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

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1. LT (2030) Vision Platform Bio-based Raw Materials on the use of biomass in the Dutch economy

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

2. 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 <u>1200 PJ_{th} or about 80 million tonnes (d.b.)</u>

2. 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 !!!

3. 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)

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

4. Conventional biomass conversion technologies

4.1 Co-firing example (1) – direct cofiring

In all 8 Dutch power plants 5 – 10% biomass is co-fired directly.
10%: 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 MW_e (net) pulverised coal fired

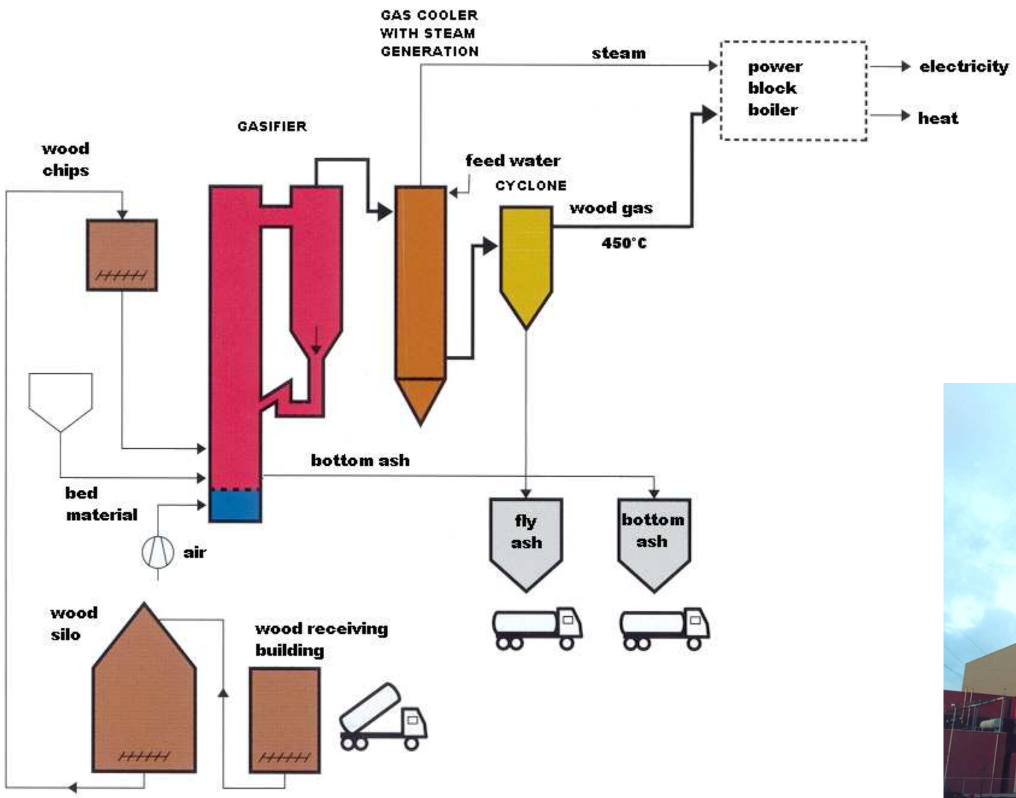
Gelderland power plant of Electrabel
602 MW_e (net) pulverised coal fired ST: 180 bar, 540℃ -> 0.04 bar, 30℃

