Outlook on Biomass Pellet Market & Biomass Processing Technologies

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May 2013
ECN-L--13-027

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Biomass Asia Conference 2013

20-22 May, Kuala Lumpur, Malaysia

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Content

- Introduction ECN
- Biomass Demand of Northwest Europe
- ECN's Biomass Technologies
  - Biomass Upgrading
  - Biomass Gasification (Combustion)
  - Biomass Refinery

Locations

ECN
Petten
(head office)

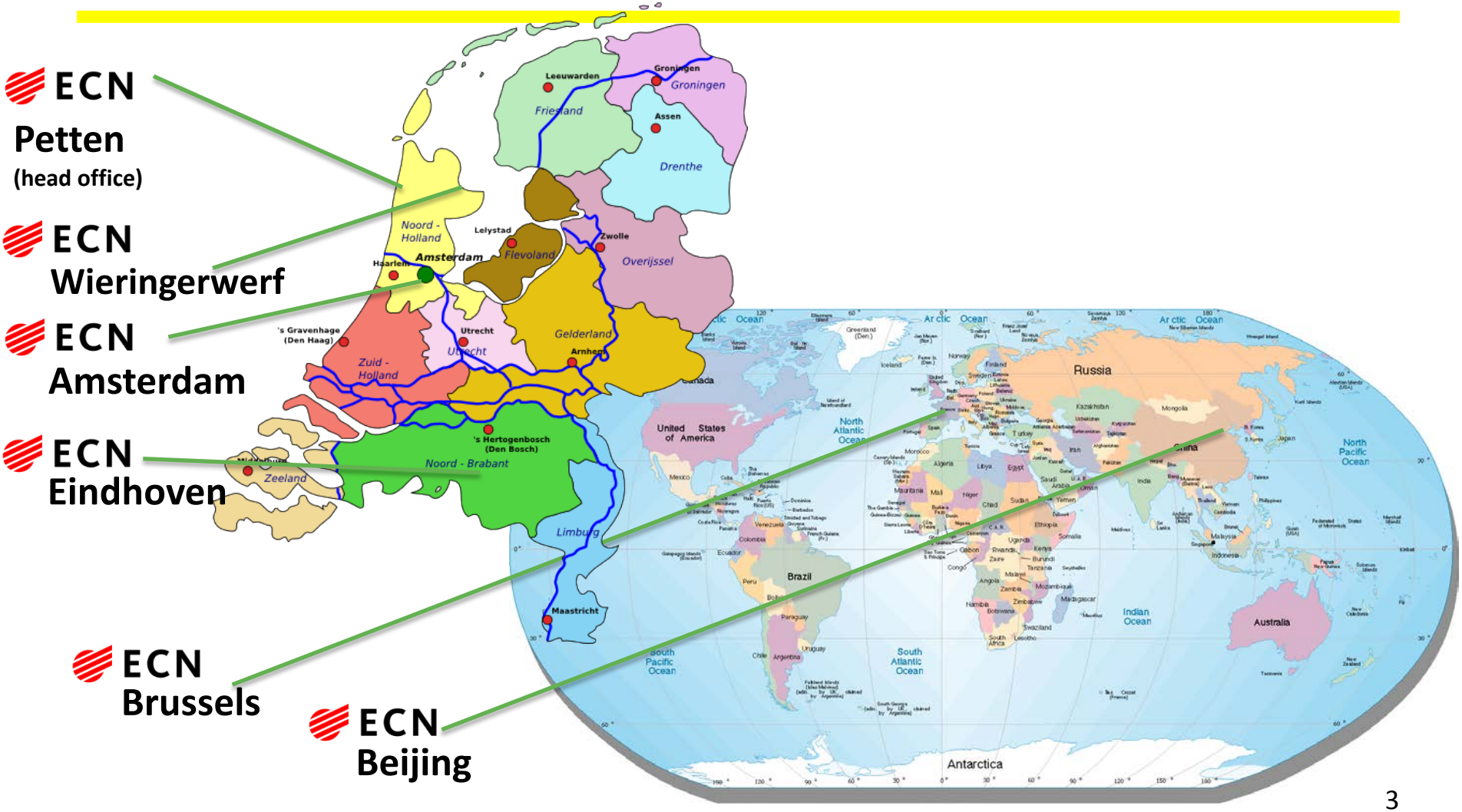
ECN
Wieringerwerf

ECN
Amsterdam

ECN
Eindhoven

