Renewable energies for manufacturing industries

IEA Workshop

A path to the electrification

of the world industries

Christophe Crocombette (EDF)

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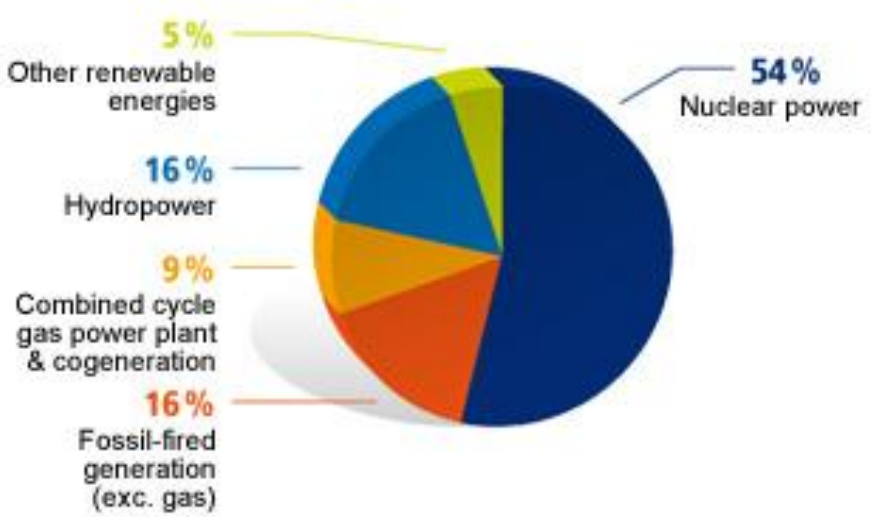
CHANGER L'ÉNERGIE ENSEMBLE

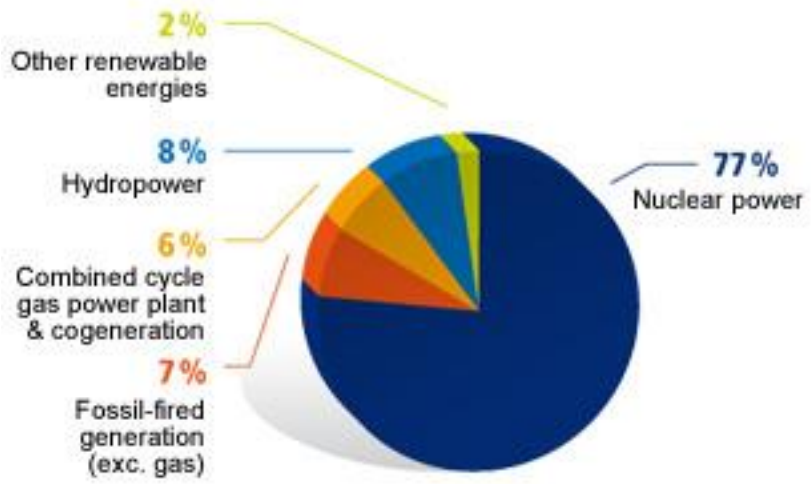
EDF, a leading worldwide energy player

€ 72.9 Bn
SALES 2014

38.5 M
CUSTOMERS

158 161
EMPLOYEES





136.2 GWe
INSTALLED CAPACITY

87 %
CO_2 FREE GENERATION

623.5 TWh
GENERATION

EDF, active in all major electricity businesses

- Inventing the electricity of the future with a low-carbon energy mix and CO_2-free power generation
  - Hydro, nuclear (France, UK, …)
  - Wind, solar (EDF Energies Nouvelles)
  - Biomass (EDF Polska)
- Promoting energy eco-efficiency products and services
  - Design, set up, management, maintenance and optimization of customers' energy facilities (DALKIA, FENICE, …)

