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PROJECT MANAGEMENT – INNOVATION – ORGANISATION – INFORMATION TECHNOLOGY

EU market for process heat applications

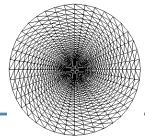
4 April 2013

OECD, Paris

Workshop on "Technical and Economic Assessment of Non-Electric Applications of Nuclear Energy“

Vincent Chauvet

vincent.chauvet@lgi-consulting.com



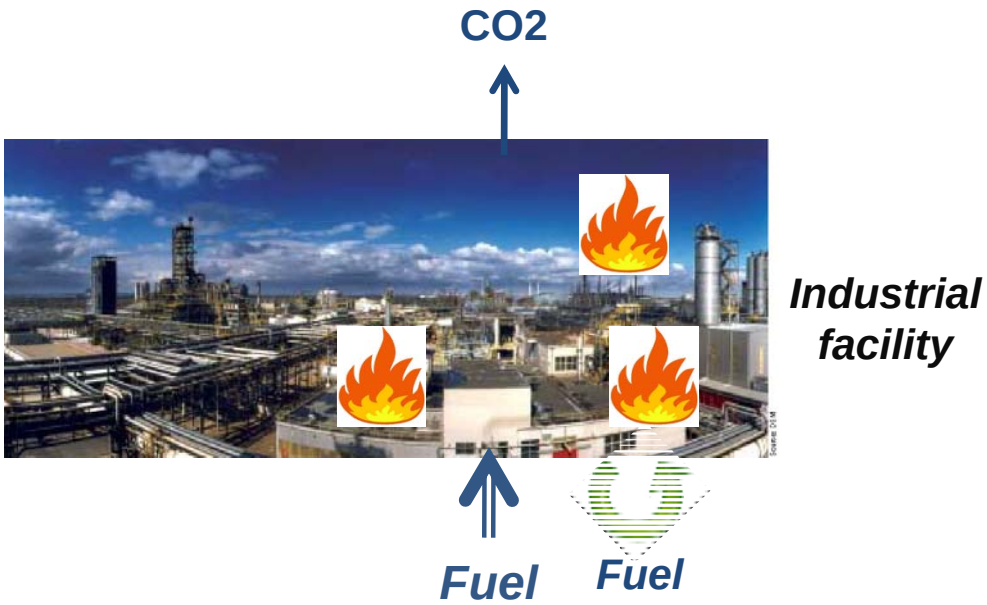
FOREWORD

This presentation is based on findings of the market study carried out by LGI in the frame of the EUROPAIRS project (2009-2011)

This project was supported by the Euratom 7th Framework Programme

www.europairs.eu

What is the “heat market”?



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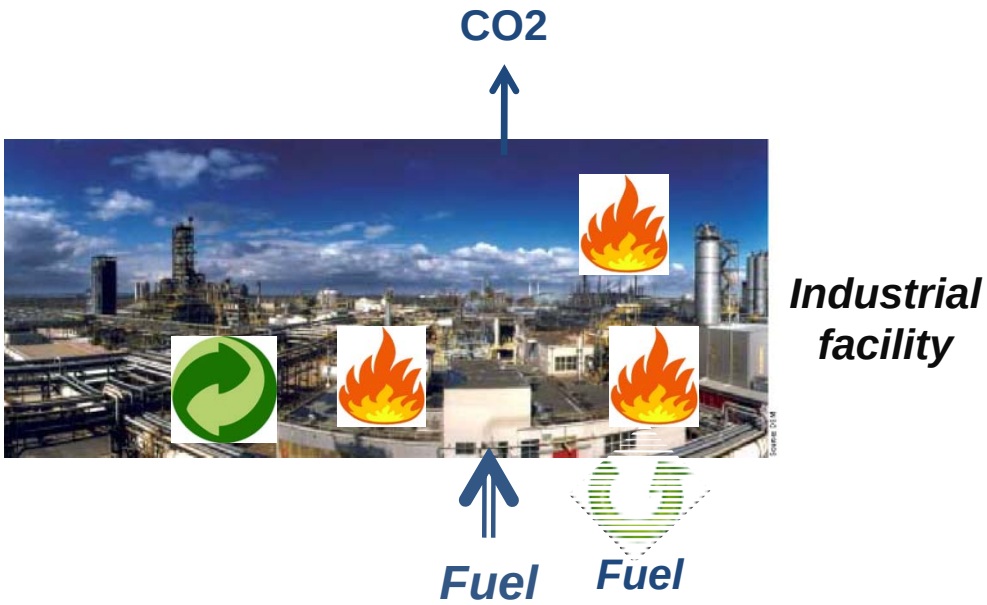

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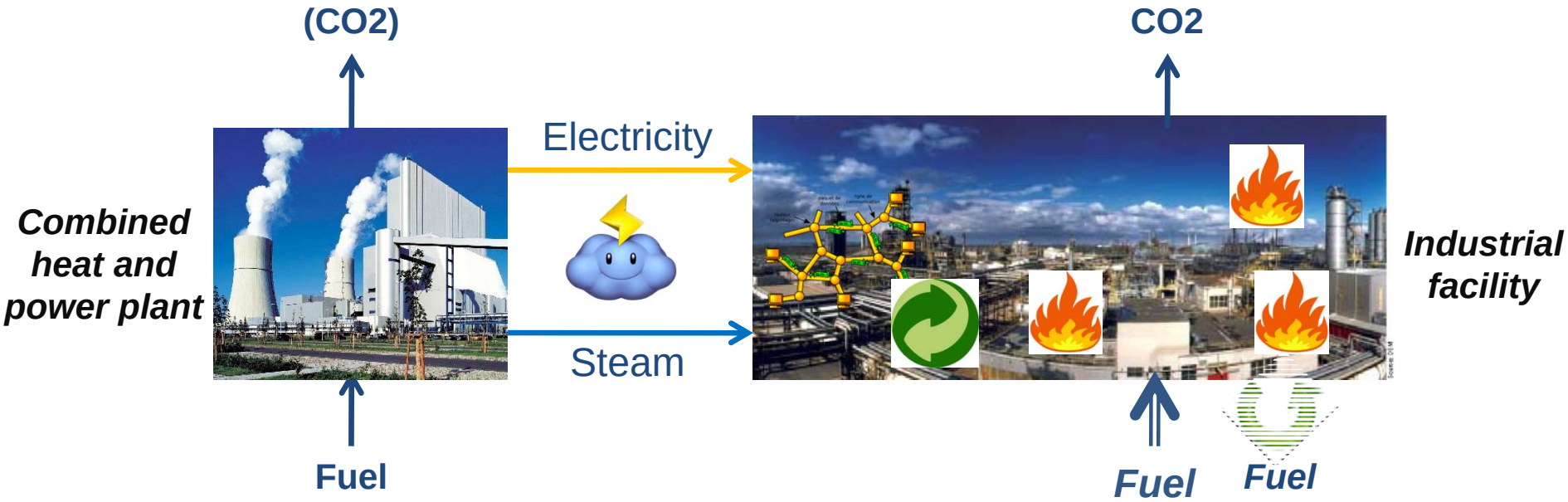

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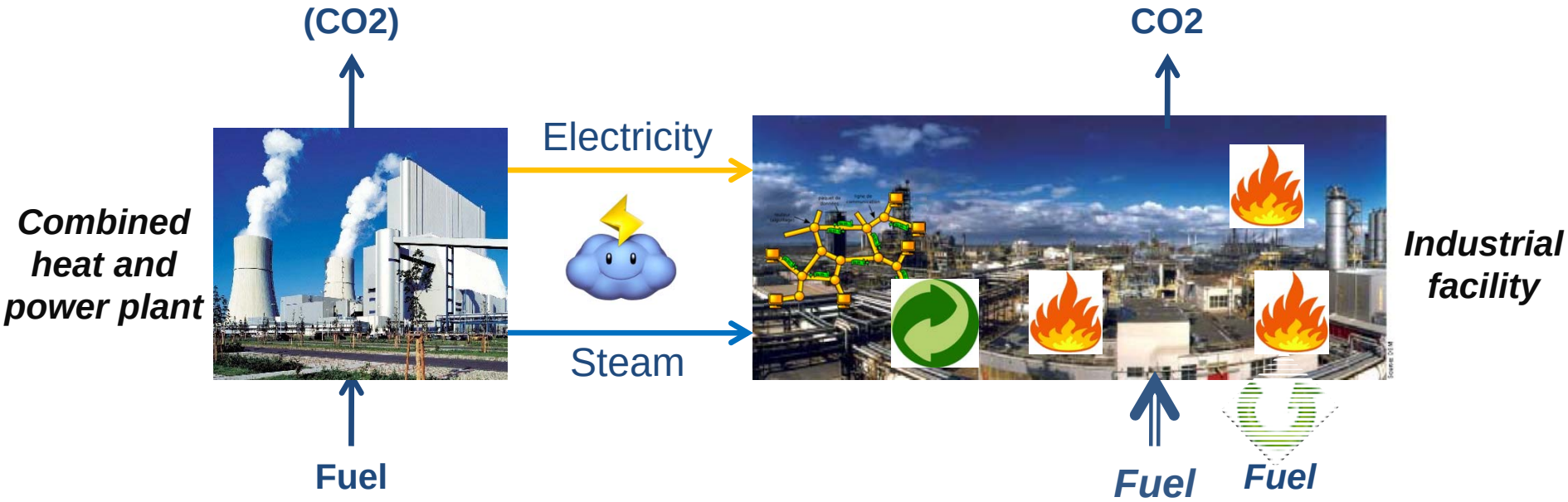

Plug-in **Extended**

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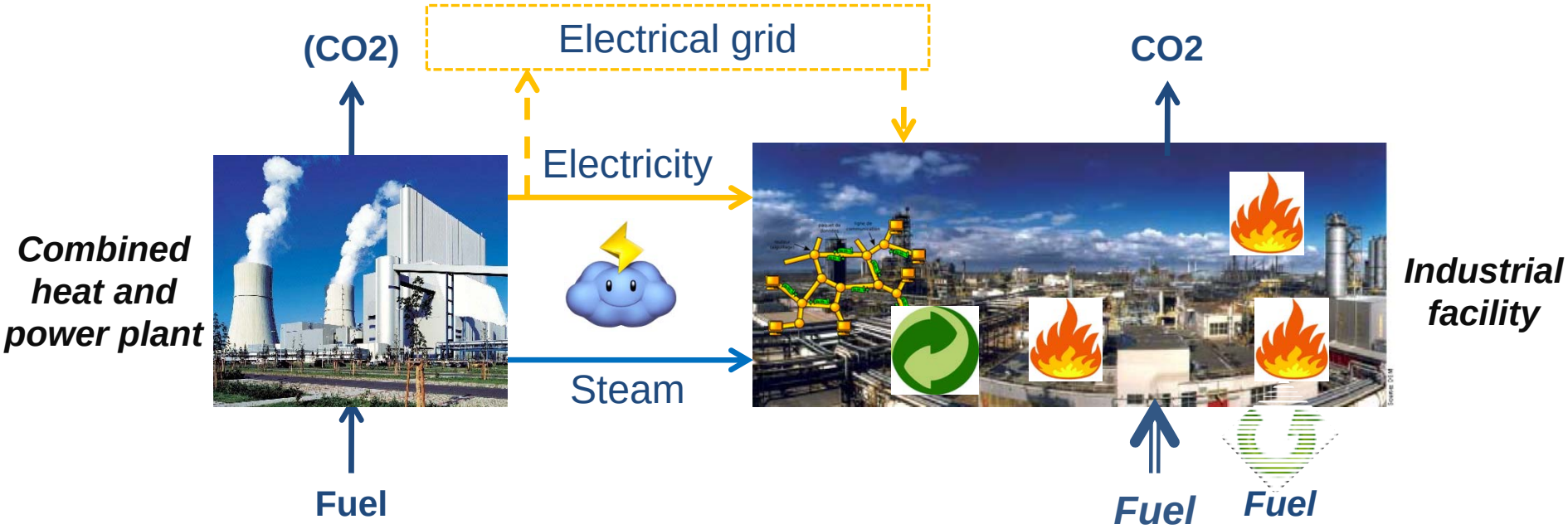

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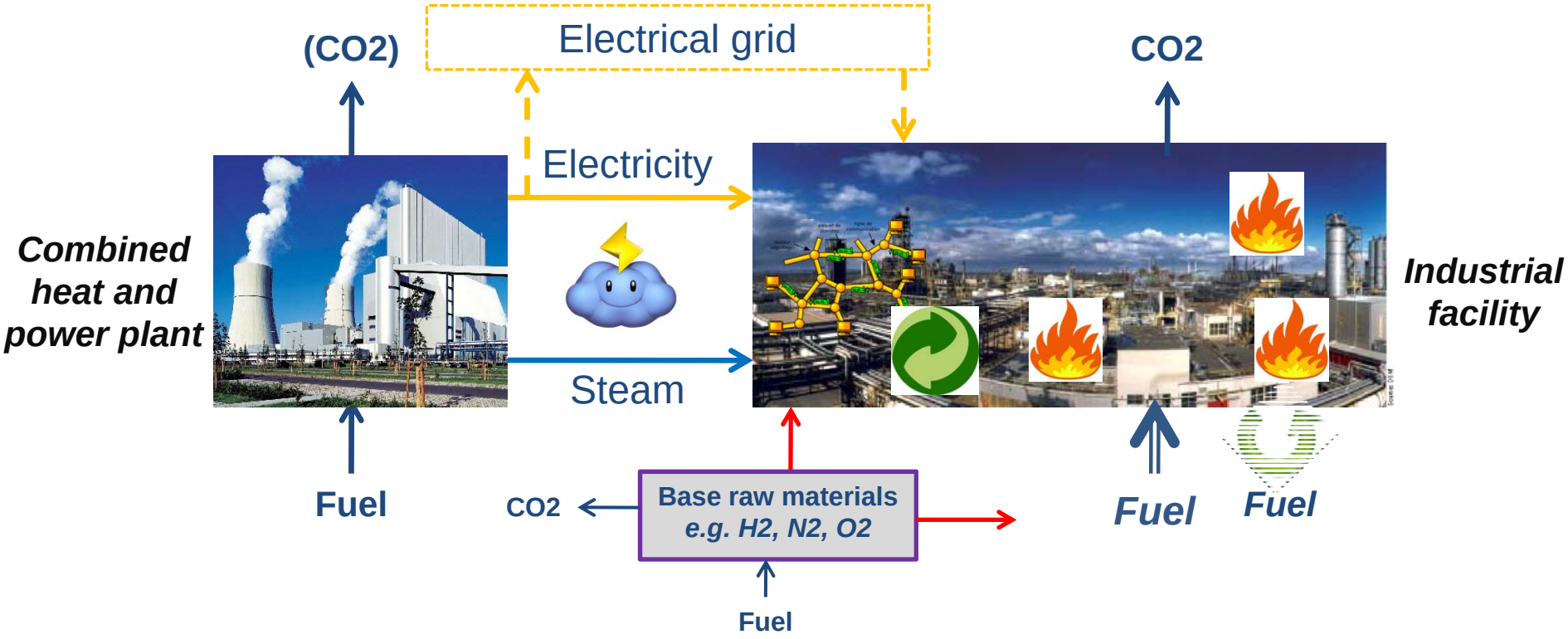

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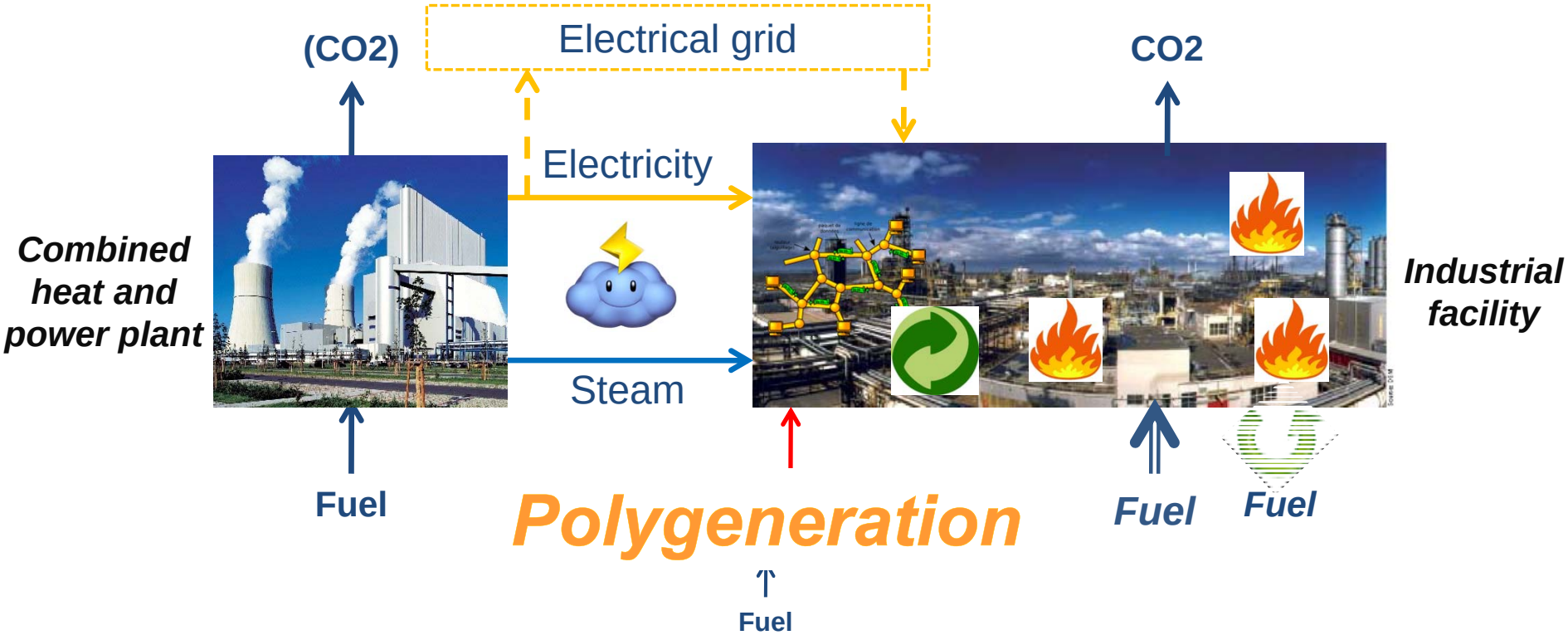