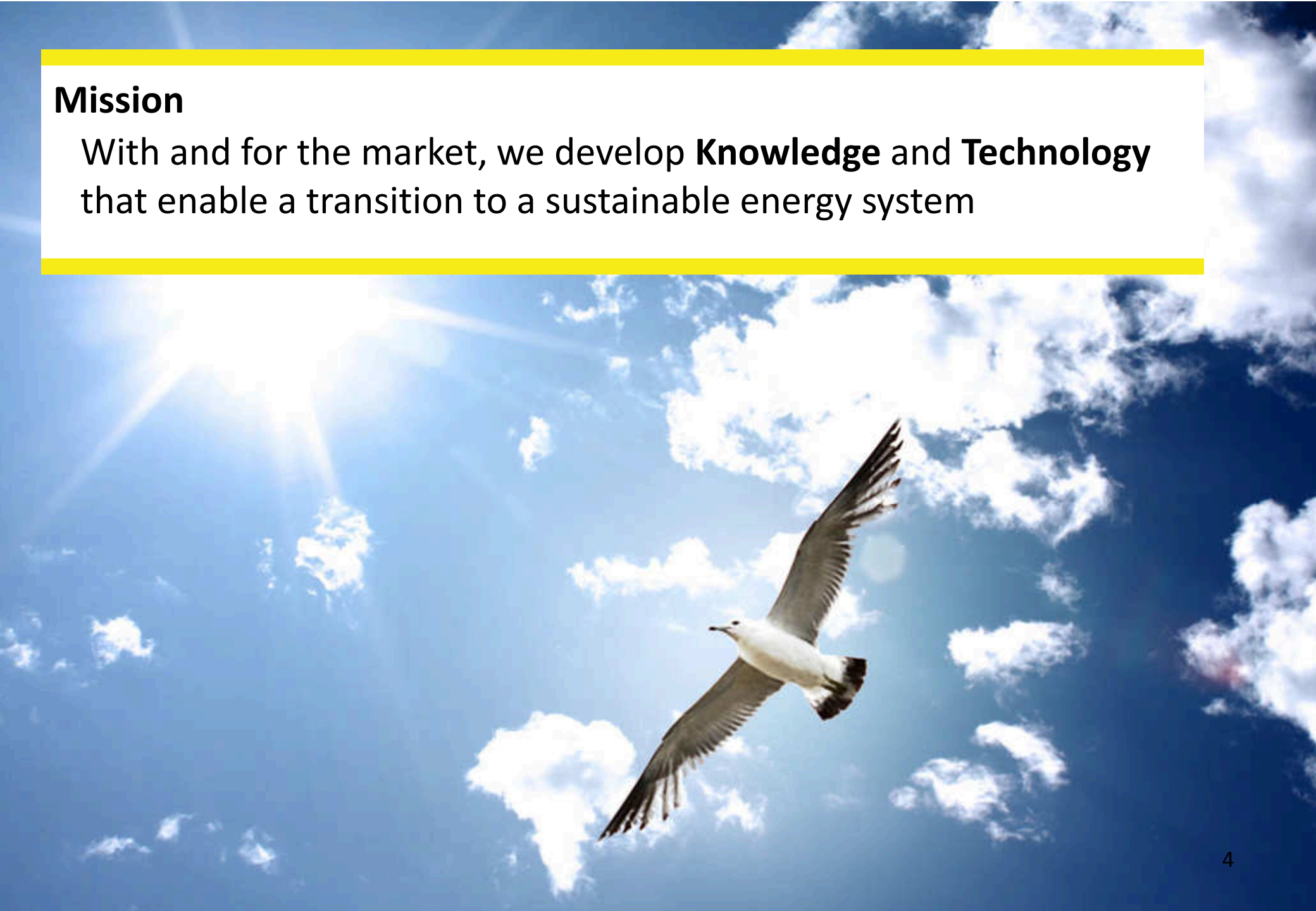
ECN
Brussels

ECN
Beijing

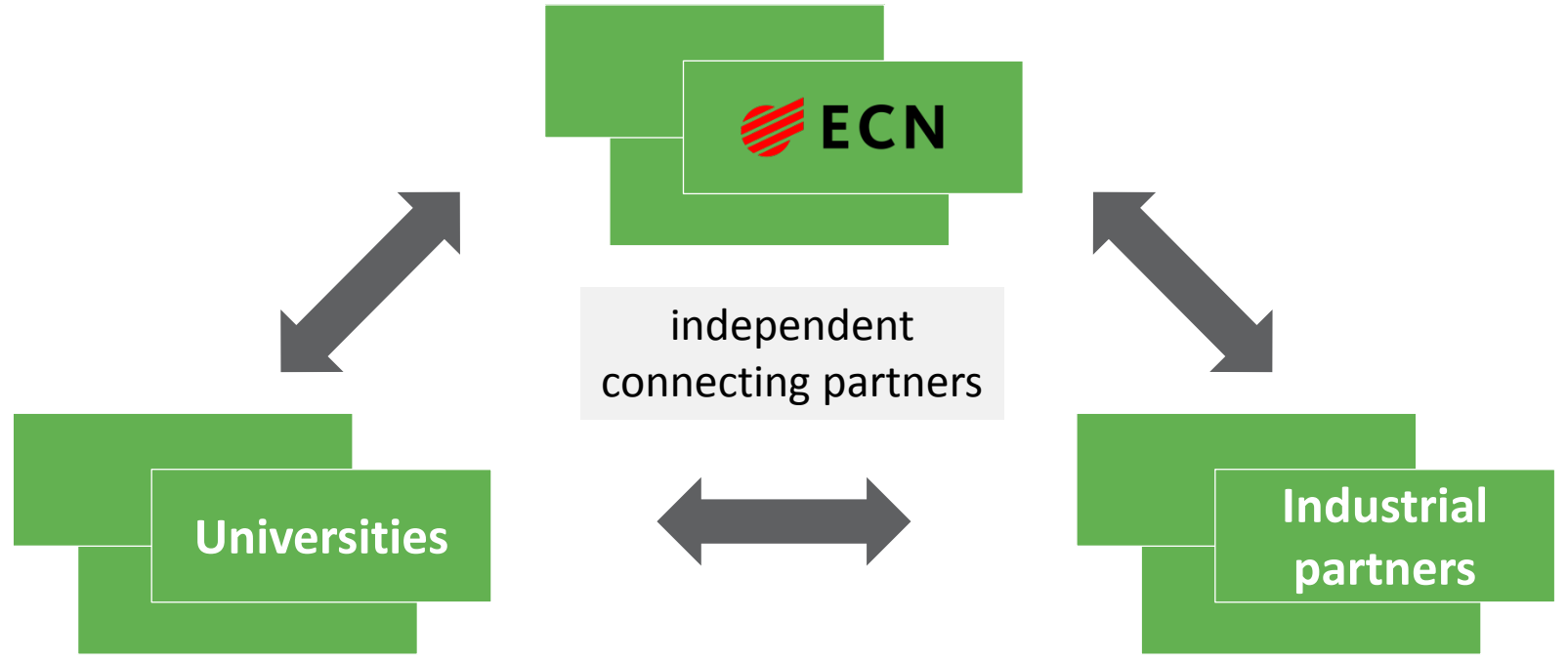


Mission

With and for the market, we develop **Knowledge** and **Technology** that enable a transition to a sustainable energy system



Our Position



R&D fields

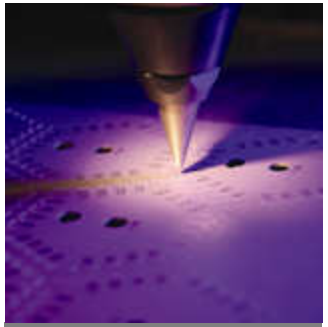
Policy Studies

Biomass

Solar Energy

Wind Energy

Energy Efficiency



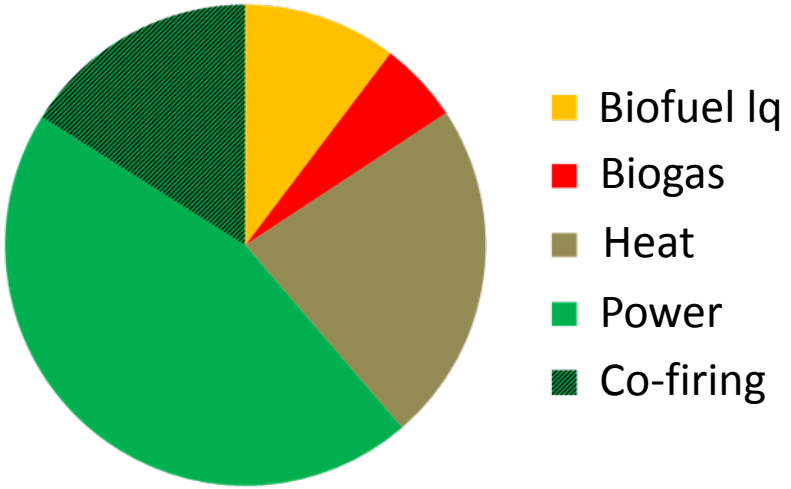
Energy Engineering

Environment

Demand for Lignocellulosic Biomass of Northwest Europe

Biomass demand & supply in The Netherlands

- Renewable energy target 2020 is 16%
  - Currently 4%
- Co-firing obligation expected