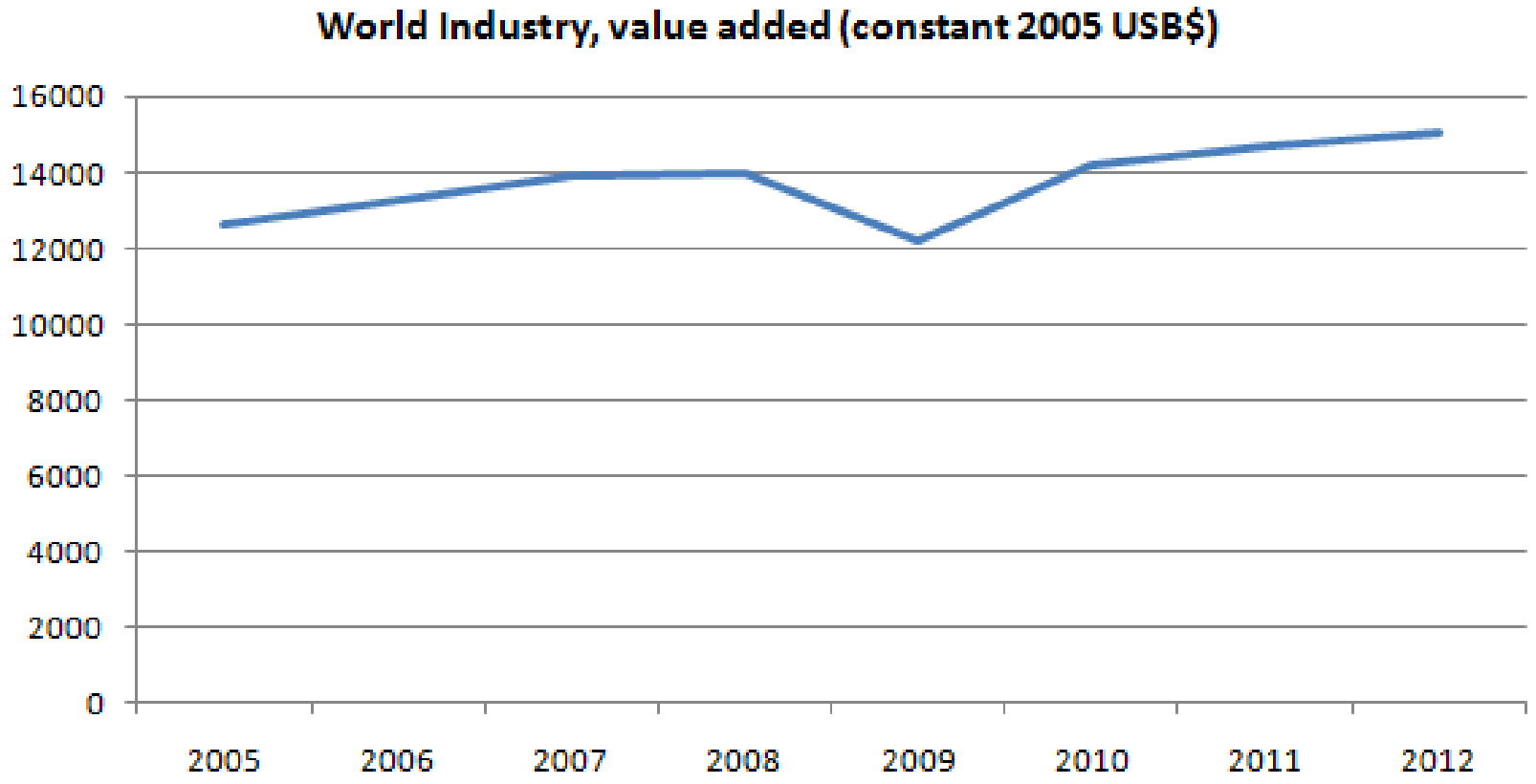
Renewable energies for manufacturing industries : topic at the crossroad of two priorities of the company

Content

- Trends in industry's energy consumption
- Four drivers for massive electrification of industries
- For industrial heating and hydrogen, fuel and feedstock switch to electricity: a technological viewpoint
- A final focus on a disruptive tech to produce green steel
- Conclusion

