DONG Energy

Pyroneer
November 2013

Status of DONG Energy's Pyroneer gasification technology for high alkaline fuels like straw: an efficient and sustainable method to replace fossil fuels in our energy system

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DONG Energy, New Bio Solutions

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DONG Energy is one of the leading energy groups in Northern Europe

Our business is based on procuring, producing, distributing and trading in energy and related products in Northern Europe.

Key figures 2012 results

Revenues:	**€9bn**
EBITDA:	**€1.2bn**
Employees	**7000**

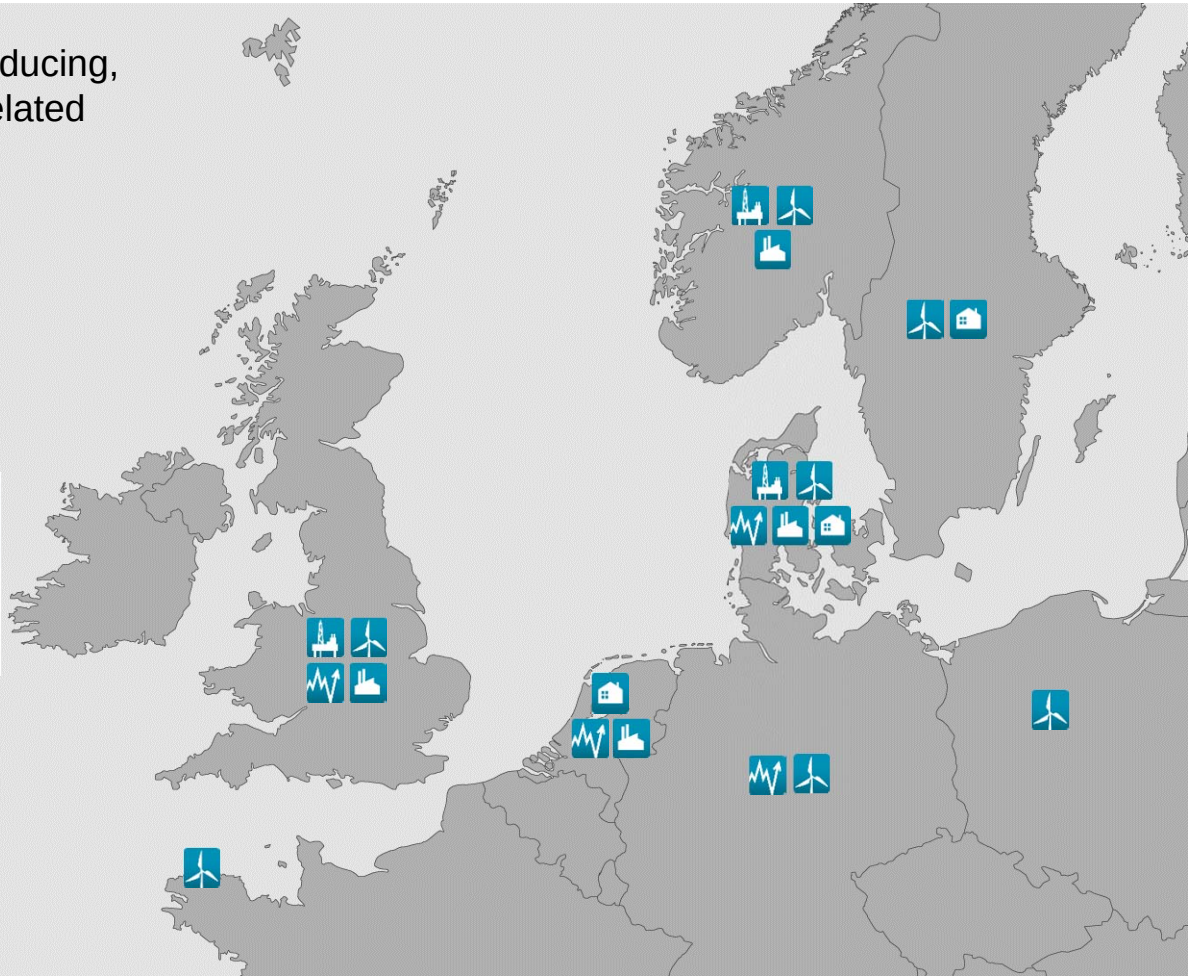
Ownership

The Danish State	**81.02%**
SEAS-NVE Holding	**10.88%**
Others	**8.10%**

Goldman Sachs

atp

PFA PENSION



- **Exploration & Production**
- **Wind Power**
- **Thermal Power**
- **Customers & Markets**