Demand and supply of lignocellulosic biomass [Mt wood pellets eq / year]

	2010	2020			2030		
		BaU	BaU-BM	SNP	BaU	BaU-BM	SNP
Demand	3.1	3.0	4.2	7.2	3.5	4.4	6.5
Domestic	1.7	2.5	1.5	2.3	2.4	2.0	2.7
Import EU	0.2	0.5	0.2	0.4	0.2	0.0	0.0
Import non-EU	1.2	0.0	2.5	4.5	0.9	2.4	3.8

Port of Rotterdam, Ric Hoefnagels et al

Biomass demand & supply in Northwest EU

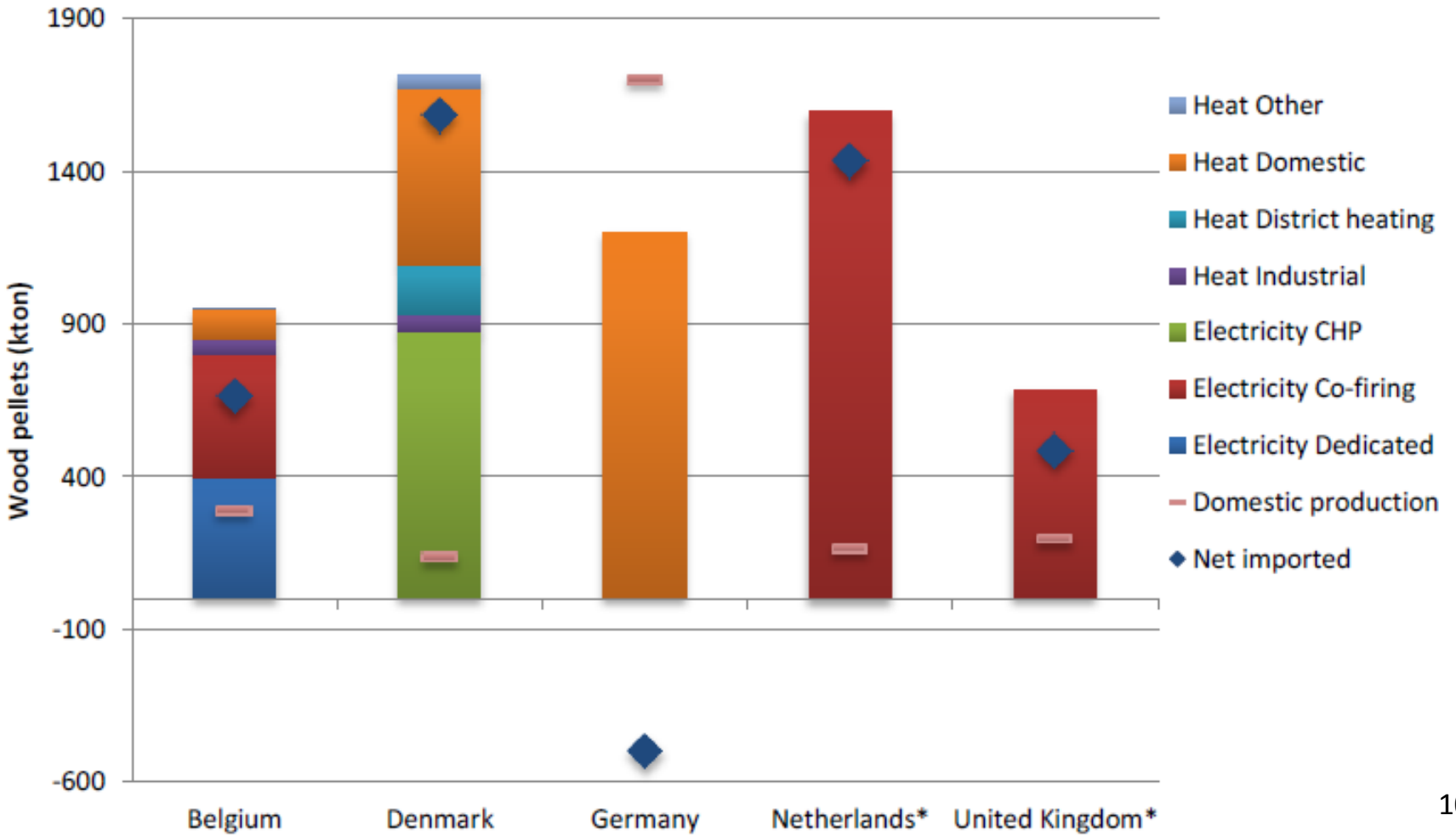
Demand and supply lignocellulosic biomass [Mt wood pellets eq / year]

- **Belgium, Denmark, Netherlands, Germany, United Kingdom**

	2010	2020			2030		
		BaU	BaU-BM	SNP	BaU	BaU-BM	SNP
Demand	45	67	78	93	78	85	109
Domestic	40	54	53	58	56	63	75
Import EU	2.2	13	18	16	4.6	2.9	0.3
Import non-EU	1.9	0.0	7.6	20	17	19	34

