

Conventional and Advanced Technologies for the Conversion of Biomass into Secondary Energy Carriers and/or Chemicals

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Content

1. National policy goals within a European framework
2. Vision LT (2030) use biomass in the Dutch economy (PGG)
3. LT Raw material requirements
4. Current use of biomass within the Dutch (energy) infrastructure
5. Conventional biomass conversion technologies (selection)
6. Advanced biomass conversion technologies (selection)
7. Technology and product transition pathways
8. Costs products and CO₂-emission reduction potential
9. Optimal biomass conversion strategy to meet future market requirements – Biorefinery?
10. Discussion - Conclusions

1. National policy goals within a European framework

- 5% renewable energy in 2010 (10% in 2020)
about 80% is expected to be bio-based
- EU-objectives: 2 and 5.75% biofuels in transportation sector in 2005 and 2010 (achieved in 2005: about 1%)
- EU Energy Package (10-01-07):
 - 20% ghg reduction in 2020 compared to 1990 (energy efficiency, nuclear, CO₂-capture/disposal, renewables)
 - 1. EC-proposal: 20% renewable energy in 2020
 - 2. EC-proposal: 10% biofuels for transport in 2020 (binding target)

2. LT Vision - use biomass in the Dutch economy (PGG¹)

30% fossil-based raw materials and fuels substitution in the Dutch economy in 2030

Application	FF substitution [%]	[PJ _{th, affu}]	CO ₂ -em.red. [Mt/a]
Biofuels for transport	60 (very ambitious)	324	24
Chemicals, materials	25 (R&D >)	140	11
Power	25 (full plant substitution necessary)	203	14
Heat	17 (mainly SNG)	185	10

¹PGG: Platform Bio-based Raw Materials; between () are comments ECN/WUR

3. LT raw material requirements (1)

Assumption:

total energy demand Dutch economy in 2030:

3000 PJ_{th} (strong energy savings required) [PGG, 2006]

30% fossil fuel and raw material substitution in 2030
corresponds to about 850 PJ_{th} [PGG, 2006]

2030 raw biomass requirement to meet demands in
different market sectors: about 1200 PJ_{th} or about
80 million tonnes (d.b.)

3. LT raw material requirements (2)

Gross national biomass production ((import-export) + production) in 2000: 42.3 Mtonnes (about 742 PJ_{th})

only a small part is available for non-food applications !

Projection national biomass availability for non-food applications in 2030:

- 6 Mt d.b. primary by-products (100 PJ_{th})
- 12 Mt d.b. secondary by-products (200 PJ_{th})
- 0 - 9 Mt d.b. energy crops (0 -150 PJ_{th}) (uncertain, multi-functional crops?)

Total: 18 - 27 Mt d.b. or 300 - 450 PJ_{th}

60 - 80% of the required biomass has to be imported !!!

4. Current use of biomass within the Dutch (energy) infrastructure [$PJ_{th, affu}$]

	Estimation for 2005 ¹	Maximally achievable in 2010 ²
Direct/indirect cofiring	29	56
Domestic waste comb.	11.5	18
Landfill gas	1.6	1
CHP – digestion	4-6	5
CHP comb./gasification	11.7	17
Biofuels for transport	< 2	23 (5.75%)
Total	about 60 (=1.8% total)	120 (3-4% total)

¹Statusdocument Bioenergie 2005, SenterNovem, 161105; ²Ecofys DEN-project 2004

5. Conventional biomass conversion technologies

5.1 Co-firing in coal-fired power plants

Direct cofiring: conversion pre-treated biomass through existing coal train

- (+) low specific investment costs (100 €/kWe)
- (+) high biomass conversion efficiency to power (39-40 %LHV)
- (-) not applicable for all biomass materials because of potential contamination coal-ash, slagging/fouling/corrosion problems, emission constraints

Indirect cofiring: conversion biomass in an upstream unit (gasification, pyrolysis, combustion) and integration (gas, oil, steam) with the coal plant

- (-) higher specific investment costs (500-1250 €/kWe)
- (-) lower biomass conversion efficiency to power (35-38 %LHV)
- (+) applicable for more biomass materials because of pre-separation potential contaminants

Expensive clean biomass -> direct cofiring (rel. cheap, high eff.)

Cheap contaminated biomass -> indir. cofiring (rel. exp., lower eff.) -> power prod.

5. Conventional biomass conversion technologies

5.1 Co-firing example (1) – direct cofiring

In all 8 Dutch power plants 5 – 10% biomass is co-fired directly.

