

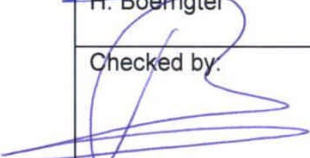


# Biomass-to-liquids

Opportunities & challenges within the perspectives of the EU Directives

*Presented at the  
5<sup>th</sup> Annual GTL (Gas-to-Liquids) Technology & Commercialization  
Conference & Exhibition, GTLtec,  
Doha, Qatar, 28-29 November 2005*

**H. Boerrigter  
A. van der Drift  
E.P. Deurwaarder**

| Revisions  |  |             |
|--|--|-------------|
| A  |  |             |
| B  |  |             |
| Made by:<br><br>H. Boerrigter | Approved/Issued by:<br><br>H.J. Veringa<br> | ECN Biomass |
| Checked by:<br><br>R. van Ree |  |             |



# Biomass-to-Liquids

**Harold Boerrigter, Bram van der Drift, Ewout P. Deurwaarder**  
Energy research Centre of the Netherlands (ECN), ECN Biomass



(1) ECN Biomass, Harold Boerrigter – 5<sup>th</sup> Annual GTL Conference & Exhibition, Doha, Qatar, 29 November 2005

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# Biomass-to-Liquids

**Opportunities & Challenges  
within the perspectives of the EU Directives**

**Harold Boerrigter**  
**Bram van der Drift, Ewout P. Deurwaarder**  
Energy research Centre of the Netherlands (ECN), ECN Biomass

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## Energy research Centre of the Netherlands ECN



- Independent energy research institute
- Founded in 1955
- 650 staff
- Annual turnover: 80 million EURO
- Activities:
  - Biomass
  - Solar
  - Wind
  - Fuel Cell Technology
  - Clean Fossil Fuels
  - Energy Efficiency
  - Policy Studies

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## Outline

- What is biomass
- EU Bio-fuel Directives
- Biomass-to-Liquids Technology
- Scale of BTL plants
- Economy
- Conclusions



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## What is biomass??

Wood, straw, grasses, etc.

willow



thinning wood  
from forests  
and parks



grassy crops

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## What is biomass??

Various (agro) residues and waste streams



straw



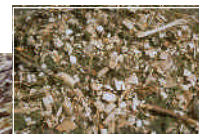
municipal solid  
waste (MSW)



recycled paper



demolition wood

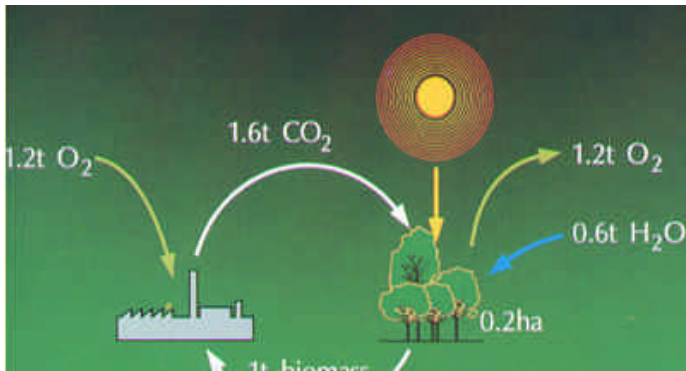


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## Biomass = renewable energy

CO<sub>2</sub> neutral



Biomass  $\approx$  CH<sub>2</sub>O

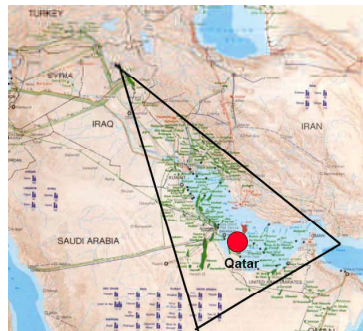
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## EU motivation

### Alternative transport fuels & Biofuels

- Reduction of Greenhouse Gas (GHG) emissions
  - Kyoto protocol (CO<sub>2</sub>)
  - Transport accounts for >30% of energy consumption and GHG emissions
  - Transport is only sector with increasing GHG emissions
- Security of supply
  - decrease dependency on one region
- Fuel diversification
  - decrease dependency on oil
- Agricultural development
  - job creation
  - rural development
- Depleting resources of fossil fuels (mainly for crude oil)



Oil triangle with 60% of remaining oil reserves  
Source: Aleklett et al.

