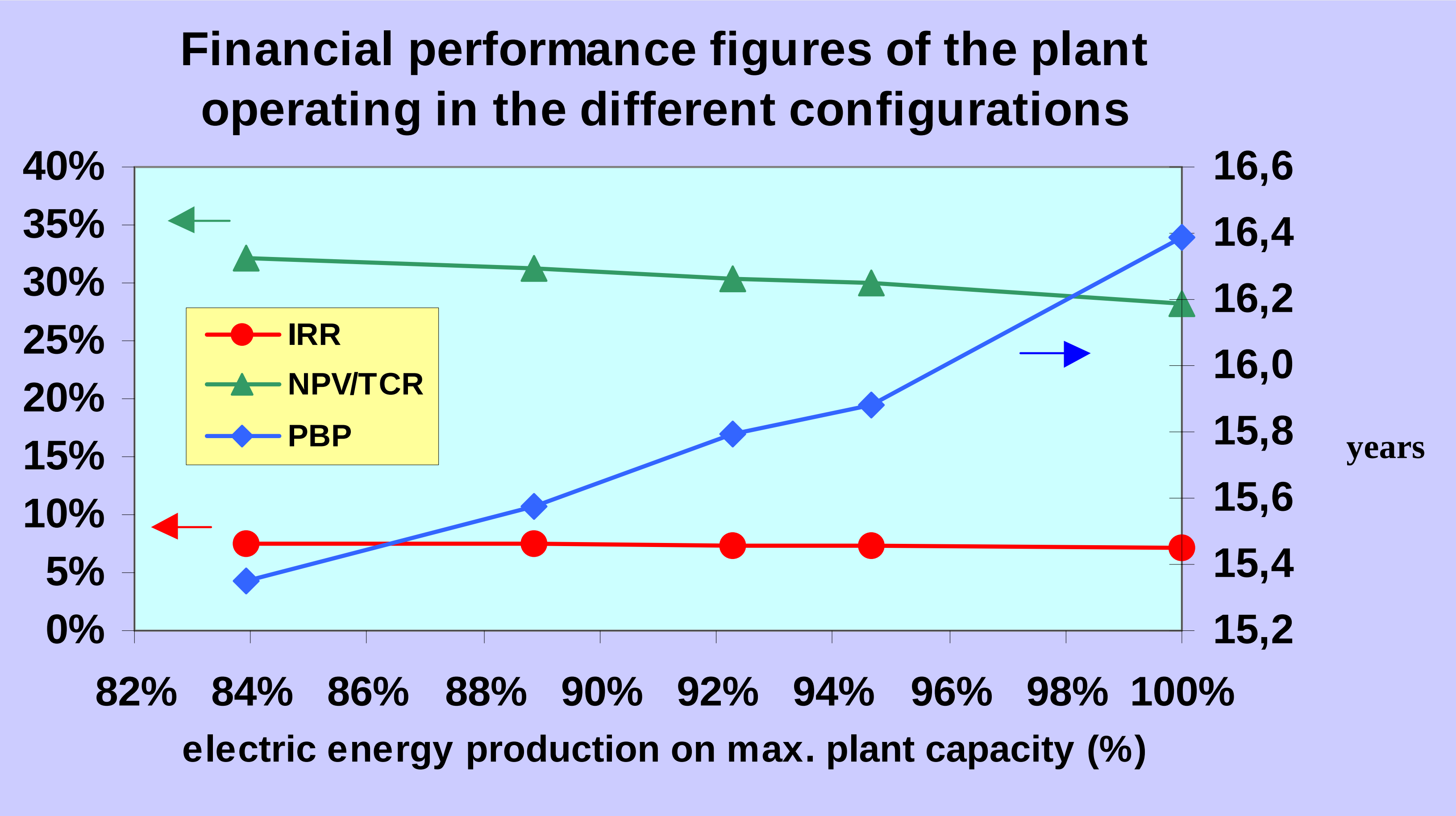
• ***for hydrogen production***

avoided CO_2 calculated as difference between specific emissions from hydrogen production by steam methane reforming (2,51 kg CO_2/kg H_2 produced) and actual emissions

• ave. CO_2 credit value, according to Italian Environment Ministry estimation for 2008 26 €/ton