1000 MW_{th} biomass input (31.5 PJ_{th d.b.}) requires about 1.5 Mt d.b./a



Hemweg power plant of NUON
630 MWe (net) pulverised coal
fired



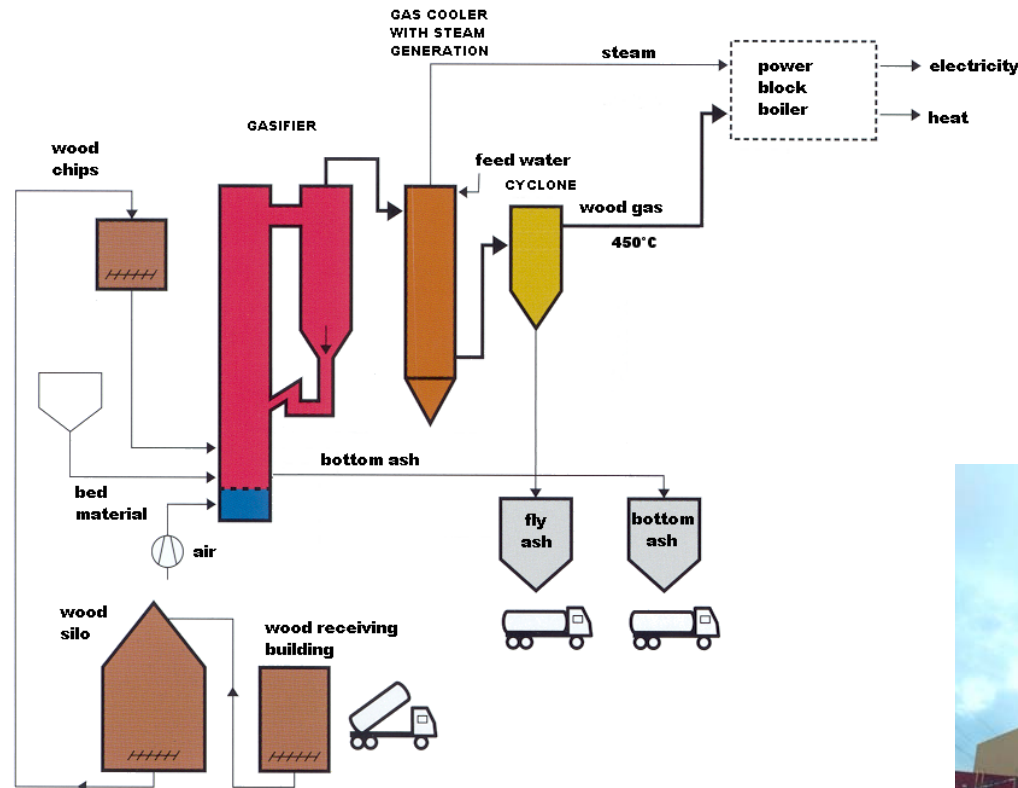
Gelderland power plant of
Electrabel
602 MWe (net) pulverised coal
fired ST: 180 bar, 540°C ->
0.04 bar, 30°C



Amer power plant of Essent
1245 MWe (net) and 600 MW_{th}
pulverised coal fired
2 CHP units AMER-8 and AMER-9

5. Conventional biomass conversion technologies

5.1 Co-firing example (2) (Amer-9 Essent)



Indirect cofiring of 150 kt/a demolition wood

Efficiency: about 38%LHV



5. Conventional biomass conversion technologies

5.2 Domestic waste combustion example (AEB A'dam)

Waste combustion was volume reduction

Now more and more modification to “high-efficient” (eff. > 30 %LHV) AVIs



5. Conventional biomass conversion technologies

5.3 Thermal processes for power, heat, CHP production

Combustion processes

- Grate combustion: (+) low investment costs; (-) low efficiency
- Fluidised bed combustion: (+) low investment at high capacity (> 10 MWth), T=c

Pyrolysis processes

- Slow conventional pyrolysis: t = 10 min – hours; heating: 0.1-100°C/s at LT -> mainly char
- Fast/flash pyrolysis: t = 0.1 – 5 sec; heating: several 100°C/s at MT -> mainly bio-oil

Gasification processes

- Fixed bed gasifiers:
- Fluidised bed gasifiers
- Entrained-flow gasifiers

Air-blown
 Steam/oxygen-blown
 Indirect

Atmospheric
 Pressurised

Atmospheric LT air-blown FB-gasifiers -> fuel / product gas -> CHP production
Pressurised HT oxygen-blown EF/FB-gasifiers -> syngas -> Synthesis processes
Atmospheric LT air-blown indirect gasifiers -> syngas -> Synthesis processes

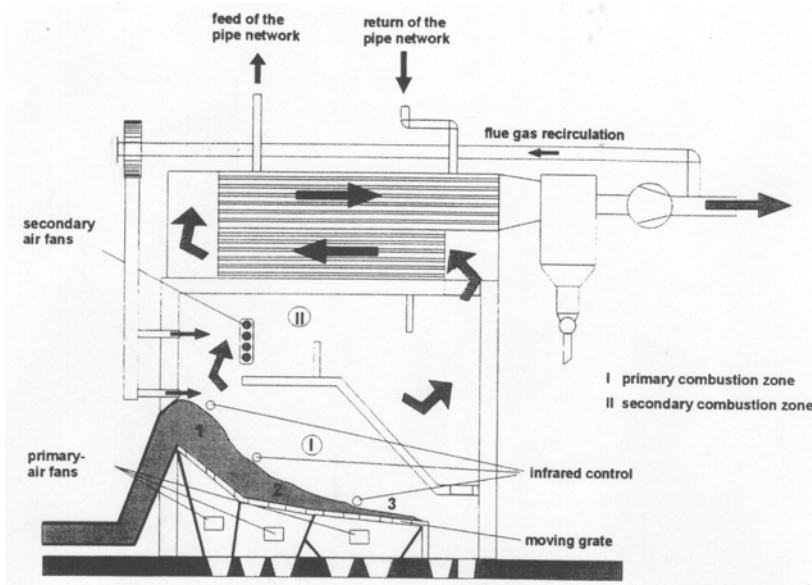
5. Conventional biomass conversion technologies

5.4 Stand-alone combustion example (Lelystad, NUON)

Input: 7.5 MW_{th} Technology: grate firing

Output: 0.7 MW_e; availability installation: 7500 hour/year; electrical eff.: 8 %LHV;
thermal eff.: 69 %LHV

Specific investment costs: 16000 €/kW_e; Technology: commercial available



Source: SenterNovem 2DEN-04.12

5. Conventional biomass conversion technologies

5.4 Stand-alone combustion example (Cuijk, Essent)

Input: 270 kton wood chips (50% moisture) = about 85 MW_{th} a year. Availability: 7600 hours/year. Technology: BFB combustion.

Output: 25 MW_e -> 190 GWh_e/year. Electrical efficiency: 30 %LHV.

Specific investment costs: 1820 €/kW_e; Technology: commercial available



5. Conventional biomass conversion technologies

5.6 Digestion for power/CHP production, example OWF digestion of Vagron in Groningen

Installation:

Input: 92 kton OWF from 168 kton domestic waste a year.