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## EU “Biofuels” Directives & Proposals

### Alternative Transportation Fuels

|                | 2005      | 2010         | 2015       | 2020       |
|----------------|-----------|--------------|------------|------------|
| biofuels       | 2%        | 5.75%        | 7%         | 8%         |
| natural gas    |           | 2%           | 5%         | 10%        |
| H <sub>2</sub> |           | -            | 2%         | 5%         |
| <b>Total</b>   | <b>2%</b> | <b>7.75%</b> | <b>14%</b> | <b>23%</b> |

- 2001: EU Directive proposal for “Alternative Transportation Fuels”
- 2003: EU Directive 2003/30/EC for period 2005-2010 for “Biofuels”
  - not mandatory, deviations should be motivated, if unjustified: mandatory targets

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## EU “Biofuels” Directives & Proposals

### Outlook beyond 2010

|                | 2005      | 2010         | 2015       | 2020       | new proposal 2020 |
|----------------|-----------|--------------|------------|------------|-------------------|
| biofuels       | 2%        | 5.75%        | 7%         | 8%         | 15%               |
| natural gas    |           | 2%           | 5%         | 10%        | 10%               |
| LPG            |           |              |            |            | 5%                |
| H <sub>2</sub> |           | -            | 2%         | 5%         | a few %           |
| <b>Total</b>   | <b>2%</b> | <b>7.75%</b> | <b>14%</b> | <b>23%</b> | <b>&gt; 30%</b>   |

- EU Alternative Fuels Contact Group proposal for period beyond 2010
- Discussions on mandatory shares for biofuels ongoing
  - *in some countries already projected*

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## Biofuels in EU-25

### Main current & future biofuels

#### Current = First Generation

|                      |                                       |
|----------------------|---------------------------------------|
| Pure Plant Oil (PPO) | <i>oil crops</i>                      |
| Biodiesel            | <i>oil crops/waste vegetable oils</i> |
| Bio-ethanol          | <i>sugar/starch crops</i>             |
| Bio-ETBE             | <i>bio-ethanol</i>                    |
| Bio-SNG              | <i>wet biomass</i>                    |

#### Future = Second Generation

|                        |                        |
|------------------------|------------------------|
| Fischer-Tropsch diesel | <i>all biomass</i>     |
| Methanol / DME         | <i>all biomass</i>     |
| Hydrogen               | <i>wet/all biomass</i> |
| Bio-ethanol            | <i>all biomass</i>     |
| Bio-SNG                | <i>all biomass</i>     |