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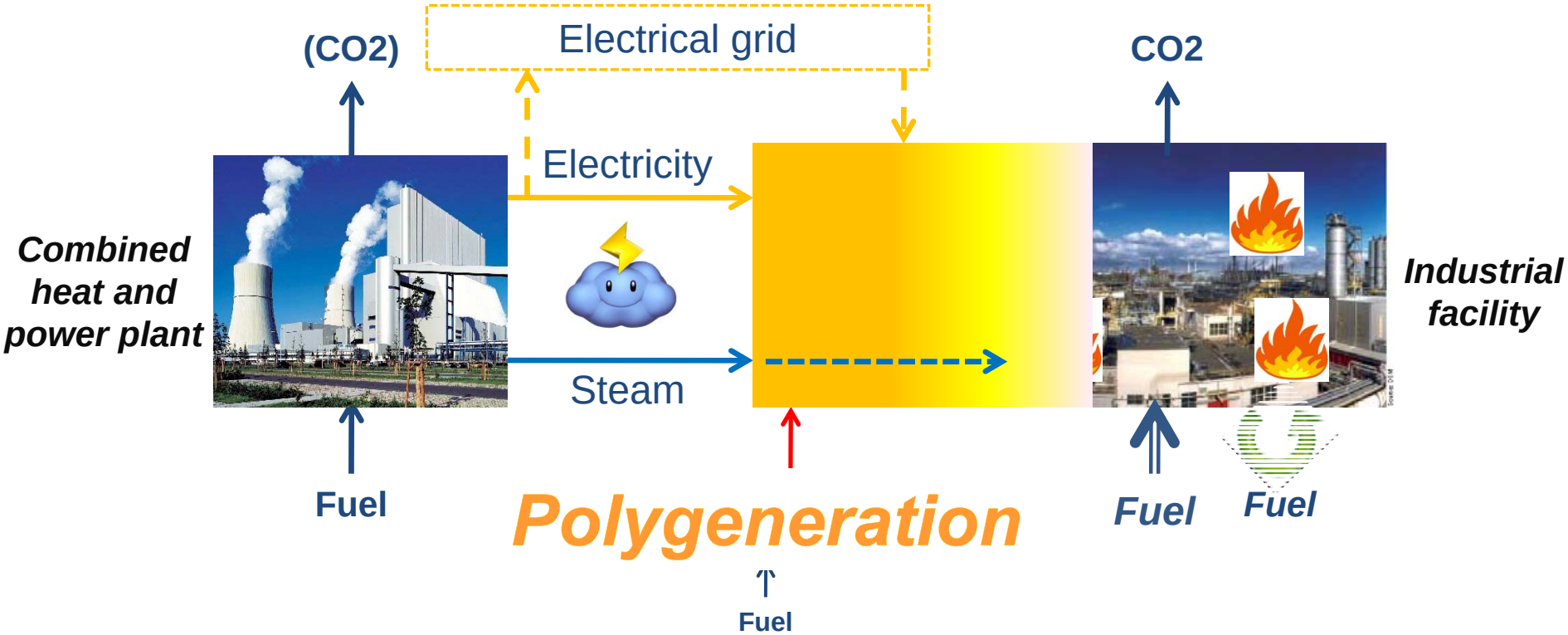

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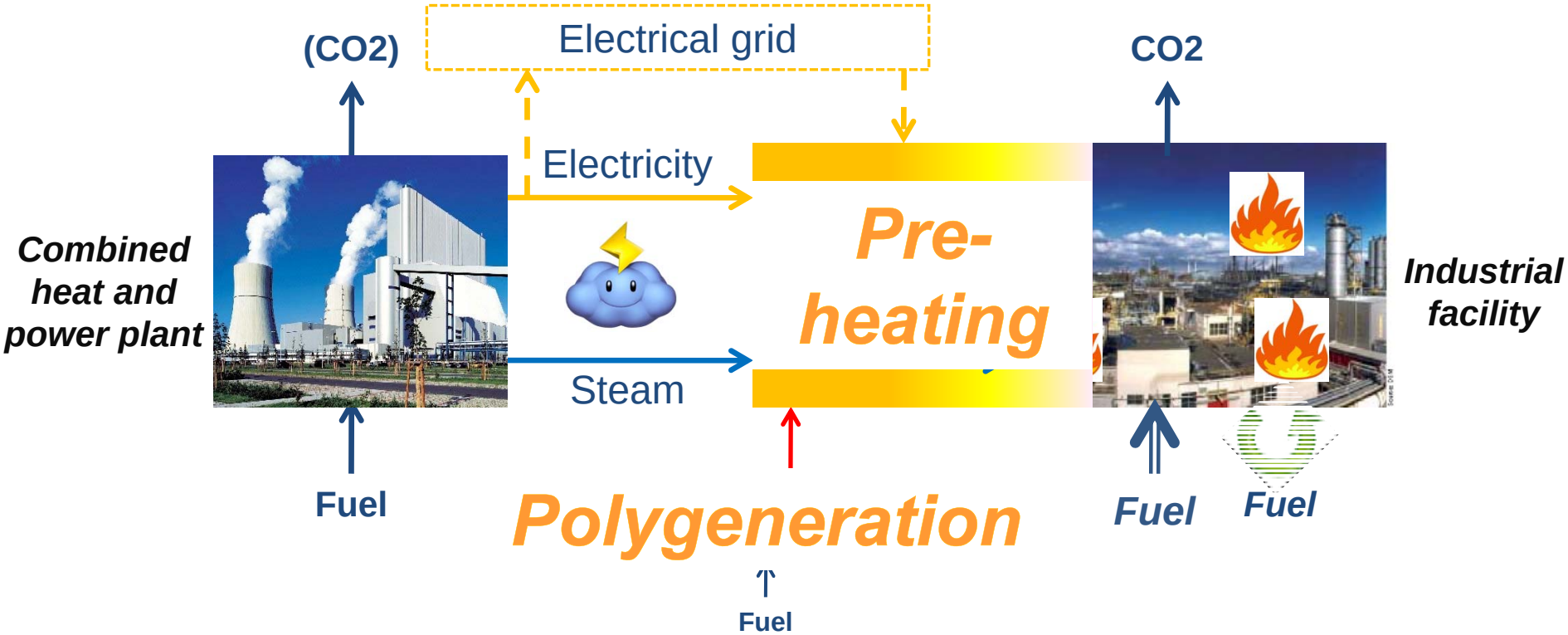


Plug-in **Extended**

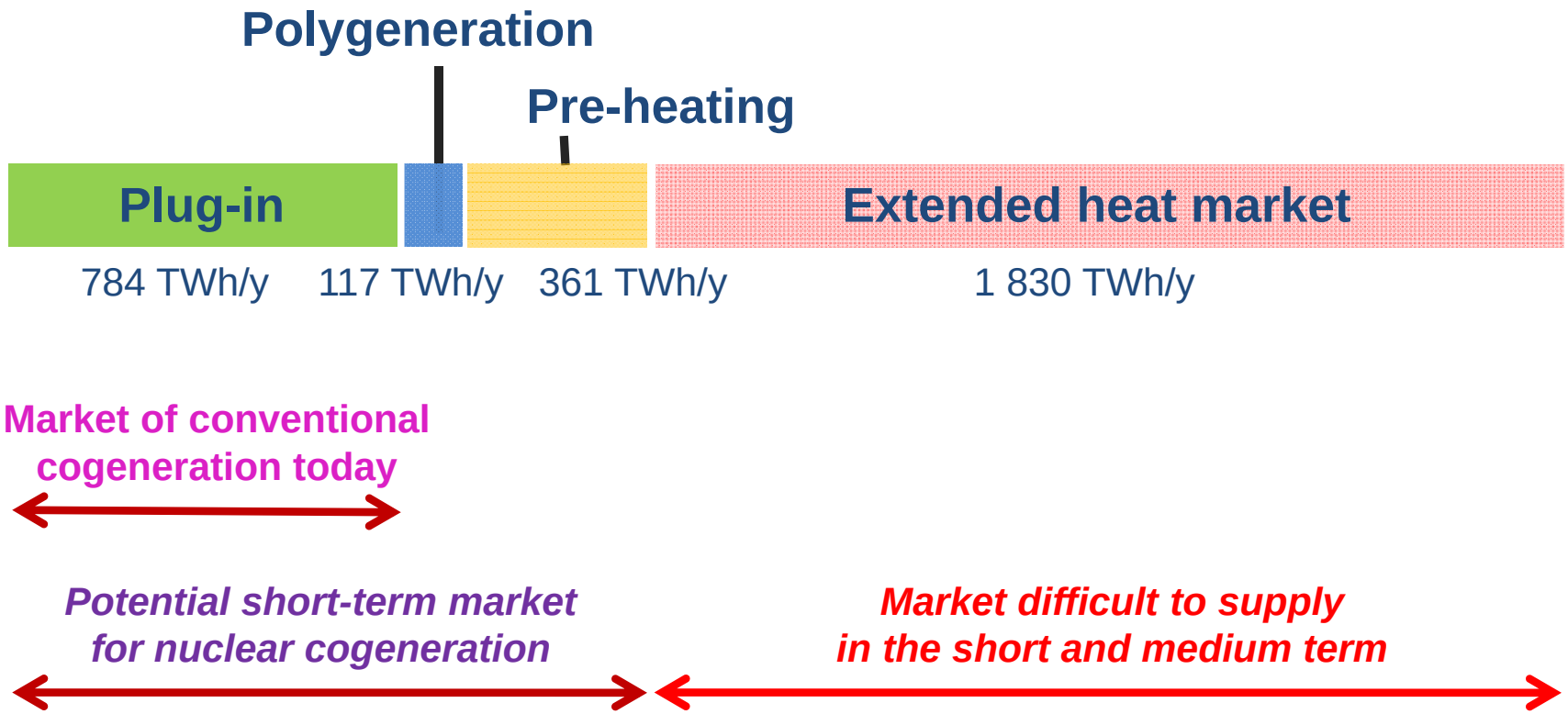
Status of cogeneration today

- **Cogeneration is a mature technology**
- **Gas is the reference technology**
- **Max process temperature ~ 550°C**

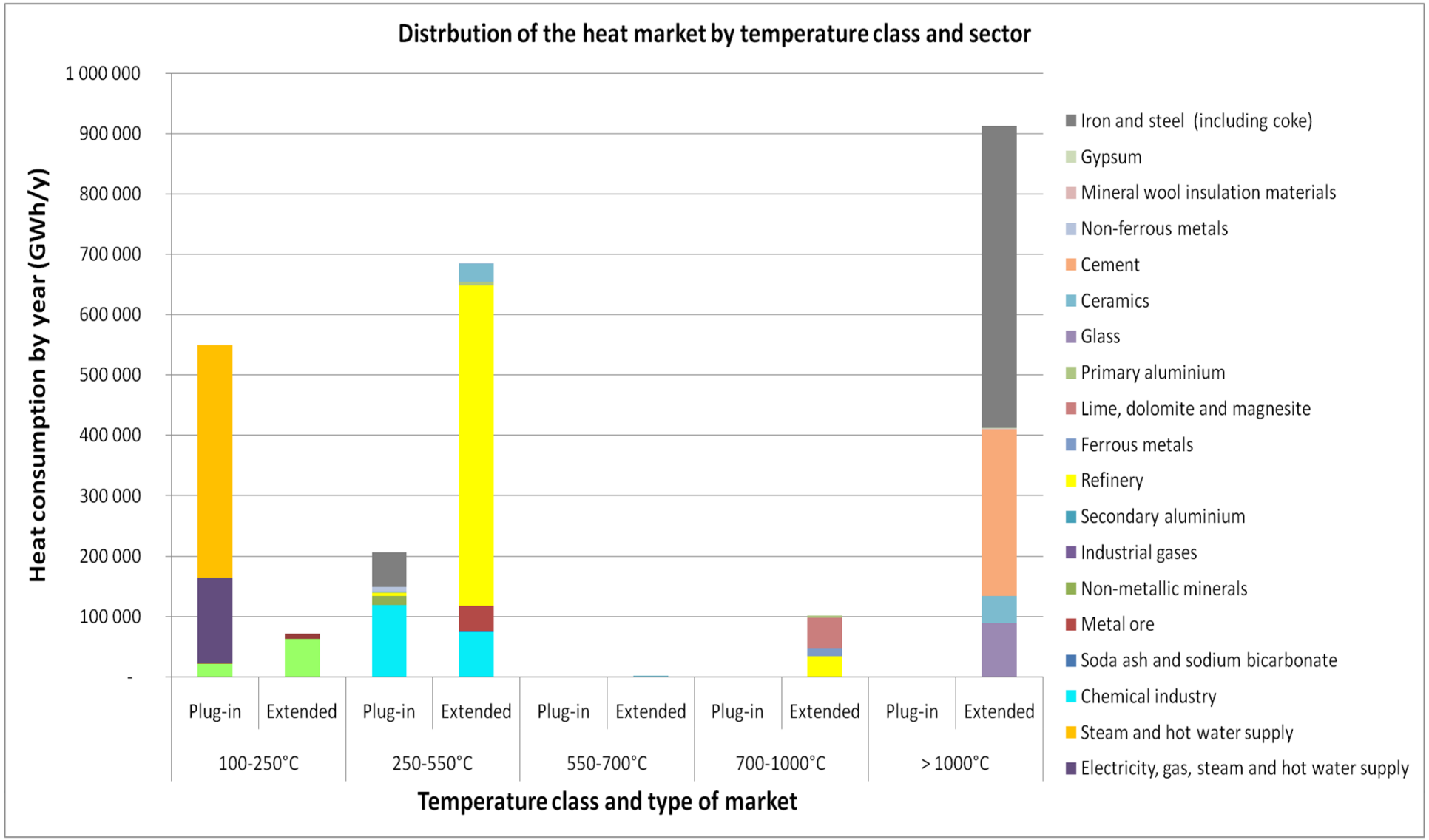
- **Nuclear cogen was proven for low temperatures (< 200°C)**
- **Europe has a leading experience**

• **district heating** (Eastern Europe, Russia)
• **paper** (Switzerland)**, salt refinery** (Germany)
• **desalination** (Japan and Kazakhstan)
• **large scale industrial park** (Canada)

Results: size of markets



Results: distribution by temperature/sector



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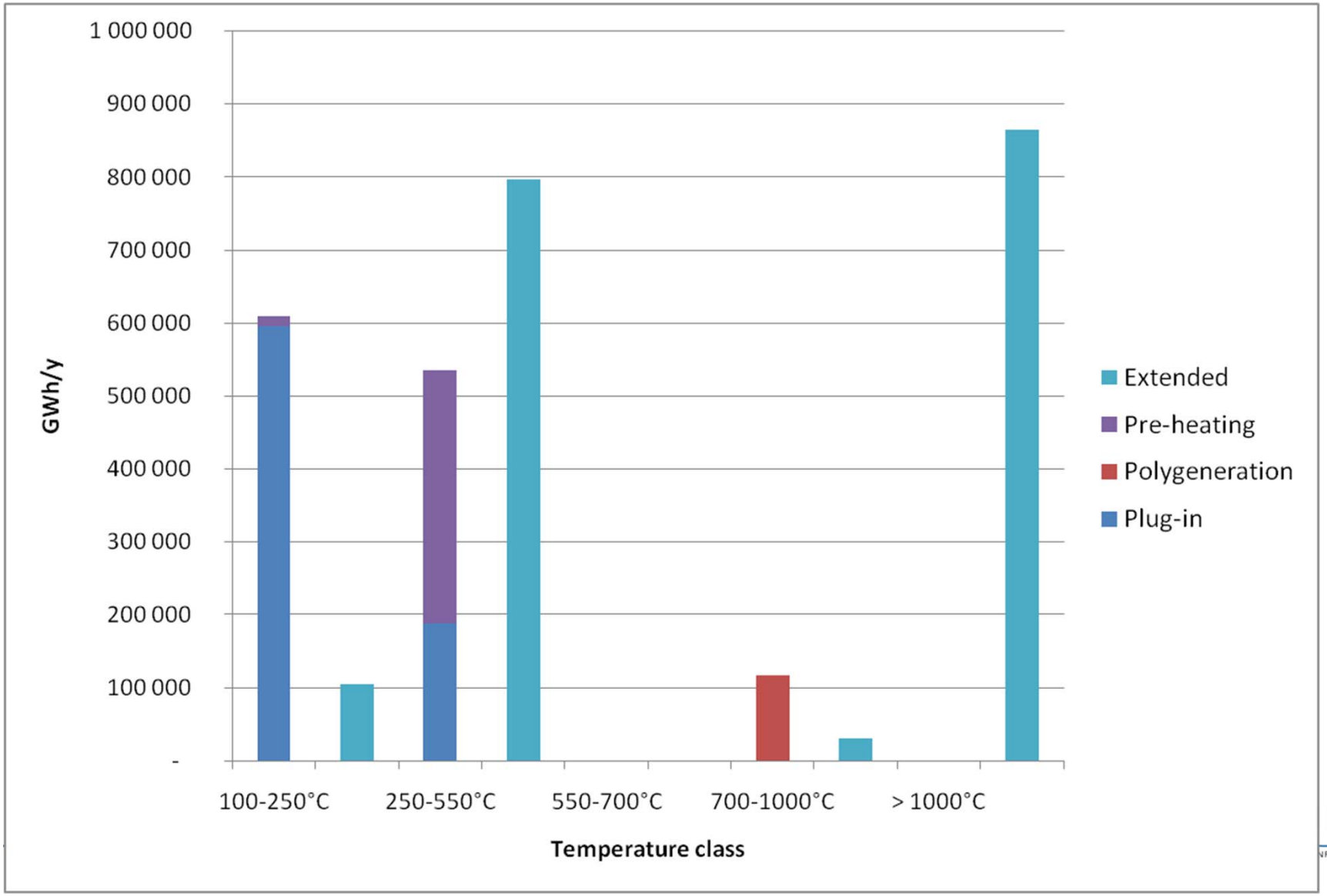

