Gasifier concepts for hydrogen and electricity co-production with CO_2 capture

Calin-Cristian Cormos[1], Fred Starr[1], Evangelos Tzimas[1], Stathis Peteves[1], Andy Brown[2]

[1] European Commission, DG Joint Research Centre, Institute for Energy, P.O. Box 2, 1755 ZG Petten, The Netherlands
[2] Progressive Energy Limited, Stonehouse, Gloucestershire GL10 3RF, UK

Content

I. Introduction

DYNAMIS is an FP6 project

The aim of Dynamis project is to prepare the ground for large-scale European facilities that co-produce hydrogen and electricity from fossil fuels with the simultaneous CO_2 capture and storage

Specific objective:

- **Determine the configuration of plants that employ:**
  - **gasification technologies for coal and lignite**
  - **reforming technologies for natural gas,**
- **to be used for a combined production of H_2 and power with carbon capture and storage**

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

Dynamis Partners

Dynamis

Joint Research Centre

ENERGY PROVIDERS

R&D PROVIDERS

MANUFACTURERS, ENGINEERING, FINANCING

POWER COMPANIES

Project website: www.dynamis-hypogen.com

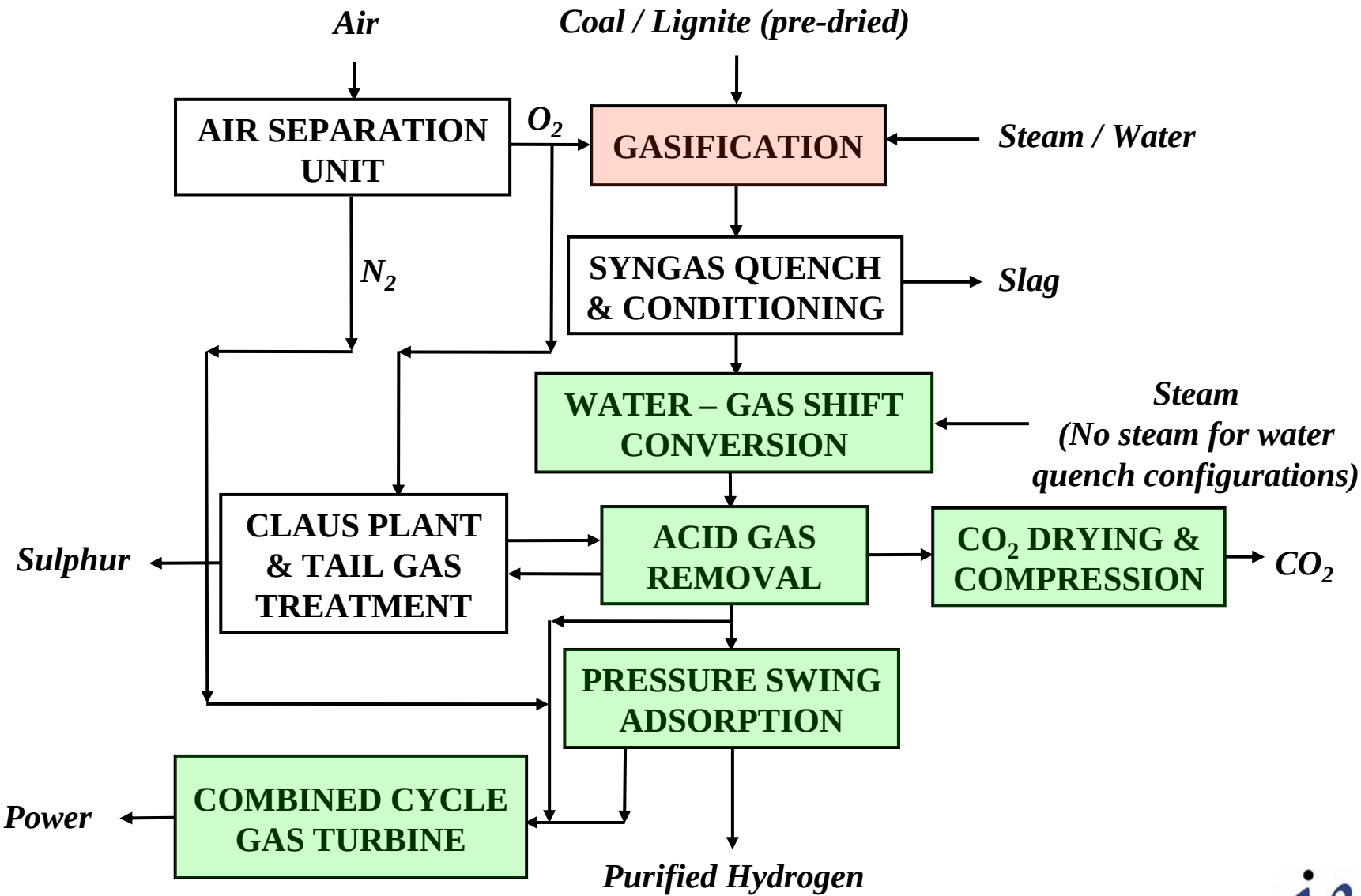
Key Objective

Evaluate and screen plants that co-produce hydrogen and electricity via the gasification of coal or lignite, whilst capturing the generated CO_2