1. TRENDS IN INDUSTRY'S CONSUMPTION OF ENERGY

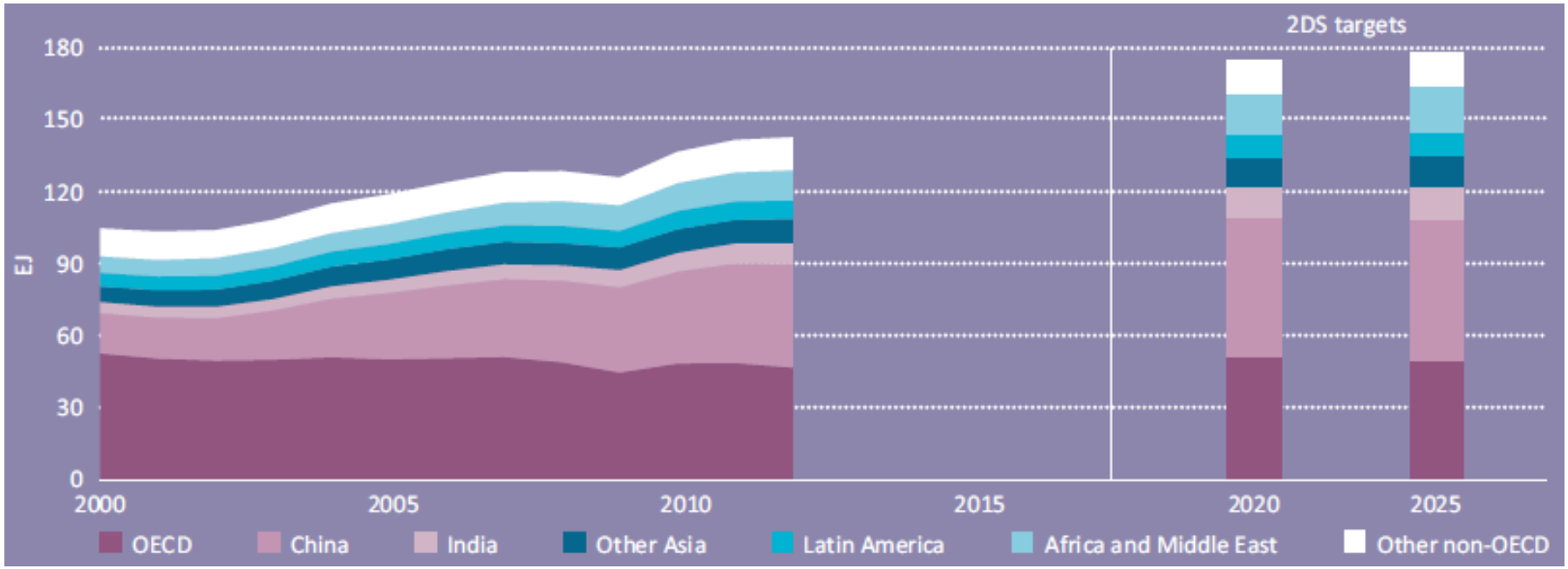
The evolution of industry activity reflects the economic growth of the world…



Source : World Bank (ISIC divisions 10-45)

… and mechanically induces an increase of the total industry sector consumption…

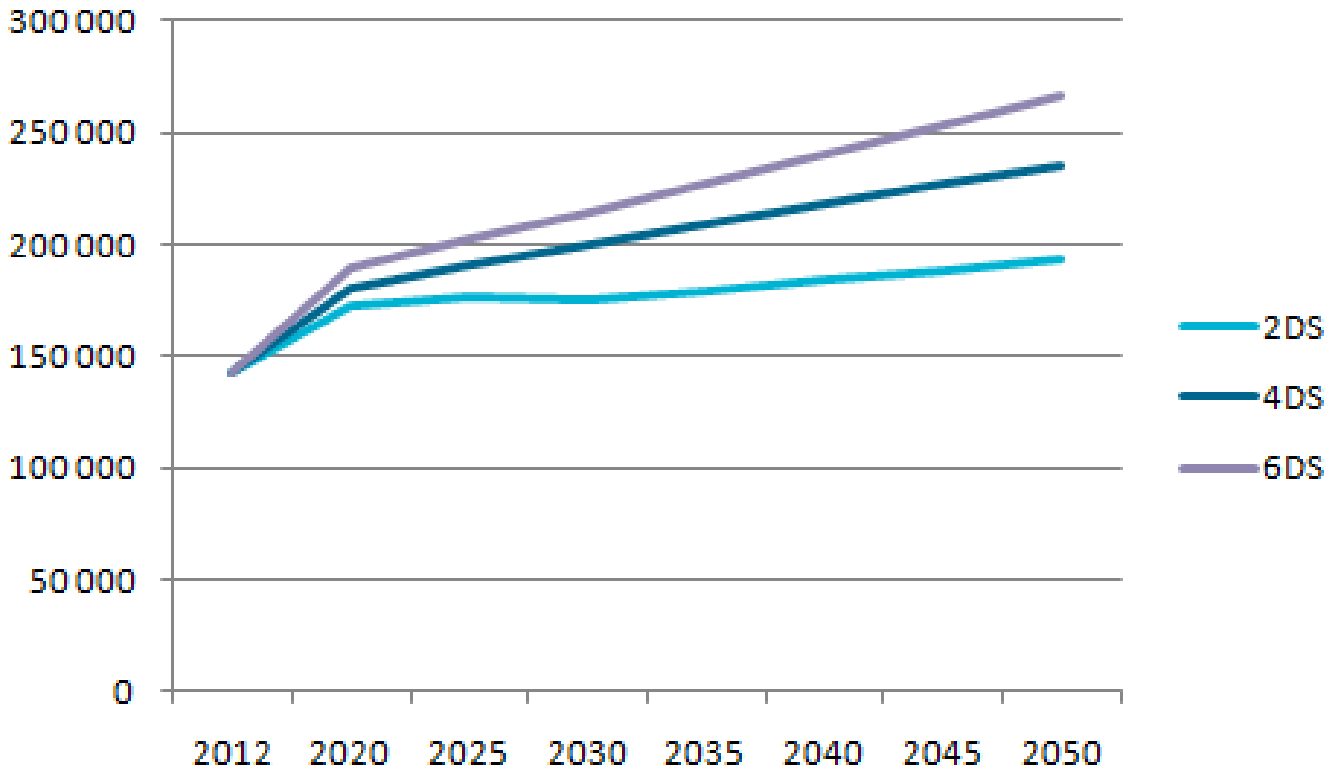
Global industrial energy use, with 2020 and 2025 IEA 2DS scenario targets (EJ)