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NFORMATION TECHNOLOGY

“Plug-in” market

- **Mostly replacing existing cogeneration plants based on fossil fuels**

Opportunities	– Infrastructures available – Operational compatibility of industrial parks – Climate policies and concerns on energy supply and costs – Several regions with significant industrial densities – Sector specific opportunities
Challenges	– Flexibility – Average installed thermal capacity per site – Availability and back-up capacities – Sector specific issues – Nuclear acceptability, contamination, safety – Industrial uncertainty

Polygeneration of hydrogen and oxygen

- **Production technologies still to be demonstrated**
- **Several advantages**
  - On-site direct added value
  - Economies of scale
  - Energy storage
  - New markets accessible
    H2 for e.g. fuel cells, ammonia synthesis and iron reduction, O2 for existing and new markets (e.g. glass, steel, clean coal techs, H2)
  - Distant supply of final consumers via industrial gas pipelines
    Europe has the largest pipeline network in the world

Nuclear pre-heating

- **Applicable in any "heating neutral" sector**
- **Significant reengineering may be required**
  - *Need for detailed analysis by sector*

- **Examples**
  - Glass: contribution to raw materials melting via a combination of nuclear pre-heating, fuel combustion (also oxy-fuel) and electrical boost
  - Iron and steel: air (or pure O2) pre-heating or steel scraps pre-heating
  - Aluminium: hydration of alumina (using steam) and contribution to alumina calcination (≈ drying process)
  - Ceramics: drying of shaped materials (moisture removal)
  - Lime, cement: raw material pre-heating

Extrapolation to the world

Region	Plug-in market	Total market	GDP 2011 (approx.)
Europe	~ 800 TWh/y *(EUROPAIRS)*	~ 3,000 TWh/y *(EUROPAIRS)*	17,000 bn€ / 25% of world
USA	~ 1,100 TWh/y *(MPR Associates)*	~ 3,600 TWh/y *(MPR Associates)*	15,000 bn€ / 22% of world
China		*1,200 – 1,700 TWh/y (est.)*	7,000 bn€ / 10% of world
India		*300 – 500 TWh/y (est.)*	2,000 bn€ / 3% of world
Russia		*300 – 500 TWh/y*	2,000 bn€ / 3% of world
Brazil		*400 – 500 TWh/y*	2,500 bn€ / 4% of world
World total	***3,000 – 5,000 TWh/y ~ 370 – 630 GW***	***11,000 – 16,000 TWh/y***	**69,000 bn€**

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World total	*3,000 – 5,000 TWh/y ~ 370 – 630 GW*	*20,000 TWh/y*	**69,000 bn€**

HTR will only address a part of this market !!!

Conclusions (1/2)

- **Europe is an attractive heat market**
  - Large heat consumption, good share already supplied by cogeneration
  - Strong industrial infrastructures

- **Nuclear reactors could supply a good share of the market**
  - Plug-in market with flexible steam and electricity production
  - Polygeneration of H2 and O2 distantly
  - Pre-heating
  - Vision of industrial ecosystems around a nuclear plant

Conclusions (2/2)

- **<u>The world may represent a very large heat market for HTR</u>**
  - Very high potential for BRICS countries and other emerging economies, and potential market growth
  - A global (cooperation to) study of the world's industrial heat market would help assess in a second step the potential market of HTR in the world and make its business case robust
  - The EU and US studies can be a good basis

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Thank you for your attention
Questions?

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Backup slides

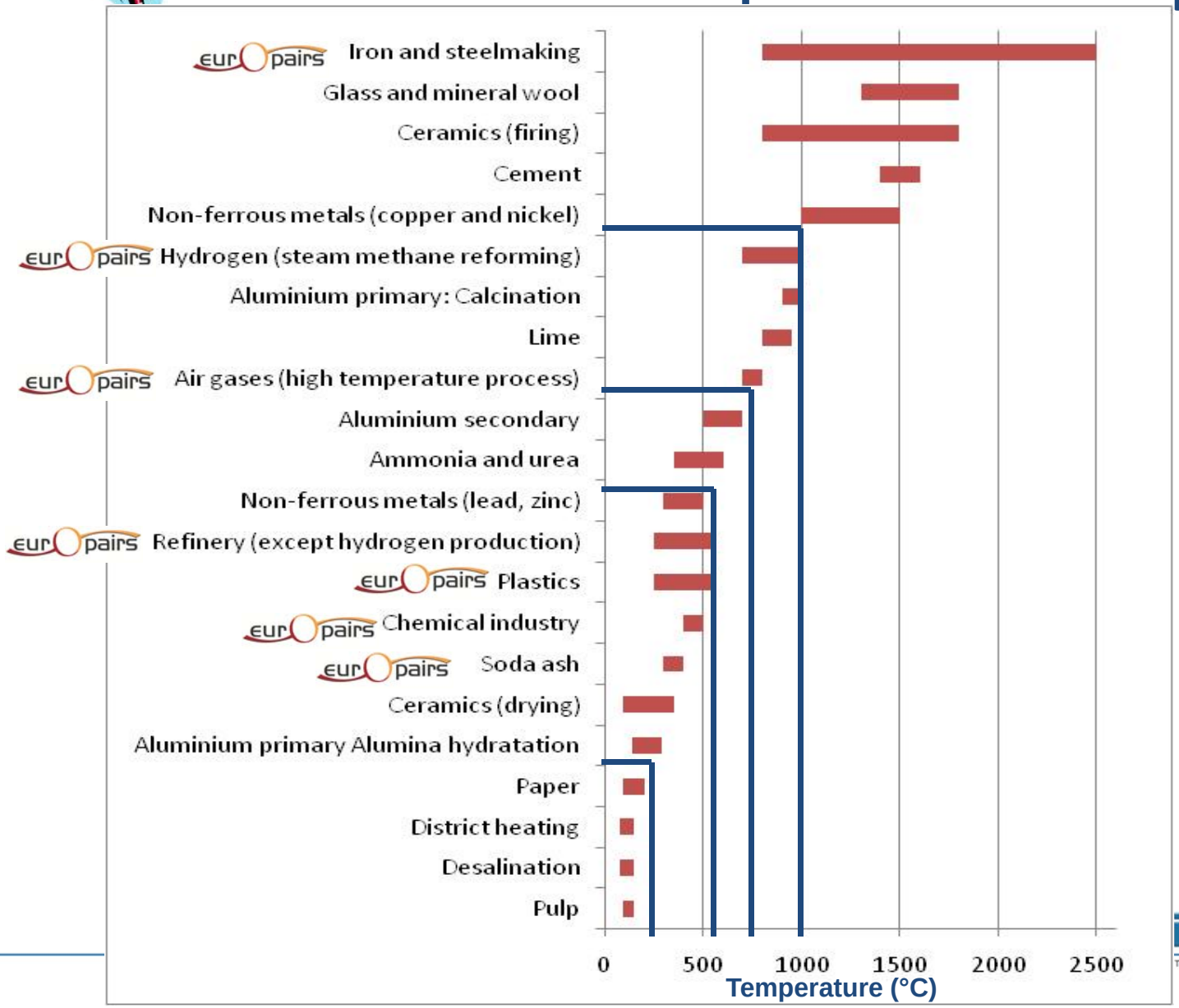
Methodology

- Dual approach:
  - ***Direct*** : Detailed analysis by industrial sector
  - ***Indirect*** : Based on CO2 emissions declared in EU ETS

- Market survey (April - September 2010)
  Responding organisations:

European associations	Individual companies
COGEN Europe	Leading oil company
European Aluminium Association	Leading pulp and paper company
European Industrial Gas Association	Leading soda ash producer
European Steel Technology Platform	Leading steelmaking company
European Lime Association	Leading lime company
Confederation of European Paper Industry	Utility of a medium-scale chemical cluster
	Fertiliser company
	Two industrial gases companies

Results: process temperatures



Bibliography

- Lack of information on heat consumption in Europe
- Statistical reporting via a common Eurostat-IEA questionnaire to Member States
- Results are
  - Unreliable: diverging estimations for the same information
  - Incomplete: only heat sold to market is considered
  - Imprecise: distribution by sector is too rough and mostly unattributed

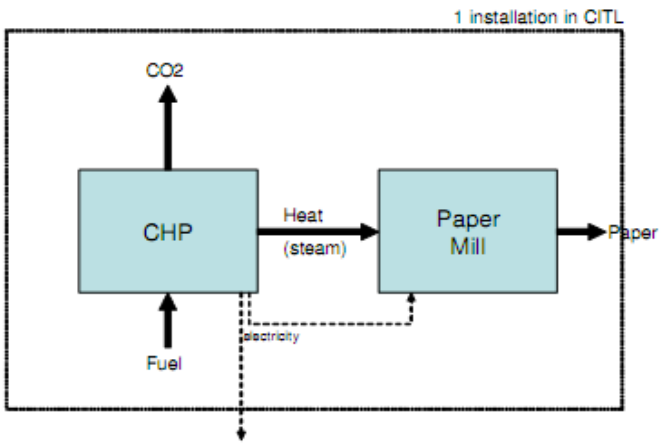
(GWh)	IEA	EUROSTAT
Heat production	766 741	1 619 086
Heat consumption	677 259	1 206 939

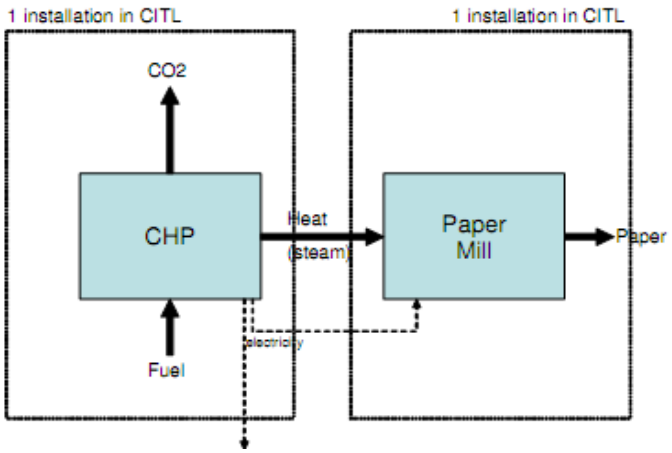
Precisions on EU ETS

- EU Emissions Trading Scheme directive dated from 1996 and amended several times

- Good fraction of the total energy market, especially the one most impacted by climate policies

- Statistical uncertainty regarding the reporting sector, in particular in sector "combustion of fuels" (total thermal input > 20MWth): *Ecofys study*





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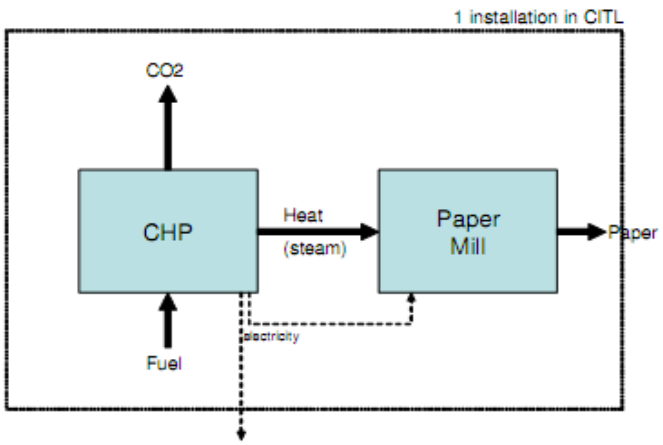
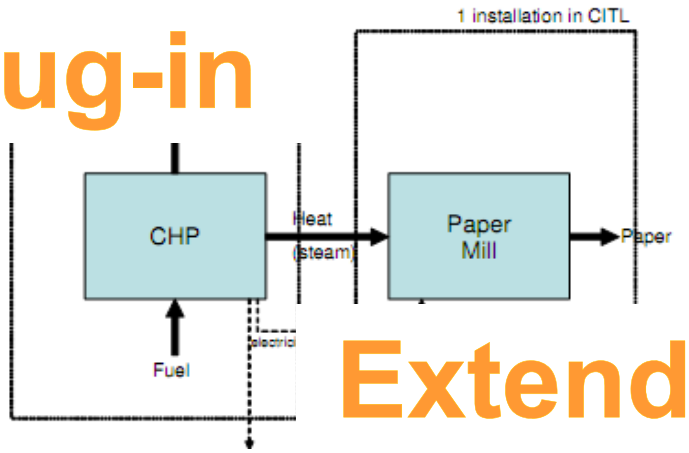
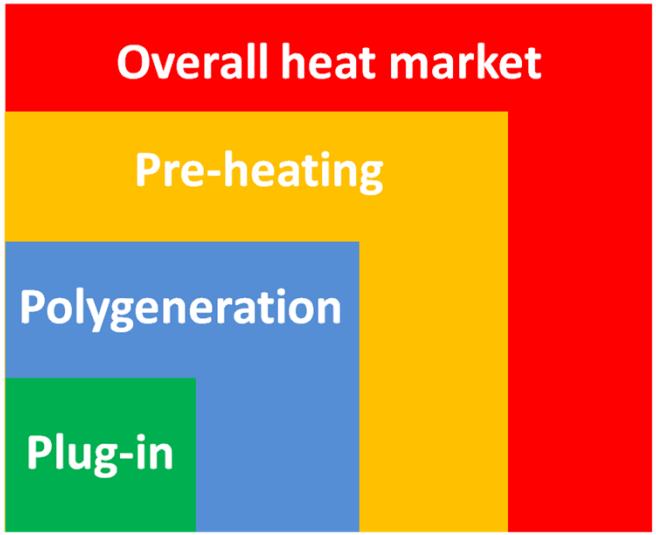


