Overview of European torrefaction landscape

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EPRI Biomass Torrefaction Workshop

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KEMA at a glance

Serving electric utilities' diverse needs from generation to retail

- Established in 1927, Arnhem, the Netherlands
- 2,000 professionals in 18 counties, 600+ in US
- Annual revenues of $350 million

Independent experts to the global utility industry

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Covering the entire energy value chain

Policy & Strategy

Production

Trading

Transport & Distribution

Use

One company serving the diverse needs of the energy marketplace

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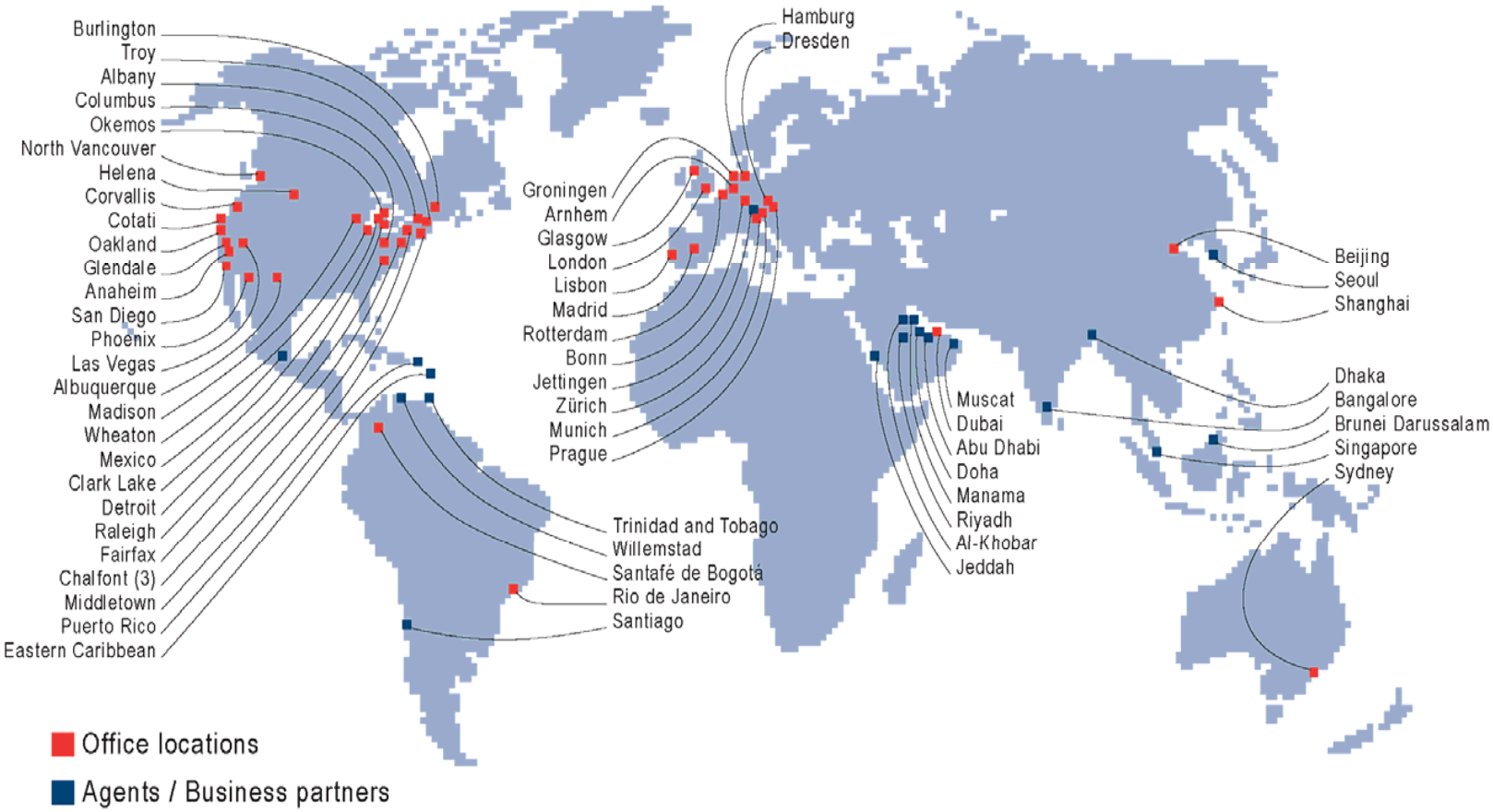
KEMA around the globe



KEMA's Torrefaction experience

- KEMA has 20 years experience with co-firing of biomass in Europe and since 2003 in US and is involved in torrefaction from the early beginning

- KEMA – as independent consultant - has supported international clients with technical, economical and strategic advice and has hands-on experience by working as a owner's representative

- KEMA serves as an service provider between torrefaction developers, governmental agencies and utilities and is dedicated in taking torrefaction to the next level for our clients