Source : International Energy Agency (2015), Energy Technology Perspectives 2015, OECD/IEA, Paris

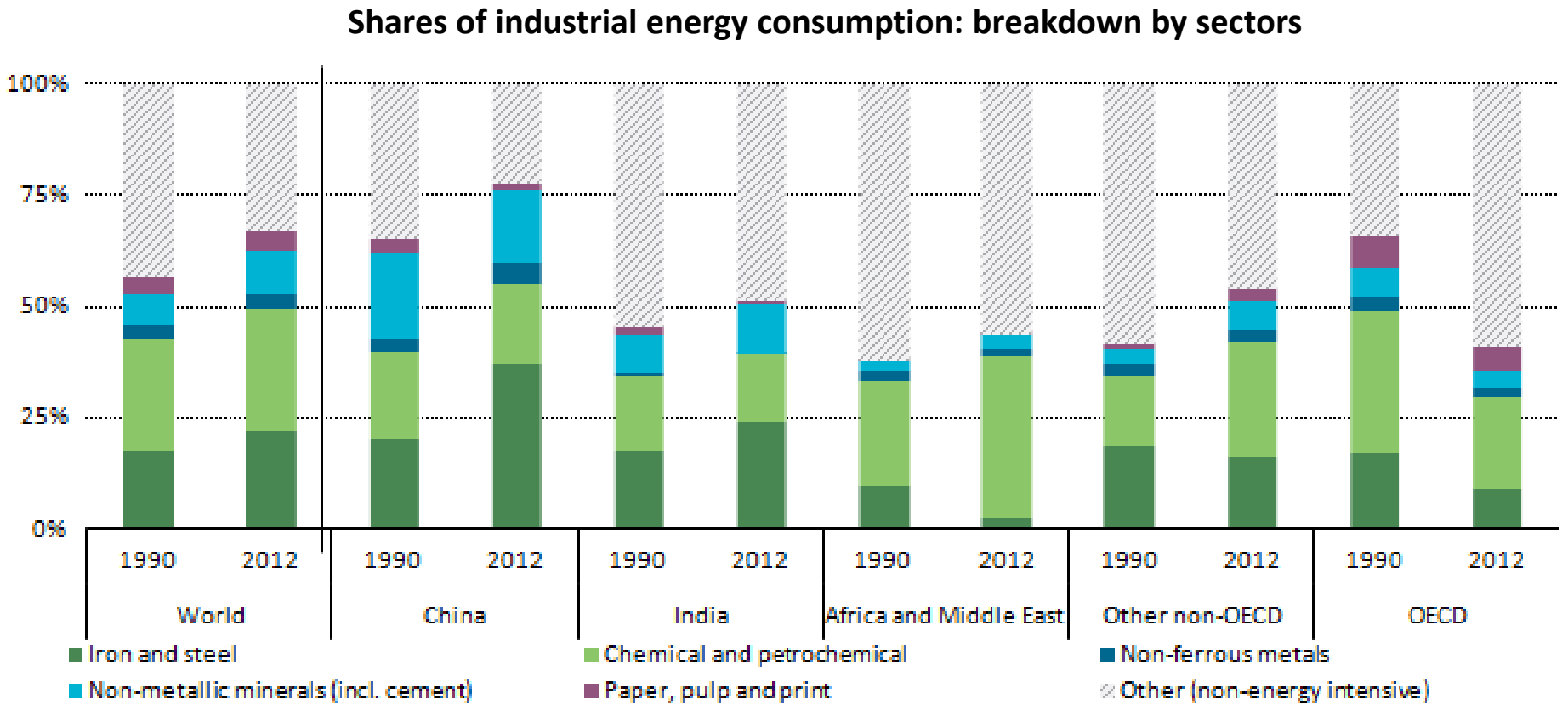
… That shall carry on for several decades