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

Inv. <, eff. >

4. Conventional biomass conversion technologies

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



Indirect cofiring of 150 kt/a demolition wood

Efficiency: about 38%LHV

Inv. >, eff. lower

4. Conventional biomass conversion technologies

4.2 Domestic waste combustion example (AEB A'dam)

Waste combustion - volume reduction

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

4. Conventional biomass conversion technologies

4.3 Stand-alone combustion example (Cuijk, Essent)

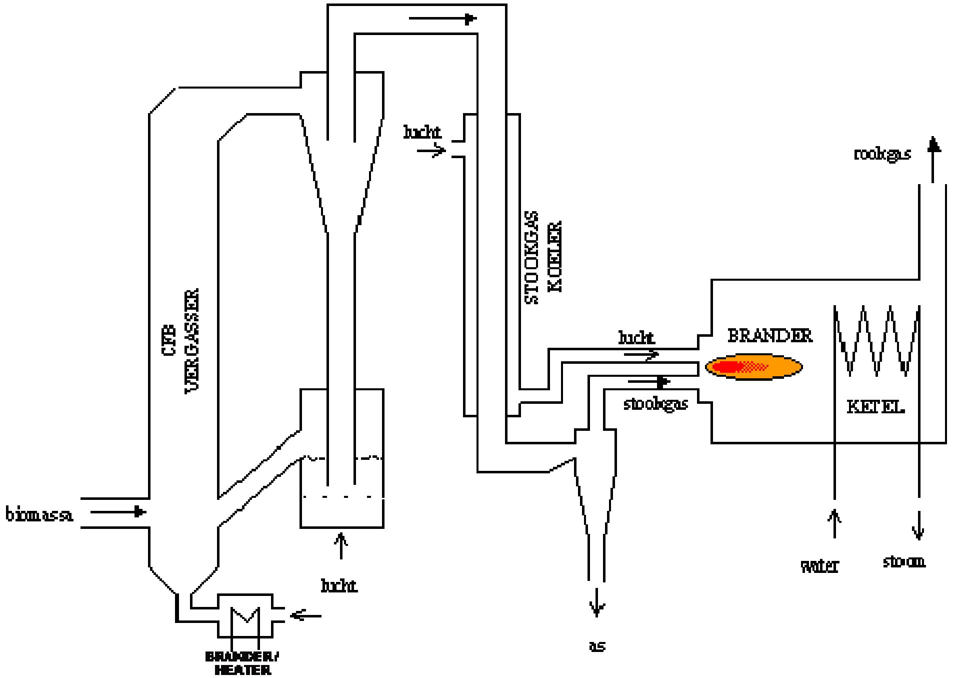
Input: 270 kton wood chips (50% moisture) = about 85 MW_{th} a year. Availability: 7600 hours/year. Technology: BFB combustion.

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

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

4. Conventional biomass conversion technologies

4.4 Air-blown atm. gasification for power/CHP production (example HoSt)



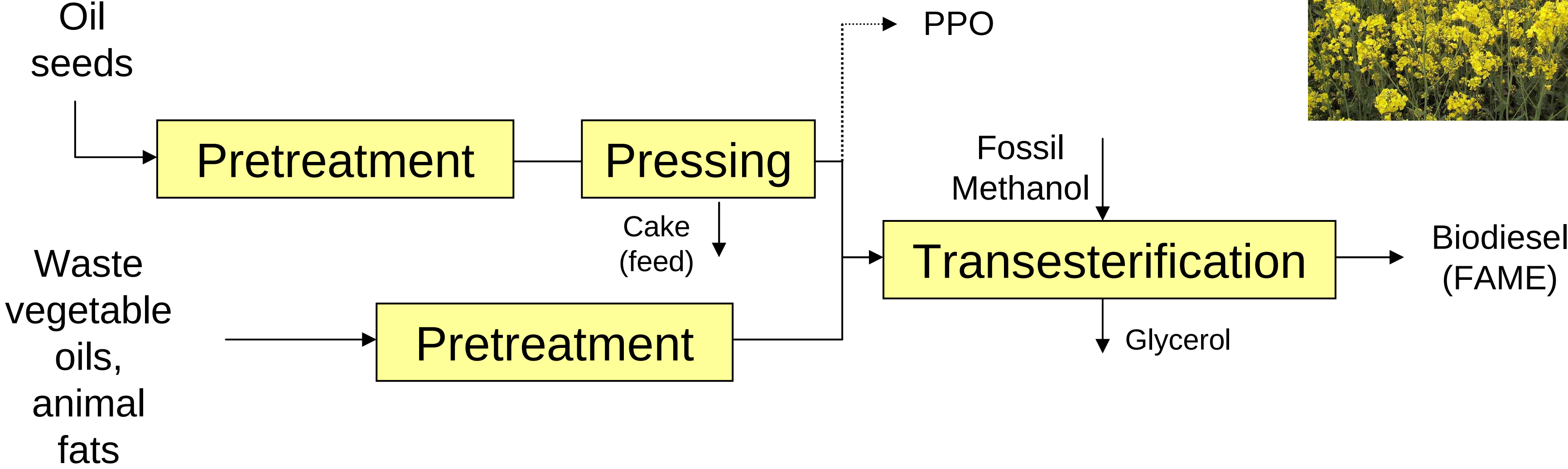
Sungas-installation in Galati, Romania

Chicken manure gasification in Friesland (Tzum)

Potential higher eff. and lower inv. costs at mean/higher capacities (> 10 MW_{th}) compared to combustion

4. Conventional biomass conversion technologies

4.5 Biodiesel production



Dutch market inititiatives:

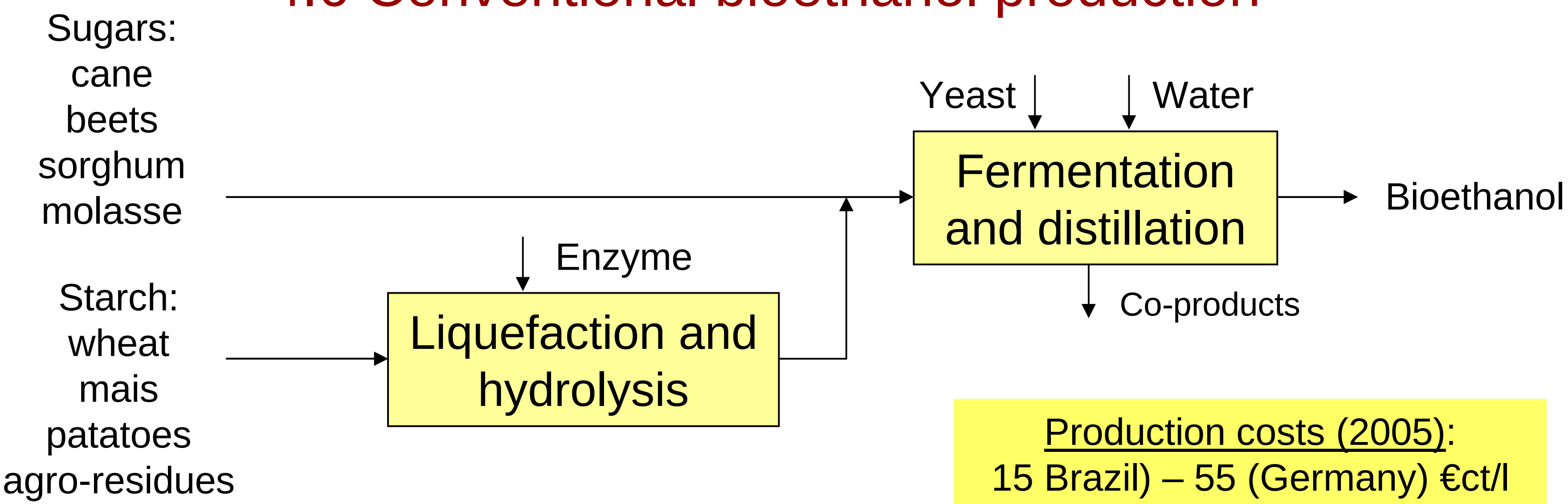
- Biofuelling (ES)/Zeeland Seaports (2008): 200 - 600 kt/a
- BioPetrol (SUI)/R’dam (2007): 400 kt/a
- Biovalue (Eemshaven): status unclear
- Sunoil Emmen (2006): 30 kt/a
- Ten Kate Ter Apelkanaal (2007): 10 Ml/a from fats

Developments:

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

4. Conventional biomass conversion technologies

4.6 Conventional bioethanol production



Production costs (2005):
15 Brazil) – 55 (Germany) €ct/l

Dutch market inititiatives (selection):

- Nedalco Sas van Gent/Cerestar (2008): 220 Ml/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
- Sabic 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

5. Advanced biomass conversion technologies

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

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

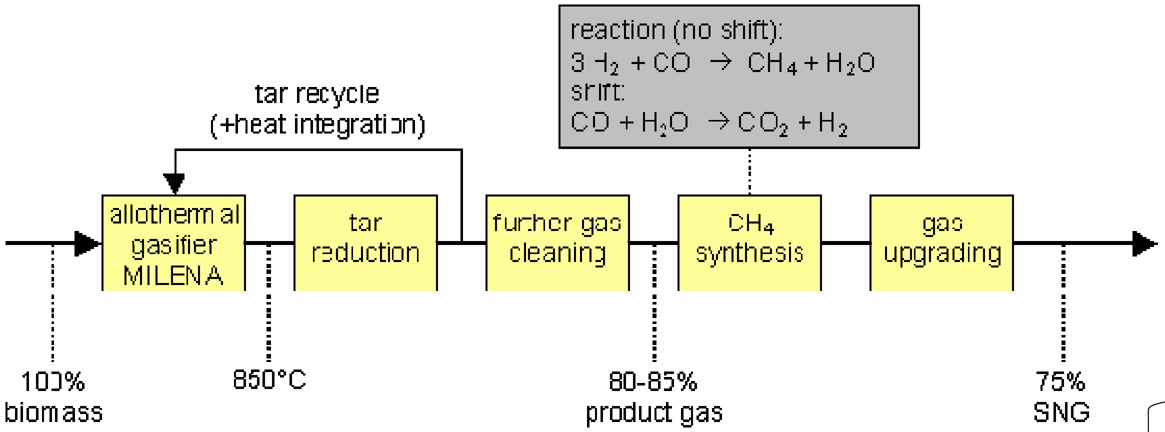
Elcogas Puertollano plant (ES): 320 MW_e