Plug-in

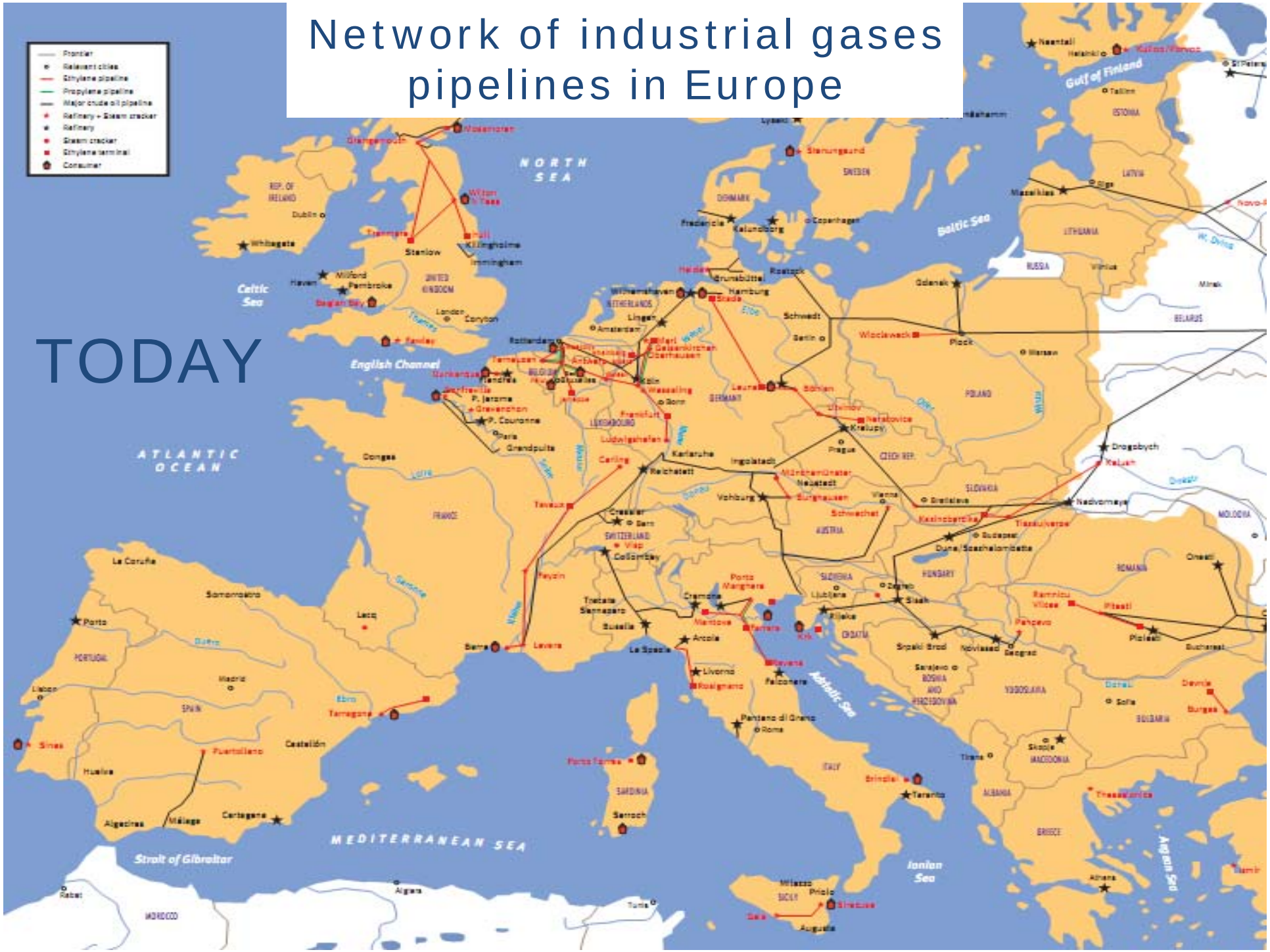


Extended

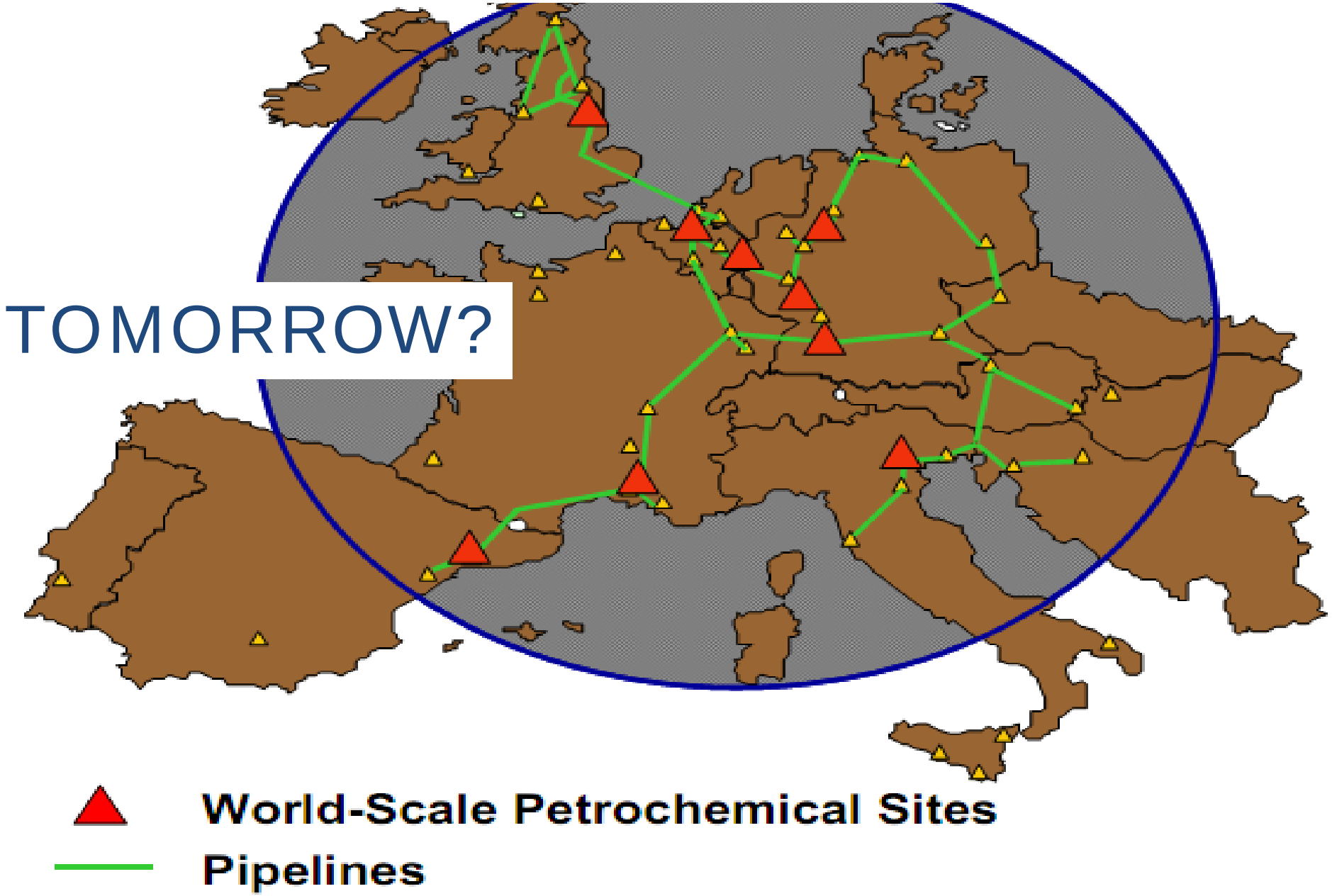

Overall heat market
Pre-heating
Polygeneration
Plug-in

Network of industrial gases pipelines in Europe

TODAY



Network of industrial gases pipelines in Europe



Europe: Air Liquide's industrial gas pipelines operated in Northern Europe

Hydrogen markets

	Consumption [bn m^3]		Growth rate [%/year]	Share of total [%]	
	2003	2008 extrapolation		2003	2008 extrapolation
Refining	30.56	44.74	7.9	49.7	58.6
Ammonia	19.44	19.50	0.1	31.6	25.5
Methanol	3.36	3.10	-1.6	5.5	4.1
Metals	2.67	3.25	4.0	4.3	4.3
Cyclohexane	1.01	1.11	1.9	1.6	1.5
Aniline	0.95	1.05	2.0	1.5	1.4
Caprolactam	0.71	0.75	1.0	1.2	1.0
H_2 Peroxide	0.70	0.75	1.2	1.1	1.0
Oxo Alcohols C8	0.34	0.35	0.6	0.6	0.5
Oxo Alcohols C4	0.26	0.27	0.7	0.4	0.4
Toluene Diiscocyanate	0.38	0.35	-1.6	0.6	0.5
Hexamethylenediamine	0.31	0.33	1.6	0.5	0.4
Adipic Acid	0.15	0.16	0.8	0.3	0.2
Hydrochloric acid	0.10	0.10	-0.4	0.2	0.1
Tetrahydrofuran	0.21	0.22	1.6	0.3	0.3
Fats and oils	0.31	0.30	-0.3	0.5	0.4
Float glass	0.04	0.05	3.4	0.1	0.1
Electronics	0.03	0.04	2.3	0.1	0.0
Total	**61.53**	**76.41**	**4.4**	**100**	**100**

Additional potential market for fuel cells:
+ 154 bnm3 (+200%)

67% produced on purpose

33% by-product

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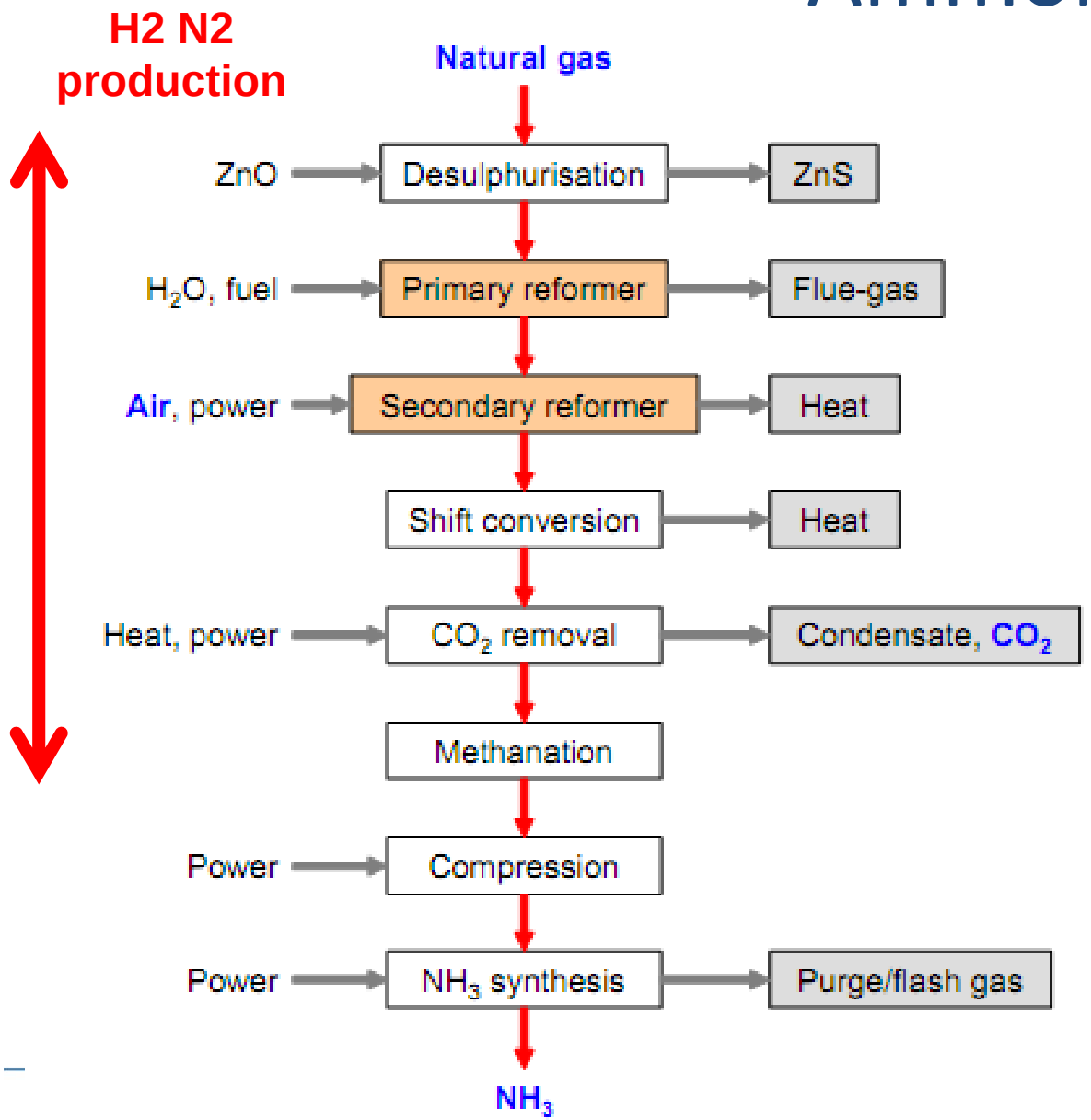
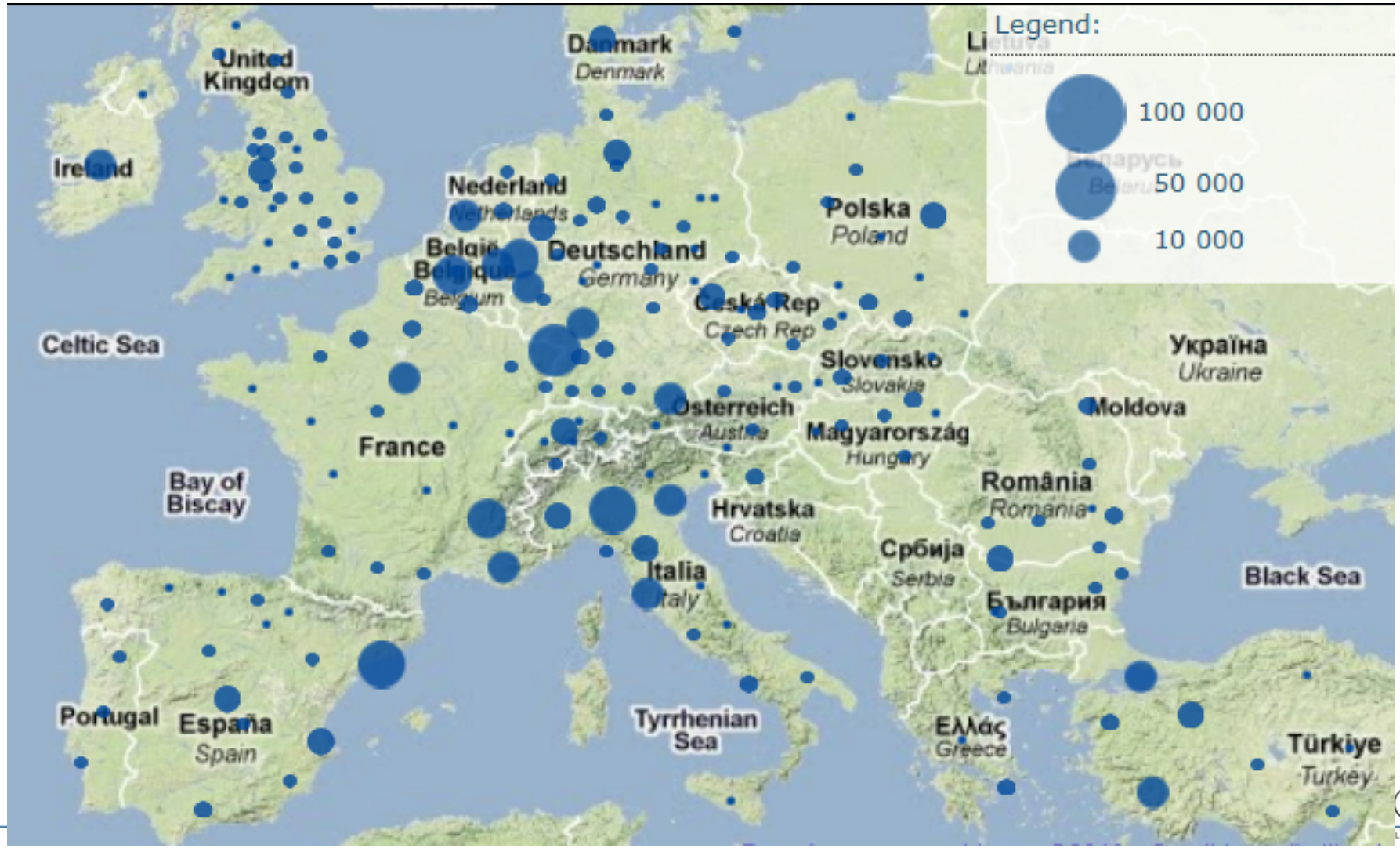
Ammonia

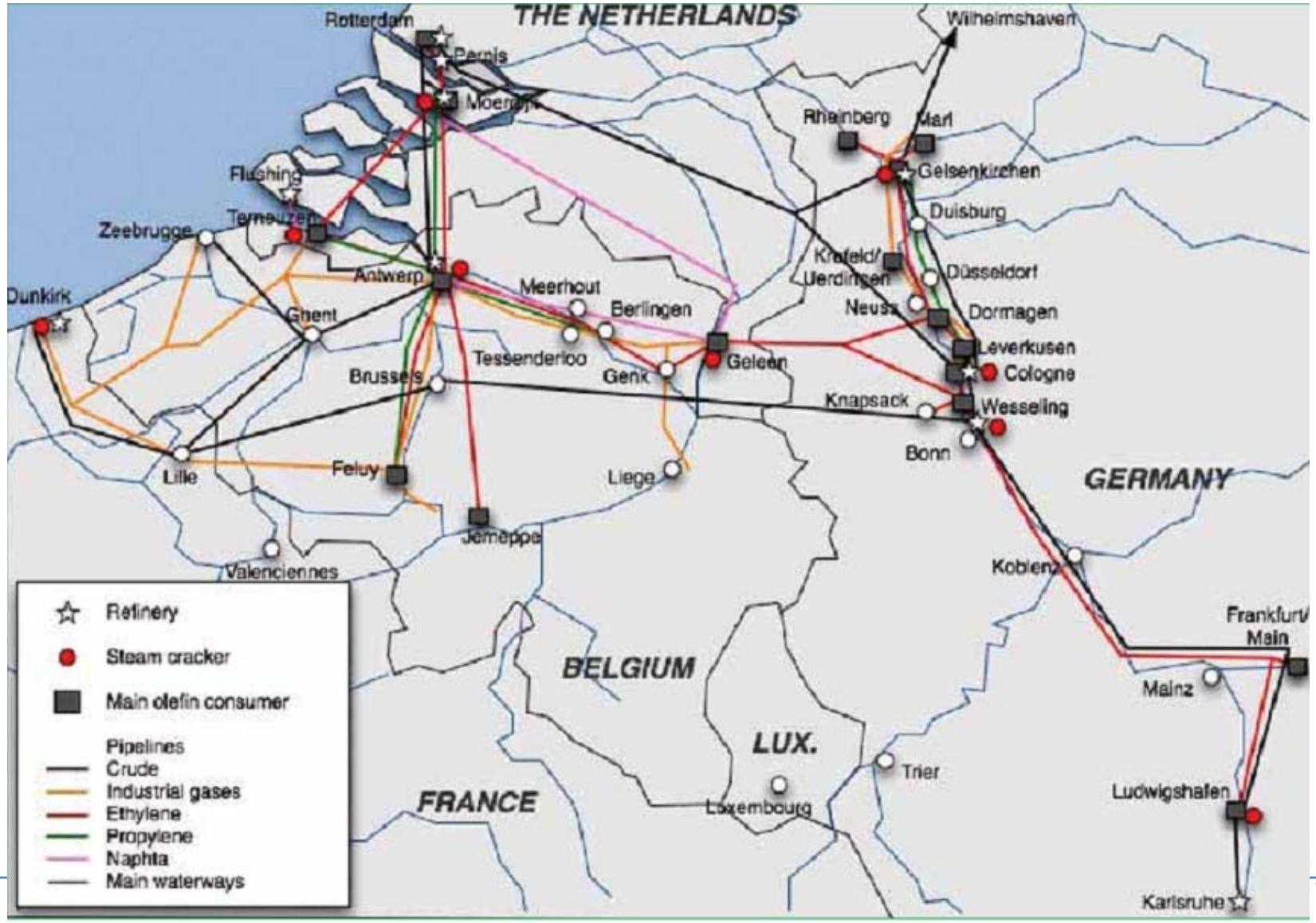


Temperature	Energy
350-400°C	Heat
400-600°C	Heat
500-600°C	Heat
350-380°C	Exothermic
	Heat / power
300°C	Exothermic
350-550°C	Power
350-550°C	Power