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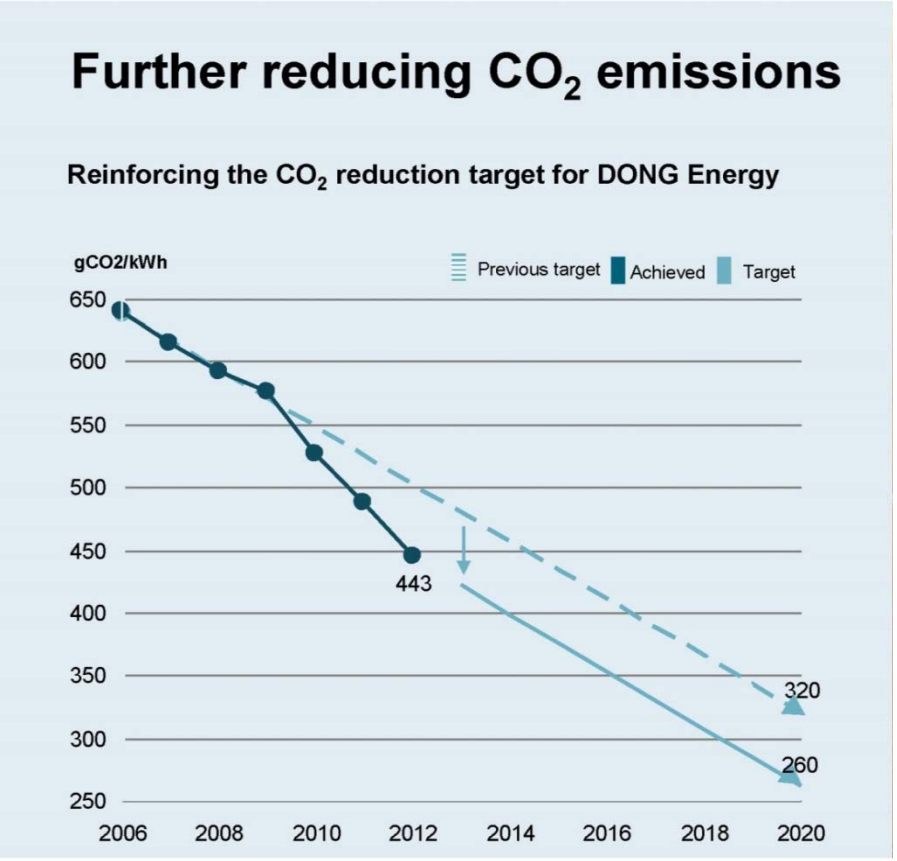
DONG Energy's strategy on power production is to expand in wind and convert from coal to biomass