Total consumption of the world industry sector according to IEA scenarios (PJ)



Source : International Energy Agency (2015), Energy Technology Perspectives 2015, OECD/IEA, Paris

Energy-intensive sectors have gained share against non-intensive sectors since 1990 in all regions except OECD countries



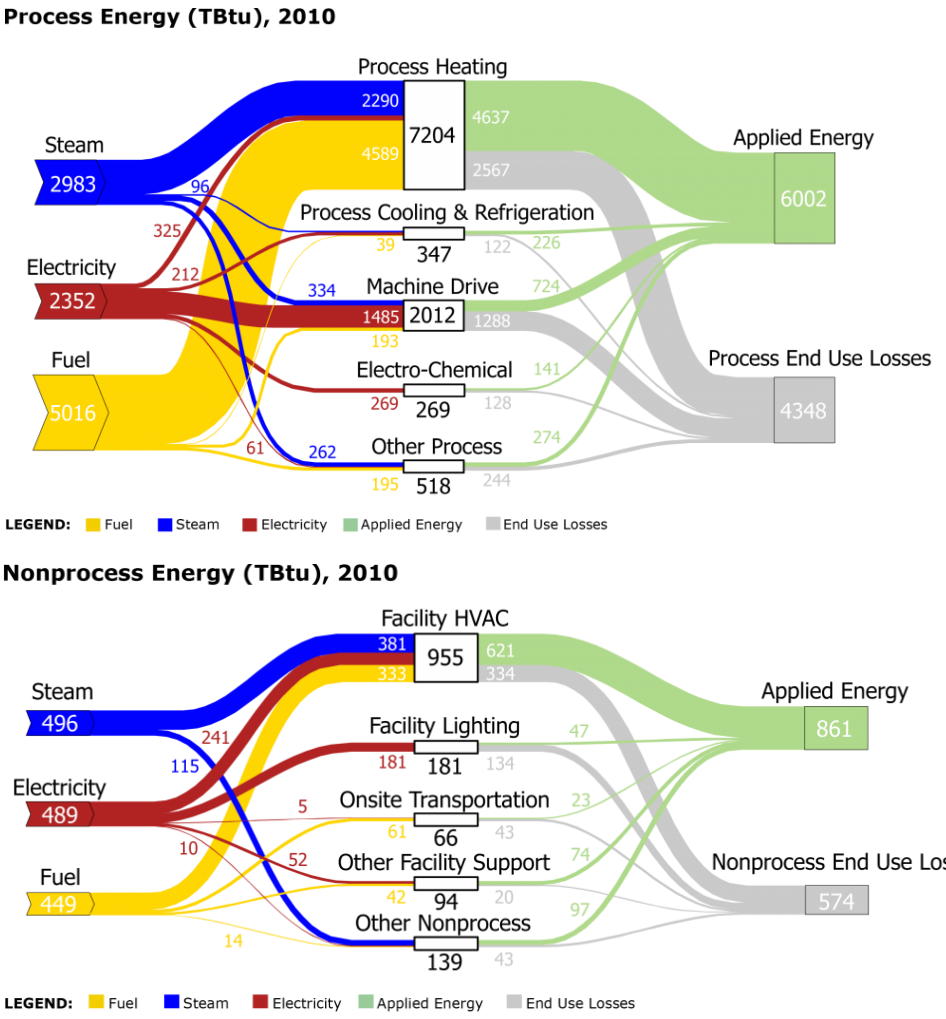
Source : International Energy Agency (2015), Energy Technology Perspectives 2015, OECD/IEA, Paris

Process heating is the big fish (e.g. in the US)