Indicative fuel properties

	Woodchips	Wood pellets	Torrefaction pellets	Charcoal	Coal
Moisture content (% wt)	30 – 45	7 – 10	1 – 5	1 – 5	10 – 15
Calorific value (MJ/kg)	9 – 12	15 – 16	20 – 24	30 – 32	23 – 28
Volatiles (% db)	70 – 75	70 – 75	55 – 65	10 – 12	15 – 30
Fixed carbon (% db)	20 – 25	20 – 25	28 – 35	85 – 87	50 – 55
Bulk density (kg/l)	0.2 – 0,25	0.55 – 0.75	0.75 – 0.85	~ 0.20	0.8 – 0.85
Volumetric energy density (GJ/m^3)	2.0 – 3.0	7.5 – 10.4	15.0 – 18.7	6 – 6.4	18.4 – 23.8
Dust	Average	Limited	Limited	High	Limited
Hydroscopic properties	Hydrophilic	Hydrophilic	hydrophobic	hydrophobic	hydrophobic
Biological degradation	Yes	Yes	No	No	No
Milling requirements	Special	Special	Classic	Classic	Classic
Handling properties	Special	Easy	Easy	Easy	Easy
Product Consistency	Limited	High	High	High	High
Transport cost	High	Average	Low	Average	Low

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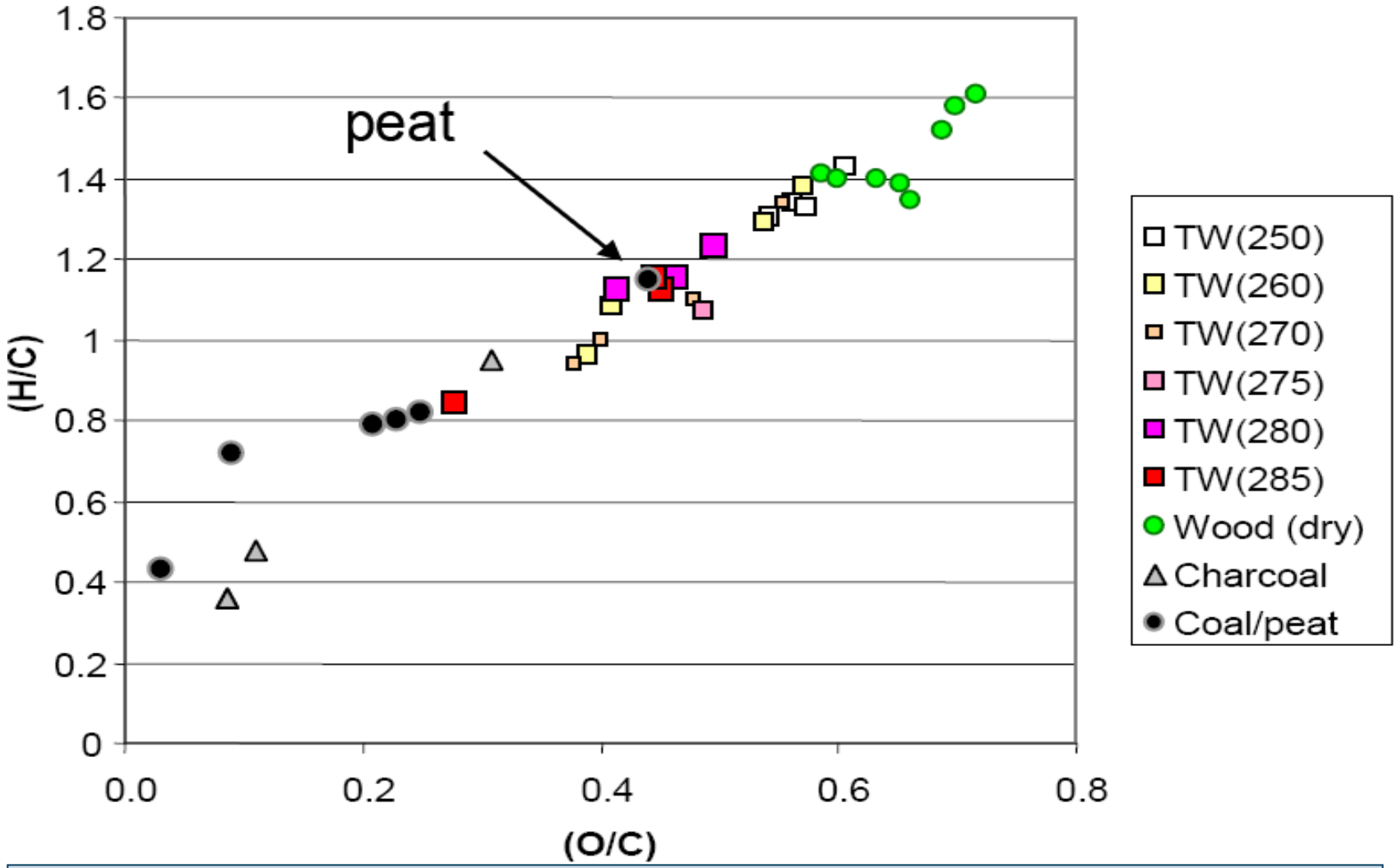