One of the few storable CO_2 neutral resources



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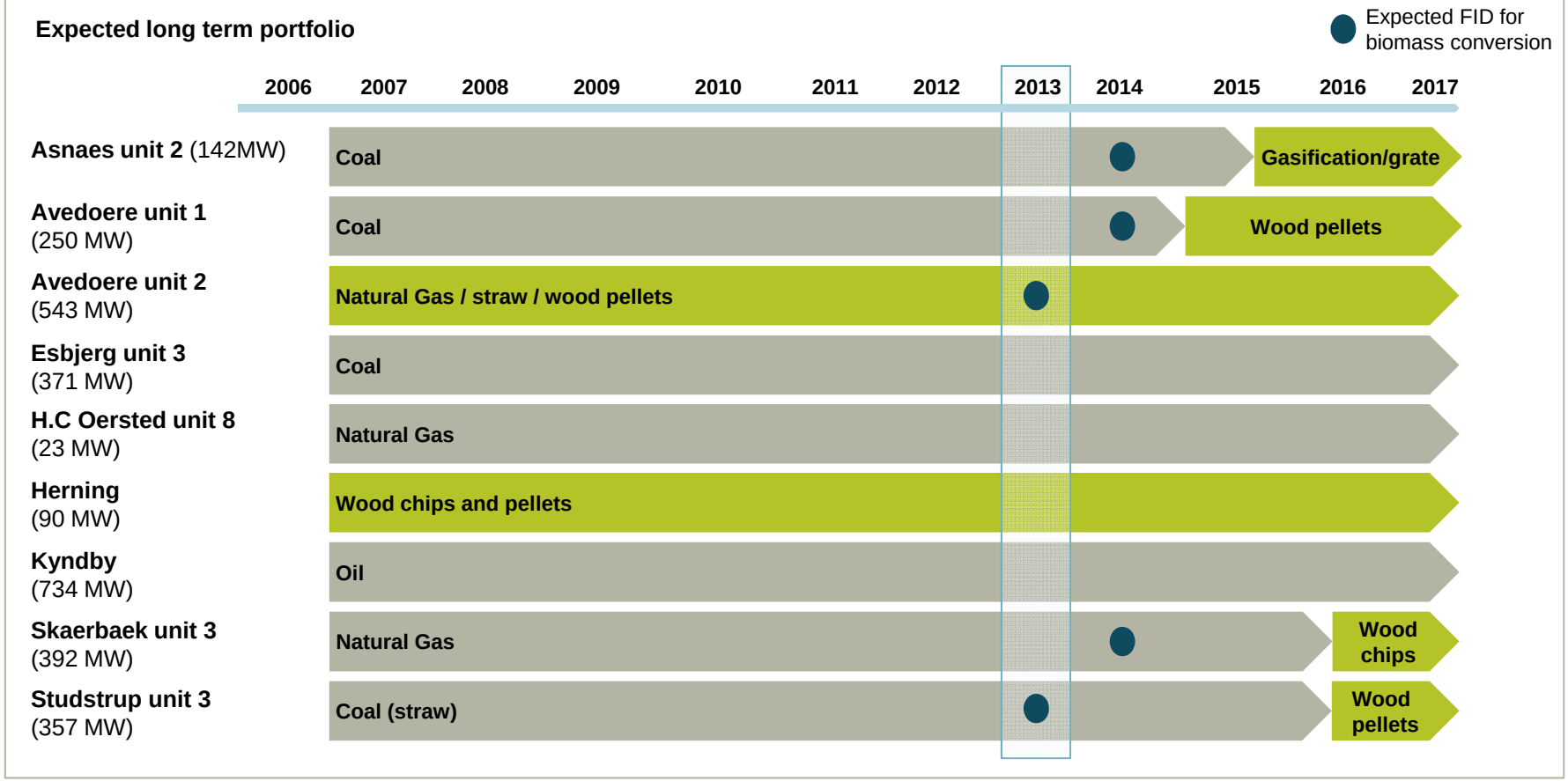
Thermal Power is front-runner in biomass-to-energy

1.8 GW converted to biomass by 2017



Source: DONG Energy Thermal Power Commercial

Sustainability is crucial when it comes to the use of biomass

- but other factors such as CO_2 and local job creation are also important

Removing the wood and leaving a dessert is not an option

Woody fuels

- Discussion on CO_2 delay
- Discussion on deforestation
- **G**lobal fuel; **G**lobal economy - limited "local" job creation

Short rotation crops / Energy crops

- Large potential for biomass supply
- Limited CO_2 discussion
- **I**ndirect **L**and **U**se **C**hange

Agri residues

- No CO_2 discussion
- Nutrient and carbon discussion
- **L**ocal fuel; **L**ocal economy – "local" job creation

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Historical use of straw within the power sector in Denmark

- Political agreement in 1993 obligated power plants to apply 1.4 million tonnes of biomass (mainly straw) for power production by 2000
- Limited national and international experience with straw combustion in1993
- Large development program for development and demonstration of straw combustion technologies initiated
- Typically 100.000 – 300.000 ton/year per site can be sourced

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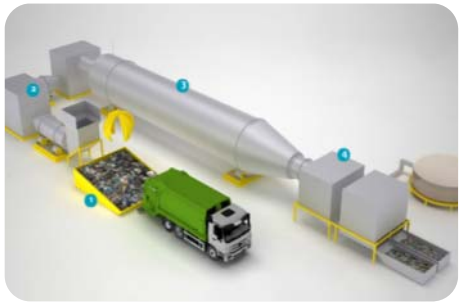
New Bio Solutions

An important part of strategy and future growth within DONG Energy Power

Inbicon

From straw to 2G bioethanol

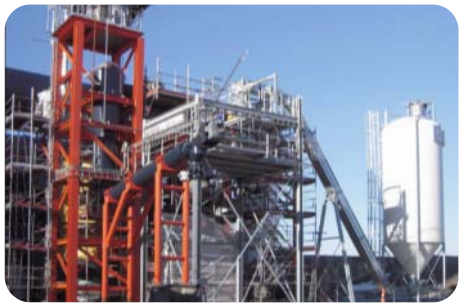
- Kalundborg is the worlds biggest 2G demonstration plant



Renescience

Efficient grading of household waste

- Succesfull demonstration of presorting of waste at Amager Combustion



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Gasification of biomass residues from agriculture and forestry