Process Energy = 10 350 TBtu
88 %

Process Heating Energy = 7 204 TBtu
61 %

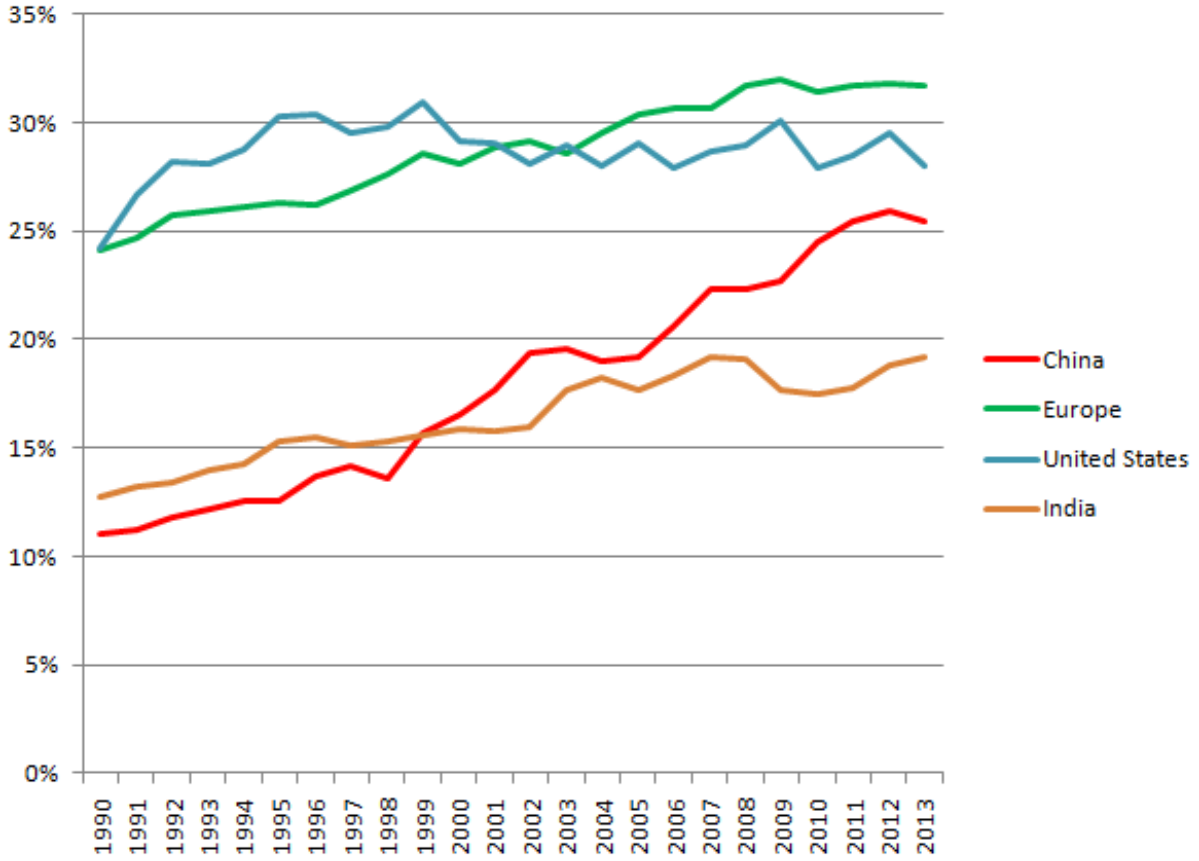
Non Process Energy = 1 434 TBtu
12%



Source : D.O.E., Office of Energy Efficiency & Renewable Energy (from MECS 2010)

Electricity share is expected to rise while new industrial powers undergo fast electrification of their production sites

Share of electricity in the total industrial energy consumption
Evolution for China, Europe, US and India between 1990 and 2013



