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LARGE-SCALE PRODUCTION OF FISCHER-TROPSCH DIESEL FROM BIOMASS

Optimal gasification and gas cleaning systems

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Presented at Congress on Synthetic Biofuels - Technologies, Potentials, Prospects
Wolfsburg, Germany, 4 November 2004

Revisions		
A		
B		
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Large-scale production of Fischer-Tropsch diesel from biomass

Optimal gasification and gas cleaning systems

Congress, Synthetic Biofuels – Technologies, Potentials, Prospects
Wolfsburg, Germany, 4 November 2004

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ECN Biomass

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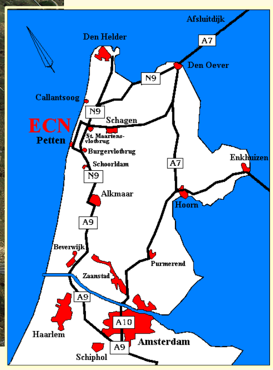
ECN Biomass

Programme Unit of the
Energy research Centre of the Netherlands



- ECN: 650 staff
  Annual turn-over: 60 M€
- ECN Biomass: 40 staff
  Annual turn-over: 7 M€

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Content

- Definitions
- Integrated biomass gasification & FT systems
  - *state-of-the-art*
  - *gas cleaning & biosyngas production*
  - *experimental demonstration & conclusions*
- Large-scale systems
  - *motivation*
  - *biomass import*
- Outlook

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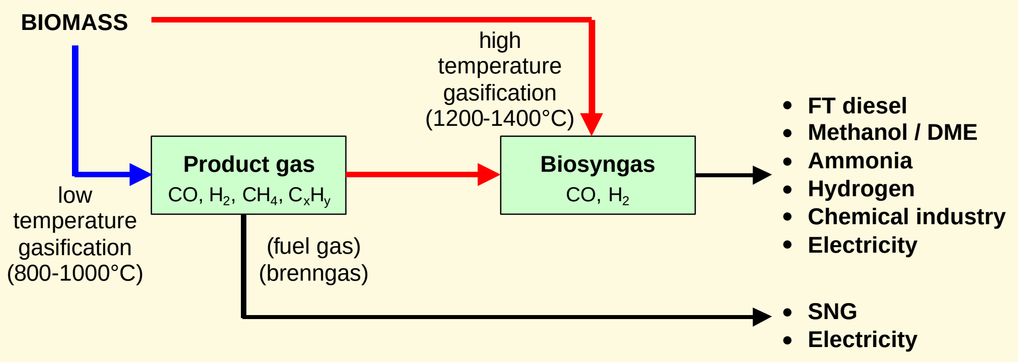
Product Gas *vs.* Biosyngas

Relations & Applications



Conversion of product gas into biosyngas:
1. Reforming
2. Tar cracking

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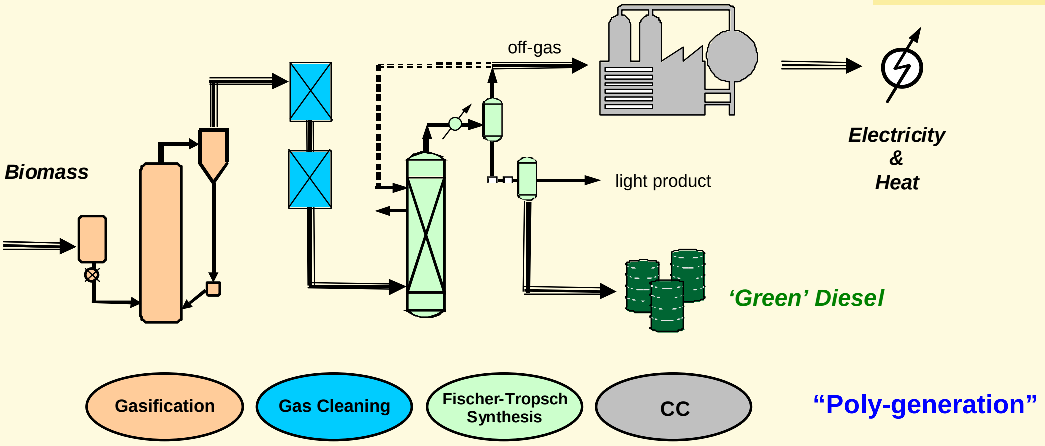
Biomass gasification & FT

Starting point: state-of-the-art gasification



- Atmospheric, air-blown circulating fluidised bed (CFB) gasification
- Typical scale: 1 – 100 MW_{th} input
- Once-through Fischer-Tropsch synthesis