- Demonstration plant commissioned at ASV

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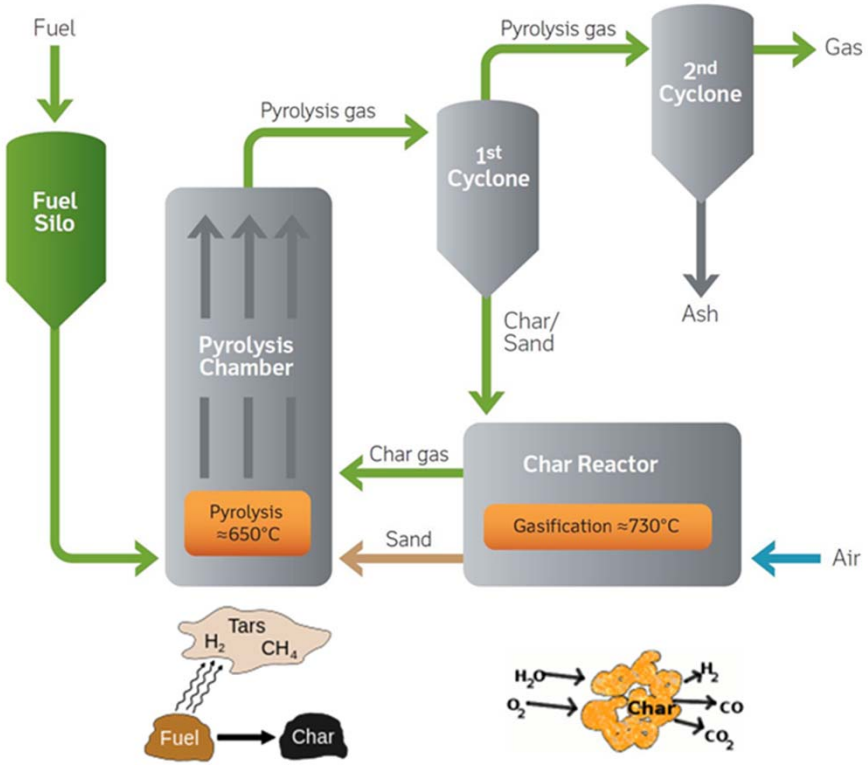
The Pyroneer technology as of today

- The fuel flexible gasifier = the basic building block for future options



Gas:
Substitution of coal, wood and HFO at power stations. Later even substitution of gas

Ash:
With accessible contents of nutrients, especially potassium and phosphorus

Efficiency around 95%

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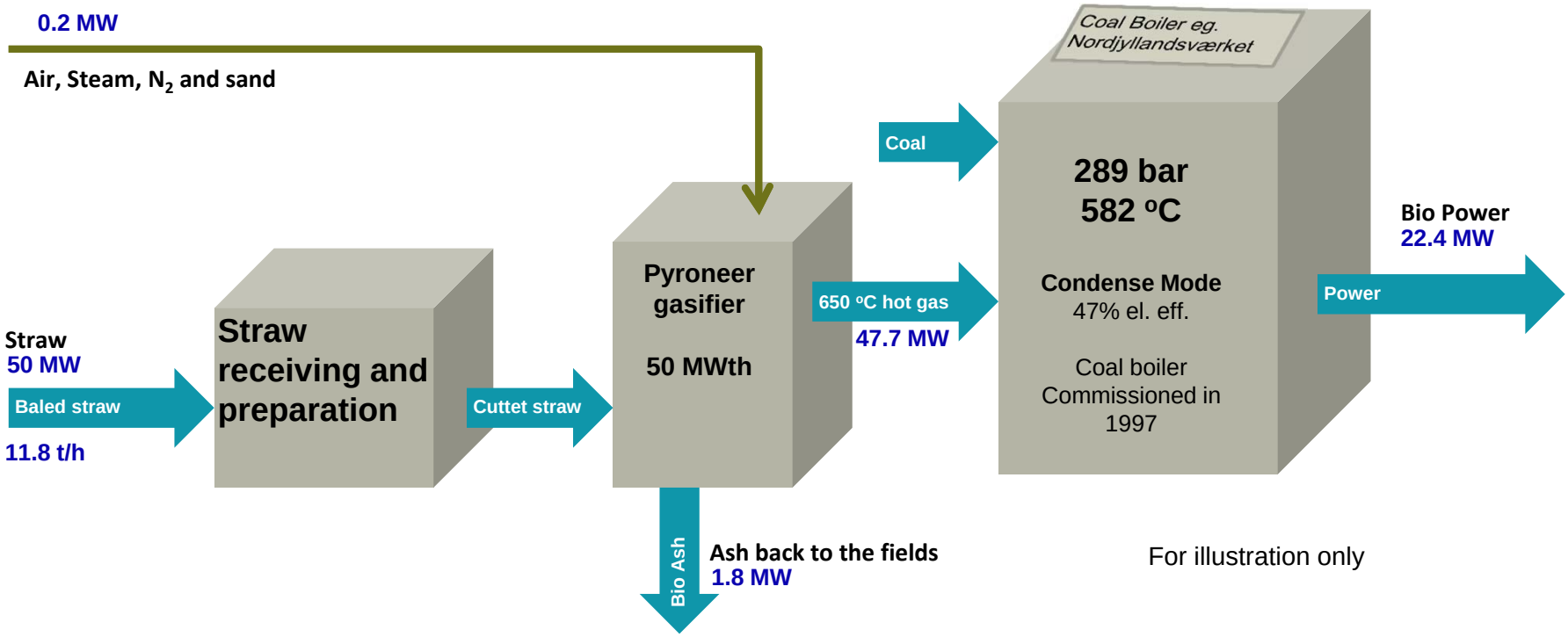
Direct replacement of fossils fuels in existing units has a high CO_2 reduction potential