Chemical industry: location of clusters



Mega cluster Antwerp Rotterdam Rhine Ruhr



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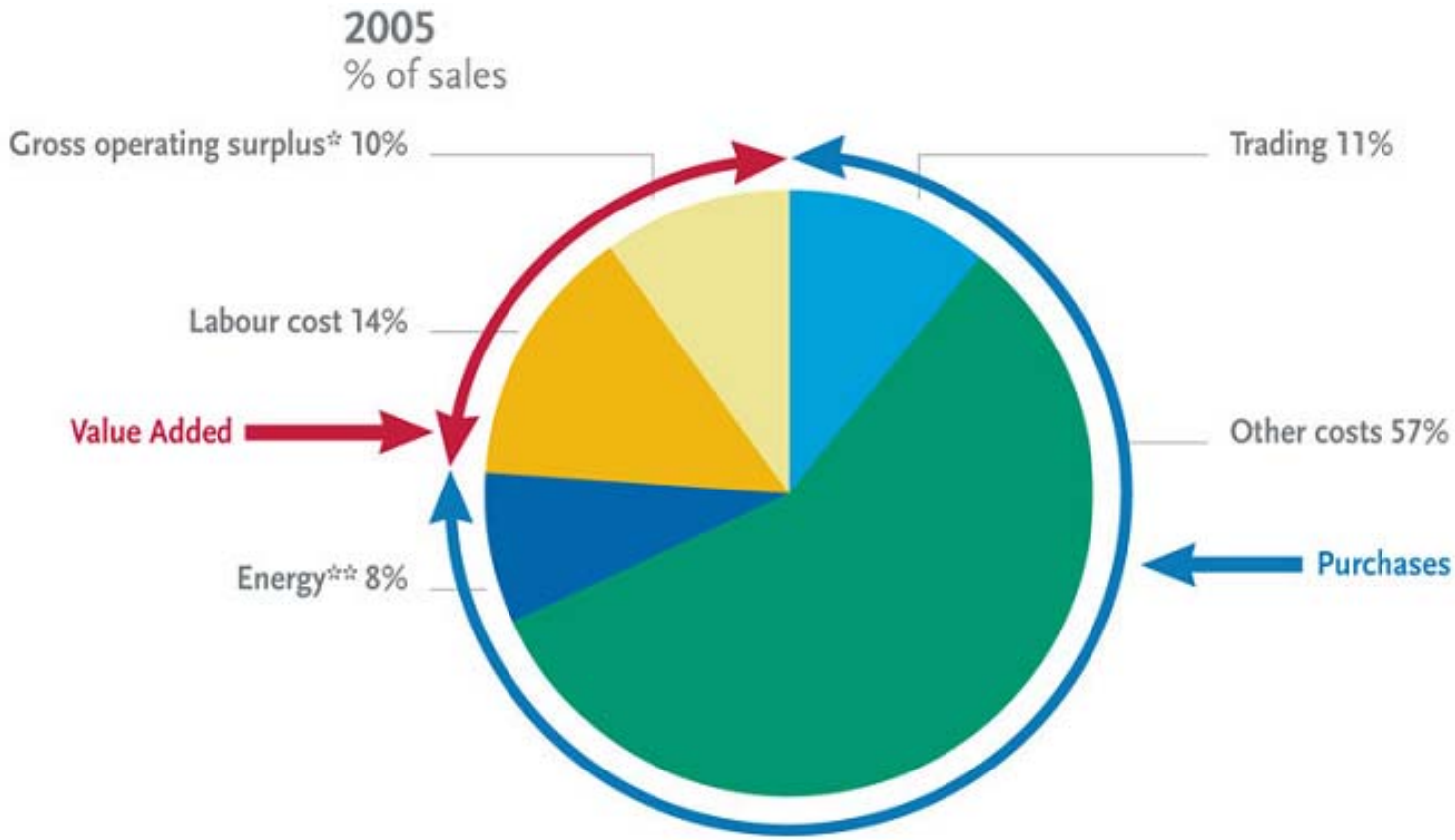
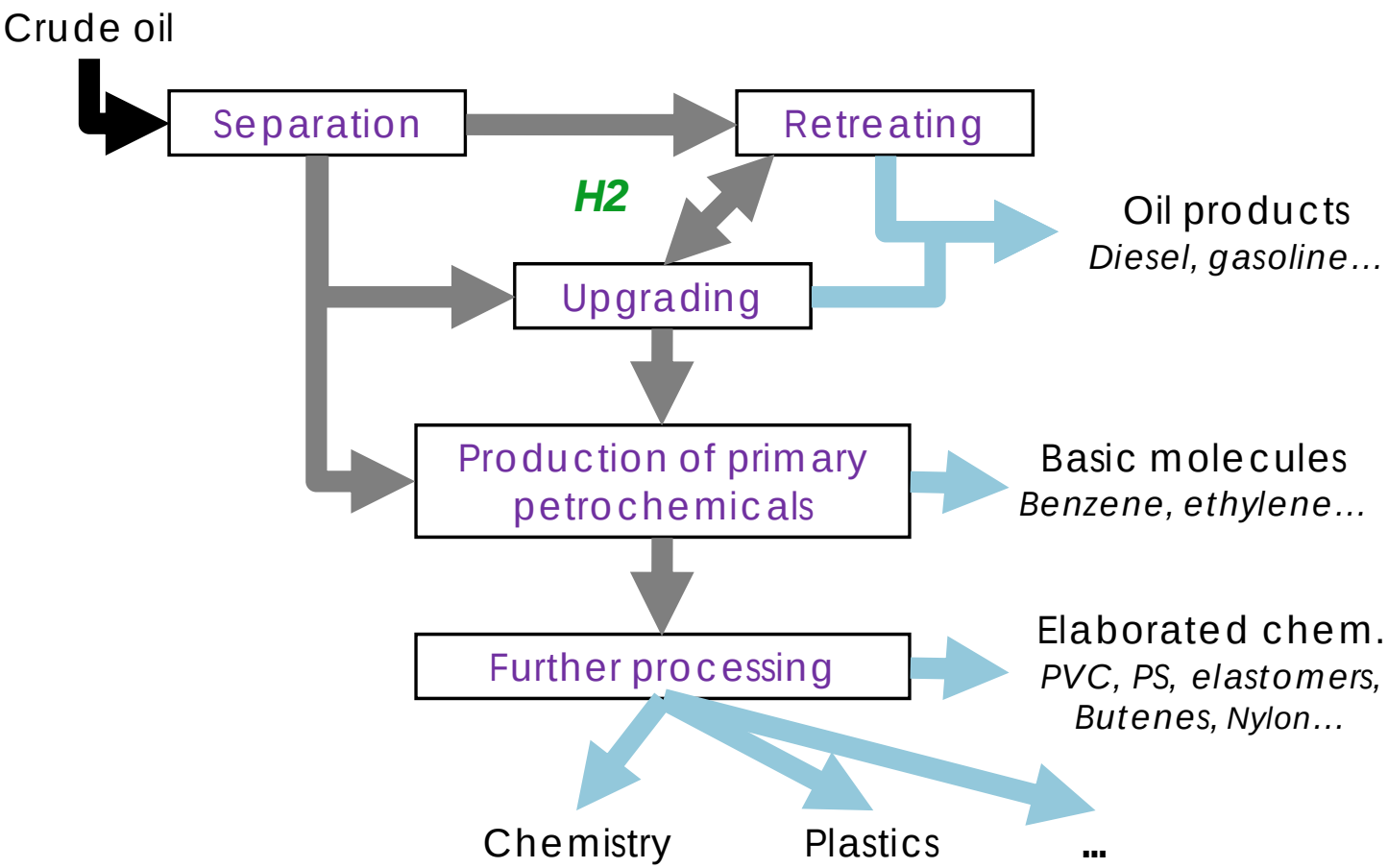
Cost structure in the chemical industry

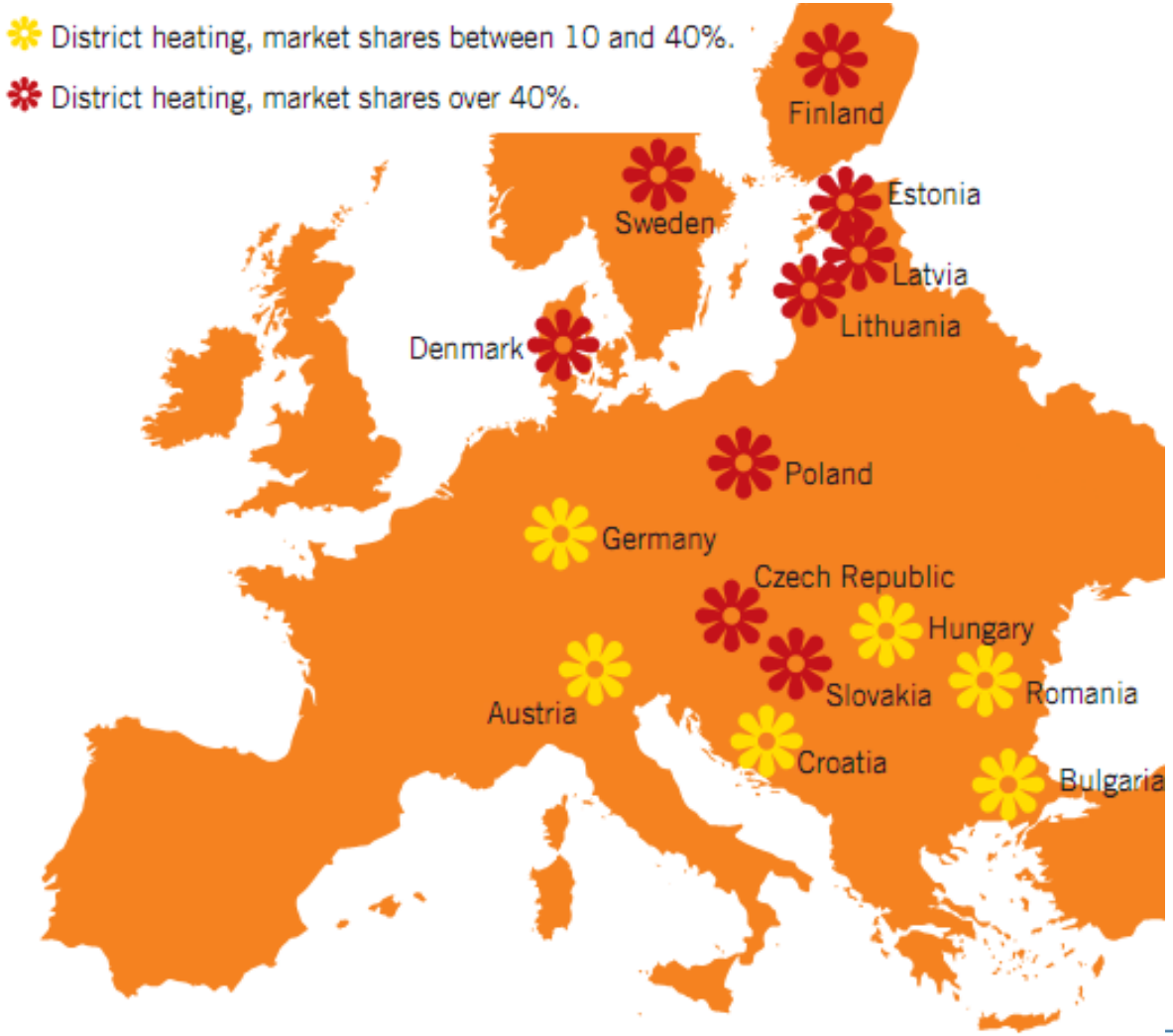


Source: CEFIC

Refinery functioning principle



District heating market share in Europe



District heating significant market shares in European countries (Source: EHP 2010)

District heating is most developed in Scandinavian and Eastern Europe

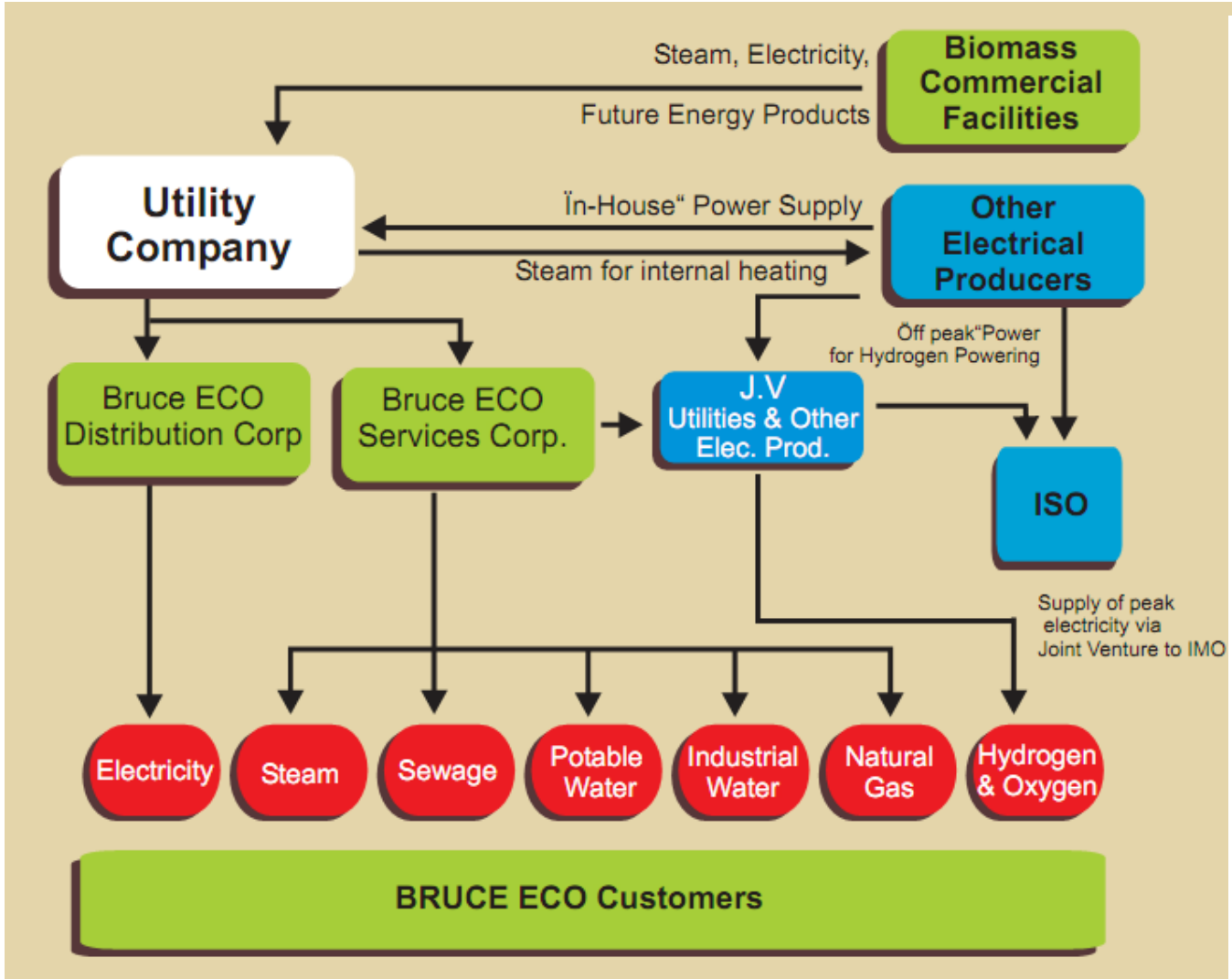
District heating typical consumptions:
600 – 1200 MWth large cities
10 – 50 MWth in smaller ones

Temperature range: 80-150°C

Max distances: 10-15 kms

Annual load factor: 50%

Bruce Eco Industrial Park utility system



Source: Bruce 2010

Cogeneration from 8 CANDU reactors and biomass

7 200 MWe nuclear
5 350 MWth steam

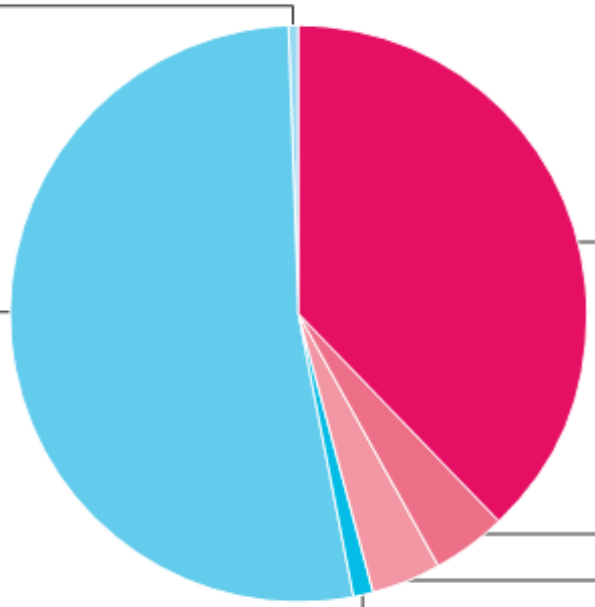
1680 kg/s MP steam
+ 315 kg/s back-up

Consumers:

heavy water production unit, plastic producer, a 30 000 m2 greenhouse, a 12 000 m3/y ethanol plant, a 200 000 t/y alfalfa plant, an apple juice concentration plant and an agricultural research facility.