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Biomass gasification

Product gas composition

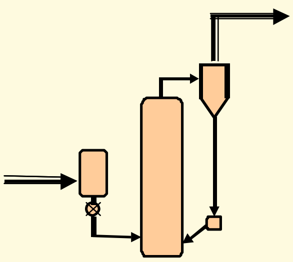
Main Constituents	*[vol%, dry]*	*[LHV%]*
CO	18	27.8
H_2	16	21.1
CO_2	16	-
N_2	42	-
CH_4	5.5	24.1
C_2H_4 (ethene)	1.7	12.4
C_2H_6 (ethane)	0.1	0.8
BTX	0.53	10.5
sum of tars	0.12	2.8
TOTAL	*100*	*100*

Impurities	*[mg/m_n^3]*
NH_3	2200
HCl	130
H_2S	150
all COS, CS_2, HCN, HBr	< 25
dust, soot, ash	2000

dilution (N_2)

energy loss for FT (CH_4, C_2H_4, C_2H_6, BTX)

catalyst poison (impurities)



Circulating Fluidised Bed (CFB) gasifier, 850°C, air-blown, atmospheric, wood; 15 wt% moisture

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Integrated BG-FT system (1)

Demonstration of feasibility

FB Gasifier → Tar Removal (OLGA) → Wet Cleaning & Filters → Gas Conditioning → FT synthesis

- Fluidised bed gasification (bubbling; oxygen-blown)
- Removal of tars & most of BTX
- Wet gas cleaning to remove NH_3 and HCl
- Gas filtering to remove H_2S & remaining traces
- Gas conditioning:
  - compressing to 40 bar
  - H_2/CO ratio adjustment

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“AGAF”

Gas conditioning

- Processing of product gas
- Compressor - up to 60 bar
- Water condensor
- Active carbon filter
- Sulphur removal filter (ZnO)

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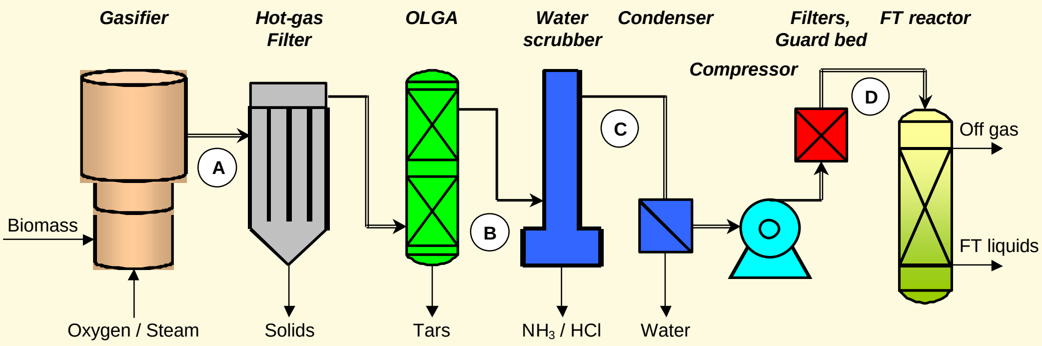
Integrated test (1)

BFB(O_2) gasification + tar removal (OLGA)



Integrated system demonstrated by 500 hour test in March 2003

- No loss of catalyst activity and selectivity
- Carbon-14 dating of FT products proves biomass origin

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Gas compositions (1)

BFB(O_2) gasification + tar removal (OLGA)

Gas		Raw product gas	OLGA gas	Scrubber gas	FT feed gas
CH_4	[vol%]	9.11	9.06	9.05	9.42
C_2H_4	[vol%]	3.08	3.21	3.21	3.00
C_2H_6	[vol%]	0.25	0.25	0.21	0.25
C_2H_2	[vol%]	0.16	0.17	0.17	0.15
benzene	[ppmV]	6813	5018	4507	101
toluene	[ppmV]	710	377	282	19
SPA tars	[ppmV]	4114	< 10	< 10	< 10
NH_3	[ppmV]	~	1304	8.5	0.06
HCl	[ppmV]	~	0.67	< 0.3	< 0.3
H_2S	[ppbV]	~	~	116496	< 10
COS	[ppbV]	~	~	4030	50
CS_2	[ppbV]	~	~	940	30
TOTAL	*[vol%]*	*100.0*	*100.0*	*100.0*	*100.0*

Gas on specification

(Experimental data)

1. C_xH_y hydrocarbons are still present
2. Tars removed to < 10 ppmV
3. NH_3 and HCl removed to < 1 ppmV
4. Total sulphur < 100 ppbV

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From biomass to FT liquids

Conclusion on gas cleaning:

- Product gas from biomass gasification can be cleaned from tars and inorganic impurities to meet FT specifications.