produced via **syngas** intermediary

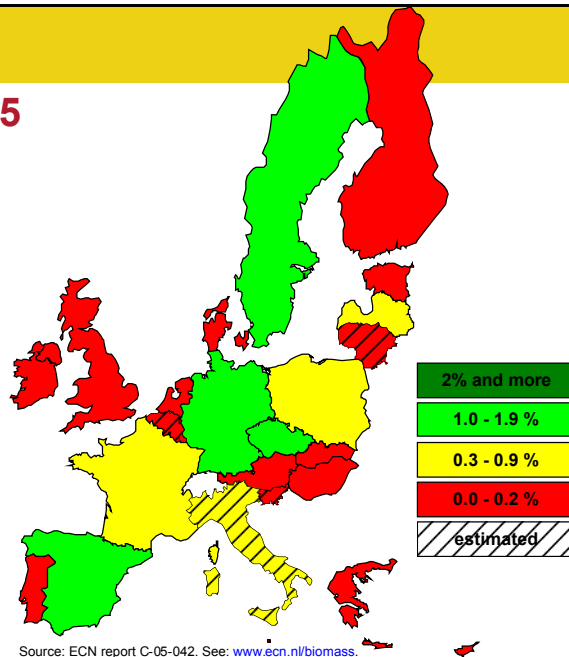


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## Biofuels in EU-25

### Situation 2003



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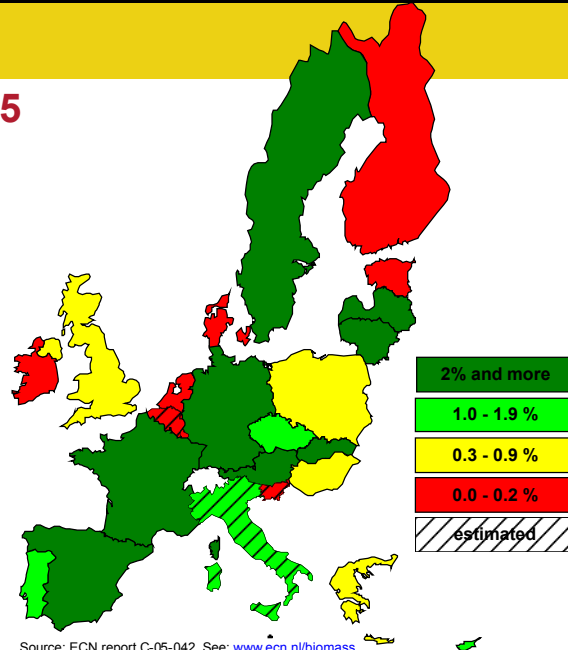
## Biofuels in EU-25

### Expected 2005

#### Main biofuels:

- Biodiesel
- Bio-ethanol & derivatives, *i.e.* ETBE
- Fuel blends
  - E5
  - E85
  - ETBE
  - *few percent biodiesel*

#### Only First Generation Fuels



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## Biofuels in EU-25

### Fuel market & biofuels potential

| Year                        |        | 2005 | 2010 | 2015  | 2020  |
|-----------------------------|--------|------|------|-------|-------|
| Biofuels substitution       | [%]    | 2.0  | 5.75 | 7     | 15    |
| Total transport fuel market | [Mtoe] | 293  | 317  | 343   | 371   |
| Biofuels market             | [Mtoe] | 6    | 18   | 24    | 56    |
| Energy equivalent           | [PJ]   | 250  | 760  | 1,000 | 2,300 |

Source: Kavalov & Peteves, EC JRC, 2005.

#### First Generation biofuels

- Potential is limited, due to:
- Feedstock requirement
- Fuel quality

#### Second Generation (synthetic) biofuels; status:

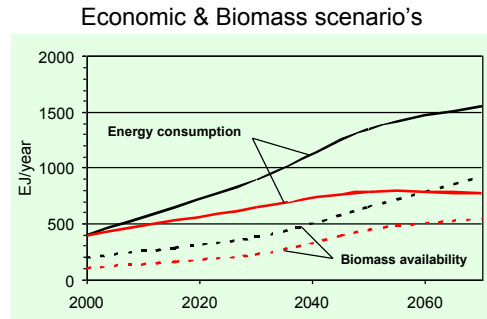
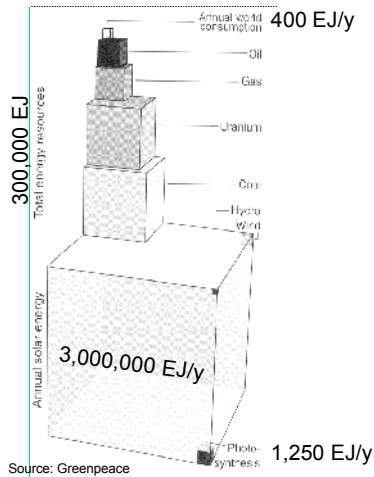
- Few engine demonstrations (on fossil fuels)
- No production capacity
- Bio-ethanol: several pilot plants

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## Biofuels in EU-25

### Enough biomass?? - two approaches



*Yes, there is enough biomass...  
to be a serious option for renewable energy  
generation and biofuel production*

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## Biofuels in EU-25

### Summarising policy & markets

- High ambitions of EU and (some) national governments
- "It" will happen: a market for biofuels is created
- Today with tax exemptions, upcoming with mandatory biofuels blending
- Quality and production costs will determine market potential
- Potential (volume, quality) of First Generation Biofuels is limited
- Second Generation Biofuels Biofuels will become dominant after 2010
- There is enough biomass