Cost structure and energy mix in the pulp and paper industry

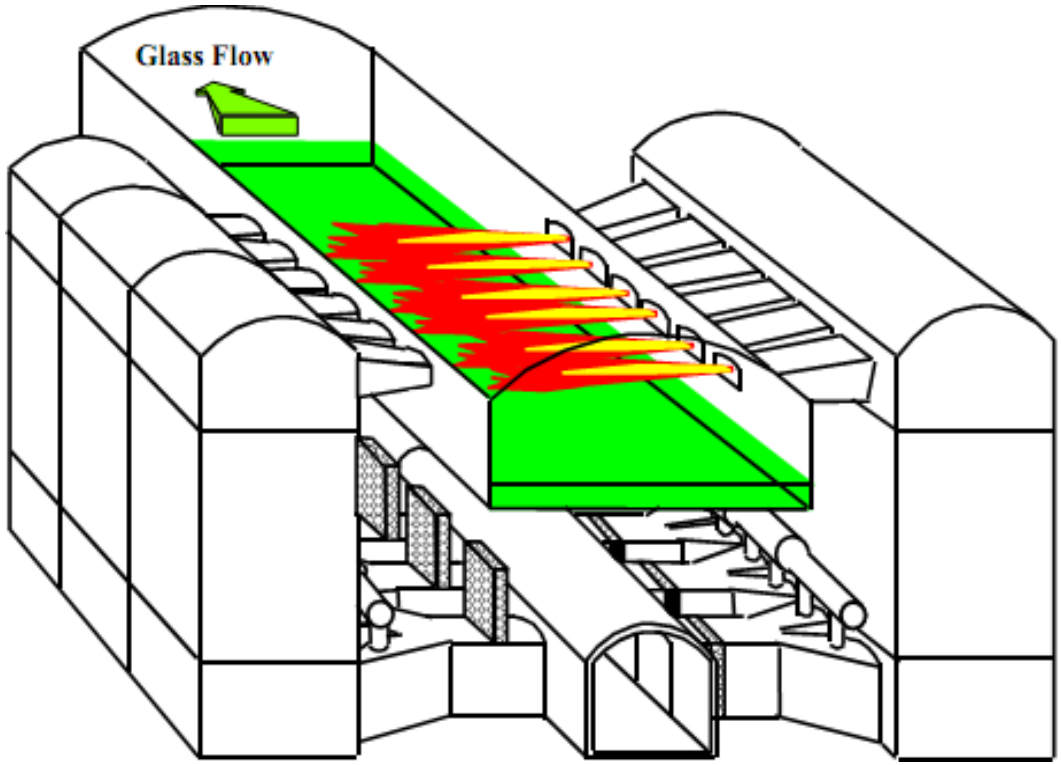
- Recovered Paper 5.1%
- Labour 12.9%
- Maintenance 9.3%
- Market Pulp 15.9%
- Electricity 9.7%
- Chemicals 17.6%
- Fuels 12.3%
- Wood 17.3%



Total Fuels Consumption: 1 226 810 TJ

Glass: regenerative melter

Principle of glassmaking:
- **melt** various chemicals (silica oxides mainly)
- **cool quickly** to keep their non-crystalline structure from liquid phase



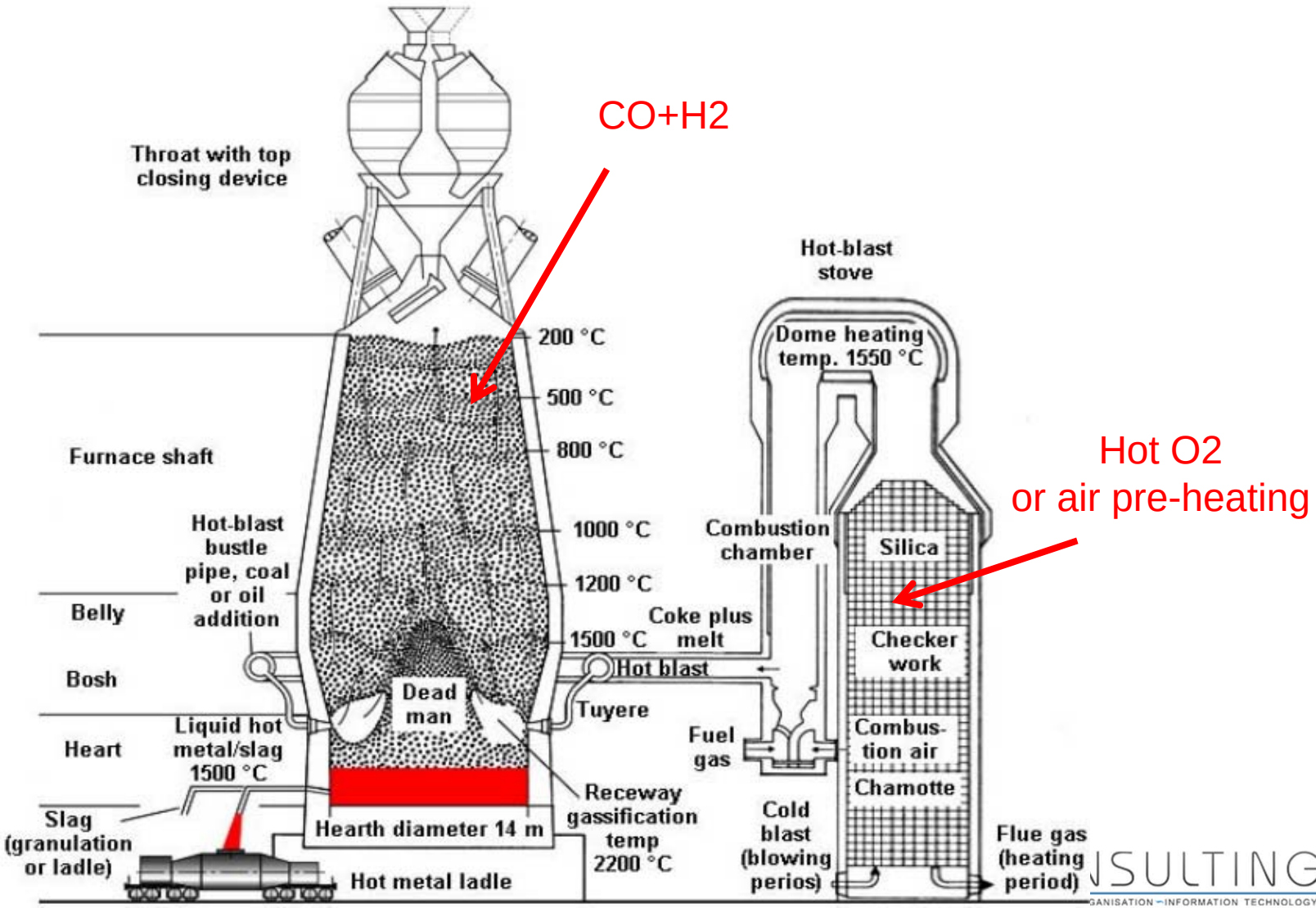
Melting = 75% of energy

Final temperature:
1300°C - 1500°C

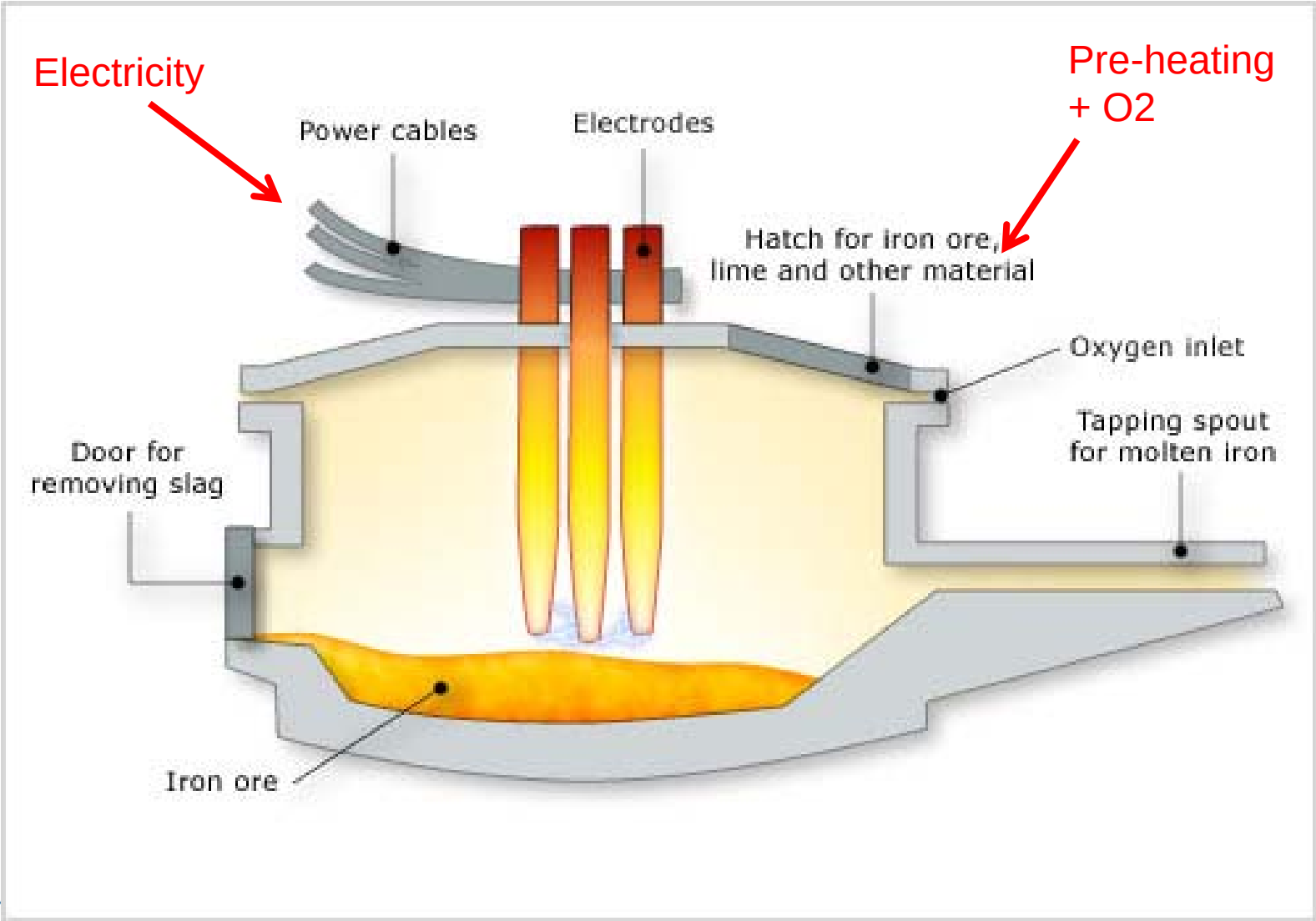
Numerous techniques including combined fuel and electric heating

Nuclear cogeneration potential:
- pre-heating up to 550°C
- heating with (oxy) fossil fuels
- electric boost