- There are <u>no biomass-specific impurities</u> that require a totally different gas cleaning approach.

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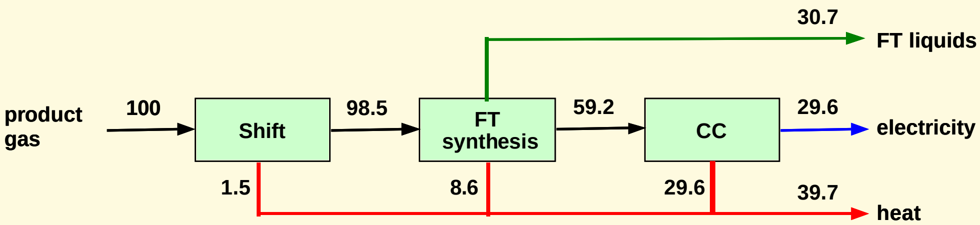
Yield of FT liquids

Base case: product gas & once-through FT



Yield FT products = (100-1.5) × **48.2%** × 90% × 80% × 90% = **30.7%**

- Shift to H_2/CO = 2 (energy loss 1.5%)
- energy content of product gas present in H_2 + CO: 48.2%
- FT conversion, once-through: 90% (of syngas components)
- heat generated: 20% of converted energy
- FT selectivity to C_5+ products (wax and liquids): 90%
- electrical efficiency CC: 50%

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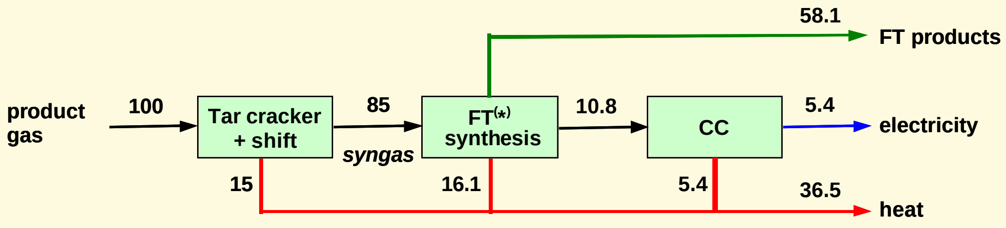
Yield of FT liquids

Optimum case: tar cracker to biosyngas

all CH_4 (24%), C_xH_y (12%), and BTX (11%) converted, and all tar cracked



Yield FT products = (100-15) × **100%** × 95% × 80% × 90% = **58.1%**

- Energy content of biosyngas used for FT synthesis: 100%
- FT(*) conversion, including recycle: 95% (of biosyngas)
- Other conditions similar

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Integrated BG-FT system (2)

Demonstration of feasibility

- Low temperature gasification
- Destruction of all tars and hydrocarbons in high temperature tar cracker (oxygen-blown)
- Wet gas cleaning to remove NH_3 and HCl
- Gas filtering to removed H_2S & remaining traces
- Gas conditioning:
  - compressing to 40 bar
  - H_2/CO ratio adjustment

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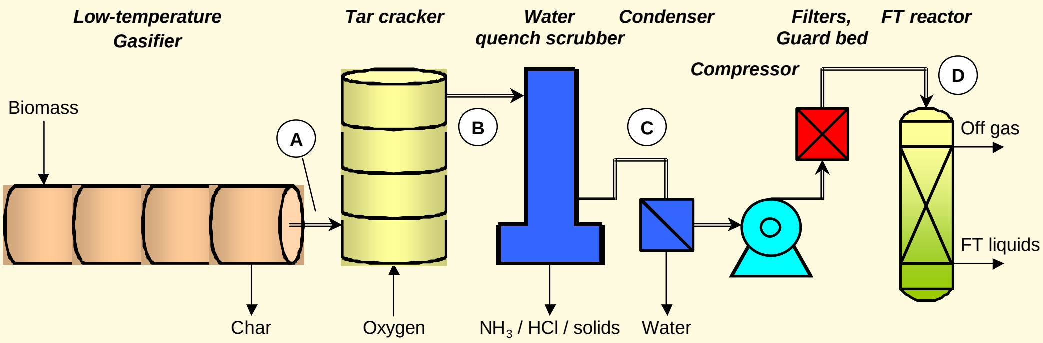
Integrated test (2)

Low temperature gasifier + Tar cracker



First production of FT-liquids from wood in December 2001

- No loss of catalyst activity and selectivity
- Carbon-14 dating of FT products proves biomass origin