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

Potential Dutch initiatives MAGNUM (NUON), 2^0-Maasvlake

5. Advanced biomass conversion technologies

5.2 Air-blown indirect gasification for SNG production

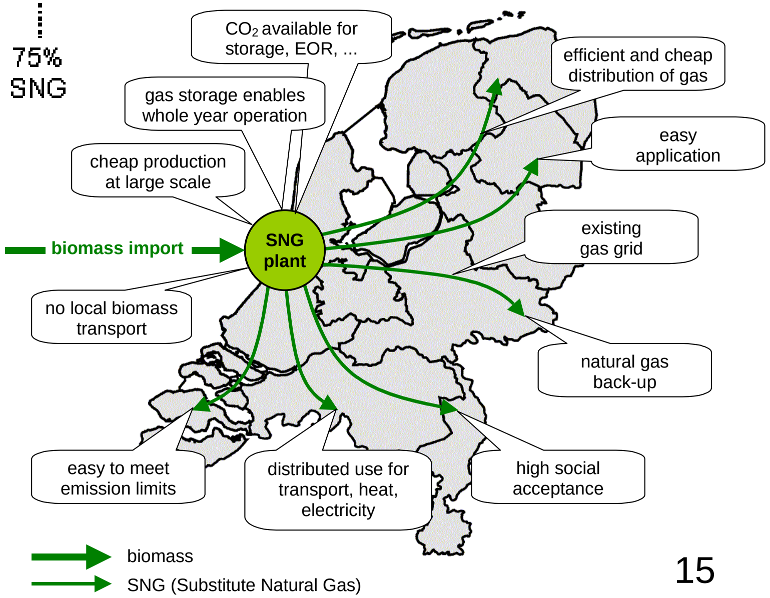


Transport losses powert (4%) versus green gas (1%)

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, …)