Investment revenue analysis

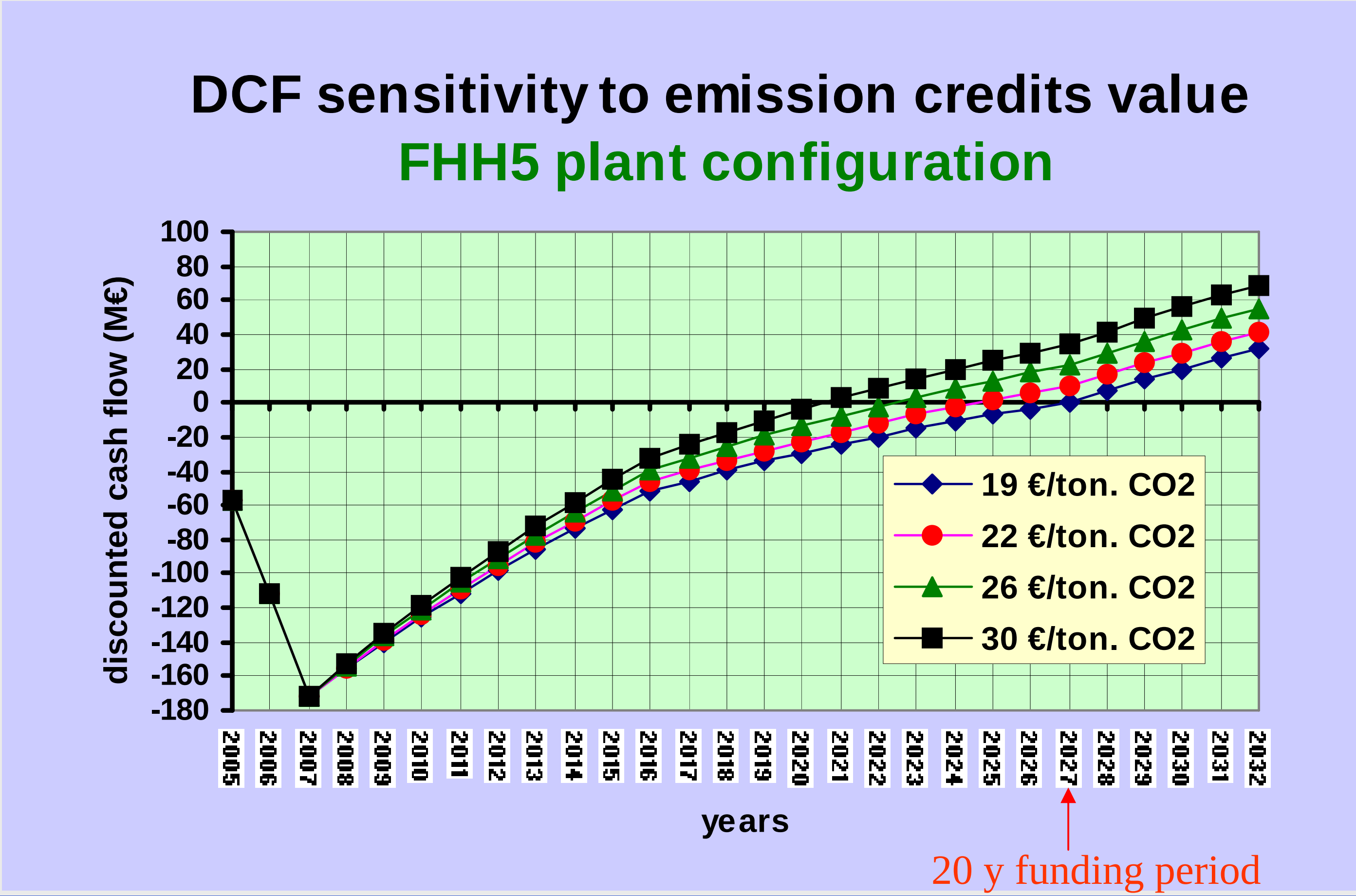
- Analysis of EE, FMH5, FMH8, FHH5 and FHH8 plant configurations
- Payback period (PBP), IRR and net present value/total capital requirement (NPV/TCR) have been calculated
- PBP shorter than the funding period of 20 years, in all cases
- Co-production configurations provide better results
- FHH5 shows the best figures: PBP= 15,3 y, IRR=7,52%, NPV/TCR=32,1%
- Sensitivity analysis:
  - for a lower value of emission credits of 22 €/ton, PBP increases to 17,6 y
  - PBP equals the funding period at emission credits value of 19 €/ton
  - ±10% coal price variation leads to +1,5 –1,1 y variation in PBP.



Configurations EE, FMH8, FHH8, FMH5, FHH5 equal respectively to 100%, 95%, 92%, 89% and 84% of the maximum electrical plant capacity

Sensitivity analysis of FHH5 plant configuration

(high hydrogen co-production, 5 hour min. continuous co-production period)



Conclusions

- An IGCC coal fed plant, with CO_2 capture and sequestration, based on state of the art technologies is technically feasible and economically viable (even if not very attractive)
- Intrinsic flexibility, obtained “by design” allows to follow the typical electricity price variations, quickly switching from “all electric” to “electric-hydrogen production”
- A dynamic simulation model is under development and will be used in order to assess the actual flexibility in the requested transients between the pure electric and the electric-hydrogen co-production configuration.

THANK YOU FOR YOUR ATTENTION !