Van Krevelen diagram of different fuels

Source: ECN

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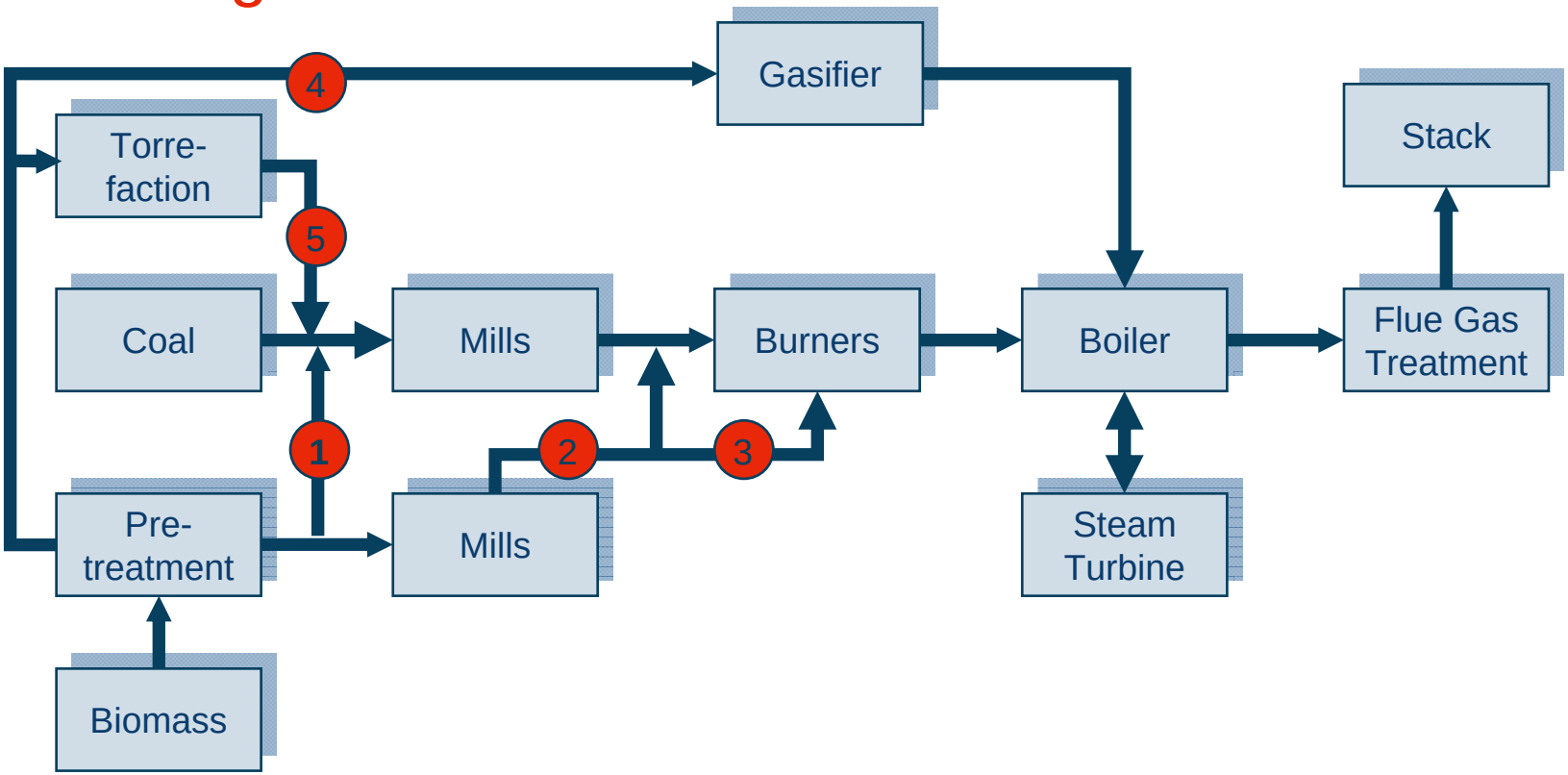
Co-firing routes



1. Co-milling of biomass with coal
2. Separate milling, injection in pf-lines, combustion in coal burners
3. Separate milling, combustion in dedicated biomass burners
4. Biomass gasification, syngas combusted in furnace boiler
5. Co-milling of torrefied biomass with coal

Each co-firing route has its own (unique) operational requirements and constraints and specific demands on the fuel quality

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The added value of torrefaction

Higher co-firing percentages	Torrefied product can be directly milled and co-fired with the coals. Product is dry (< 5%) and has a calorific value of 20 – 24 MJ/kg (8600-10300 BTU/lb). The product is brittle and easily breaks down in small particles
Capex savings at the power plant	A smaller mass stream and when pelletized also a smaller volume stream of biomass is needed for the same amount of energy production, which reduces the dimensions of biomass equipment. Further, less biomass equipment (silo's, dedicated feeding system, biomass mills and burners) is needed.
Cost savings long distance transport	The volumetric energy density of torrefaction pellets is 16 GJ/m^3 compared to 10 GJ/m^3 for wood pellets. This implies significant cost savings

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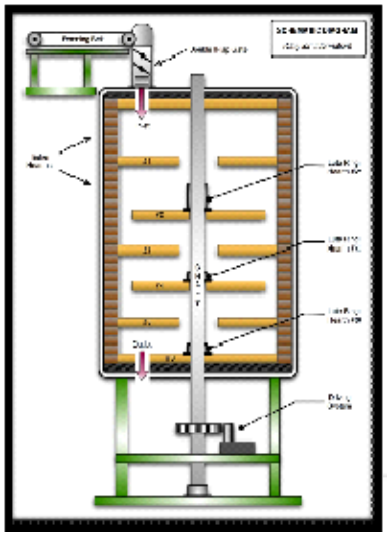
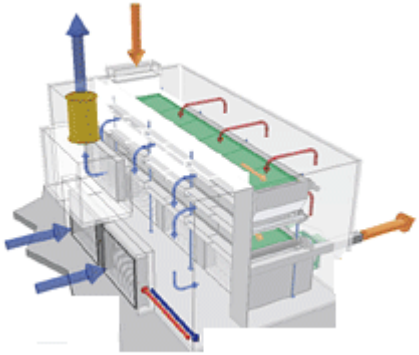
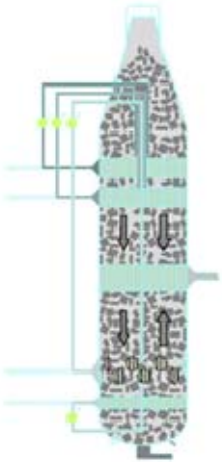
Torrefaction technologies