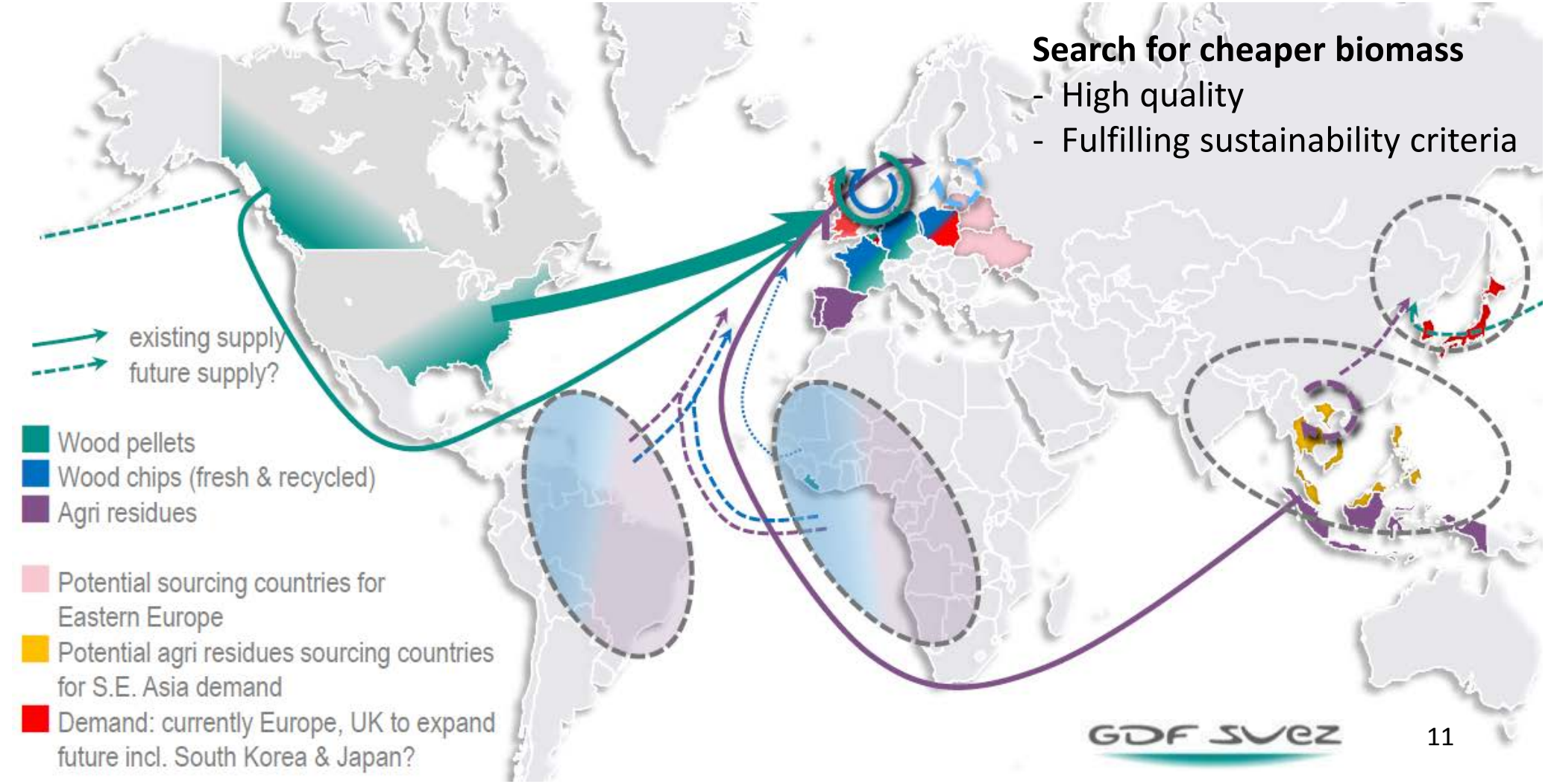
Port of Rotterdam, Ric Hoefnagels et al

Wood pellet consumption per sector in 2010



Based on Chocchi et al

Biomass pellets import / export

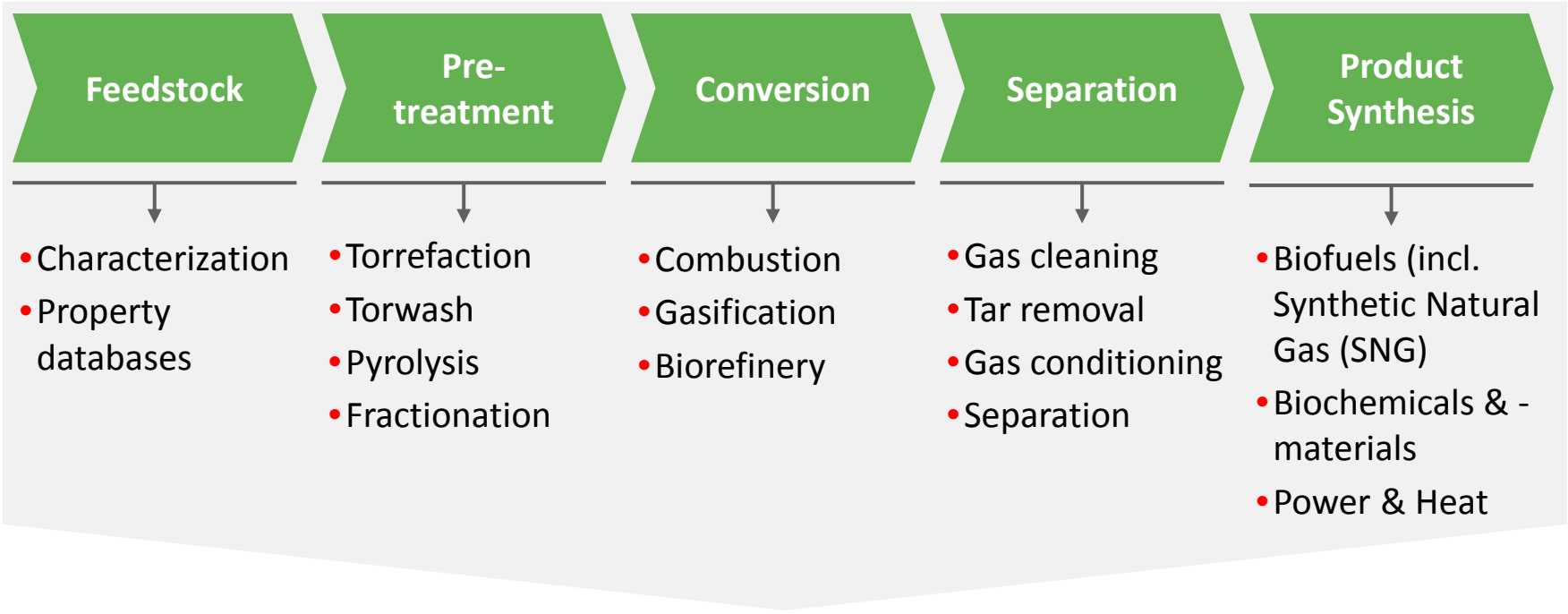


Biomass

Revolutionizing a Global Primary Energy Source

Making bioenergy work

Focus on thermochemical processing



Higher efficiencies, higher availability, lower environmental impact, higher public acceptance, lower CAPEX/OPEX, new applications

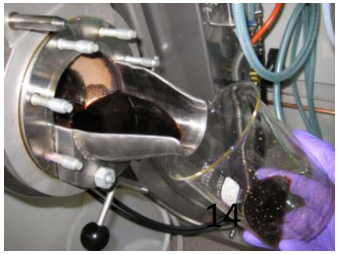
Feasibility studies, techno-economic evaluations, LCA, sustainability assessments

Main biomass R&D areas

- Upgrading: Biomass to commodity fuel
  - Torrefaction: ECN technology available on full scale
  - New technology for torrefaction of wet biomass: TORWASH

- Combustion: Biomass boilers and co-firing
  - Fuel behavior during combustion
  - Ashes, slags, agglomeration behavior