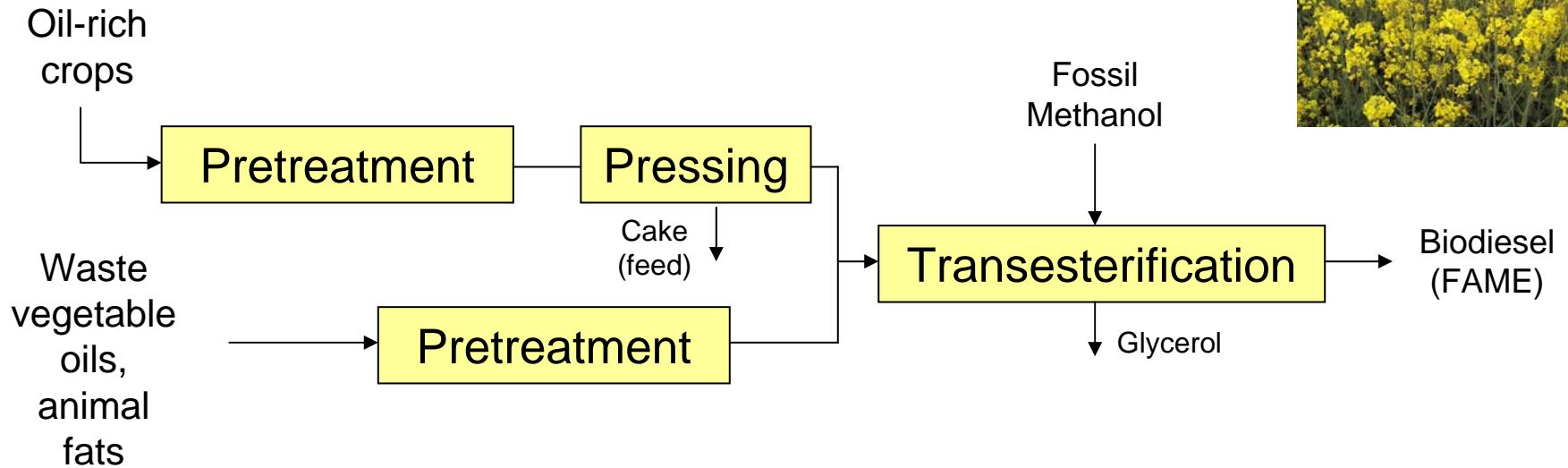
Output: 8.5 MMNm³ biogas (about 55% CH₄) a year -> 4 * 630 kW_e = about 2.5 MW_e
-> 14.3 GWh_e

Specific investment costs: 7800 €/kW_e.



5. Conventional biomass conversion technologies

5.7 Biodiesel production



Dutch market initiatives:

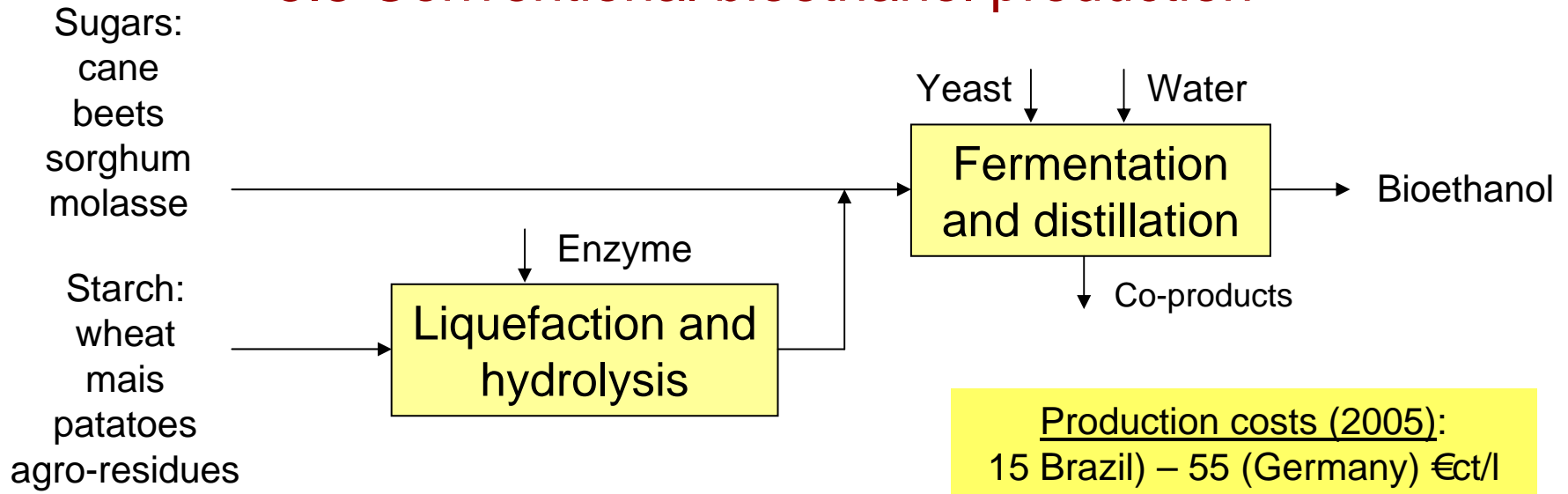
- Biofuelling (ES)/Zeeland Seaports (2008): 200 - 600 kt/a
- BioPetrol (SUI)/R'dam (2007): 400 kt/a
- Biovalue (Eemshaven): status unclear
- Sunoil Emmen (2006): 30 kt/a
- Ten Kate Ter Apelkanaal (2007): 10 MI/a from fats

Developments:

- Former Methanol: biodiesel-derived glycerol
-> biomethanol -> transesterification
-> 100% green biodiesel
- Use of ethanol instead of methanol

5. Conventional biomass conversion technologies

5.8 Conventional bioethanol production



Dutch market initiatives (selection):

- Nedalco Sas van Gent/Cerestar (2008): 220 MI/a (400 kt/a) based on organic residues, integration 2⁰-generation technology?
- BER/HES Beheer Rotterdam (2007): 100kt/a
- Lyondel Botlek: 600 kt/a ETBE
- Harvest Biofuels A'dam (2007): 110 kt/a
- Sabc Geleen: 140 kt/a ETBE
- Argos Oil R'dam: Argos e-fuel (5% eth.)