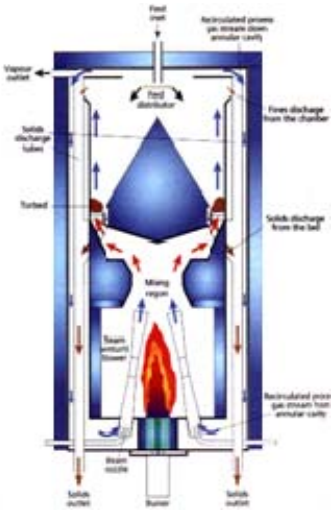
MHF



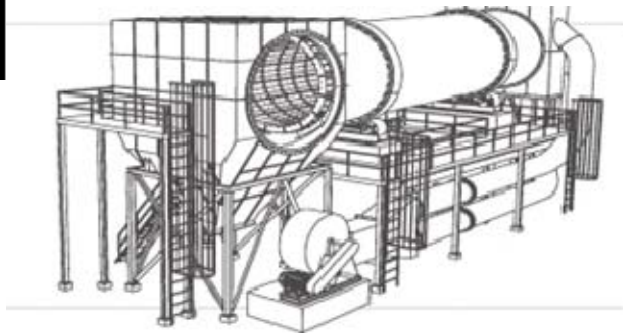
Oscillating belt reactor



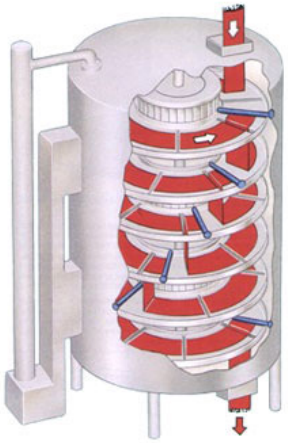
Moving bed reactor



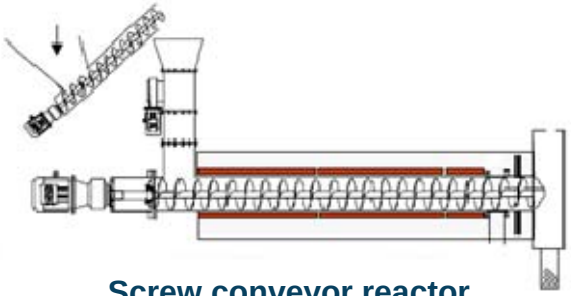
Torbed reactor



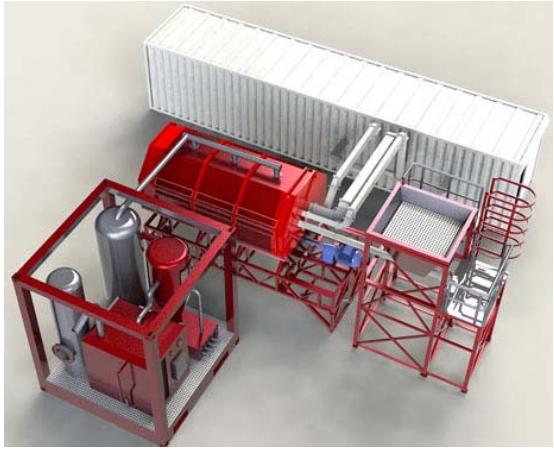
Rotary drum reactor



TurboDryer



Screw conveyor reactor

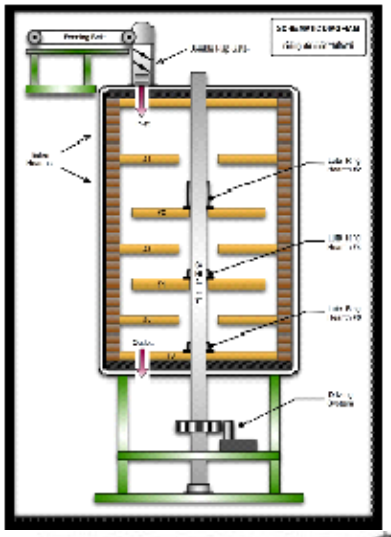


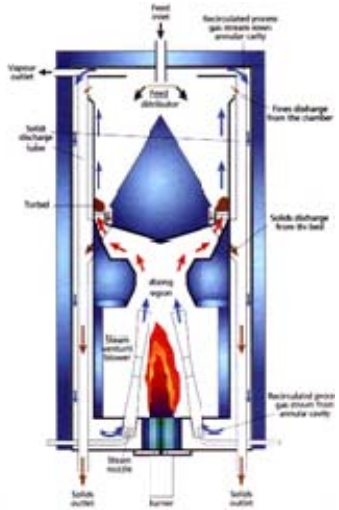
Mirco wave reactor

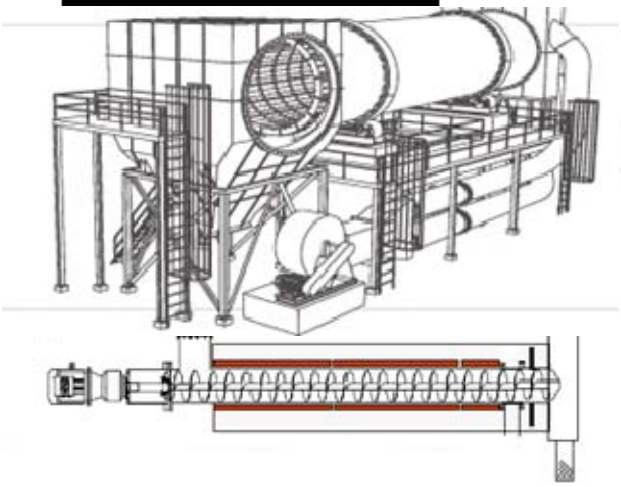
Torrefaction benchmark: technical evaluation

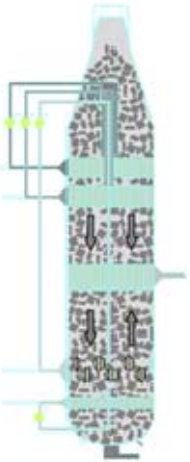
- Evaluation of torrefaction technologies
  - Reactor technologies