- Gasification: Production of power or fuels
  - Development of gasification technology: MILENA
  - Tar removal and product synthesis
  - Test equipment and expertise to provide services
- Biorefinery: Technology for a biobased economy
  - Organosolv fractionation into cellulose, hemicellulose, and lignin
  - Conversion of fractions into marketable products



Biomass Upgrading

Torrefaction

- Converting biomass into commodity fuel

Tough and fibrous
LHV = 9 - 12 MJ/kg
Hydrophilic
Biodegradable
Heterogeneous

Torrefaction

Brittle and less fibrous
LHV = 18 - 24 MJ/kg
Hydrophobic
Preserved
Homogeneous

Pelletisation

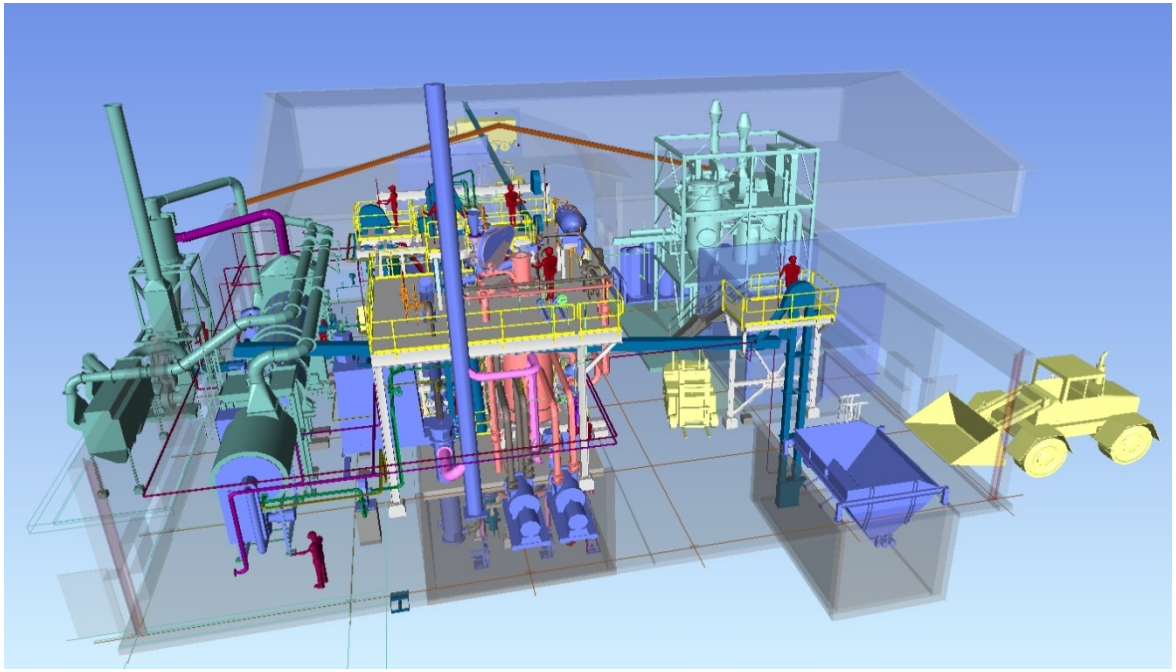
Bulk density 650-800 kg/m^3
Bulk energy density = 12 - 19 GJ/m^3

Torrefaction
Facilities & Services

- Torrefaction reactors
  - 5 kg/h screw reactor
    - Testing torrefaction for various biomass types
  - 50 - 100 kg/h pilot unit
    - Production of 1 to 10 tonne torrefied biomass pellets
- Knowledge and test-equipment on pelletisation
- Test quality of torrefied biomass for combustion and gasification
- Pyrolysis
  - Production of biochar

Torrefaction licensed to Andritz

- Industrial demo plant in Sønder Stenderup, Denmark
  - Operational since September 2012
  - Produces 1 tonne/hour black pellets
- Strong combination of industry and R&D



Biomass feedstocks for thermal conversion

✓ Directly suitable for feedstock

✗ Requires pre-treatment, e.g. TORWASH

waste | wood | (agricultural) residues | energy corps | aquatic biomass

Sources of biomass fuels for TORWASH

- Difficult materials
  - too high water content
  - seasonal harvesting and bio-degradable
  - too high salt content
  - bulky material with low energy density
  - tenacious, springy materials

- Essentially, the growing parts of plants

- Some attractive but difficult feedstocks
  - grass, reeds, park maintenance
  - palm fronds, leaves of sugar cane
  - wet residues from food and agro industry, e.g. brewer's grains and digestate

Combination of Washing and Torrefaction

Torrefaction + Washing = TORWASH

- Combines advantages and eliminates disadvantages
  - Torrefaction
  - Salt removal
  - Dewatering
- Aim: maximum energy recovery in the form of solid residues
- Product: torrefied fuel pellets with high added value or briquettes or powder
- By-product: biogas

Biomass Upgrading

ECN helps its customers to:

- Convert their biomass feedstock into an energy carrier
- Develop technology for torrefaction and Torwash

Customers

SIEMENS

MITSUBISHI HEAVY INDUSTRIES, LTD.

STORAENSO

UBE / UBE INDUSTRIES,LTD.