Developments:

- Use of more difficult raw materials
- Pathway to lignocellulosic bioethanol



6. Advanced biomass conversion technologies

6.1 Oxygen-blow press. IGCCs for power/CHP production



NUON Buggenum coal/biomass
fired plant (NL): 250 MW_e

Large-scale high-efficiency
(45- 50 % (LHV))
BIG/CC-technology

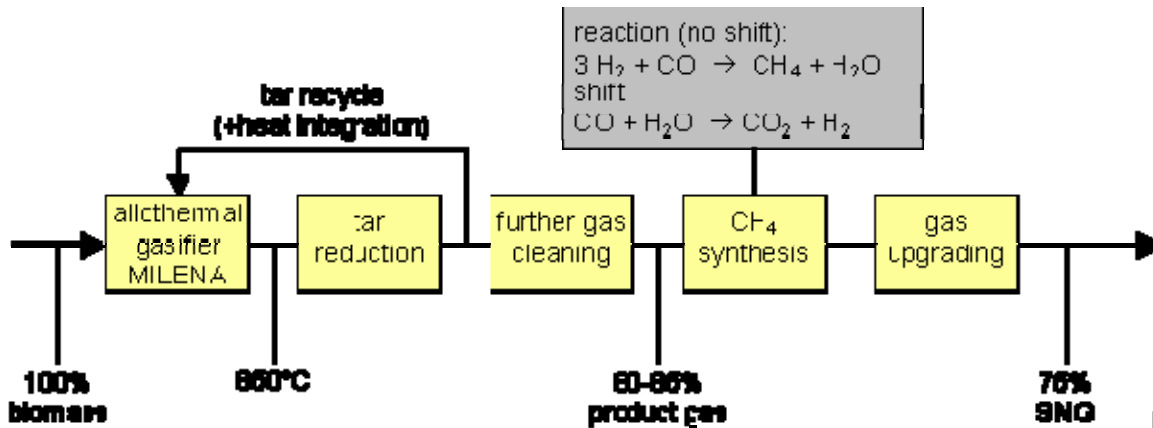


Elcogas Puertollano plant (ES): 320 MW_e

Potential Dutch initiatives
MAGNUM (NUON),
2⁰-Maasvlake

6. Advanced biomass conversion technologies

6.2 Air-blown indirect gasification for SNG production

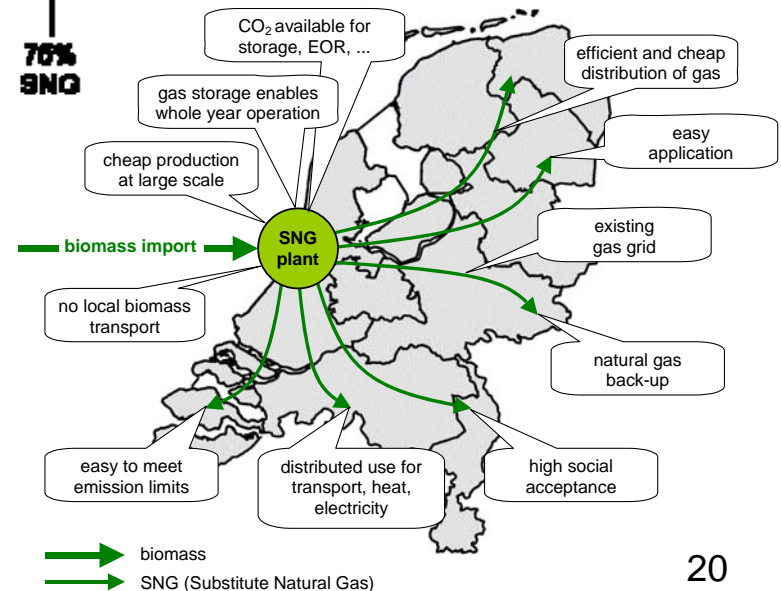


Transport losses power (4%) versus green gas (1%)

2003: World's first "green gas" production at lab-scale (ECN)

Currently basic-design pilot installation at ECN ("Milena")

Discussions about demo-installation (R'dam, Energy Valley, ...)



6. Advanced biomass conversion technologies

6.3 Biomass-to-Liquids (BtL) (1)



Reference GtL:
Demonstration plant
Bintulu, Malaysia

Capacity:
- 14,000 bbl/day
- 28 PJ fuel product
- 1400 MW_{th} BioSyngas

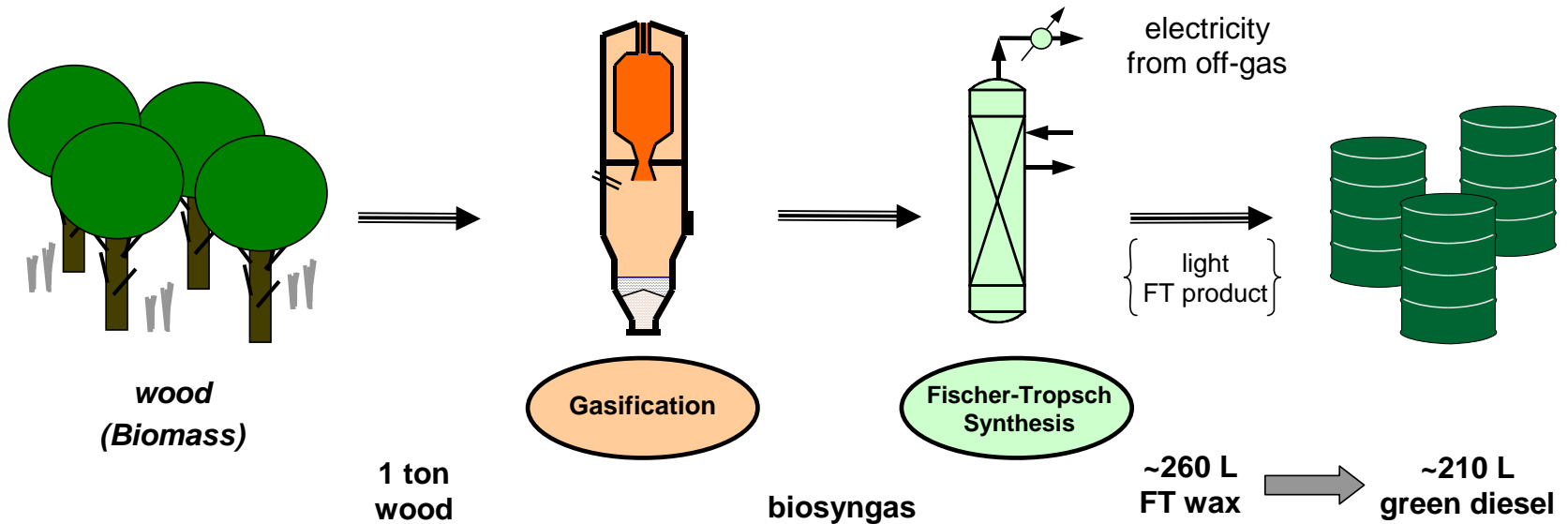
Equivalent to:
- 1,700 MW_{th} raw biomass