  - Heat integration design

- Performance evaluated quantitatively and qualitatively:
  - Energy yield
  - Thermal efficiency
  - Product quality
  - Fuel flexibility
  - Process control
  - Throughput
  - Tar emissions
  - And ....



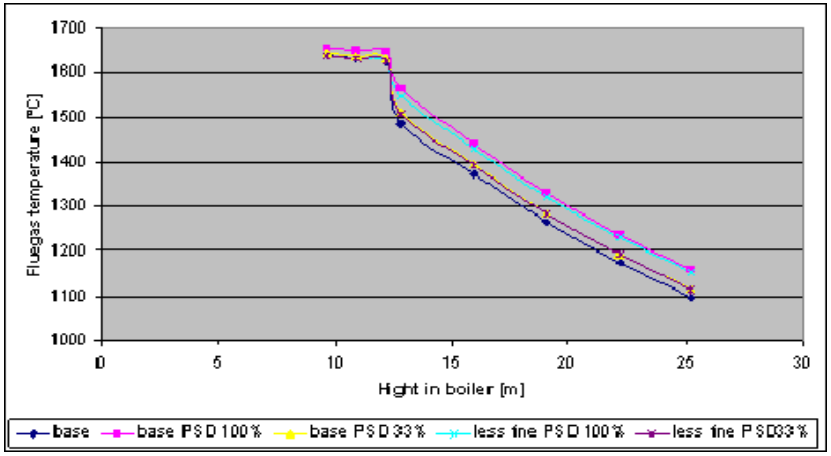


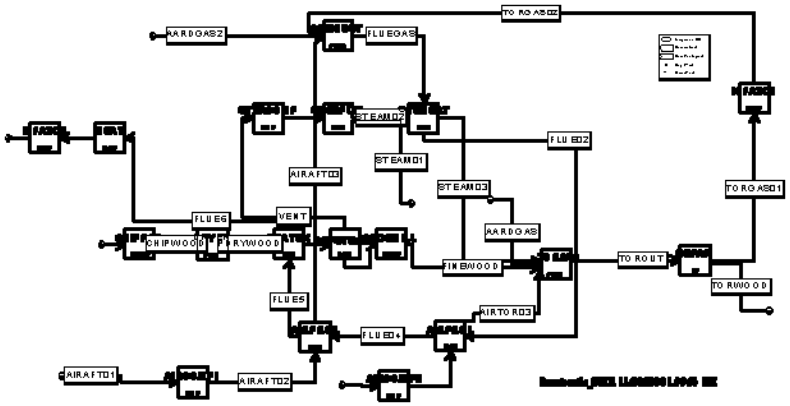




Technical feasibility

- Spence simulations of co-firing torrefied biomass, impact on plant performance
- Spence simulations of a heat integrated torrefaction plant, mass and energy balance calculations
- Heat integration options of torrefaction (direct or indirect heating)
- Conceptual design and lay out of torrefaction plant