1 GJ straw can replace 0,95 GJ coal, this is very efficient

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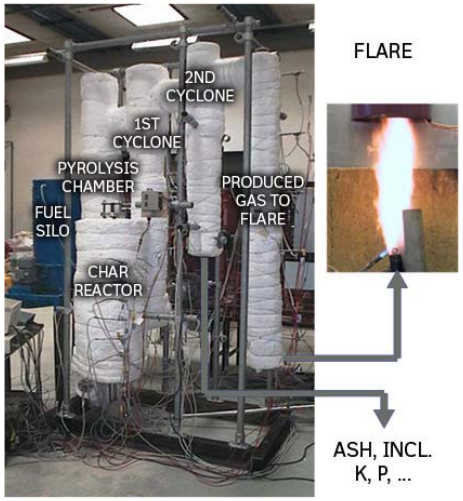
Milestones in developing the low temperature gasifier



1999 – prototype
50 KW gasifier at DTU

2003 – Up-scaling
500 KW gasifier at DTU

2007 – Several Fuels
100 KW gasifier at DTU

- DONG Energy Procured the rights to the technology in 2009
- Next step was to construct a 6 MW demonstration gasifier

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The 6 MW test facility located next to a coal boiler

- The plant is located next to an existing coal boiler at Asnæs, Kalundborg
- Gasifier commissioned 2011
- The gas is combusted in a separate burner
- The ash is utilised in full scale fertiliser experiments
- Used in campaign operation, to support 60 MW design

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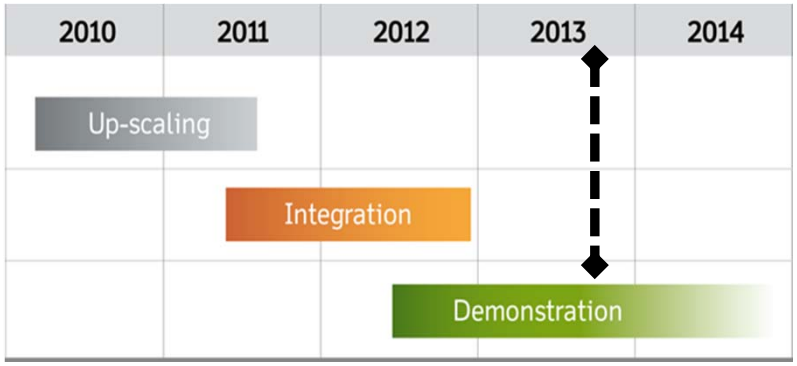
Status development of the Pyroneer gasification technology

Key figures for the demonstration plant

- 1800 operation hours with air blower incl. start-up and cold test
- 1300 tons of straw gasified

Results

- Fuel feed from 5 MW to 7,2 MW
- Stable and safe operation
- Automated start-up after trip to full load in less than 10 min
- Partly automated start-up from cold in less than 24 hours
- Automated and partly unmanned operation



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Result from operation of the demonstration plant

- Gas composition
  - H_2 : ~ 6%
  - CO : ~ 11%
  - CO_2 : ~ 13%
  - N_2 : ~ 34%
  - H_2O : ~ 29%
  - CH_4 +: ~ 7%
- Tar compounds are an essential contributor to the LHV of 5.9 MJ/kg
- Good combustion
- Good ash quality

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The ash is low in heavy metals and can be distributed on farmland as a fertiliser