Full-scale SMDS in Qatar
- 75,000 bbl/day
- about 10,000 MW_{th} biomass

6. Advanced biomass conversion technologies

6.3 Biomass-to-Liquids (BtL) (2)

Yield from tree-to-barrel

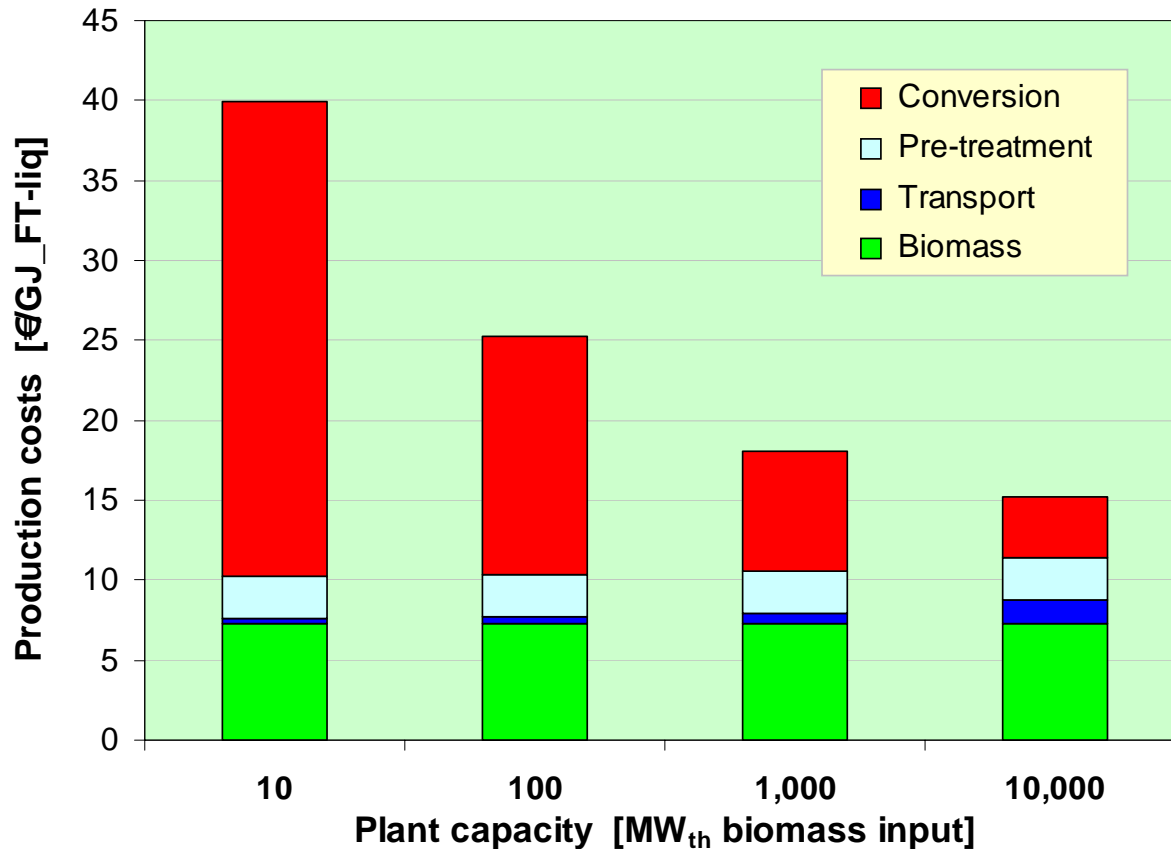


Energy efficiency from wood to diesel = ~44%, light products: 11%, power: 14% -> total energetic efficiency: 69%

Optimised technology; 7% moisture; 78% CGE to syngas; 95% FT conversion; 92% C5+ yield; 80% wax-to-diesel yield; EE to light product 11%; EE to electricity 14% (55% CC, 25% heat); overall EE 69%

6. Advanced biomass conversion technologies

6.3 Biomass-to-Liquids (BtL) (3)



For reference: 15 €/GJ = 55 €/t/L

Scale factor = 0.5 for scale < 2,500 MW_{th}, results in:

- 100 €/GJ_{FT} at 10 MW_{th}
- 40 €/GJ_{FT} at 100 MW_{th}
- 20 €/GJ_{FT} at 1,000 MW_{th}