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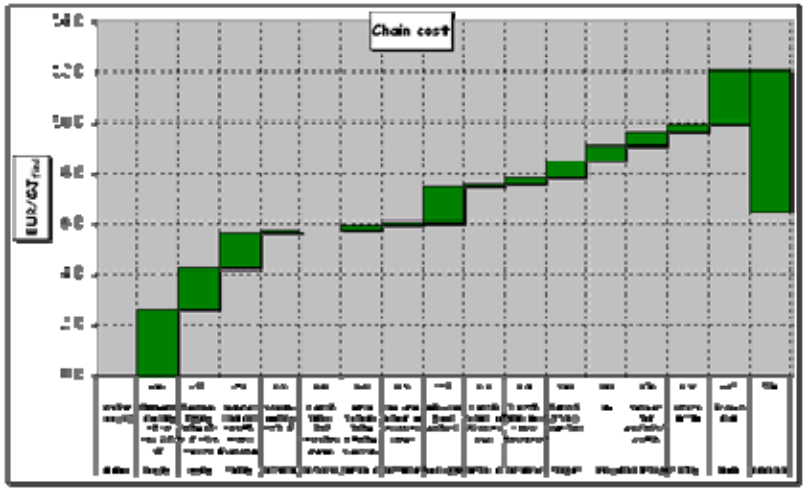
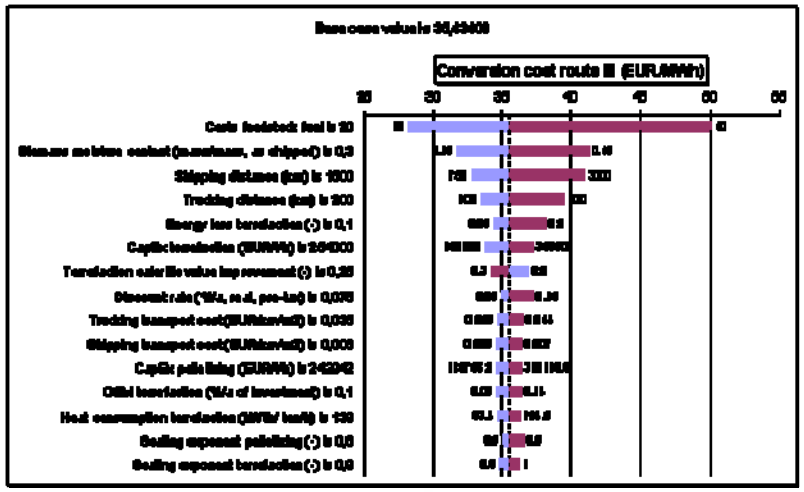
Economic feasibility of torrefaction business case

- Define business case(s)
  - standalone torrefaction plant
  - integrated to power plant
  - compare to wood pellets
  - ……..

- Assessment of complete value chain
  - Accumulated cost over the chain
  - Accumulated emissions over the chain
  - CO_2 efficiency

- Sensitivity analysis (Tornado Chart)
  - Top 15 variables determining value
  - Scaling effect on business case





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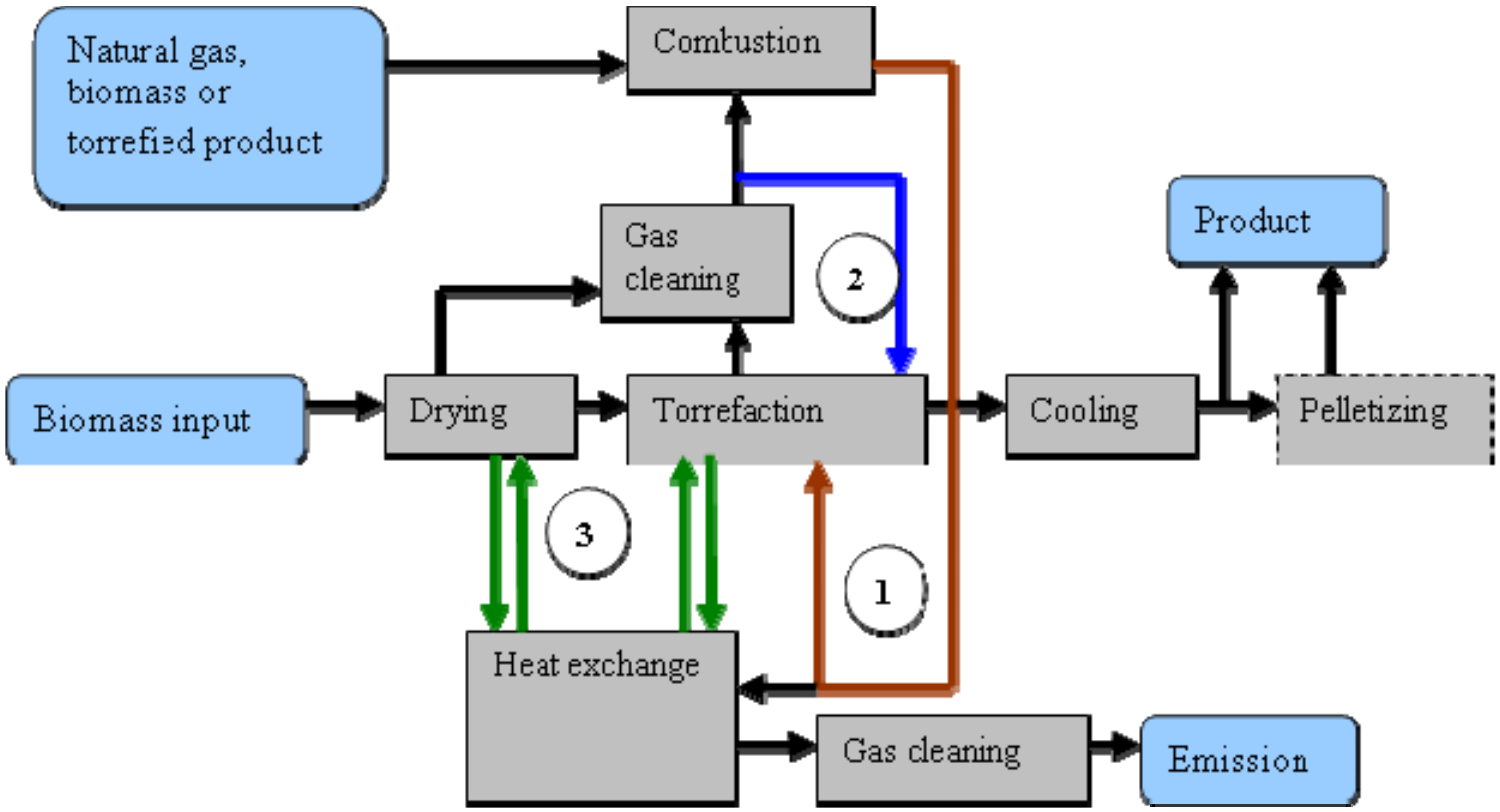
Torrefaction technology