5. Advanced biomass conversion technologies

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

Reference GtL:
Demonstration plant
Bintulu,Malaysia

Capacity:
- 14,000 bbl/day
- 28 PJ fuel product
- 1400 MWth BioSyngas

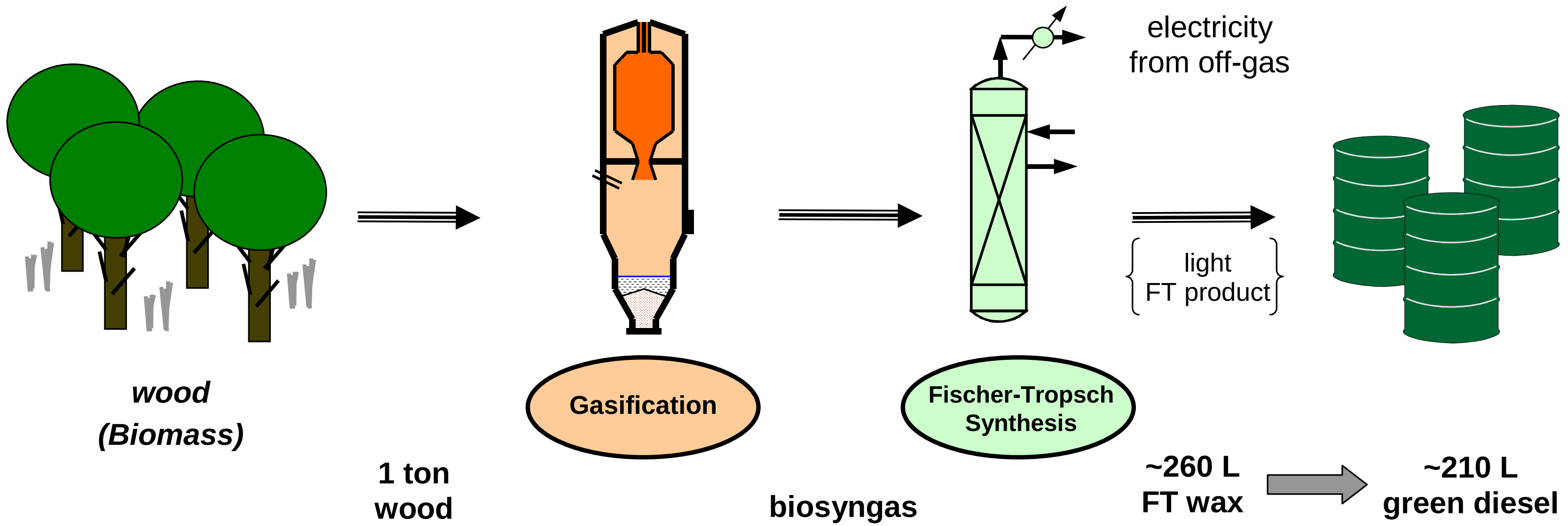
Equivalent to:
- 1,700 MWth raw biomass

Full-scale SMDS in Quatar
- 75,000 bbl/day
- about 10,000 MWth biomass

5. Advanced biomass conversion technologies

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

Yield from tree-to-barrel

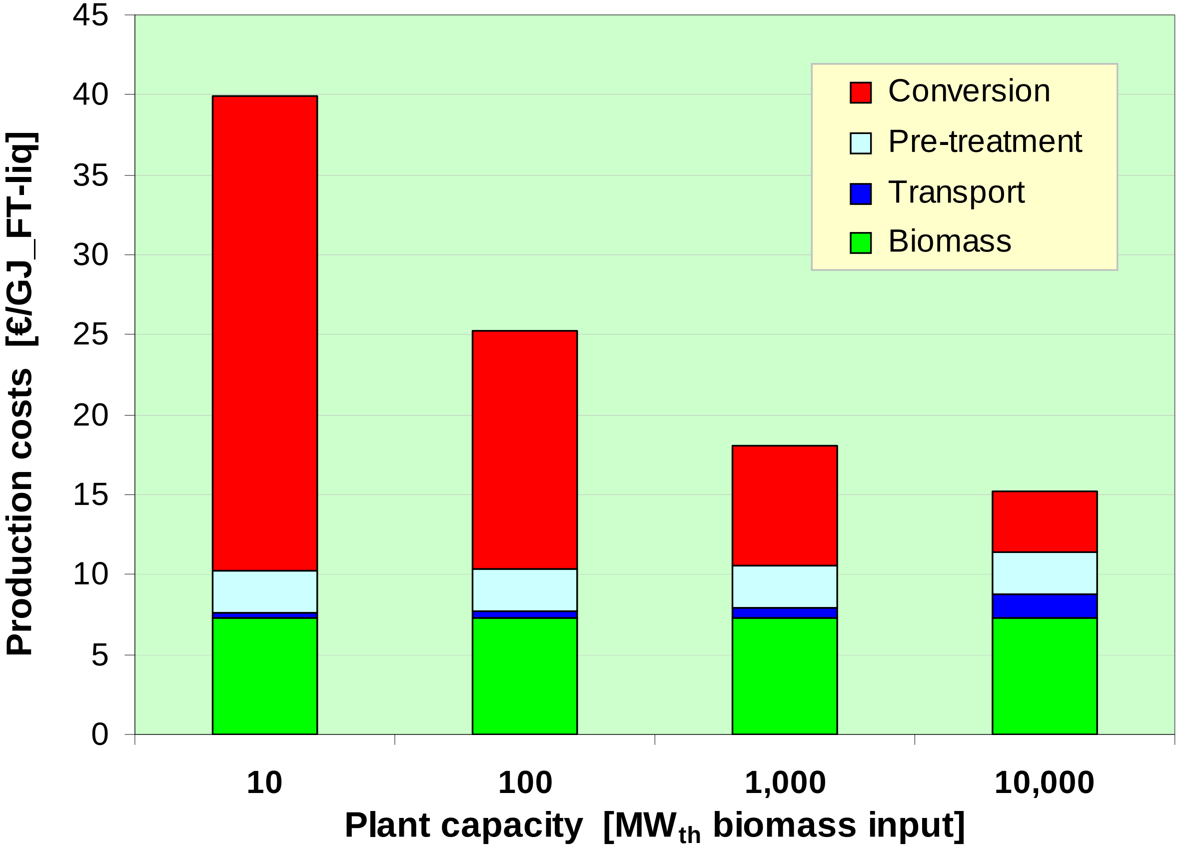


Energy efficiency from wood to diesel = ~44%, light products: 11%, power: 14% ->
total energetic efficiency: 69%