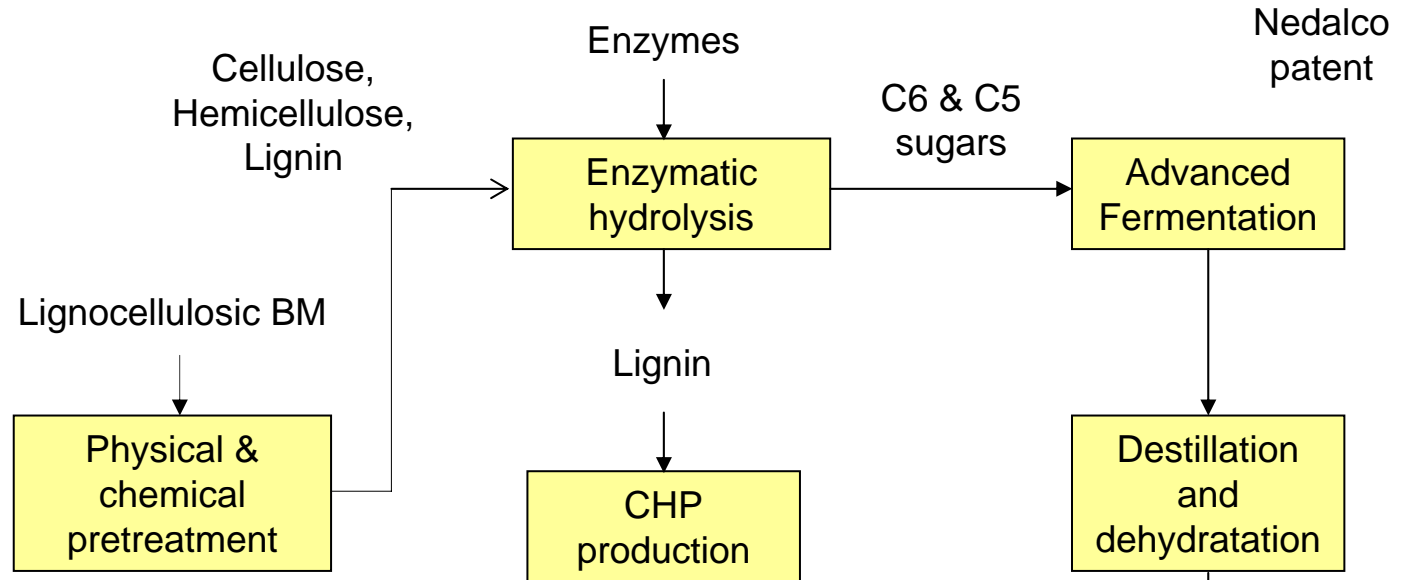
- Biomass costs = 4 €/GJ_{ar}
- Pre-treatment costs = 1.5 €/GJ_{ptt_bm}
- Local biomass (truck transport)
- Variable transport costs: 0.08 €/ton/km
- Deprecation = 10 years (linear)
- Required IRR = 12%
- O&M costs: 7%
- Scale factor = 0.7 (whole range)
- Availability = 8,000 h/y
- Pre-treatment efficiency (torrefaction) = 97%
- Gasification efficiency (biomass to biosyngas) = 80%
- Conversion efficiency (biosyngas to FT C₅+ liquids) = 71%

6. Advanced biomass conversion technologies

6.4 Depolymerisation/hydrolysis/fermentation (1)

Example of
lignocellulosic BM:
Wheat straw

Composition [wt% ar]
Cellulose: 24.8
Hemicellulose: 24.4
Lignin: 25.2
Other organics: 8.0
Ash: 6.7
Moisture: 10.9



Critical R&D-issues:

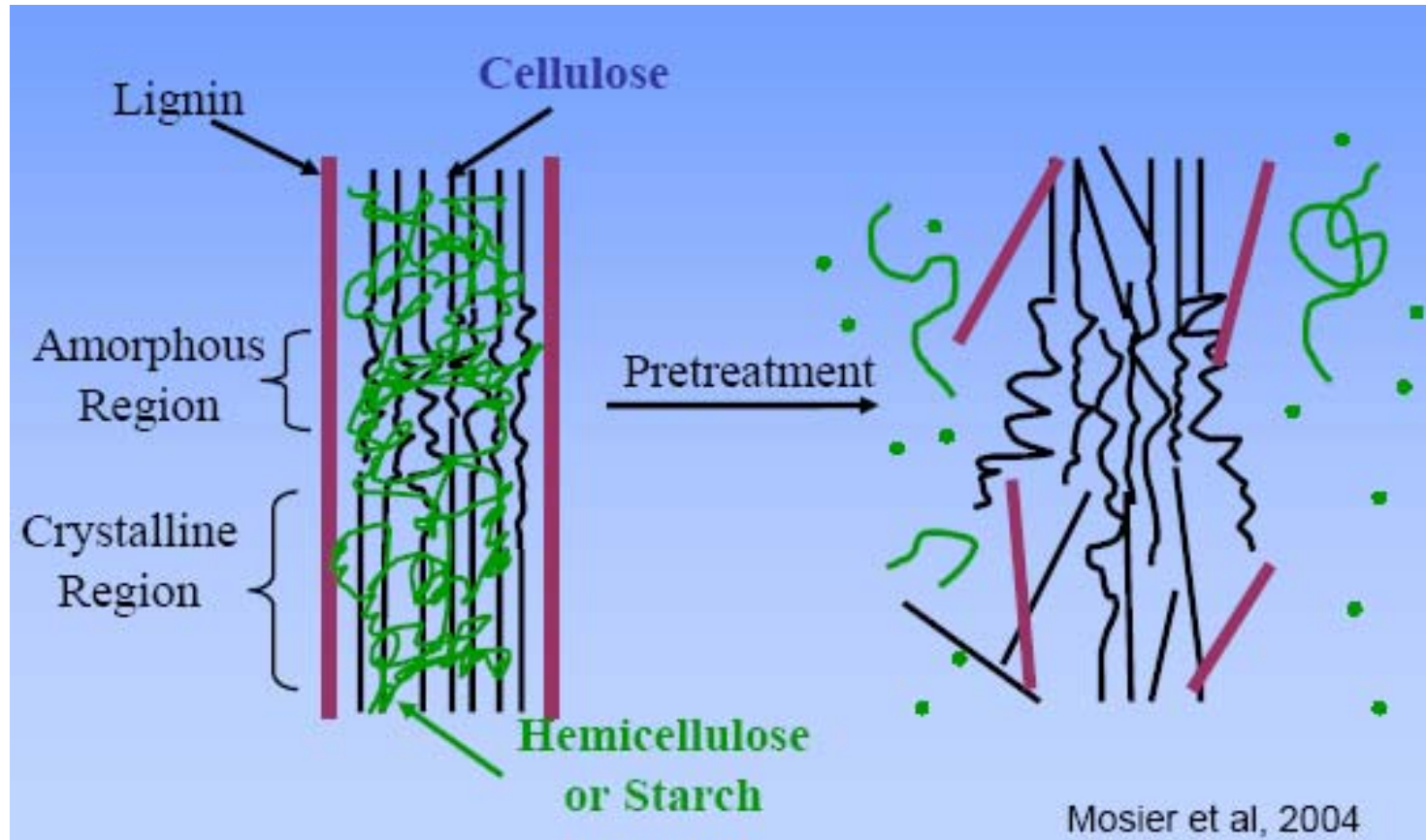
- Physical/chemical pretreatment
- Enzymatic hydrolysis
- Co-fermentation C6/C5 sugars
- Process integration (heat, water, ...)