CHOREN

VATTENFALL

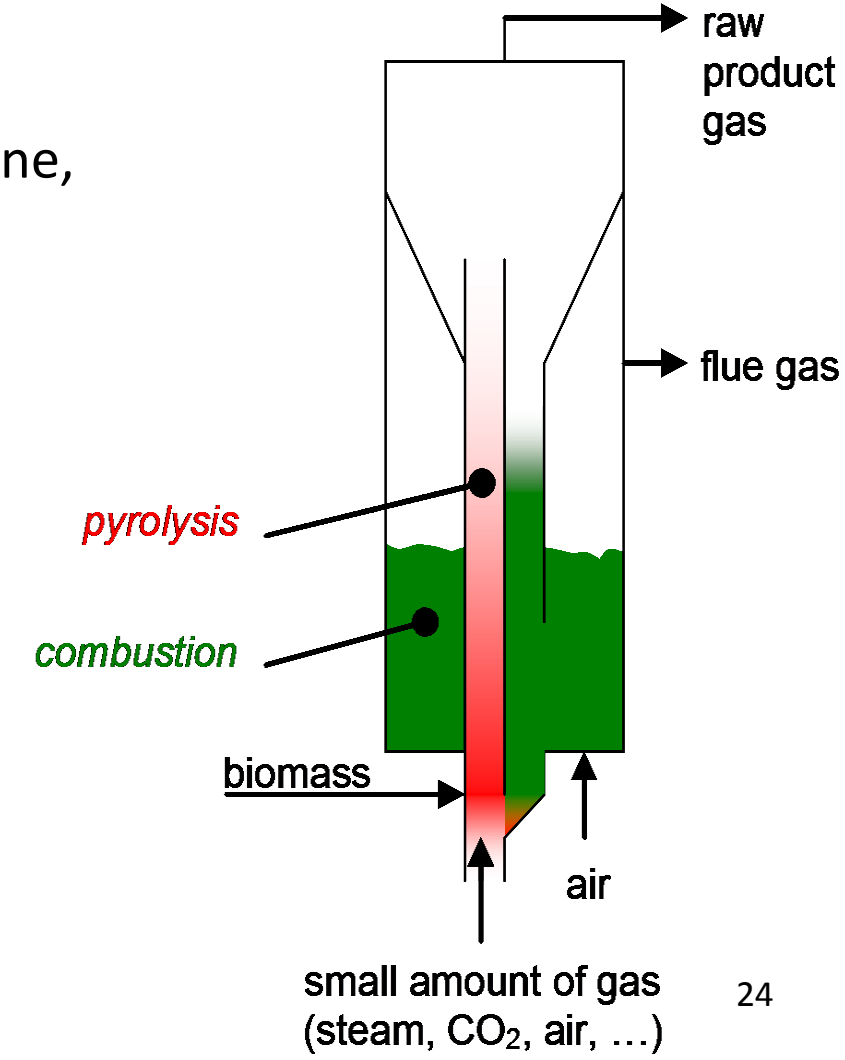
Braskem

DIEFFENBACHER

Biomass Gasification and Tar removal

MILENA Indirect Gasification

- Temperature level 850°C
- Product gas contains methane, ethylene, benzene, and tars
- Complete conversion of the fuel
- Carbon free ash
- High efficiency
- Very little nitrogen in producer gas
- Heat transfer through bed material
- One single vessel: compact design
- Fuel flexible



Comparison

	MILENA	CFB/BFB	Downdraft
Conversion	100% / white ash	~90% / black ash	~90% / black ash
Cold Gas Efficiency	~80%	~70%	~70%
Temperature control	Good control, no char accumulation	Lower control ability due to char hold-up	Very heterogeneous
Temperature versus Efficiency	lower temperature = higher efficiency	lower temperature = lower conversion	lower temperature = lower conversion
Fuel flexibility	waste, agricultural residues any size	less freedom any size	woody only large chunks
Gas	12-15 MJ/Nm^3 essentially N_2-free	5-6 MJ/Nm^3 ~50% N_2	5-6 MJ/Nm^3 ~50% N_2
Scale	Scalable (>100 MW)	Scalable (>100 MW)	Max. 1 MW

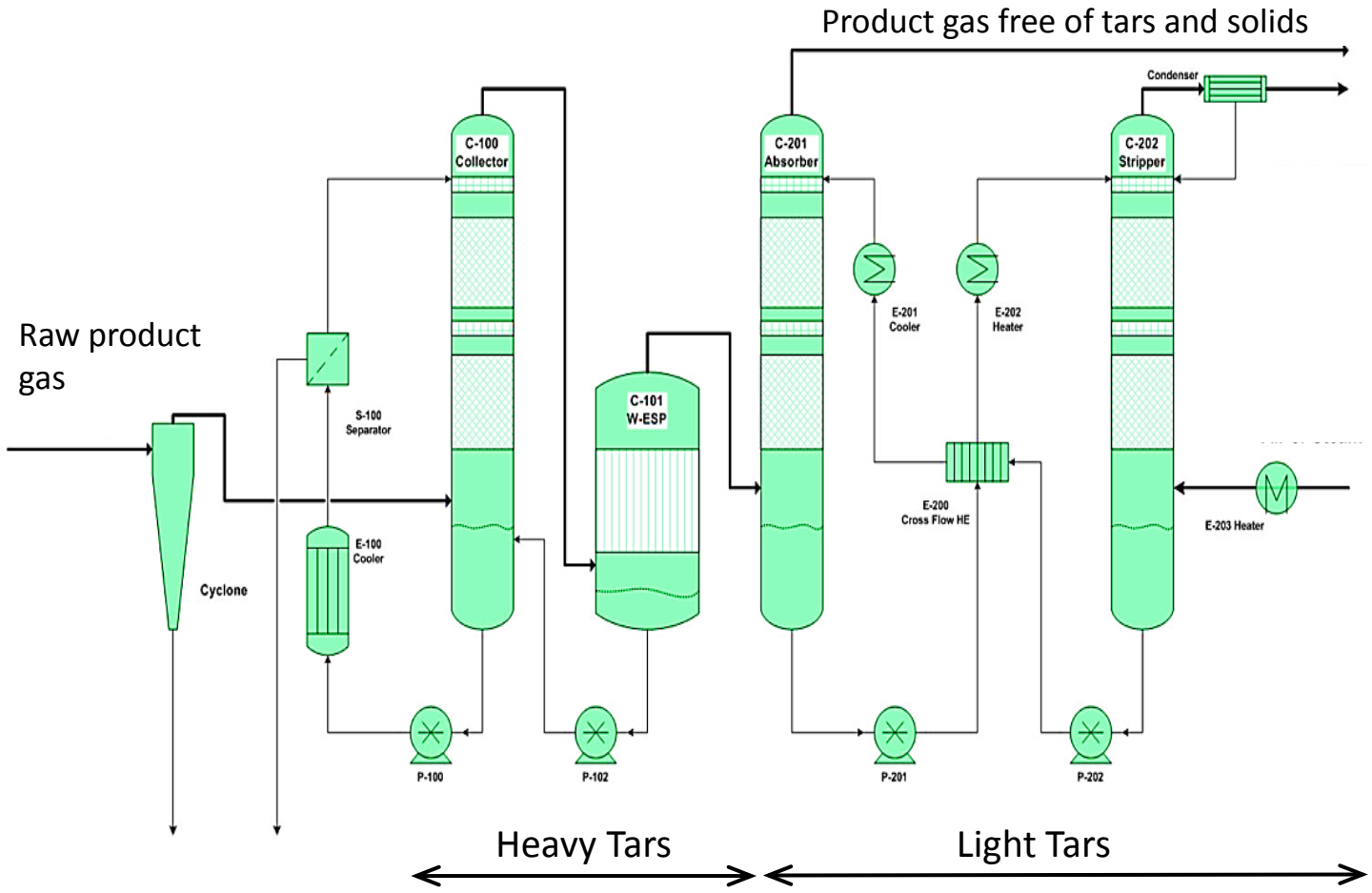
Tested feedstocks

- Clean Wood
- Demolition Wood
- Straw
- Soya stalk
- High-ash coal
- Lignite
- RDF
- Sunflower husks