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%

5. Advanced biomass conversion technologies

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



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 C_5+ liquids) = 71%

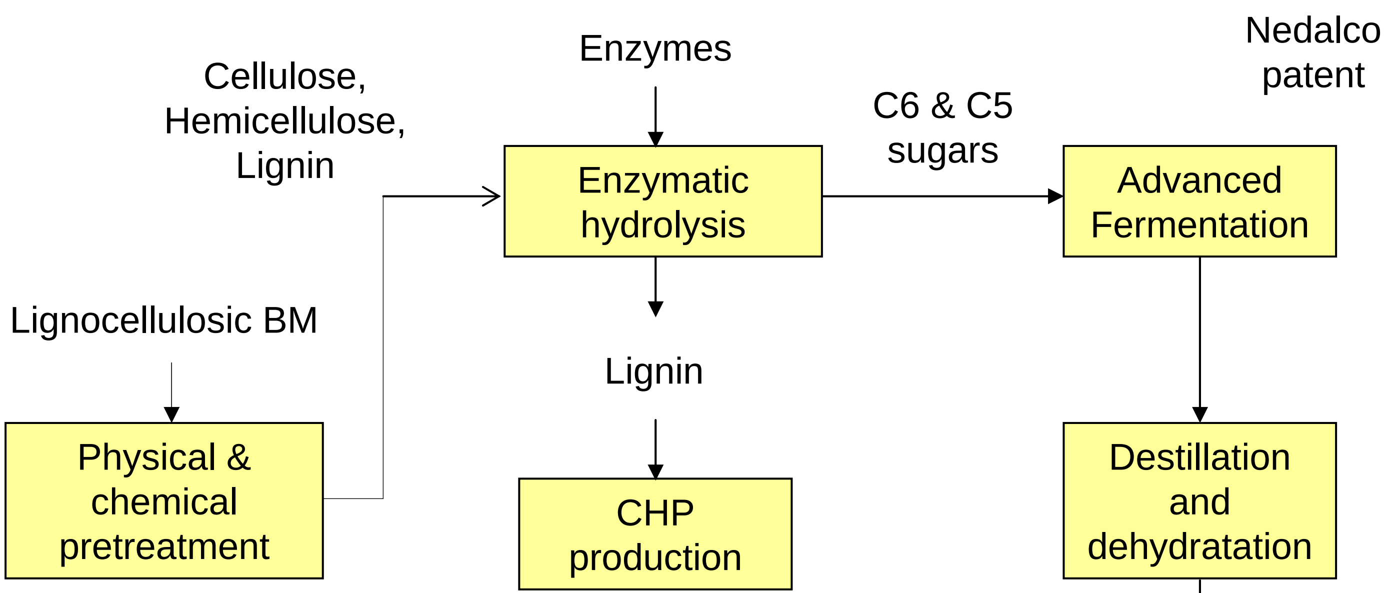
For reference: 15 €/GJ = 55 €ct/L

5. Advanced biomass conversion technologies

5.4 Depolymerisation/hydrolysis/fermentation (1)

<u>Example of lignocellulosic BM: Wheat straw</u>

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



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

Cellulosic ethanol 99.7 vol%

<u>Critical R&D-issues:</u>
- Physical/chemical pretreatment
- Enzymatic hydrolysis
- Co-fermentation C6/C5 sugars
- Process integration (heat, water, …)

5. Advanced biomass conversion technologies

5.4 Depolymerisation/hydrolysis/fermentation (2)

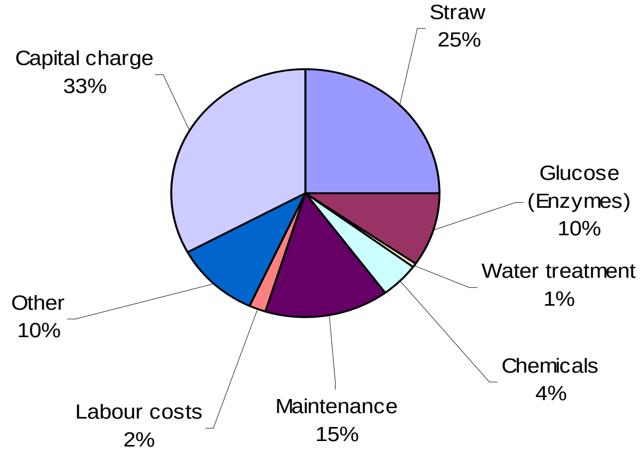
Basic Design 190 Ml/yr 99.7vol% ethanol from wheat straw

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

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

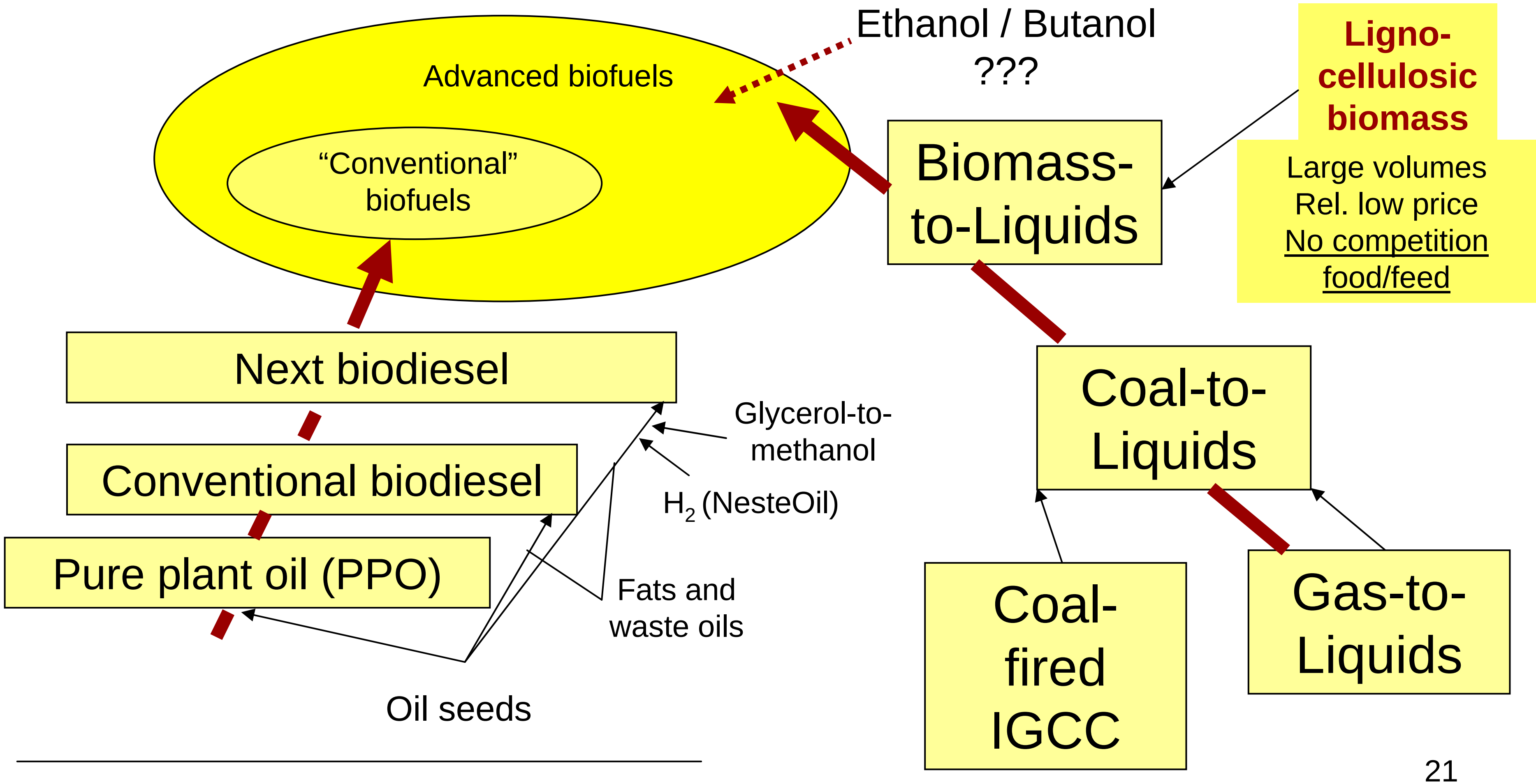
Straw: 38.5 €/t d.b.
2.5 €/GJ a.r.