- Most reactor technologies applied for torrefaction are proven in other applications (combustion, drying, gasification etc.)
- Overall thermal efficiency very much depends on heat integration design (direct or indirectly heated)
- Process control is the key for good performance and product quality (residence time, temperature, particle size feed, mixing)
- The key for commercial torrefaction will be the trade-off between economic and technical optimization (e.g. lower energy yield versus higher throughput)

Heat integration options



1. Direct heating by recycling flue gas: efficient heat/mass transfer, loss of product
2. Direct heating by recycling torrefaction gas: efficient heat/mass transfer, tar formation
3. Direct or indirect heating by recycling steam: risk on carbonization

The product of torrefaction (1/2)

Storage and handling	Industrial scale experience and validated data is needed on handling, storage (hydrophobic) , milling, explosion risk, dust and odor emissions, combustion properties (burn-out, reactivity) of the product
Pelletization	Low torrefaction temperatures (260 - 300ºC, 500-570 F) lead to best results (due to lignin as natural binder), different additives are being explored and used (e.g. glycerin). Effects on product properties not yet known
Combustion behaviour	Quick devolatilization, a slightly longer burn-out.

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The product of torrefaction (2/2)

Sustainability	Sustainability is an important topic for the EU biomass market. CEN 383 group is working out the EU policy. CO_2 balance over the value chain will be the most important criteria. Thus carbon footprint of torrefaction installation as low as possible.
Standardization	Market needs standardization of product quality and specifications. Currently, large differences in product quality
Price	Most utilities are considering a wood pellet price of 120 – 130 EUR/ton CIF ARA as reference for the price of torrefied wood pellets plus a correction for the energy content of the product. This leads to a product price of about 150 – 190 EUR/ton. However, without subsidies, the coal price serves as reference + CO_2 credit price + savings on power plant = 100 – 120 EUR/ton

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EU market drivers of torrefaction

Financial incentives	Renewable production subsidies, CO_2 credits, cost savings at the power plant, cost-effective method to co-fire biomass, lower transport cost
Technical incentives	Security of supply of fossil fuels, higher co-firing percentage possible, no dedicated biomass equipment (like hammer mills) needed, reduce cost of entrained flow gasification
Environmental incentives	CO_2 emissions, renewable energy targets, making waste stream (agricultural residues) available for energy production, sustainability criteria in Europe
Strategic incentives	Secure biomass supply by taking position upstream, cost-effective method to comply with energy policy, life-time extension of aging assets

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Strategy /position of European coal-fired pp

- Keep the asset operational, but risk increasing environmental fees (renewable energy targets, CO_2 emission credits)
- Decommission asset before economical lifetime, representing a huge capital loss and possibly a shortage of base load electricity production
- Repower the asset to a 100% biomass plant, which will require significant investments and brings along considerable (operational) risks
- Keep asset operational by co-firing biomass, which also requires significant investments in biomass pre-treatment, storage and handling equipment

Market potential of torrefied biomass in EU

Market segment	Conversion process	Conversion technology	State-of-the-art biofuel	Pre-treatment requirements	Advantages of torrefaction	Market potential
Large-scale Power production	Co-firing	Coal-fired boilers	Wood pellets	High	Process with the coal, higher co-firing rates	High
	(Co)gasification	Entrained flow gasifiers	Wood pellets	Very high, due to particle size	Size reduction, fluidization,C/H/O ratio, very dry	Limited
	Stand-alone Combustion (>20 MWe)	CFB boilers	Wood chips	Moderate	Limited, relatively expensive	Small
Industrial heating	Combustion	Blast furnaces	none	Moderate	Handling, C/H/O ratio, energy content	High
Residential/ District heating	Combustion	Stoves	Wood pellets	High, decentralized	Transport savings	High

European torrefaction initiatives

Developer	Technology	T. Supplier	Location(s)	Production capacity (t/a)	Starting operation
Topell Energy B.V. (NL)	Torbed	Torftech Inc (UK)	Duiven (NL)	60,000	Q4 2010
Stramproy Green Investment B.V. (NL) / 4Energy Invest (BE)	Oscillating belt reactor	Stramproy Group (NL)	Steenwijk (NL), Amel (BE)	45,000 38,000	Q3 2010
Torr-Coal B.V. (NL)	Rotary drum	Torr-Coal technology B.V. (NL)	Dilsen-Stokkem (BE)	35,000	Q3 2010
Lantec Group (SP)	Moving bed	Thermya (FR)	San Sebastian (SP)	20,000	2011
Vattenfall/ Nuon (NL)	Moving bed	ECN (NL)	Delfzijl (?)	20,000 (?)	Unknown
FoxCoal B.V. (NL)	Screw conveyor	FoxCoal B.V. (NL)	Winschoten (NL)	35,000	2012
BioLake B.V. (NL)	Screw conveyor	Unknown	Eastern Europe	5,000 – 10,000	Q4 2010 ?
BioEndev (SE) / ETPC (SE)	Rotary drum	Unknown	Ö-vik (SE)	25,000 – 30,000	2011/ 2012
EBES AG (AT)	Rotary drum	Andritz (AT)	Frohnleiten (Austria)	10,000	2011
Atmosclear SA (CH)	Rotary drum	Airless Systems (UK)	Rezekne (Latvia), New Zealand, US	50,000	Q4 2010

*** This is not the full list and figures are based on statements of developers**

European torrefaction outlook

- Increasing demand for larger volumes of affordable, reliable and sustainable co-firing fuel, that can meet EU sustainability criteria.