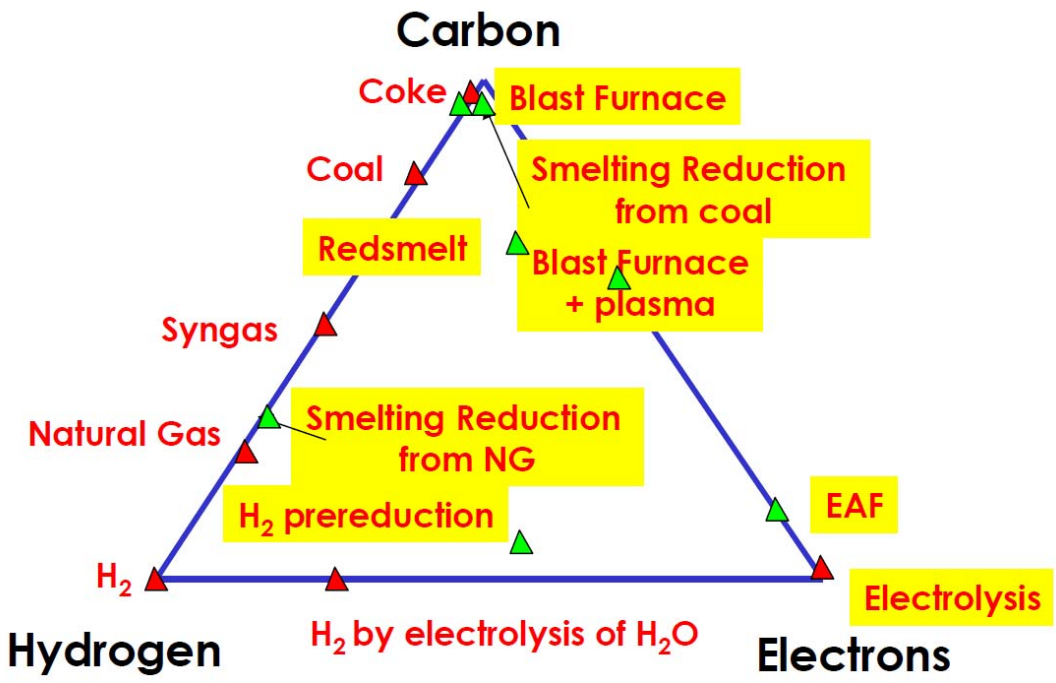
Steel: blast furnace

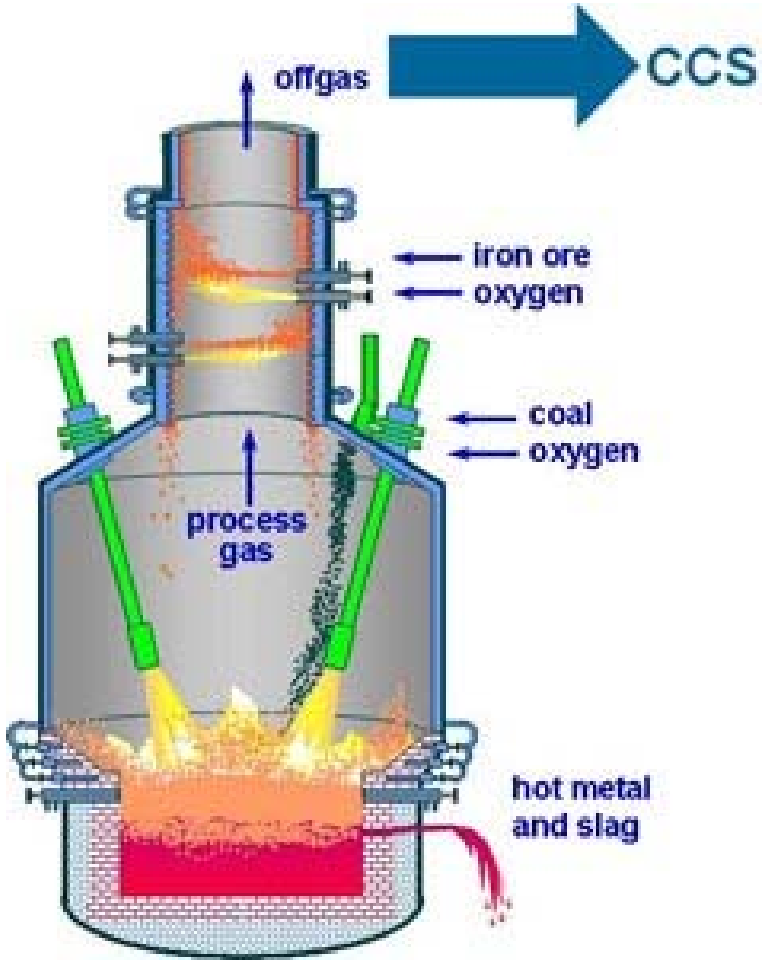


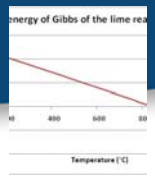
Steel: Electric arc furnace



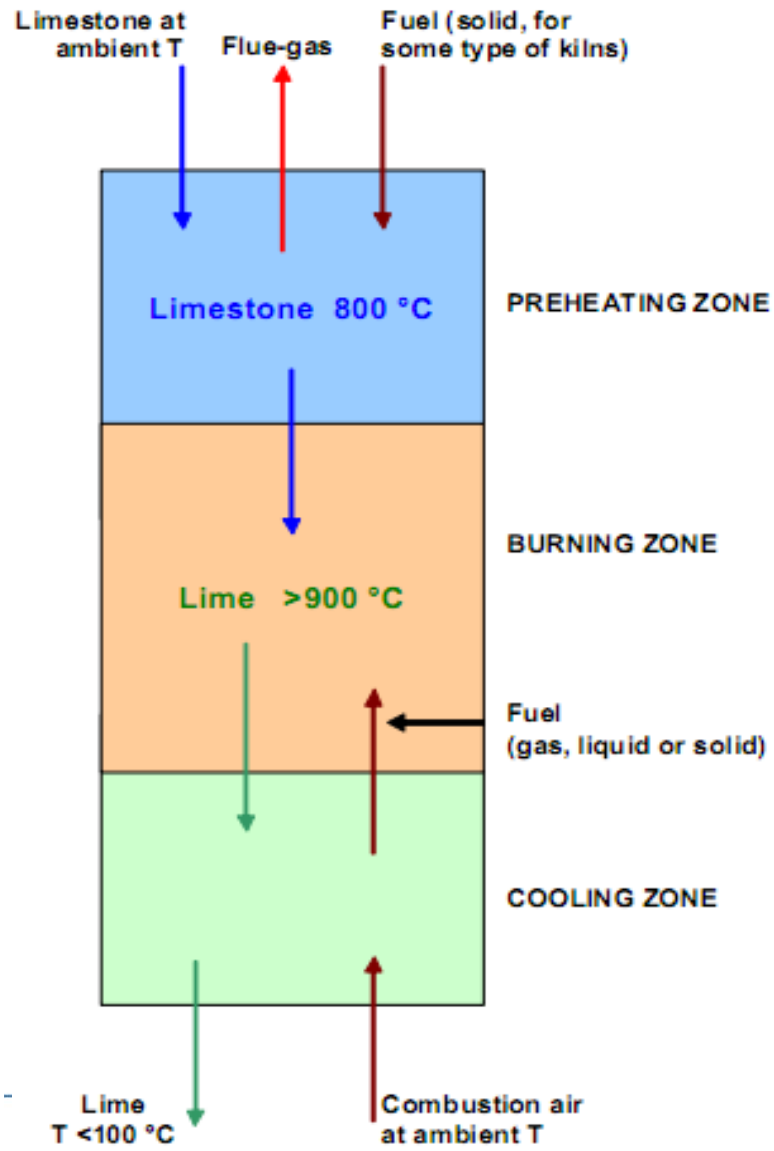
Steel: new concepts



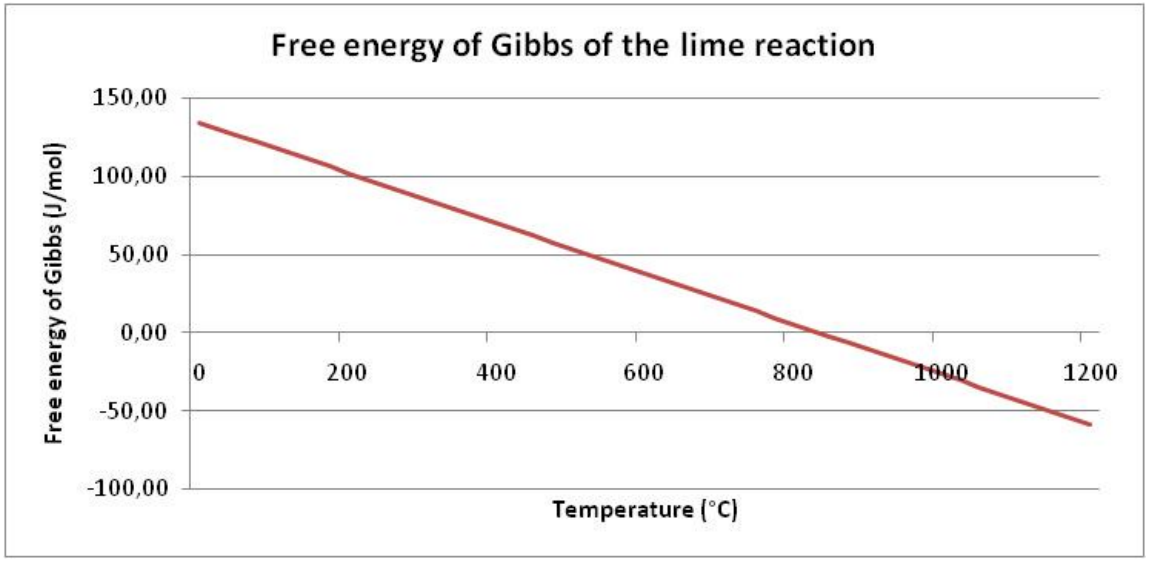




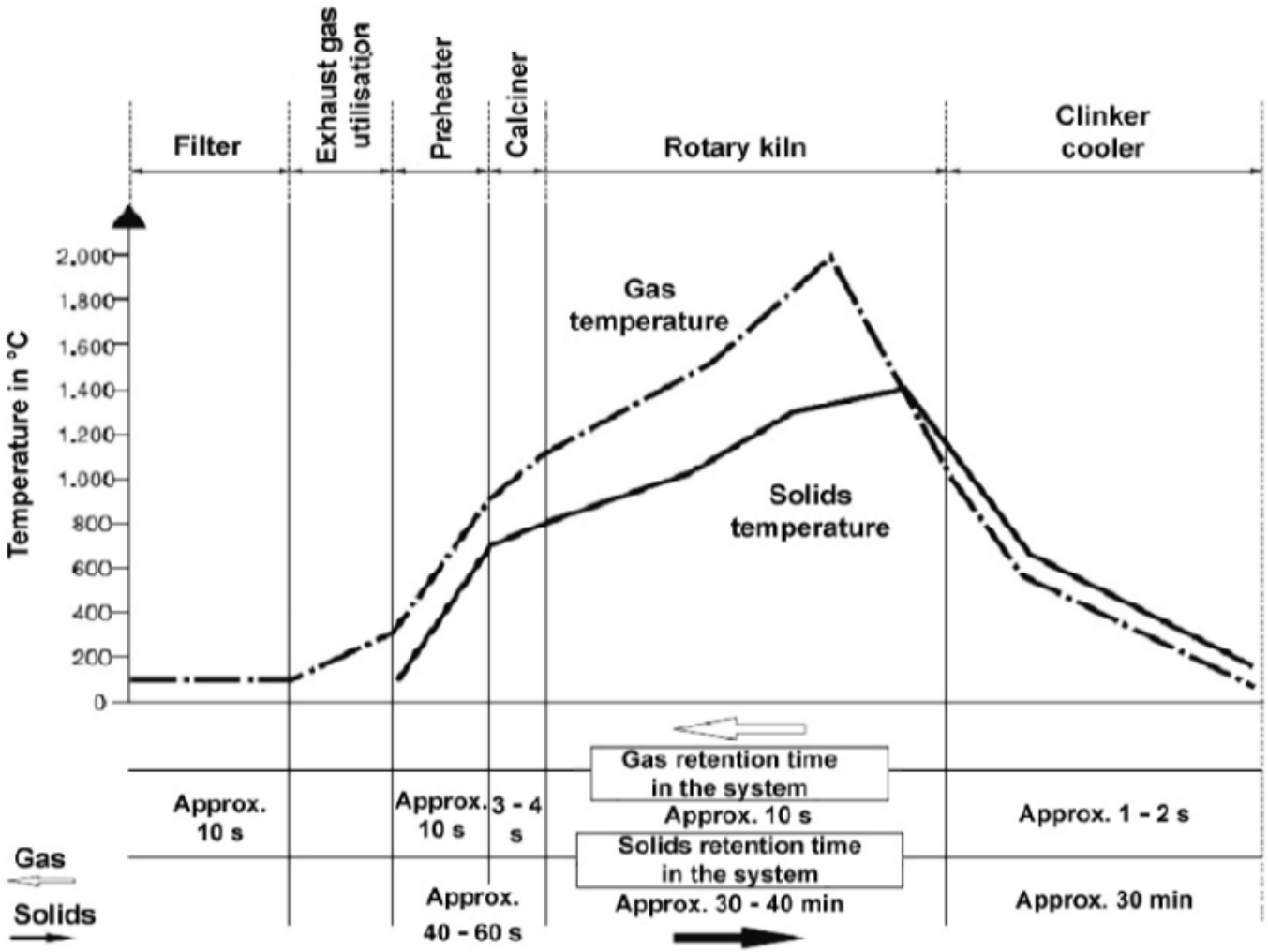
Lime: production concept



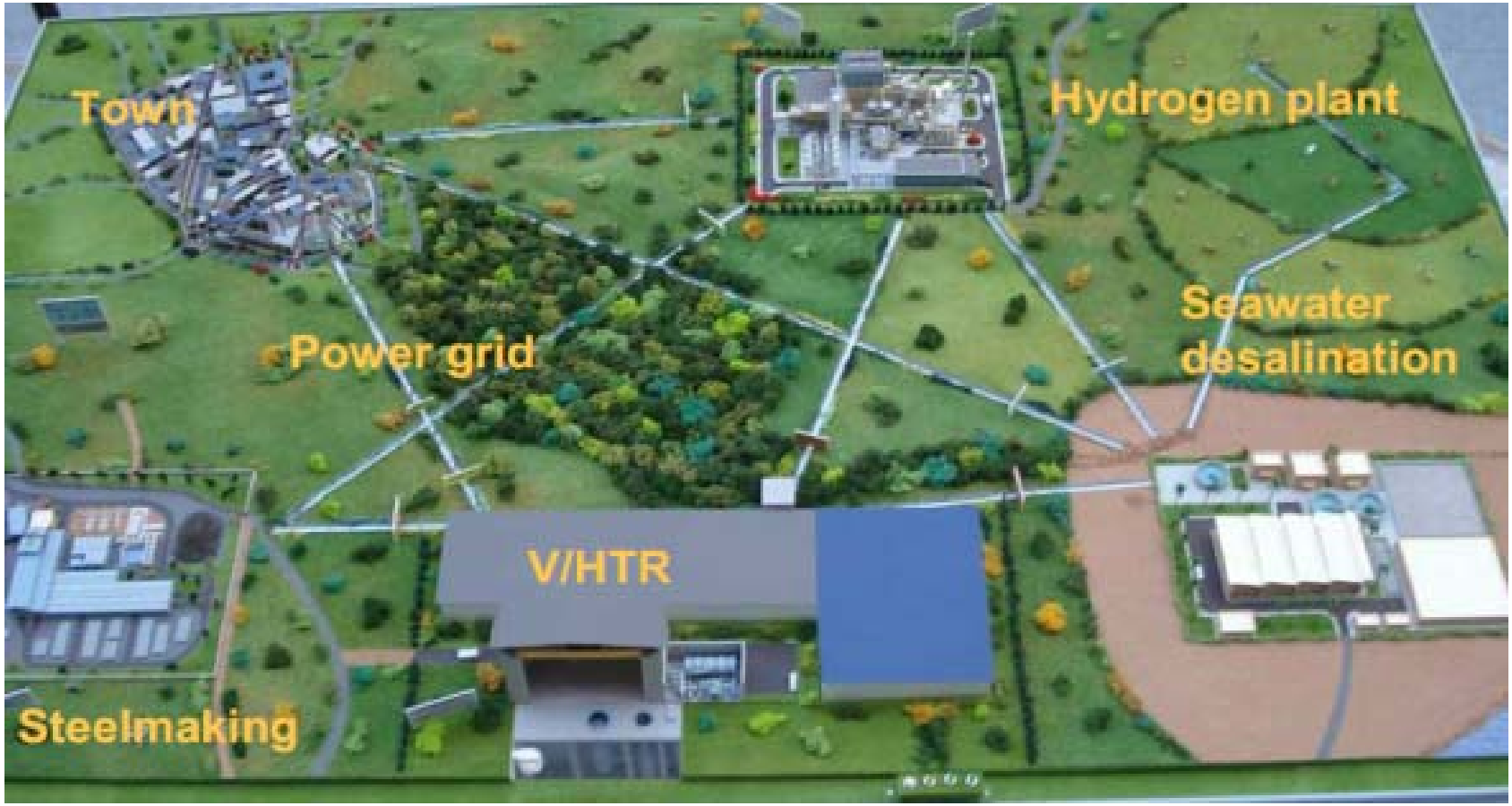
$CaCO_3 \rightarrow CaO + CO_2$ (1 d, >835°C)
$CaO + CO_2 \rightarrow CaCO_3$ (3 w., < 835°C)



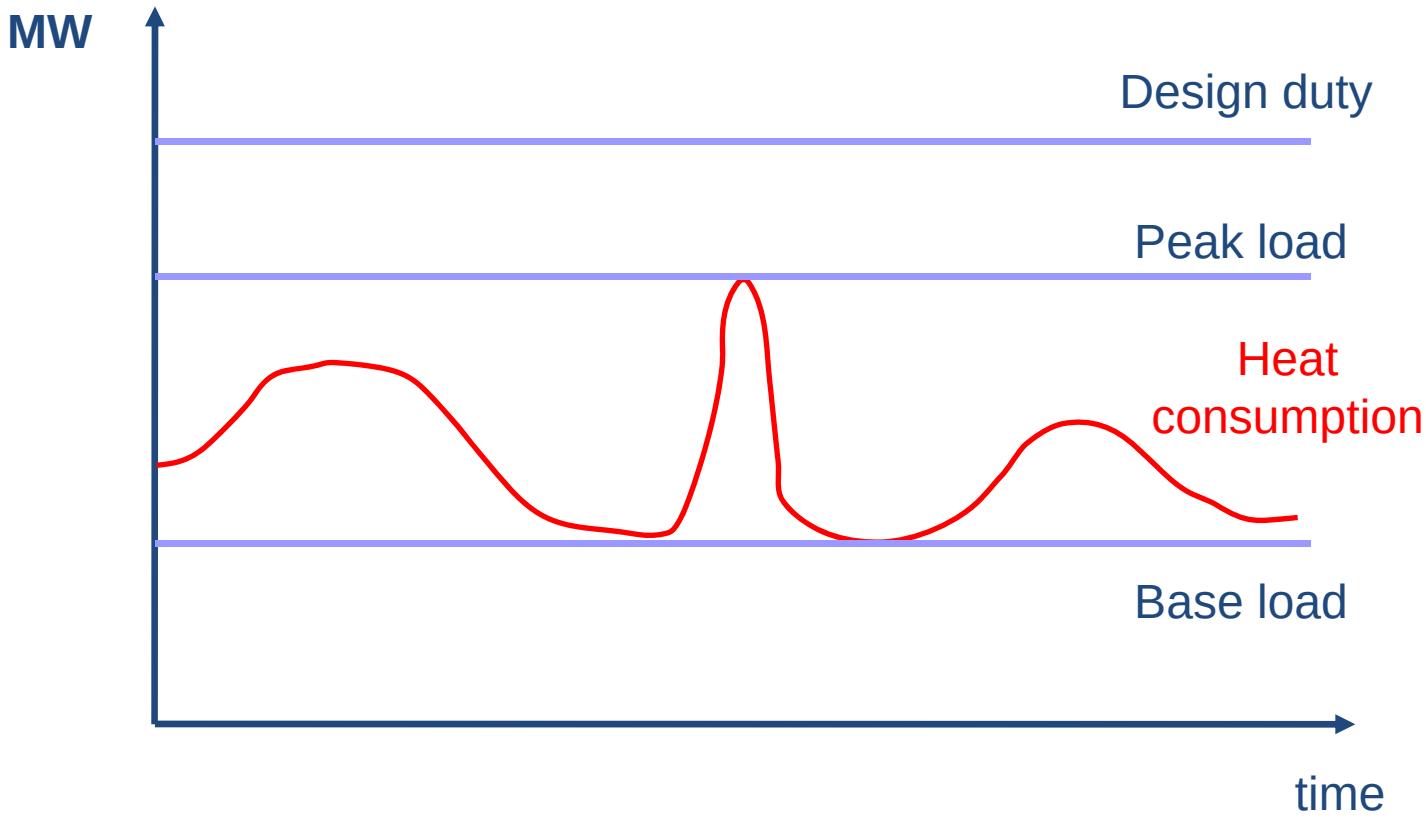
Cement: rotary kiln gas-solid heat propagation