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



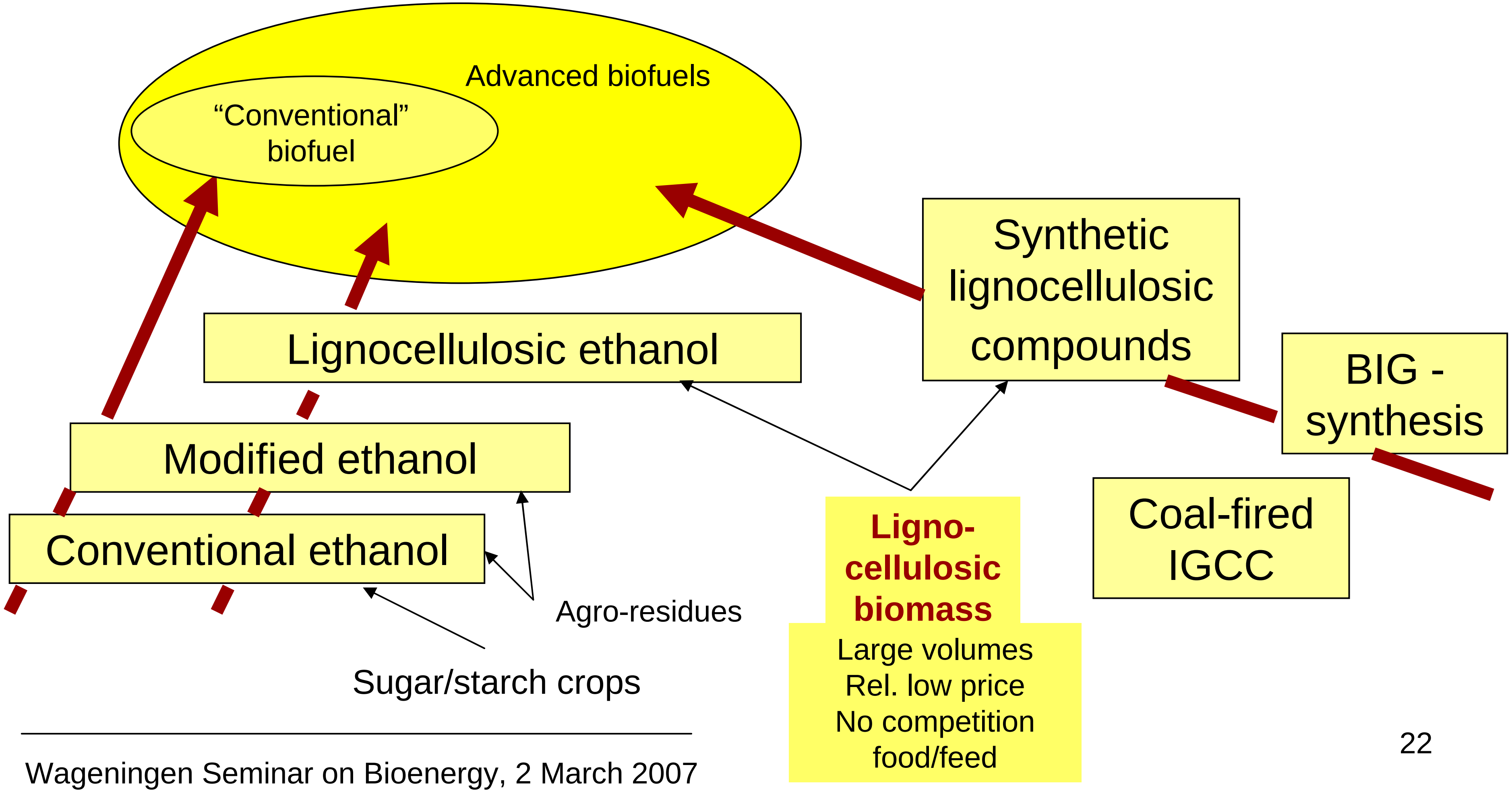
6. Technology and product transition pathways