Mg/kg	PAH	Cd	Cr	Hg	Ni	Pb
Average figures	6,3	<0,09	17	<0,0012	5,6	3,9
Data variation	+- 3	+- 0,01	+- 5	+- 0,0003	+- 1,8	+- 2
Limits to be meet for straw ash[1]	**12**	**5**	**100**	**0,8**	**60**	**120**

All limits set by regulators can be met with large margin

Conclusion:

Ash can be distributed on farm land

Note 1: Danish legislation "Biomasseaskebekendtgørelsen"

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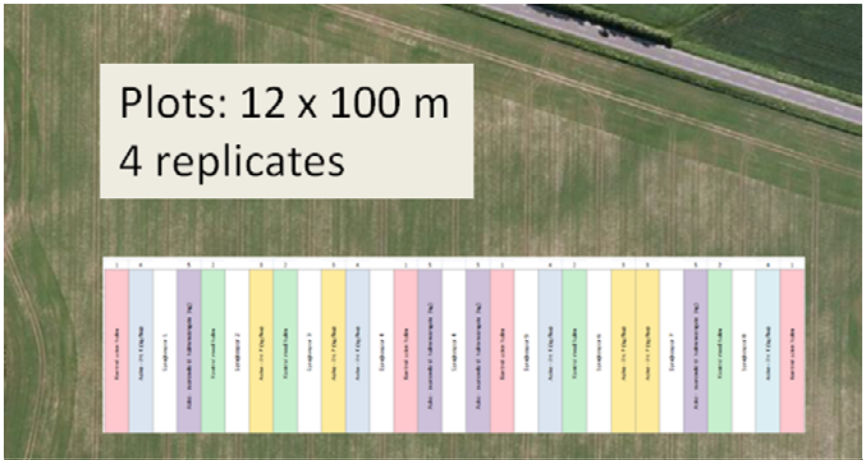
The Pyroneer ash is being tested as fertilser at the Bregentved Estate in a 3 year R&D program evaluated by agro institutes

- Ash produced in 6 MW Demo plant
- Ash distributed on trial plots in 2012 and 2013
- **Result after 2013 harverst: The ash works as good as NPK**