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Gas compositions (2)

Low temperature gasifier + Tar cracker

Gas		Raw product gas	Cracked product gas	FT feed gas
CH_4	[vol%]	6.42	0.01	0.01
C_2H_4	[ppmV]	5936	< 5	< 5
C_2H_6	[ppmV]	7359	< 5	< 5
BTX	[ppmV]	1266	< 5	< 5
Tars	[ppmV]	+/- 50%	< 10	< 10
NH_3	[ppmV]	~	516	0.02
H_2S	[ppbV]	~	23789	< 10
COS	[ppbV]	~	47578	278
CS_2	[ppbV]	~	207	< 10
TOTAL	*[vol%]*	*100.0*	*100.0*	*100.0*

Gas on specification

(Experimental data)

1. All organic C_xH_y converted
2. Tars converted
3. NH_3 removed to well below 1 ppmV
4. Total sulphur ~300 ppbV

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From biomass to FT liquids

Conclusion on FT synthesis:

- Experiments prove technical feasibility of producing FT liquids from biomass.

- Performance of FT synthesis and catalyst with biosyngas similar to 'normal' syngas.

"POTTOR" – Fisher-Tropsch reactor
- Shell reactor - operated by ECN
- Fixed-bed reactor
- Cobalt-based catalyst

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Integrated BG-FT system (3)

Preferred technical configuration

- One-step high-temperature gasification is preferred over CFB gasifier + tar cracker
= *entrained flow (EF) gasification*

- Pre-treatment of solid biomass is necessary to allow feeding into the gasifier
= *real challenge in EF gasification of biomass*

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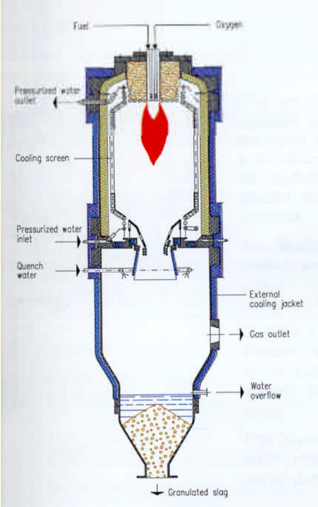
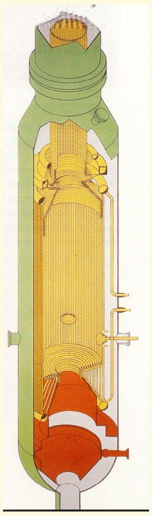
Entrained flow gasification

Examples of suitable slagging gasifiers



Future Energy



KruppUhde/Shell

Characteristics:

- Small feed particles / liquid
- Fuel flexible
- Slagging
- Temperature: 1200-1500°C
- Syngas
- Conversion: >99%
- Pressure: 20-40 bar
- Oxygen

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Large-scale BG-FT systems

Motivation for large scale

- Economy of scale for investment: reduce production costs,
  cf. refineries and the new GTL plants are typically several 1000 MW
- Process integration: increase efficiency (!!!)
- Dedicated BG-FT plants – no poly-generation
  => electricity can be produced via other routes,
  e.g. by wind, solar, biomass combustion or from product gas
- Large production capacity needed to meet EU targets of 5.75% biomass-based fuels in 2010:
  - For the Netherlands:
    ~25 PJ/y biofuels => ~1,200 MW_{th} biomass input
  - Do we build 50 small BG-FT plants, or 1-2 large plants?

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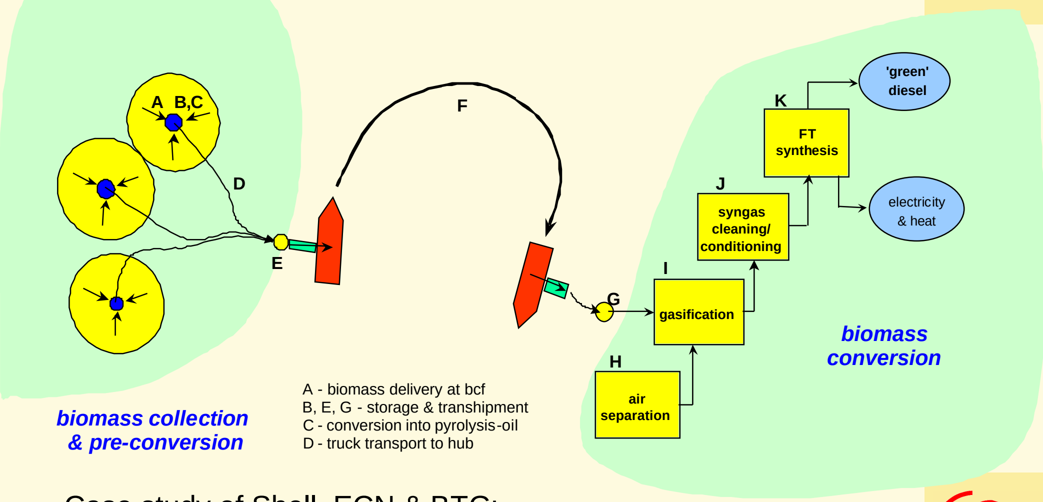
Large-scale BG-FT systems