Source : ENERDATA

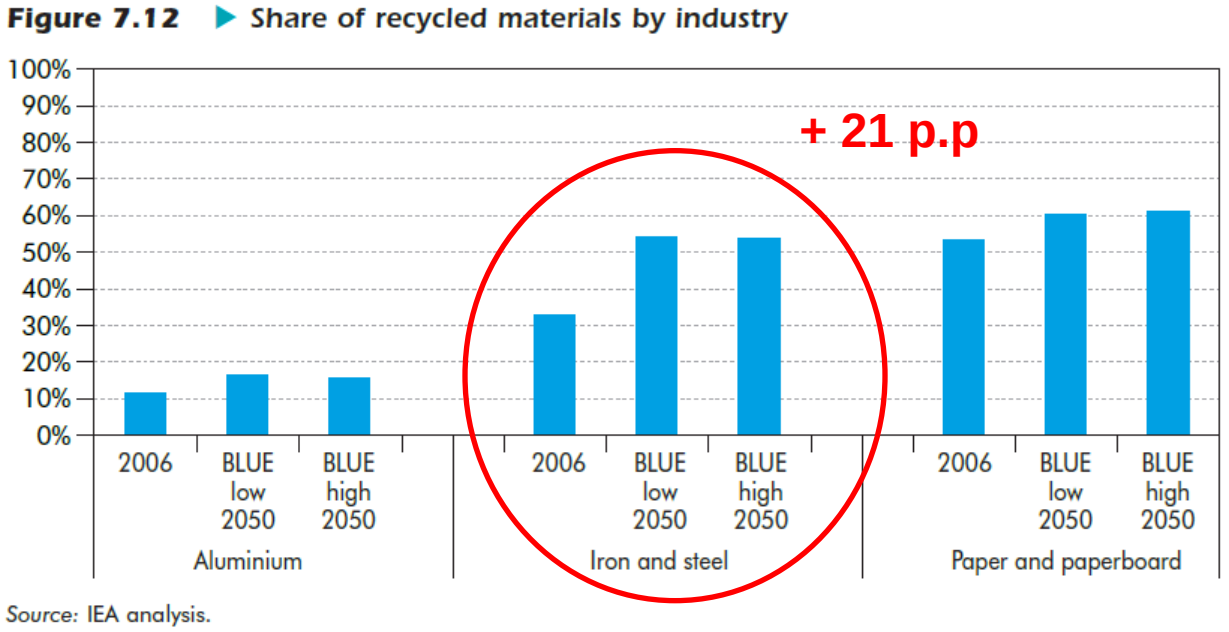
2. FOUR DRIVERS FOR MASSIVE ELECTRIFICATION OF INDUSTRIES

First Driver: environmental issues

- The use of electricity allow to reduce pollutants emissions at the local level (cities, valleys …)
- The use of electricity as a substitute of fossil fuels allows industrials to shift their direct CO_2 emissions to the electricity sector
- A high carbon price should be a booster to adopt electrotechnologies connected to decarbonised electricity (renewables & nuclear)
- Relative prices of electricity with other fossil energy sources remain crucial parameters

Second Driver: ferrous metal recycling

- Recycling will reduce energy intensity, but the shift from primary steel (Blast Furnace) to secondary steel (Electric Arc Furnace) may have a huge effect on electricity demand
- The primary source of obsolete steel is vehicles which have relatively short life spans: increased demand for vehicules in developing countries should lead to a dramatic rise in the amount of scrap in the next years



Source : Energy Energy Transitions for Industry (IEA, 2009)

Third Driver: advanced manufacturing

- Smart sensors to better monitor the process lines (e.g. in chemicals sector)
- Further automation, IT systems
- Advanced robotics & cobotics (robots working alongside people)

Fourth Driver: additive manufacturing

- 3-D printing saves energy by eliminating production steps, using substantially less material, enabling reuse of by-products, and producing lighter products
- Now, this technology is particularly advantageous in low-to-moderate volume markets: defense, aerospace, …
- In the future, automotive, healthcare, food industries, etc. might be revolutioned by these additive techniques
- Electricity is the energy of choice for additive manufacturing

3. FOR INDUSTRIAL HEATING AND HYDROGEN, FUEL AND FEEDSTOCK SWITCH TO ELECTRICITY:

A TECHNOLOGICAL VIEWPOINT

Among realistic fuel switch options, switching to decarbonised electricity is the most climate friendly

- Switching to less carbon intensive fuels such as replacing coal with natural gas
- Co- firing with,or switching to waste and biomass
- 3.1 Switching to decarbonised electricity
- *3.2 Switching to hydrogen (provided the hydrogen is produced via a low CO_2 process, for example using decarbonised electricity to electrolyse water)*

3.1 Electrotechnologies offer a wide range of heating techniques…

Focuses

Resistance and infrared heating	Production micro electronic switching circuit	**High Frequency heating**	Welding of plastic
	Electrolytic smelting		Several applications in food industry (drying, tempering, pasteurisation)
	Electroslag remelting		Several applications in textile industry (drying, preheating, tissue treatment, fixation of dyes)
	Graphitising of green carbon		Drying applications in paper and cardboard industry
	Electric glass melting	**Microwave heating**	Several applications in food industry (drying, pasteurisation, sterilisation, vacuum dehydration)
	Electrode boiler		Several applications in rubber industry (preheating before extrusion, rubber vulcanisation, resin polymerisation)
	Heating of food		Several applications in chemical industry (vacuum drying, sterilisation, microwave assisted chemical reactions)
Induction heating	Melting of metals		Sintering of ceramics
	Electric glass melting	**Arc furnaces**	Steel recycling
	Welding	**Heat pumps**	Vapour mechanical compression for heating and drying
	Brasing		
	Surface treatment		