Markets for MILENA gasifier

- Co-firing in coal boilers or gas turbines
  - Clean gas feeding to boiler or turbine
  - With Milena lower grade biomass or waste can be used, rather than the clean wood pellets needed for direct co-firing in boilers
- Combined heat and power
  - On-site conversion of waste to energy
  - In combination with gas engine or small gas turbine
  - Milena produces high calorific gas, not diluted with nitrogen
- Substitute Natural Gas production
  - High methane content of producer gas makes Milena very suitable for SNG production
- Production of fuels or chemicals

ECN OLGA gas cleaning



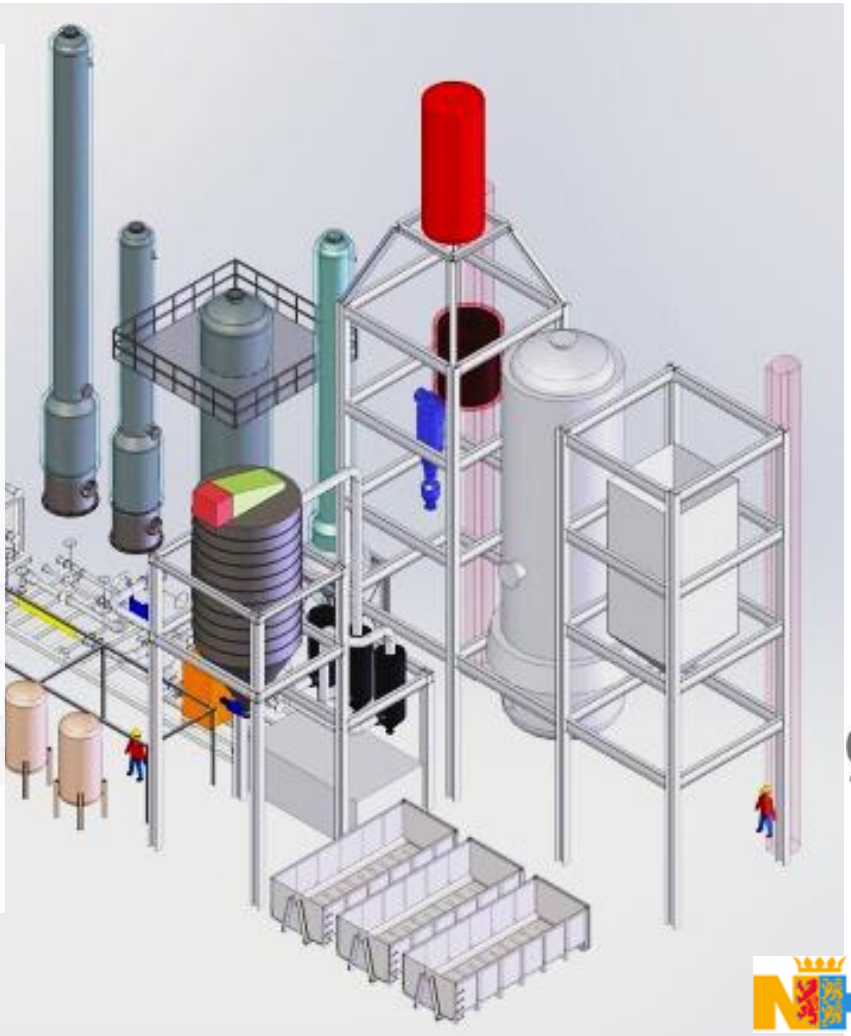
- Tar dew point 10°C
- Tar cleaning above water dew point
  - No mixing of water and oil

All tars recycled back to gasifier, i.e. no energy loss, no waste streams

Tondela, Portugal

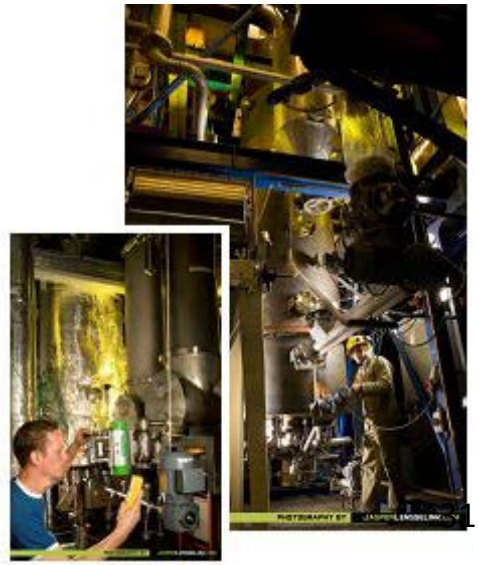
Project in Development in Alkmaar, The Netherlands

- 12 MW_{th} MILENA and OLGA producing green power
- Side stream SNG production, i.e. green methane
- Royal Dahlman will build the plant
- Currently detailed engineering
- FID in mid 2013
- Construction 2013/2014
- Start-up 2015



Biomass Gasification and Combustion Service and technology offering

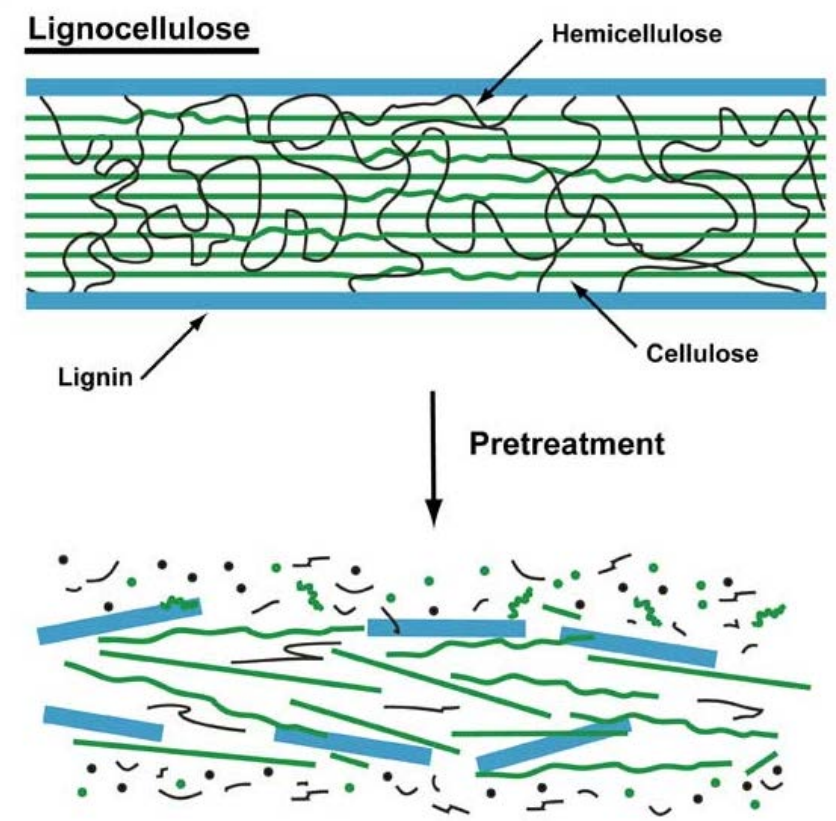
- MILENA indirect gasifier: high efficiency, produces gas with high energy content
- OLGA tar removal technology and other solutions for tar removal
- Consultancy on biomass feeding, milling, gas cleaning, synthesis processes
- Any gasification/combustion process with any fuel can be investigated in one of our lab-scale simulators
- Tar, dust, aerosol, slagging and fouling analysis in the lab but also on-site