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## Biofuels in EU-25

### Synthetic biofuels

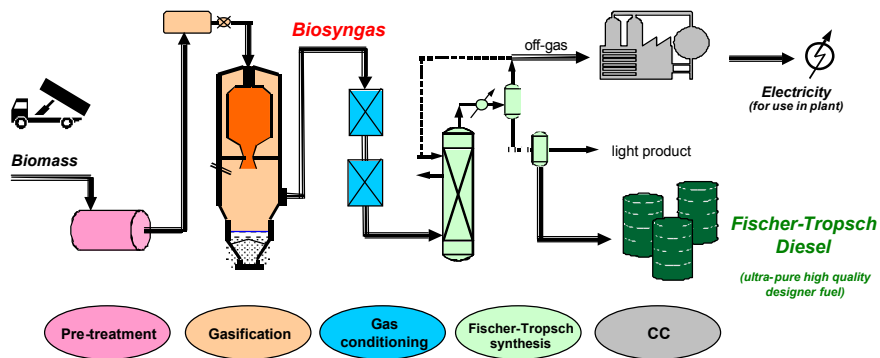
- Most developments in EU converge to bio-ethanol and Fischer-Tropsch diesel as Second Generation Biofuels
- Ligno-cellulose (wood, straw) most important feedstock
- Bio-ethanol (in general) as gasoline substitute
- Fischer-Tropsch fuels for diesel market
- DME production highest well-to-wheel efficiency, but not applicable in existing fuel infrastructure. Only Sweden aims at DME
- Some oil companies produce diesel by upgrading biodiesel (hydro-treating) ⇒ intermediate solution
- This presentation: *Biomass-to-Liquids (BTL)*  
*Production of FT-fuels from biomass via syngas intermediary*

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## Biomass-to-Liquids

### System line-up of integrated BTL plant

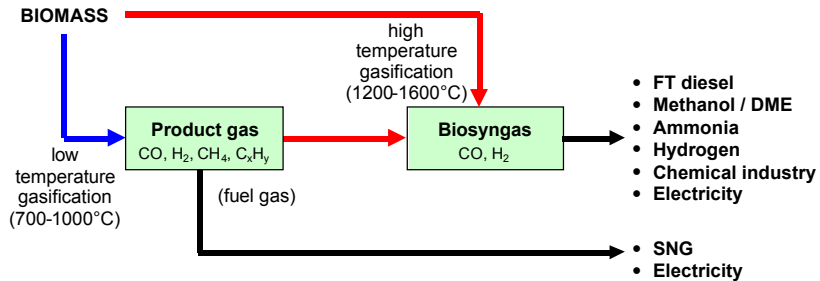


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## Optimum gasification technology

“Biosyngas” versus “Product gas”



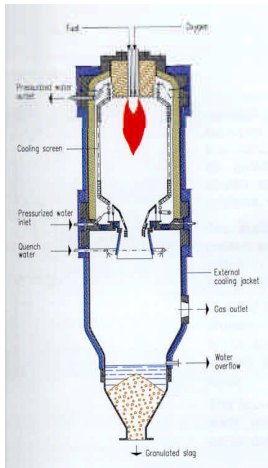
Conversion of product gas into biosyngas by:

1. Reforming (catalytic)
2. Tar cracking (thermal)

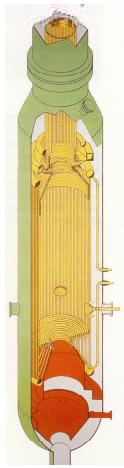
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## Entrained flow gasifier



Future Energy



Shell/Uhde

### Dry feed slagging gasifiers

Characteristics:

- Temperature: 1200-1600°C
- Syngas
- Pressure: 20-40 bar
- Oxygen
- Slagging
- Conversion: >99%
- Efficiency (LHV): 80%
- Fuel flexible
- Small feed particles
- Proven for coal

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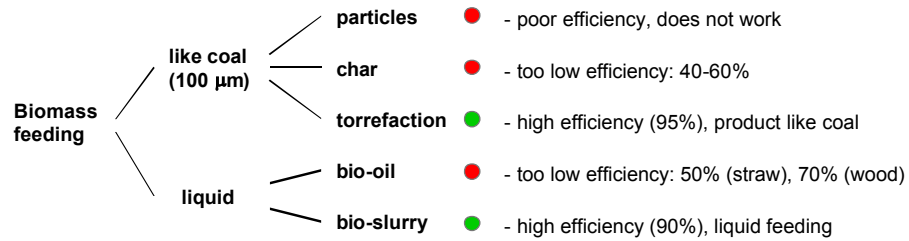
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## Biomass pre-treatment

### Motivation & options

Pre-treatment of biomass is desired / required to:

- allow stable feeding into the gasifier with minimum inert gas consumption
- allow stable operation of the gasifier (*i.e.* increase energy density)
- reduce transport cost due to volume reduction



Source: ECN report C-04-039. See: [www.ecn.nl/biomass](http://www.ecn.nl/biomass).