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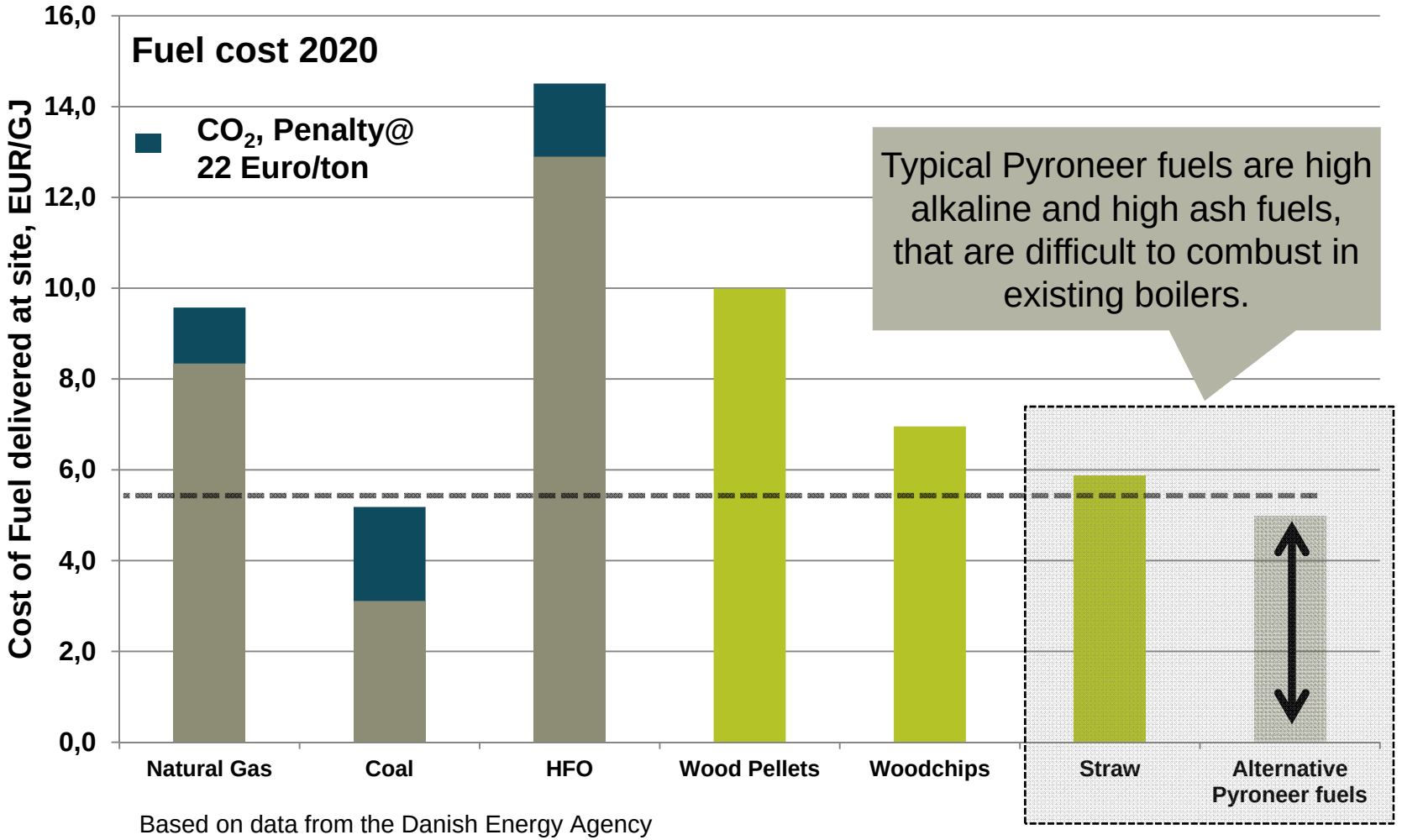
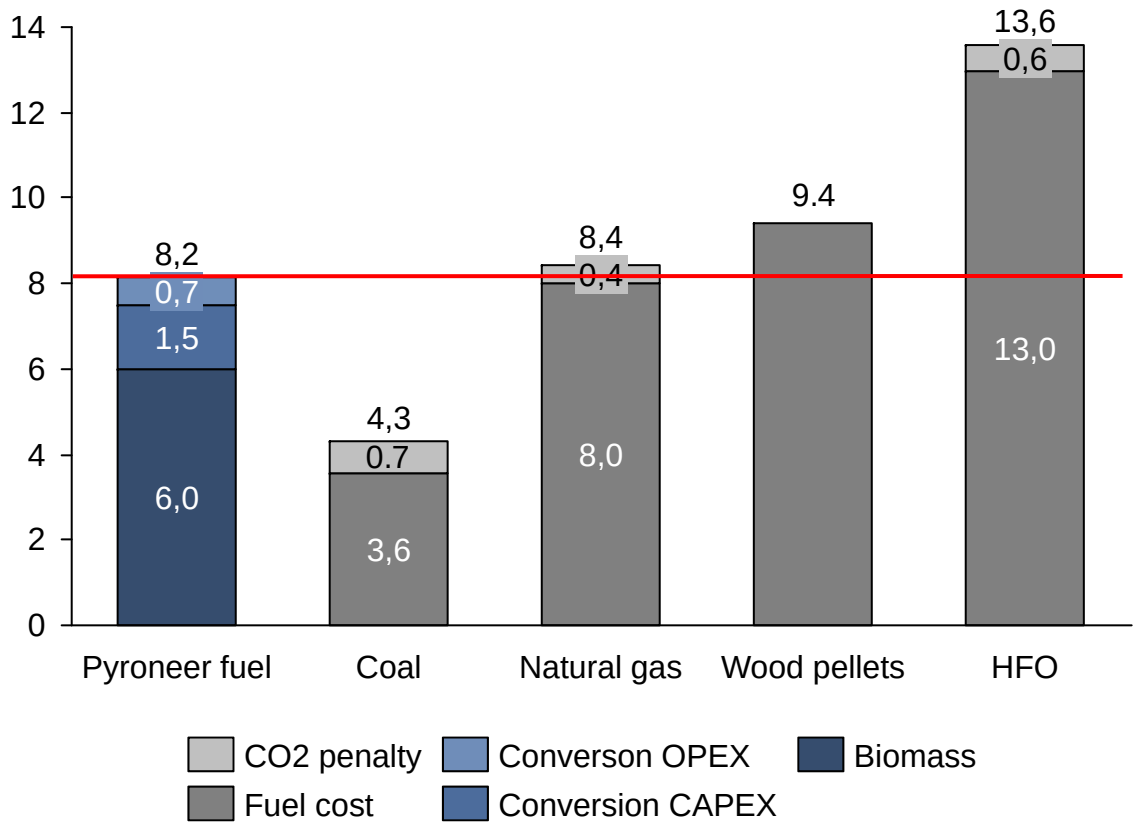
Economic drivers for the Pyroneer technology is to be able to use low cost biomass fuels