- Heat for processes
- Power for processes and grid
- Minerals for building materials, fertilizers?

6. Advanced biomass conversion technologies

6.4 Depolymerisation/hydrolysis/fermentation (2)

Physical/chemical pre-treatment of raw biomass



6. Advanced biomass conversion technologies

6.4 Depolymerisation/hydrolysis/fermentation (3)

Basic Design 190 MI/yr 99.7vol% ethanol from wheat straw

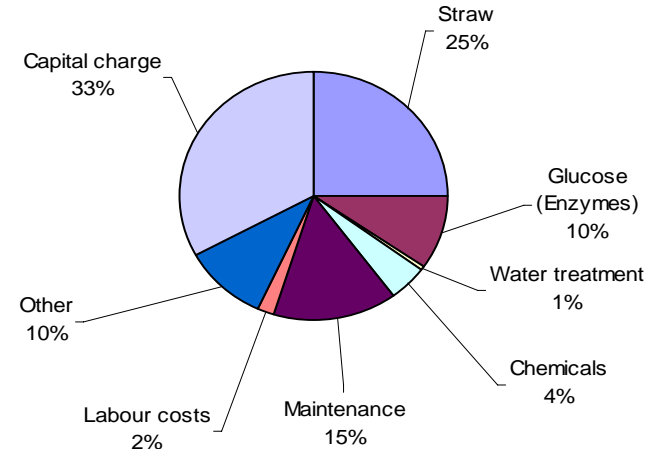
Energy balance Net out: ethanol ($139 \text{ MW}_{\text{th}}$) and power (25 MW_e) / raw materials in ($380 \text{ MW}_{\text{th}}$) = 43 % (LHV)

Total Capital Investment: about 320 M€
about: 50% for CHP-unit and 10% for pretreatment

Straw: 38.5 €/t d.b.
2.5 €/GJ a.r.

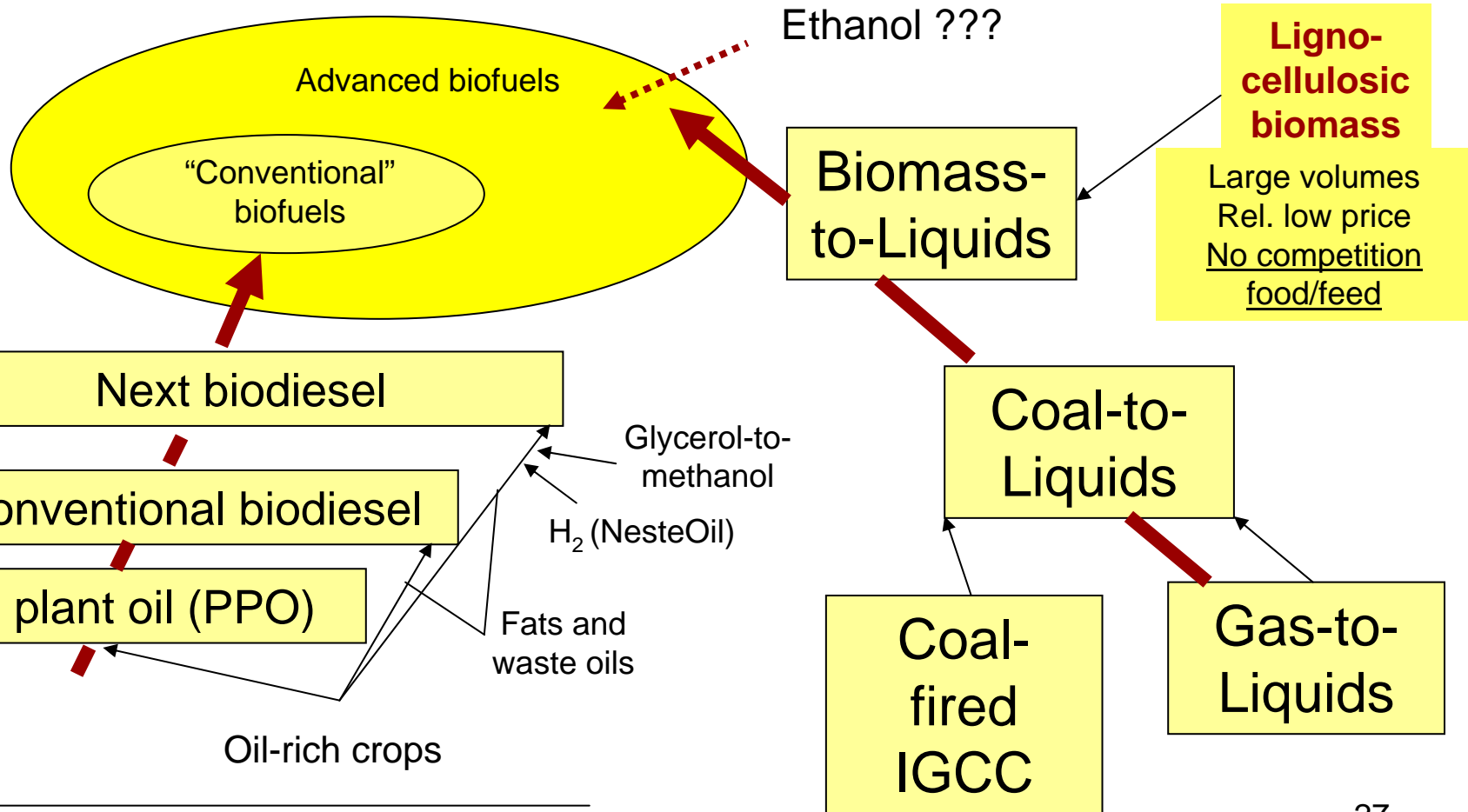
Ethanol production costs:

- about 0.52 €/litre
- minimum selling price: 0.75 €/l (IRR: 15%)



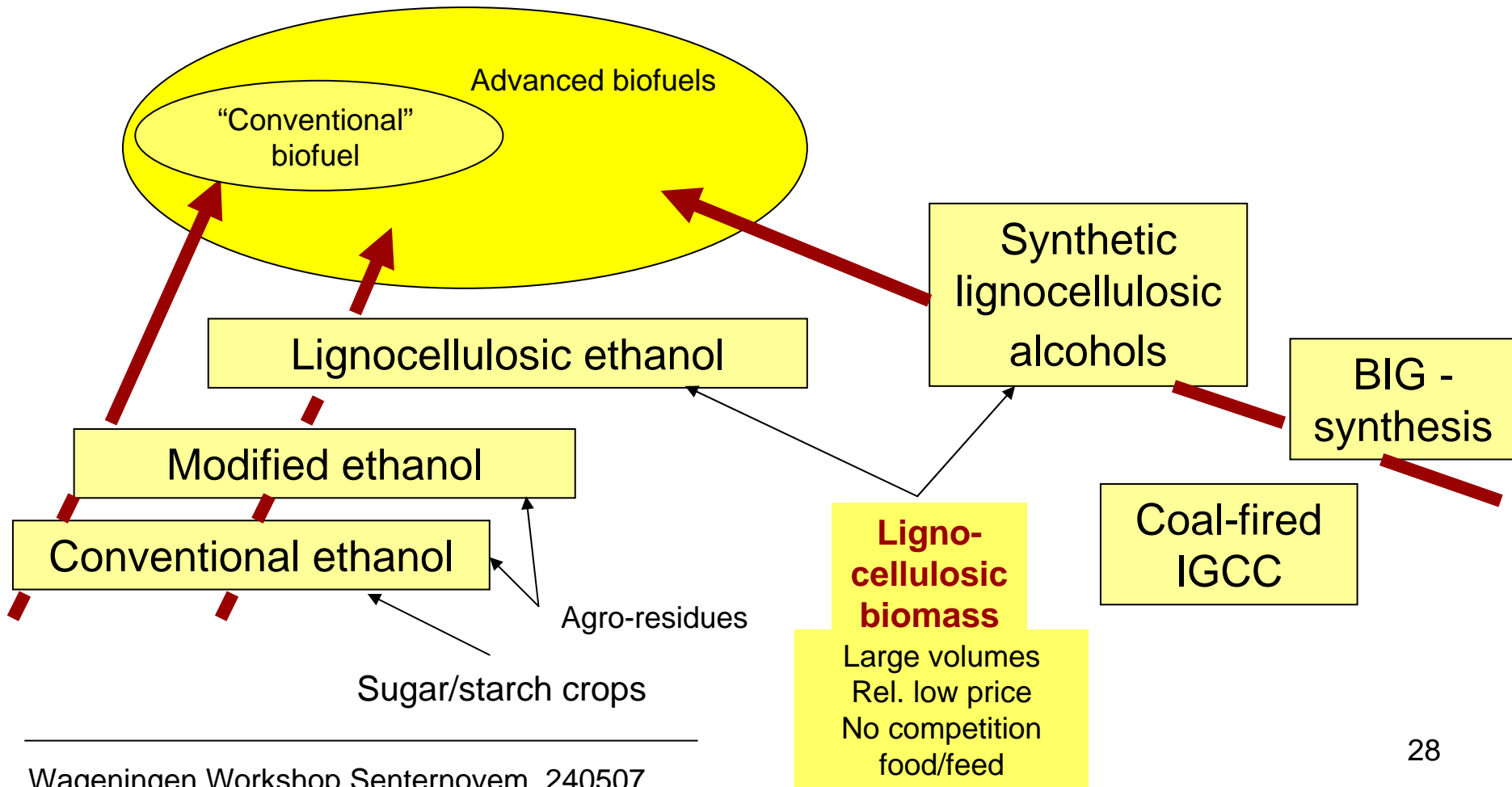
7. Technology and product transition pathways

7.1 Fossil diesel substitution (example)



7. Technology and product transition pathways

7.2 Fossil gasoline substitution (example)



10. Discussion - Conclusions

It is expected that biomass and biomass-derived intermediates will play a predominating role in the transition to – and the realisation of – a more sustainable Dutch economy.

Biomass will be applied in almost all economic sectors.

Because of contractability and financial economic issues it is expected that biomass will be applied on the longer-term preferably for: food, feed, materials, chemicals, transportation fuels, gaseous energy carriers, power and finally heat.

The domestic available biomass in the Netherlands – i.e. agro-cultural residues, wood residues, forest residues, ... and specific grown crops – will not be enough to meet the longer term market demand.

Large-scale import of relatively expensive biomass, biomass-related intermediates (or final products) require high-efficient conversion processes for profitable business.

Biorefinery processes are expected to become major players in the future Bio-based Economy (high-efficiency, low environmental impact).

For the full presentation (34 slides)

www.biorefinery.nl

More information

www.ecn.nl

www.biobasedproducts.nl