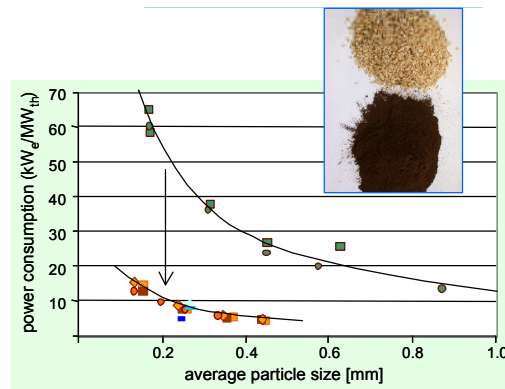
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## Torrefaction

### Upgrading biomass to coal properties

- Mild thermal treatment (250-300°C), *i.e.* “roasting” to evade CO<sub>2</sub>, H<sub>2</sub>O, acids
  - homogenising biomass
  - increase heating value
  - increase density
  - loss of fibrous character
- Increase grindability
  - reduce electricity consumption
  - increase mill capacity
- Allow feeding with existing pneumatic coal feeding systems
- Pellets from torrefied biomass (“TOP”) have excellent transport properties
  - hydrophobic



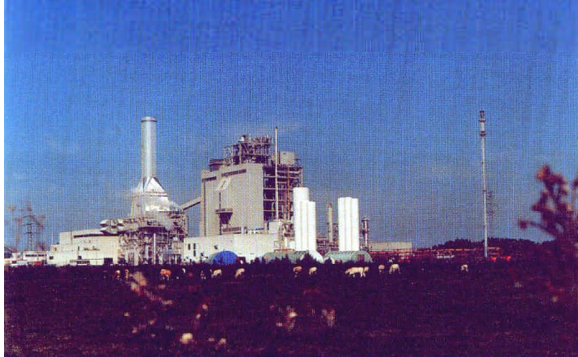
Source: ECN reports C-05-013, C-05-067, C-05-073. See: [www.ecn.nl/biomass](http://www.ecn.nl/biomass).

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## EF gasification of biomass

### Co-gasification with coal



**Reference:**

NUON utility company owned  
Buggenum, the Netherlands

**Specifics:**

- Coal-fired power station
- 600 MW<sub>th</sub> / 250 MW<sub>e</sub>
- Shell SCGP technology

**Biomass co-gasification:**

- up to 34 wt% demonstrated
- or ~20% on energy basis

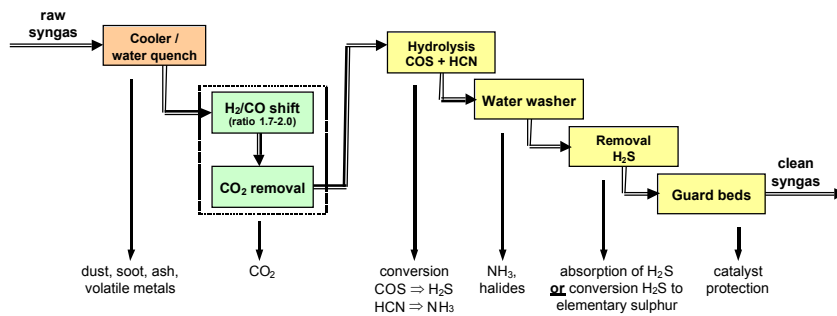
**~100 MW<sub>th</sub> biosyngas**

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## Syngas treating

### Example of line-up for cooling, condition, and cleaning



- There are no biomass-specific impurities that require a totally different gas cleaning approach.
- Syngas from biomass gasification (“biosyngas”) can be cleaned to meet FT specifications with proven and commercial available technologies

Source: ECN report C-04-056. See: [www.ecn.nl/biomass](http://www.ecn.nl/biomass)

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## Fischer-Tropsch synthesis

Example: Shell SMDS plant



Reference:  
 Demonstration plant  
 Bintulu, Malaysia

Capacity:  
 - 14,000 bbl/d  
 - 28 PJ fuel product  
 - 1,400 MW<sub>th</sub> syngas

Equivalent to:  
 - 1,700 MW<sub>th</sub> biomass

Full-scale SMDS (Qatar):  
 - 70,000 bbl/d fuel  
 - 8,500 MW<sub>th</sub> biomass

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## Fischer-Tropsch potential in EU-25

Within EU Bio-fuel Directives

Potential for second generation synthetic FT diesel from biomass:

- Assume a 1:1 fuel mix of gasoline and diesel
- First Generation Biofuels for diesel fixed to 150 PJ
- Potential of Fischer-Tropsch diesel = **1,000 PJ or 24 Mtoe** (2020)
- Number of plants required to meet targets

| 2010 | 2015 | 2020 | Biomass input |  |
|------|------|------|---------------|--|
| 2    | 3    | 7    | BTL plants of | 8,500 MW <sub>th</sub> ("Qatar")         |
| 8    | 13   | 36   | BTL plants of | 1,700 MW <sub>th</sub> ("Malaysia")      |
| 56   | 86   | 247  | BTL plants of | 250 MW <sub>th</sub> ("Typical biomass") |

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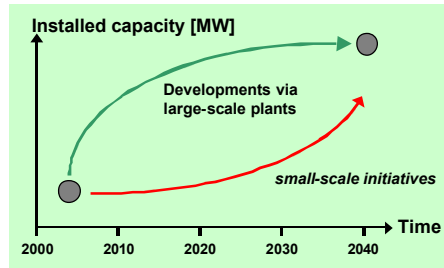
## Required bio-fuel production capacity

### Motivation for large-scale plants

- Large number of small plants required to meet targets
- Not sufficient locations
- Legislation & permitting
- Objectives are easier and faster fulfilled with few large plants:

### Additional

- In many EU countries biomass import required
- Most biomass is available on a few locations (*i.e.* harbours)
- Integration in existing chemical infrastructures



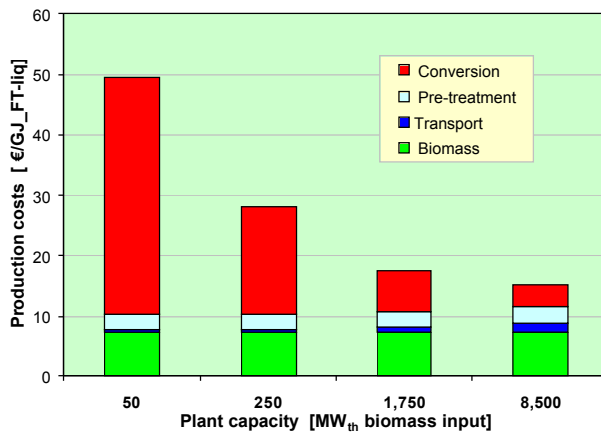
Source: ECN report RX-05-181. See: [www.ecn.nl/biomass](http://www.ecn.nl/biomass).

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## Total FT fuel production costs

### Scale dependency



- Biomass costs = 4 €/GJ<sub>ar</sub>
- Pre-treatment costs = 1.5 €/GJ<sub>ptt\_bm</sub>
- Local biomass (truck transport)
- Variable transport costs: 0.08 €/ton/km
- Depreciation = 10 years (linear)
- Required IRR = 12%
- O&M costs = 7%
- Scale factor = 0.7 (>2,000 MW<sub>th</sub>)  
0.5 (<2,000 MW<sub>th</sub>)
- Availability = 8,000 h/y
- Pre-treatment efficiency (torrefaction) = 97%
- Gasification efficiency (biomass to biosyngas) = 80%
- Conversion efficiency (biosyngas to FT C<sub>5+</sub> liquids) = 71%

For reference: 15 €/GJ = 55 €/t/L

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## Conclusions

- Biofuels are going to play an important and significant role in the future (European) fuel infrastructure
- Second Generation (synthetic) Biofuels will take the largest market share:  
⇒ Biomass-to-Liquids (BTL)
- The heart of a BTL plant is a slagging entrained flow gasifier
- Gas conditioning is proven and available
- Pre-treatment is required for feeding;  
torrefaction is most attractive option, *i.e.* make biomass behave like coal
- Implementation (initially) via co-gasification with coal
- Large-scale plants are required to:  
(1) thrive implementation and (2) allow cost effective fuel production
- At large scale BTL fuels are competitive with fossil fuels (@ 50-60 \$/bbl)

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## Thank you for your attention

**For more information,  
please contact:**

Dr. ir. Harold Boerrigter  
phone +31 224 56 4591  
fax +31 224 56 8487  
email [boerrigter@ecn.nl](mailto:boerrigter@ecn.nl)

Publications can be found on:  
[www.ecn.nl/biomass](http://www.ecn.nl/biomass)

Visit also: "Phyllis" - internet database for biomass, coal, and  
residues: [www.phyllis.nl](http://www.phyllis.nl)

"Thersites" – internet model for tar dewpoint calculations:  
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## ECN Biomass - 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)*