Based on data from the Danish Energy Agency

Using Danish straw price, the Pyroneer gas cost is similar to the cost of natural gas

Comparable prices for power production fuels, EUR/GJ



- The total Pyroneer conversion cost is approximately 2,2 EUR/GJ (incl. CAPEX)
- Using Danish straw at a price of 5.6 EUR/GJ as input the price of the Pyroneer gas will be around 8,2 EUR/GJ
- Alternative low cost biomasses will further reduce the cost of the Pyroneer fuel

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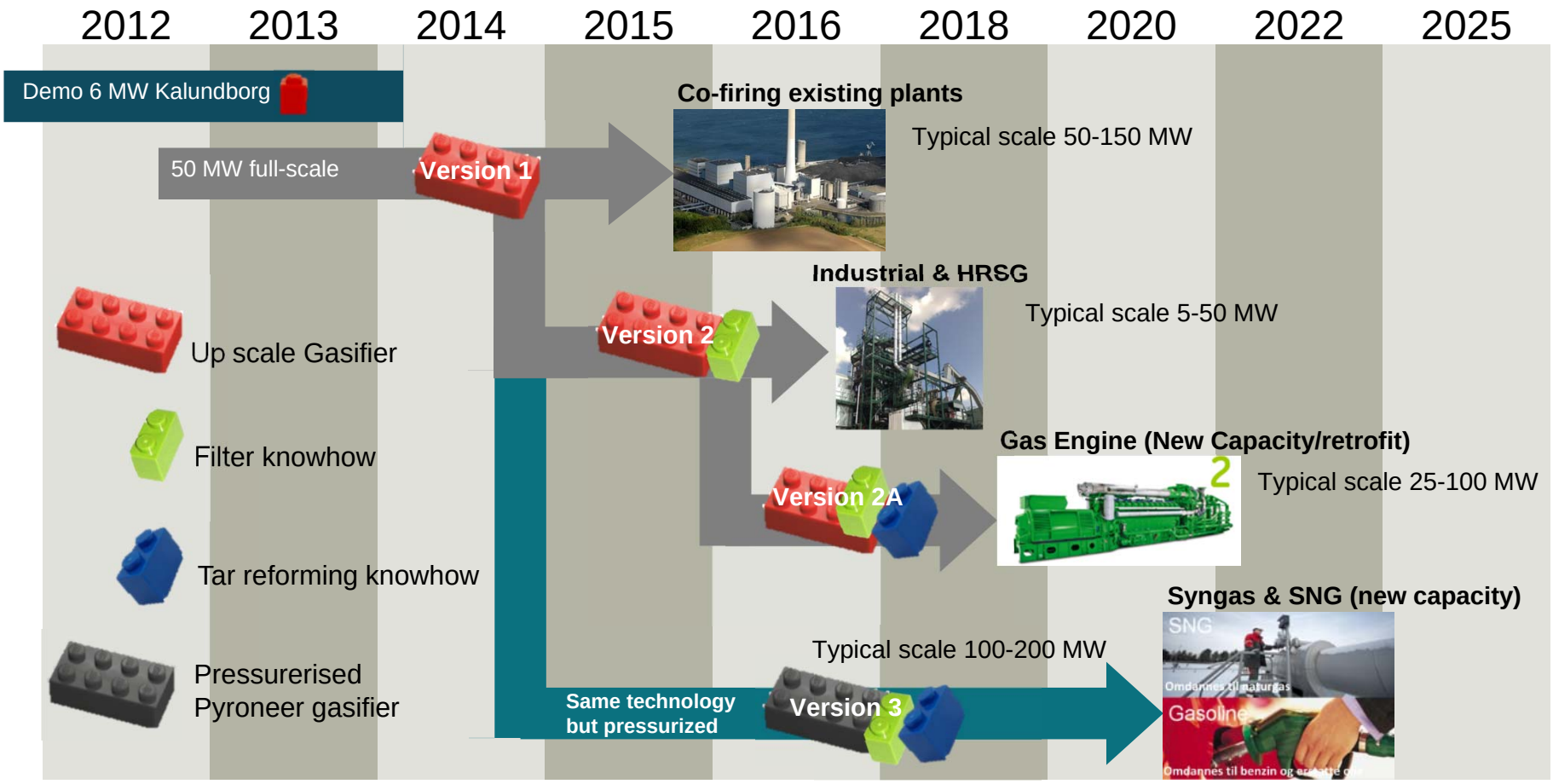
Outlook – potential application areas – but one step at a time



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