6.1 Fossil diesel substitution (example)



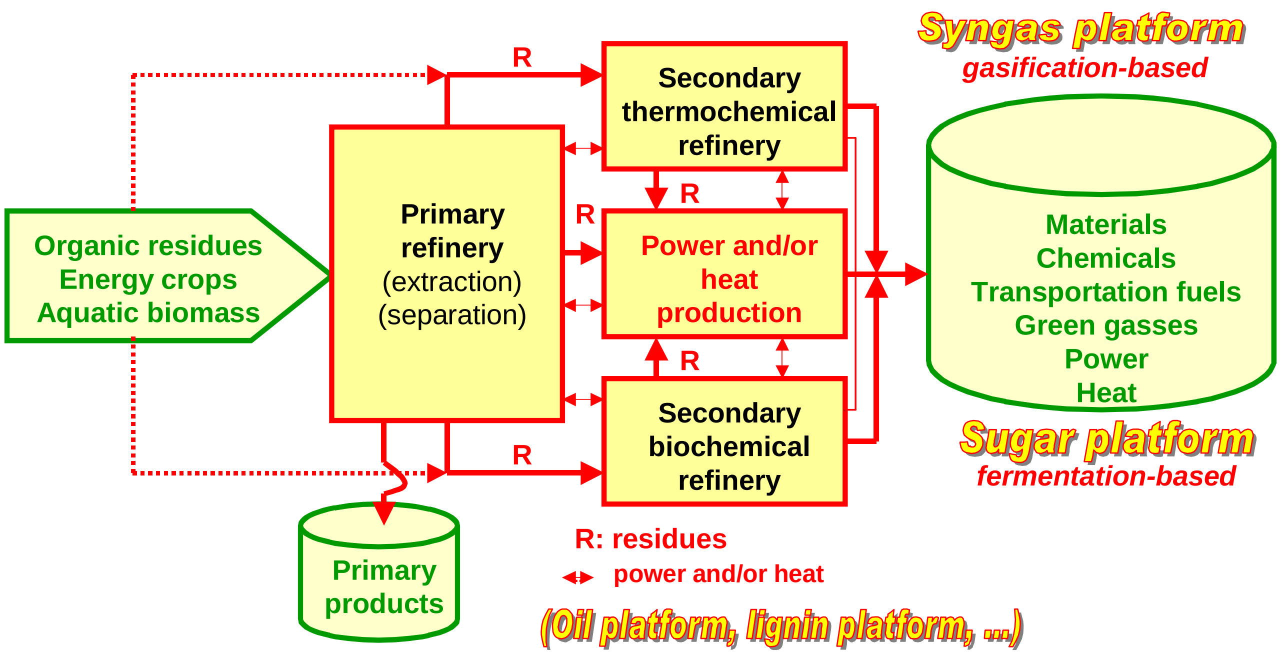
6. Technology and product transition pathways

6.2 Fossil gasoline substitution (example)



7. Optimal biomass conversion strategy to meet future market requirements - BIOREFINERY ?

A Biorefinery is an integrated facility for efficient co-production of materials, chemicals, transportation fuels, gaseous energy carriers, power and/or heat from biomass (analogeous to today's petroleum refineries)



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Programmatic biorefinery-based co-operation

Upstream and (bio)chemical expertise

www.bio2value.nl

Downstream and (thermo)chemical expertise

Dutch Knowledge Network on Biorefinery

www.biorefinery.nl

IEA Bioenergy Task 42 Biorefineries

National and EU-funded projects

EU IP BIOSYNERGY
EU SSP BIOPOL

8. Discussion - Conclusions

It is expected that biomass and biomass-derived intermediates will play a dominating role in the transition to – and the realisation of – a more sustainable Dutch economy. Biomass will be applied in almost all future market 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. agricultural residues, wood residues, forest residues, … and specific grown arable crops – will not be enough to meet the longer term market demand. Synergistic co-operations to make full use of this domestic potential should, however, be supported, especially for the short and midterm.

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

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

For the full presentation

www.biorefinery.nl

More information

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