Case: imported biomass from Baltic countries



Case study of Shell, ECN & BTG:

- 8,000 MW_{th} biosyngas in Rotterdam harbour
- transport of wood logs

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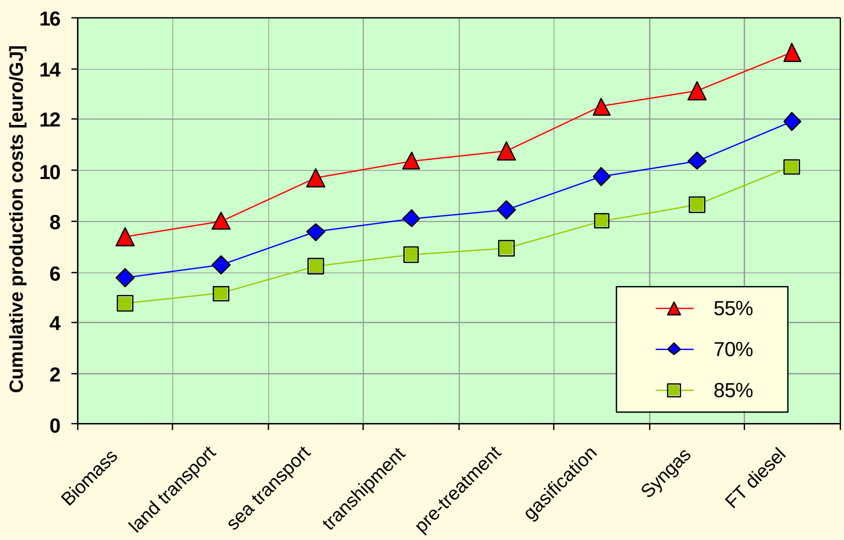
Large-scale BG-FT systems

Importance of biomass-to-biosyngas efficiency



Biomass costs (in Baltics): 4 €/GJ

High efficiency is crucial for economic feasibility

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Large-scale BG-FT systems

Outlook

- Large BG-FT plants of several GWs
- Based on slagging entrained flow gasification to produce biosyngas
- BG-FT plants are part of larger chemical / industrial complexes for maximum integration
- Plants located near harbours and waterways to allow cost-effective import of "cheap" biomass (4 €/GJ)
  – in EU there is not sufficient cheap biomass to meet targets
- Local biomass is transported to BG-FT plants, possibly after conversion in bioslurry
  - depending on economics
- Limited application for small-scale plants

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Large-scale BG-FT systems

ECN development approach

- Start from existing large-scale coal EF gasification technology (*i.e.* Buggenum and Puertollano)
- Gasifier is fuel-flexible, *i.e.* suitable for solid woody biomass, bioslurry, as well as coal.
- Focus development on feeding systems for biomass, with minimal need for pre-treatment (*i.e.* efficiency loss)

- All aimed at implementation on short-term and with large installed capacities (to reach targets)

*… because: FT from natural gas (**GTL**) is today…*

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But for tomorrow…

is Fischer-Tropsch from biomass: "**BTL**"

Shell SMDS plant, Bintulu, Malaysia

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Thank you for your attention

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Publications can be found on:
www.ecn.nl/biomass

Visit also: "Phyllis" - *internet database for biomass, coal, and residues:* *www.phyllis.nl*

"Thersites" – *internet database for tar dewpoint calculations:* *www.thersites.nl*

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Mission

Contributing to the implementation of biomass (and waste) in the Dutch and global (energy) infrastructure by means of short-term, mid-term, and long-term research, technology development, and knowledge dissemination.

ECN Biomass is a business unit of the
Energy research Centre of the Netherlands (ECN)

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Research clusters

Power Generation

➔ Slagging, fouling, co-combustion, co-firing, ash-quality

Heat and Power

➔ Gasification, combustion, gas clean-up, prime-movers

Fuels and Products

➔ liquid fuels, gaseous energy carriers, biosyngas, bio-refinery, co-generation

Implementation time

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