Specific Aims:

- Identify shortcomings in existing technologies
- Improve efficiency and reduce costs
- Highlight areas that require further developments
- Configure the plants

II. Plant Configuration



Major Design Assumptions

1. Plant size: ~400 MW_{el}, 0 – 50 MW_{H2} (HHV)
2. Carbon capture rate: >90 %
3. H_2 purity & pressure: 99.95 % (vol.) / 70 bar
4. CO_2 purity & pressure: >95 % (vol.) / 110 bar
5. 50 % capture cost reduction, from a current level of €50 – 60 / tonne of CO_2 captured
6. Fuel type: Douglas Premium coal
   East German lignite

III. Gasifier Options

MAIN AIM:

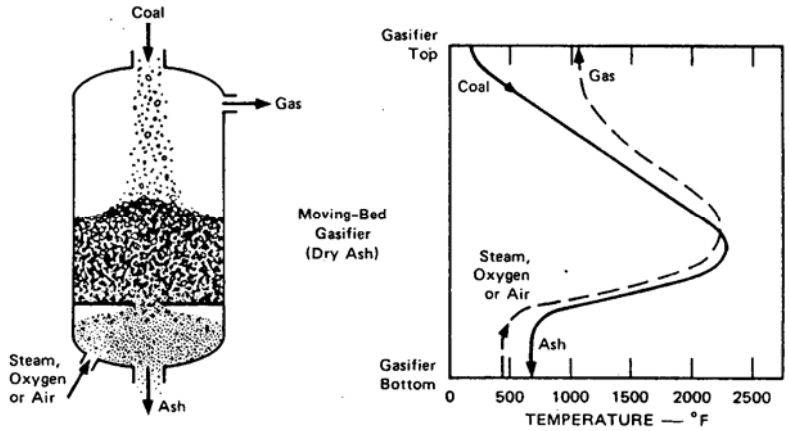
Select three most appropriate gasifiers for coal & lignite

Why was an evaluation needed?

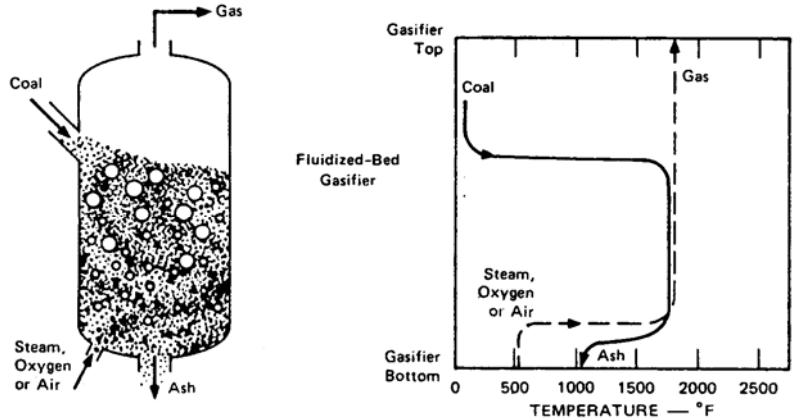
- Need to select the most promising gasifiers
- Many are not commercially proven
- Not all are suitable for a carbon capture IGCC with H_2 as an output
- Lignite gasifiers represent a special challenge for Dynamis

Main Types of Gasifiers

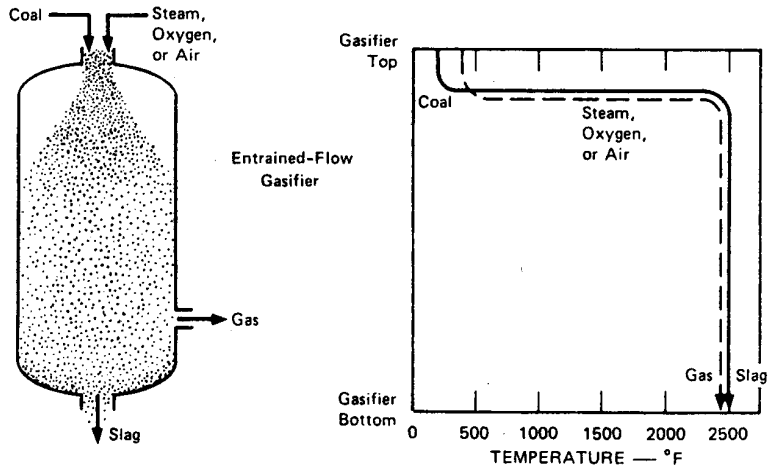
Moving-Bed



Fluidised-Bed



Entrained-Flow



Comments on Gasifier Suitability

Entrained-Flow:

- High temperatures ideal for non-reactive feedstocks such as coal
- Very low tars, phenols and methane
- High gasifier throughput
- High temperature heat recovery desirable
- Wet feedstocks lead to high oxygen demand – an issue for lignite

Fluidised-Beds:

- Bed temperature limited by ash agglomeration
- Only suitable for reactive feedstocks such as lignite
- More complex designs needed to recycle unreacted char

Moving-Beds:

- Good in-bed heat exchange
- Exit gas contains high levels of tars, phenols and methane
- Reduced drying requirement for lignite

Gasifier Options

Moving-bed:

1. Dry ash
2. Slagging conditions

Fluidised-bed:

3. Dry ash

Entrained-flow:

4. Dry feed & heat recovery
5. Dry feed & water quench
6. Slurry feed & water quench
7. Slurry feed & heat recovery
8. Slurry feed & heat recovery (2 stages)

IV. Selection Criteria

- Gasifier throughputs
- Reliability and experience
- Gasifier pressure
- Cold gas efficiency and carbon conversion
- Capital cost
- Range of coals and lignites

- Water / steam requirement
- Downstream gas clean up issues
- Implication of gasifier selection for AGR system
- Hydrogen production potential
- Hydrogen purification
- Oxygen purity

V. Analysis of Coal Gasifiers

Gasifier	Proven on coal	P_{out} (bar)	Cold gas efficiency (%)	Carbon conversion (%)	Hydrogen production potential	Syngas clean up issues	Carbon capture capacity
Case 1	Yes	<100	85 – 87	>92	Low	High	Low
Case 2	Yes	<60	82 – 87	>99	Medium	High	Medium
Case 3	No	<30	80 – 85	<95	Medium	Medium	Medium
Case 4	Yes	<40	74 – 77	>99	Good	Low	Good
Case 5	Yes	<40	76 – 79	>99	Good	Low	Good
Case 6	Yes	<100	60 – 65	>95	Medium	Low	Good
Case 7	Yes	<100	60 – 65	>95	Medium	Low	Good
Case 8	Yes	<40	68 – 71	>98	Medium	Medium	Medium

Good | OK | Bad

V. Analysis of Lignite Gasifiers

Gasifier	Proven on lignite	P_{out} (bar)	Cold gas efficiency (%)	Carbon conversion (%)	Hydrogen production potential	Syngas clean up issues	Carbon capture capacity
Case 1	Yes	<100	85 – 87	>92	Low	High	Low
Case 2	Yes	<60	82 – 87	>99	Medium	High	Medium
Case 3	Yes	<30	80 – 85	<95	Medium	Medium	Medium
Case 4	No	<40	74 – 77	>99	Good	Low	Good
Case 5	Yes	<40	76 – 79	>99	Good	Low	Good
Case 6	No	<100	60 – 65	>95	Medium	Low	Good
Case 7	No	<100	60 – 65	>95	Medium	Low	Good
Case 8	Yes	<40	68 – 71	>98	Medium	Medium	Medium

Good | OK | Bad

Selected Gasifiers

Coal:

- Entrained-flow gasifier with dry feed and heat recovery
- Entrained-flow gasifier with dry feed and water quench
- Entrained-flow gasifier with slurry feed and water quench

Lignite:

- Slagging moving-bed gasifier
- Dry ash fluidised-bed gasifier
- Entrained-flow gasifier with dry feed and water quench

VI. Future Developments

1. Hydrogen-fuelled gas turbines
2. Reducing ancillary power demand
3. Flexibility in co-producing H_2 and electricity
4. Carbon capture rate for some lignite gasifiers
5. Increasing hydrogen pressure
6. Improving hydrogen purity

VII. Conclusions

- Not all conventional IGCC are suitable for carbon capture IGCC with H_2 and electricity co-production
- Entrained-flow gasifiers are favourite for coal-based systems
- No simple choice for lignite-based systems, fluidised-bed and moving-bed gasifiers tend to be favourite

Thank you for your attention!

Contact:

Calin-Cristian Cormos
calin-cristian.cormos@jrc.nl

http://ie.jrc.ec.europa.eu/

The interpretations and opinions contained in this presentation are solely those of the authors and do not necessarily represent the point of view of the European Commission