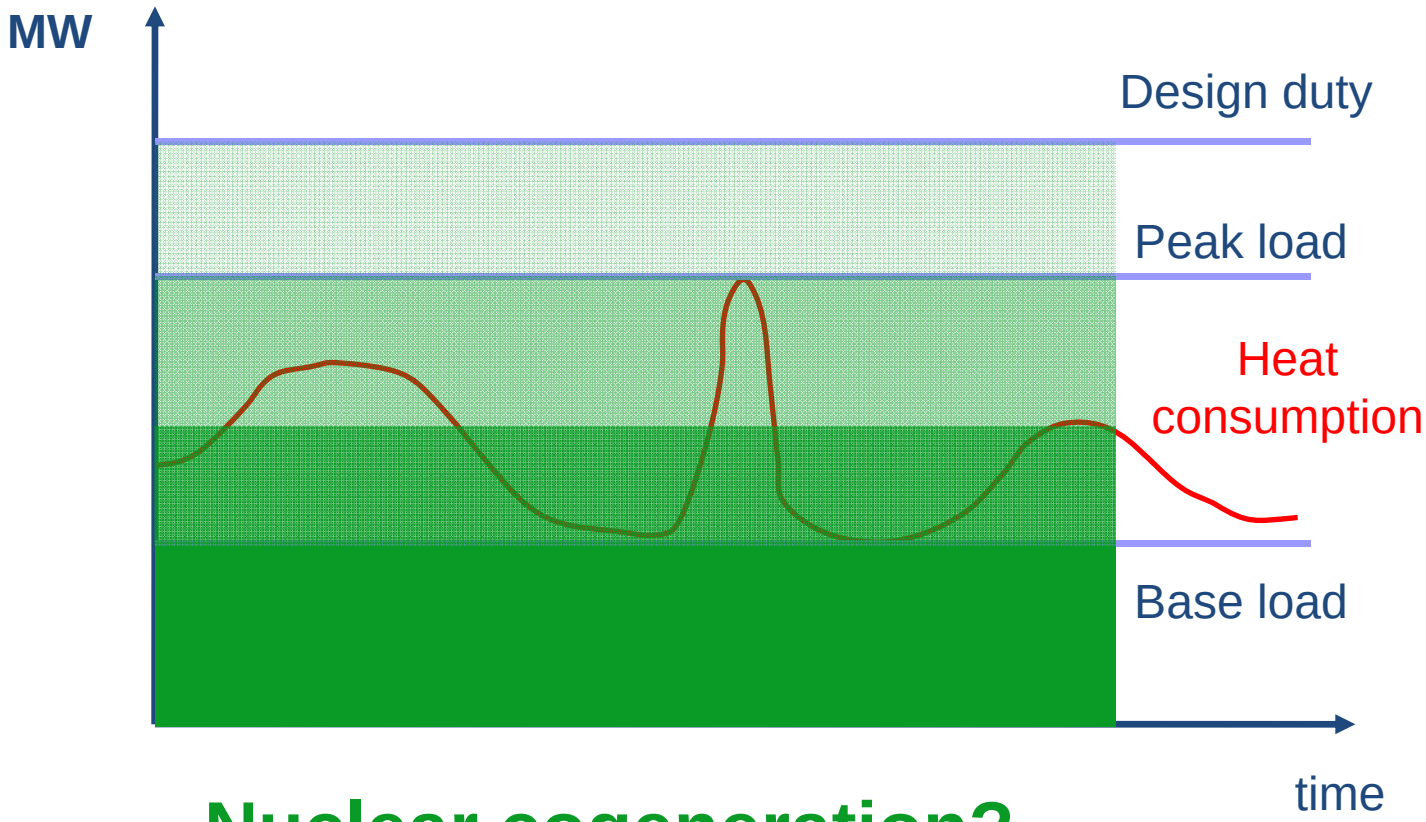
Vision of an industrial ecosystem



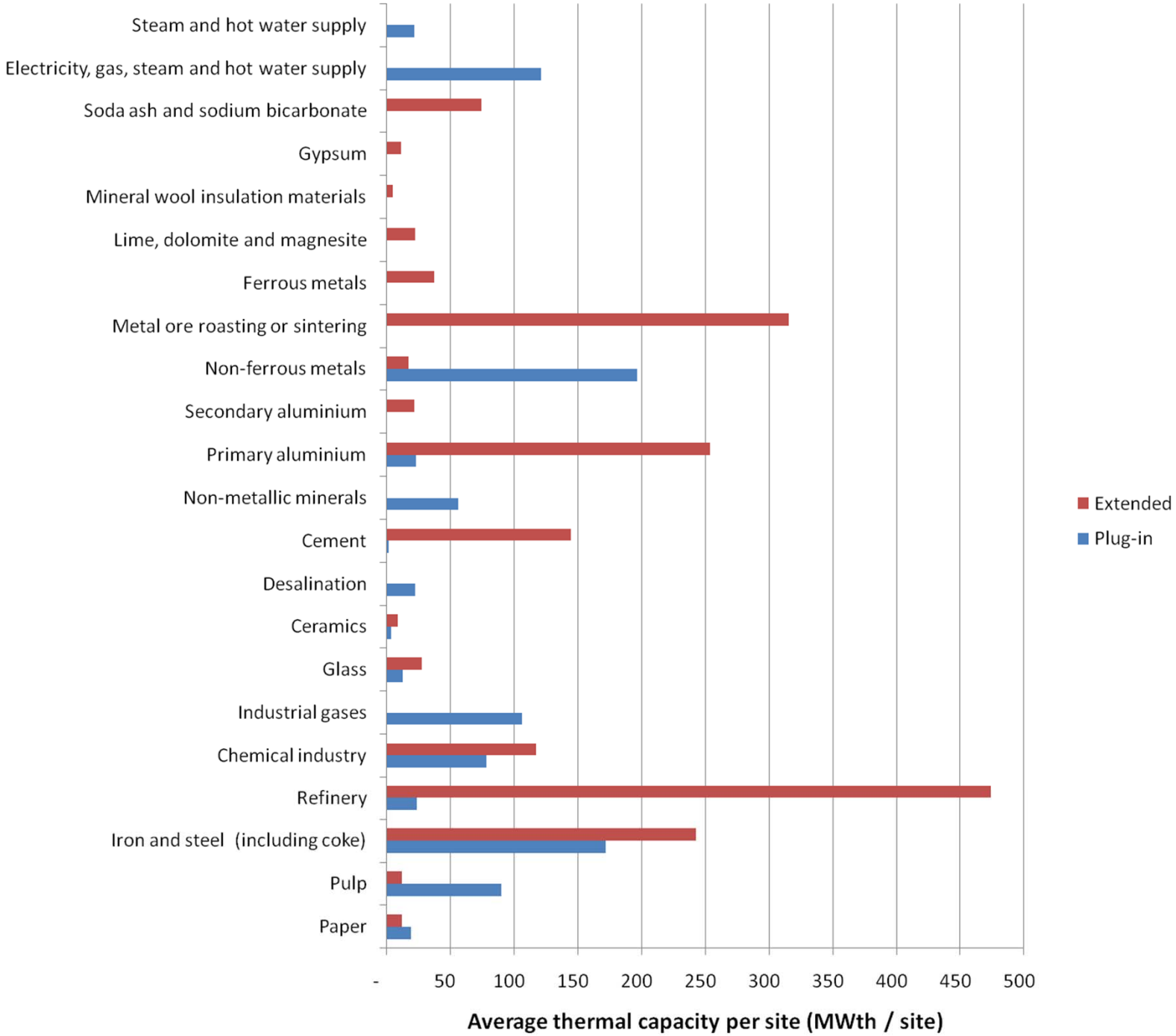
Which thermal power?



Which thermal power?



Nuclear cogeneration?



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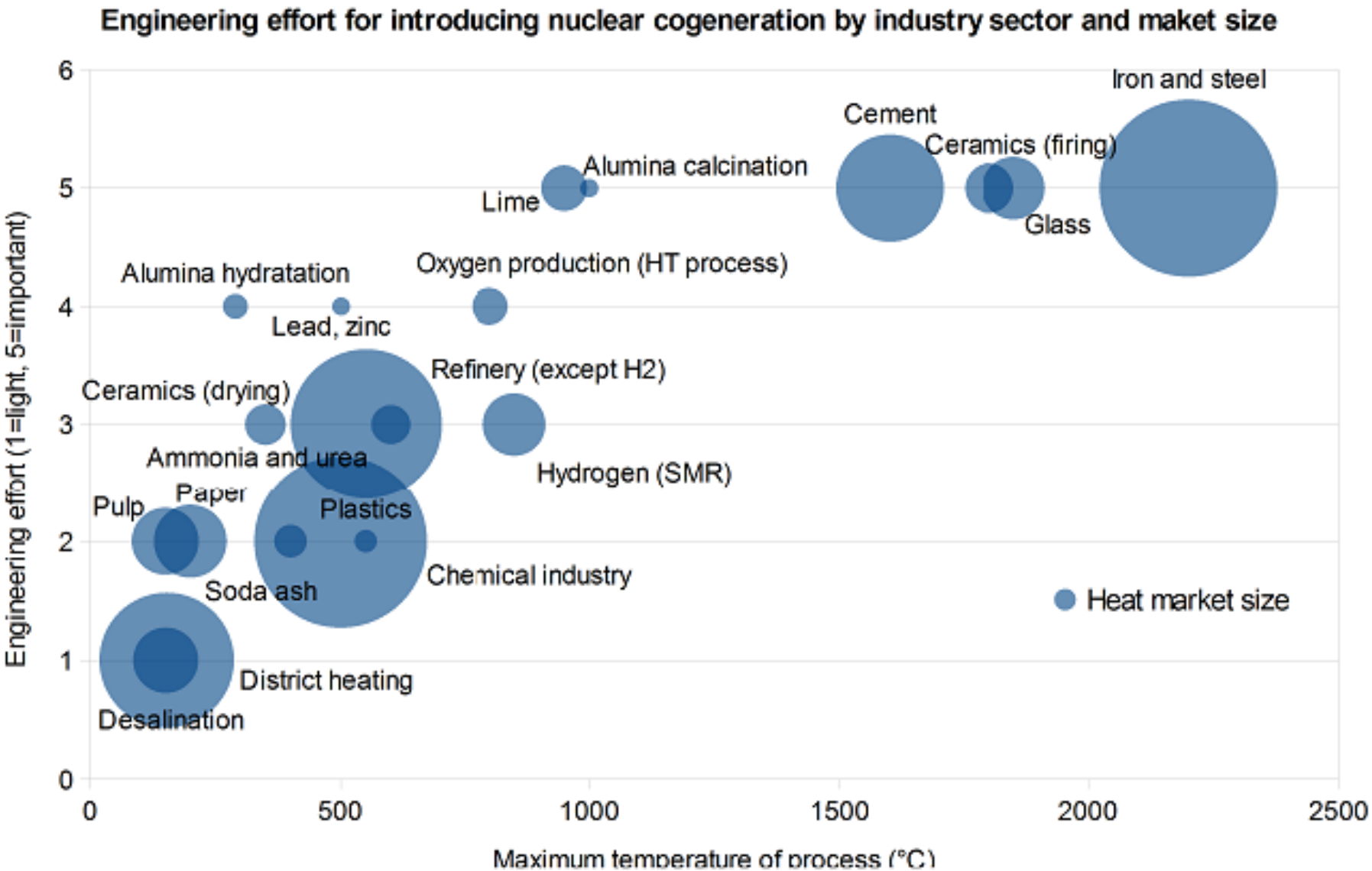
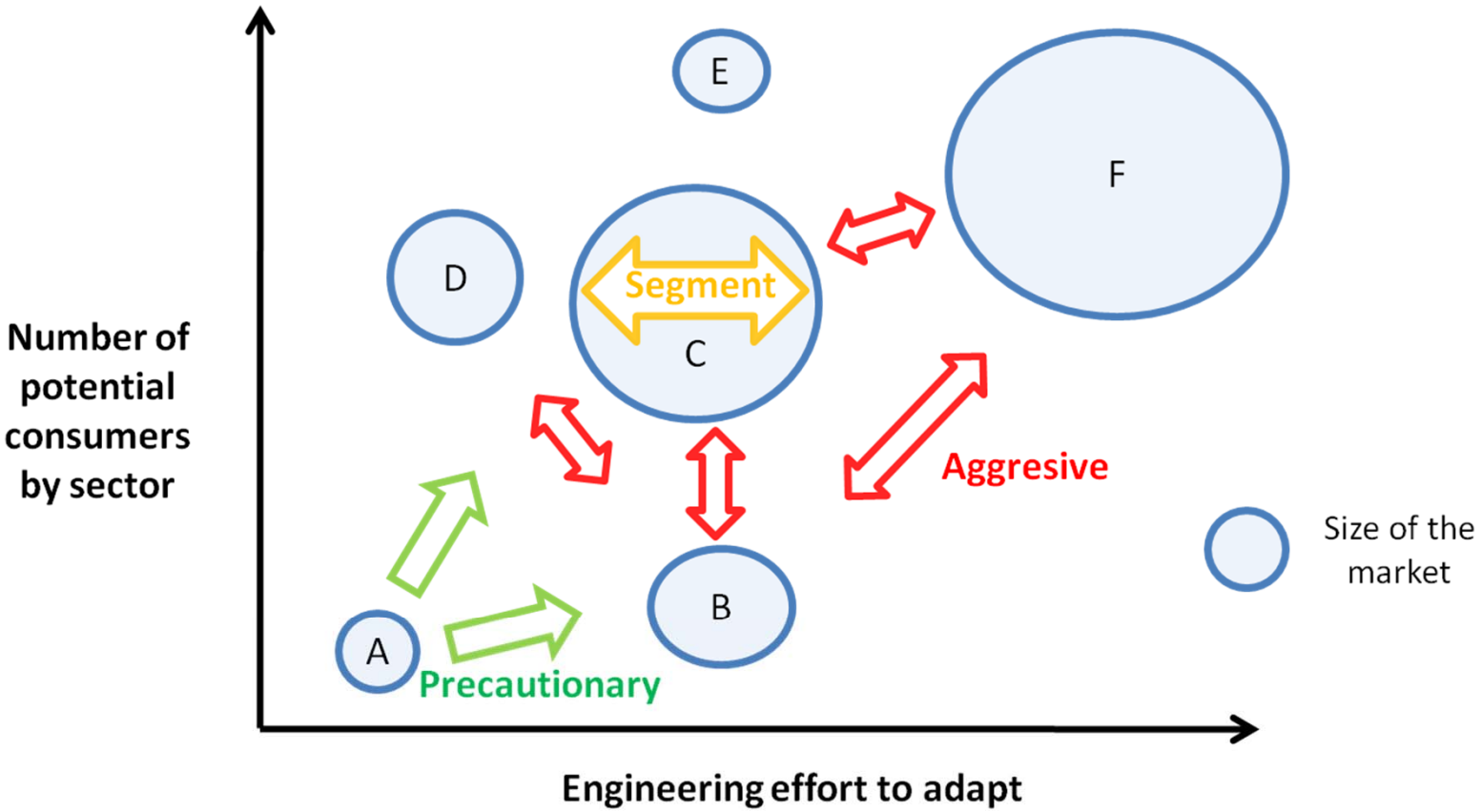

Engineering effort for introducing nuclear cogeneration by industry sector and maket size
Engineering effort (1=light, 5=important)
Maximum temperature of process (°C)
0
1
2
3
4
5
6
0
500
1000
1500
2000
2500
Iron and steel
Cement
Ceramics (firing)
Alumina calcination
Lime
Glass
Alumina hydratation
Oxygen production (HT process)
Lead, zinc
Refinery (except H2)
Ceramics (drying)
Ammonia and urea
Hydrogen (SMR)
Pulp
Paper
Plastics
Chemical industry
Soda ash
Heat market size
District heating
Desalination

Results

(GWh/y)	Plug-in	Poly-generation	Pre-heating	Extended market	TOTAL
Indirect calculation	755 730			1 771 021	**2 526 751**
Direct calculation	783 989	116 636	361 113	1 829 715	**3 091 432**

- The European heat market is large
  - 289 to 353 GWth equivalent to 577 to 706 reactors of 500 MWth
- 30% of the existing heat market is externalised ("plug-in")
  - 87 to 89 GWth equivalent to 173 to 179 reactors of 500 MWth
- Polygeneration and pre-heating are hypothetical additional heat markets which may become significant
  - Around 54 GWth equivalent to 108 reactors of 500 MWth

Strategies for entering the heat market



Recommendations

- Liaise with organisations having an operational experience in nuclear cogeneration (in Europe, Canada, Russia, Japan, Kazakhstan) and with the International Atomic Energy Agency in order to benefit from their experience feedback
- Focus in the short term on the market below 550°C, where the “plug-in” market concentrates
- Limit the reactor thermal capacity (to around 100 MWth) to increase the number of potential customers
- Identify prominent personalities in heat end-users susceptible to adopt nuclear cogeneration and determine a structured market approach (precautionary, segment, aggressive)
- Launch a detailed analysis for each priority segment in order to identify the most relevant sites (size compatibility, flat consumption, long-term industrial visibility, balance of calorific off-gases or by-products, cogeneration plant to be replaced, nuclear acceptance, water availability...)
- Investigate with the main technology providers in each industrial sector the potential of coupling a nuclear reactor with their processes and possibly launch common R&D projects

Recommendations

- Partner with industrial gases producers and research organisations to develop hydrogen and air gases production technologies and the coupling with a nuclear reactor, as polygeneration may offer many advantages in terms of siting, acceptance, coupling, economics, and large-scale heat consumption
- Analyse the regulatory, economic and fiscal contexts for cogeneration and nuclear energy in each Member State in order to identify the most relevant countries for nuclear cogeneration
- Develop the business case of nuclear cogeneration in order to prove the competitiveness of the technology in each priority market segment (against the reference technology)
- Identify early potential adopters, specialised engineering companies and consultancies in each sector and collaborate to develop technically and economically the coupling concepts; relevant professional associations, European Technology Platforms and European R&D projects should also be approached
- Investigate the potential of nuclear pre-heating with a detailed sector analysis, in particular for glassmaking, iron and steel, and lime