- Several Torrefaction demo plants in Europe, have to prove they are able to continuously produce large volumes of high quality torrefied product (specifications of off-takers)

- As a next step multiple commercial sized (100 kton/yr) torrefaction plants will be erected for supply to Europe, especially in regions where biomass is widely available and and relatively cheap
    - Russia, Belarus, Ukraine, Slovakia
    - *Brazil, Africa, Canada, US*

Latest on torrefaction initiatives in EU

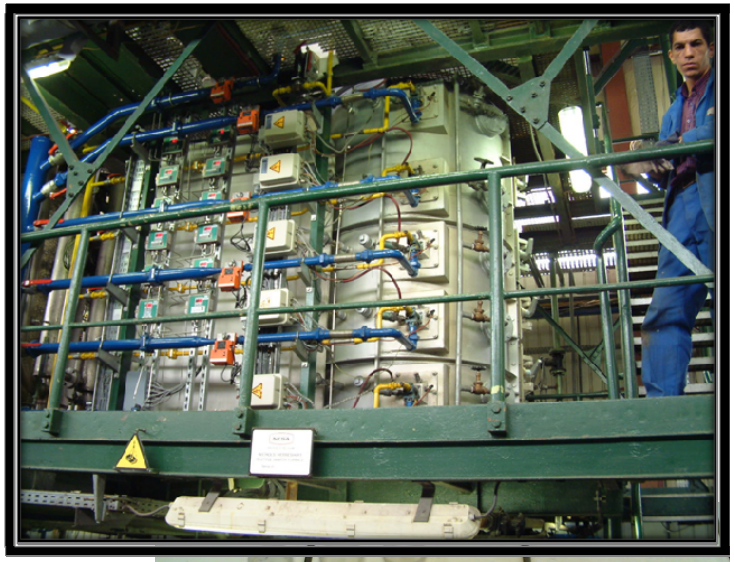
- Topell Energy commissioned and in operation (8 t/h)
- Stramproy Green Investment has stopped production due to operational problems. Stramproy delivered first batch to Essent/ RWE and the product did not (yet) meet the requirements
- Torr-Coal has started up demo plant, but is not operating at full capacity. Delivers product as powder to utility in Belgium

First batch of Cool Coal (Stramproy Green Energy)

Amer power plant of Essent, 29 July, 2010

Torrefaction demo plant of Topell Energy (60 kton/yr)

Pilot plant measurements at CMI-NESA (Multiple hearth furnace)



The major technical challenges of torrefaction

Feedstock flexibility	Currently torrefaction technologies are mainly processing wood chips for a narrow bandwidth of particle size. Agricultural residues are still a challenge, because it ignites easily, has a low bulk density and has long fibers
Process validation	Although experience has been gained with pilot plant testing, real operational data will reveal the performance of the torrefaction process. Important is the trade-off between energy yield, product quality and production cost.
Product validation	Although the pilot plant test results are promising, the product needs to be validated by large co-firing trials. Are torrefaction suppliers able to commercially provide a product which meets the specifications of an utility? And is the product really sustainable?

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The major business challenges of torrefaction

Financing	Most torrefaction developers are small companies with a limited financial base. Convincing investors to finance the necessary R&D and up-scaling efforts is a real challenge
Market maturity	One or more torrefaction concept will emerge out of a large variety of technologies and initiatives. But have torrefaction suppliers enough development power to optimize and scale-up their torrefaction concept? A product standardization is needed to make the market more transparent and reliable
Availability of product	The demand is significantly higher than the supply. Torrefaction suppliers are facing the challenge to scale-up their first commercial demonstration plants in a rapid pace

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Future of co-firing and repowering in Europe

- Significant investments needed to enable using of a more expensive fuel…
- Low incentives from current CO_2 price
- Limited or no real political and financial incentives in many (EU) countries
- Biomass suppliers suffer from uncertainties
- Biomass politically not fully undisputed

Future of co-firing and repowering in Europe

- However…
  - most large scale alternatives i.e. wind power are more expensive (EUR/MWh)
  - significant renewable targets to be achieved relatively shortly (2020)
  - wind power comes with high investment costs and complex permitting issues
  - existing coal fired unit owners are keen to find alternatives
  - co-firing and repowering could be the short term option for politics to meet renewable targets

2011 Year of Torrefaction !?

Profitable

Sustainable

Reliable

Co-firing

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KEMA as partner in torrefaction business

Torrefaction opportunities

- Torrefaction strategy: buy technology or product
- Investment decisions, business case
- Selection of torrefaction technology that best fits clients business
- Selection of torrefaction supplier
- Selection of EPC contractor
- Process validation
- Product validation
- Biomass certification
- Product standardization

Cooperation

KEMA services

- Support business strategy
- Torrefaction technology benchmark
- Evaluation of initiatives and projects
- Techno-economic feasibility study
- Evaluation of business case
- Contractor survey, Coordination of tendering phase
- Pilot plant testing, Factory acceptance test
- Small scale combustion tests
- Coordination of co-firing trials
- Sustainability of total value chain

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