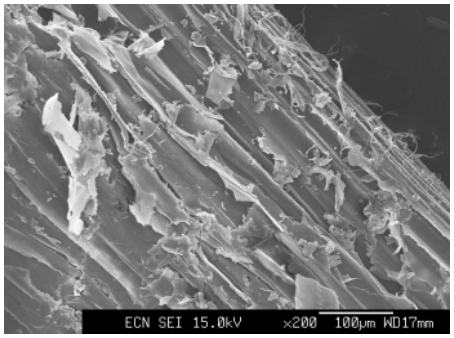
Biorefinery

Organosolv process

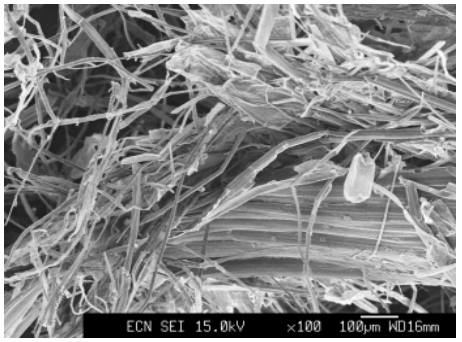
- Optimal valorization of lignocellulosic biomass
  - Lignin
  - Cellulose -> ethanol
  - Hemi-cellulose
- High-purity streams for direct use in downstream processes



Straw

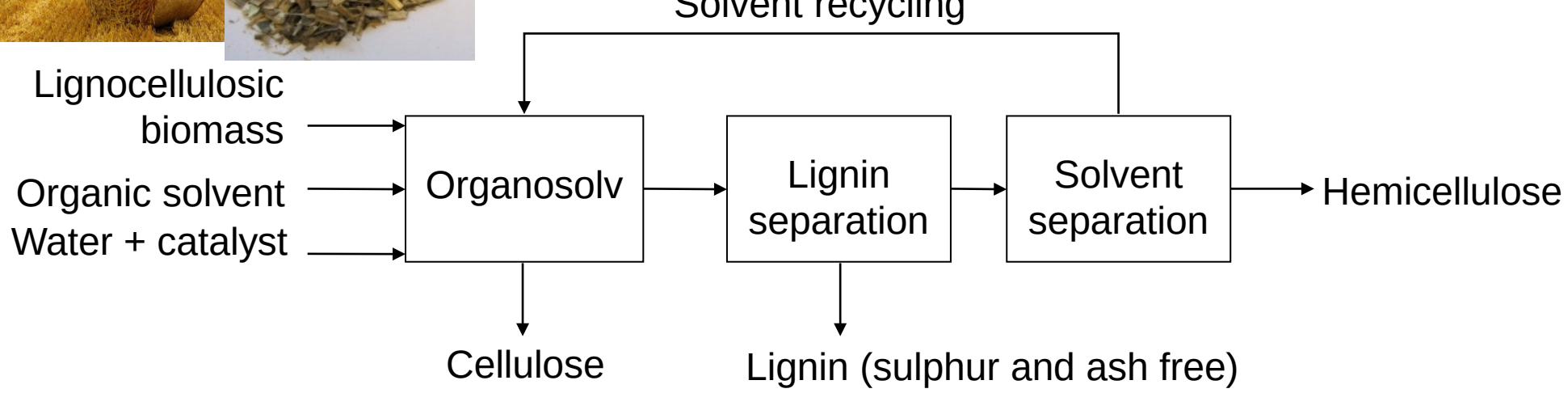


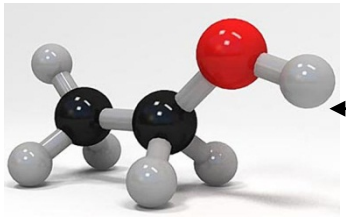
Pre-organosolv



Post-organosolv

Organosolv process fractionation into cellulose and lignin

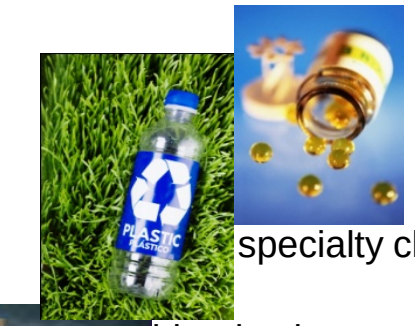




Lignin valorization

low volume, high value market 10 000 €/ton

- Potential feedstock for wide range of chemicals (aromatics!) and performance products.
- Valorization lignin improves carbon footprint & economics lignocellulose Biorefinery.



specialty chemicals

bio-plastics

bio-resins for wood-adhesives

activated carbon, carbon-fibres and carbon-black

fuel-additives

bio-bitumen for asphalt

bio-char for soil improvement

bio-fuel for CHP

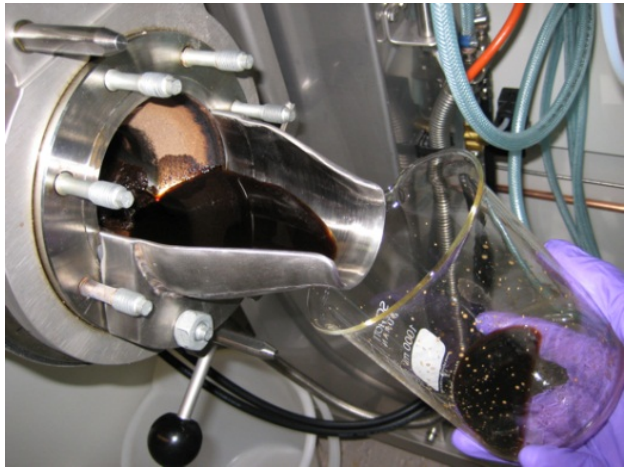
high volume, low value market 100 €/ton

- No large-scale commercial market for lignin at the moment

Biorefinery and Processing

ECN helps its customers to

- Develop strategies and business cases to convert biomass into high-value products
- Develop technologies to convert raw biomass into fractions for further processing
- Optimize the value chain for seaweed and especially the synthesis of products from seaweed



Thank you for your attention
and
looking forward to cooperate with you
on profitable biomass projects

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