Source : Electrification of heating and cooling (EURELECTRIC, 2011)

… Covering all manufacturing sectors and potentially all needs

- **Electron beam**: leather products, textile/clothing, steel, fabricated metal products, transportation equipment, aerospace, chemicals, electronics, defense equipement
- **Microwave**: food products, paper/wood products, pharmaceuticals, textiles,chemicals, rubber and plastics, leather, textiles, construction materials
- **Plasma:** primary metals, metal casting, fabricated steel products, electronics, chemicals, miscellaneous manufacturing
- **Radio-Frequency:** food processing, textiles, clothing, wood products, furniture, paper products, printing, rubber and plastics, chemicals, glass, fabricated metal products, machinery, electronics, transportation equipment, instrumentation, miscellaneous manufacturing
- **Indirect Resistance:** food processing, textiles, furniture, printing, chemicals, rubber and plastics, leather products, stone, glass and mineral products, steel, metal casting aluminum, fabricated metal products, machinery, electronic equipment, transportation equipment, instrumentation, miscellaneous manufacturing
- **Industrial Process Heat Pumps: food processing, tobacco products, textiles, wood** products, furniture, paper, chemicals, petroleum, rubber and plastics, electronic equipment

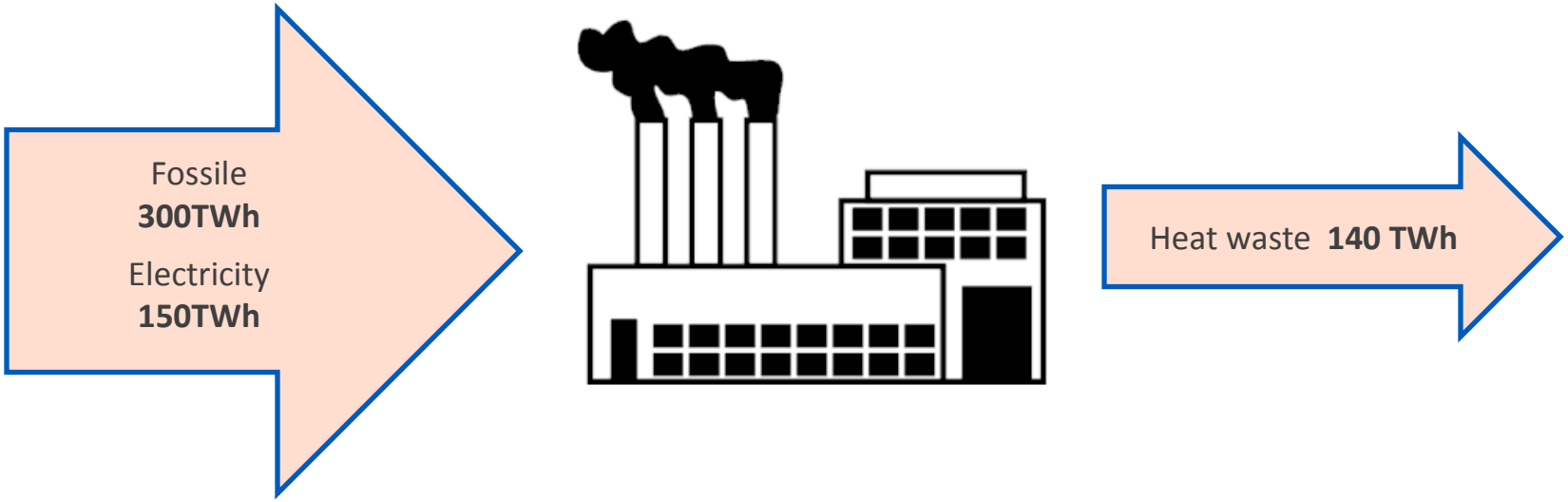
Focus 1: heat pumps, best technology to switch to electricity and to recover low temperature heat

- Commercially available technology: output temperature up to 100°C
- Current research to reach 140°C

Reference: IEA HPP / IETS Annex 35/13 « Application of Industrial Heat Pumps » workshop paper

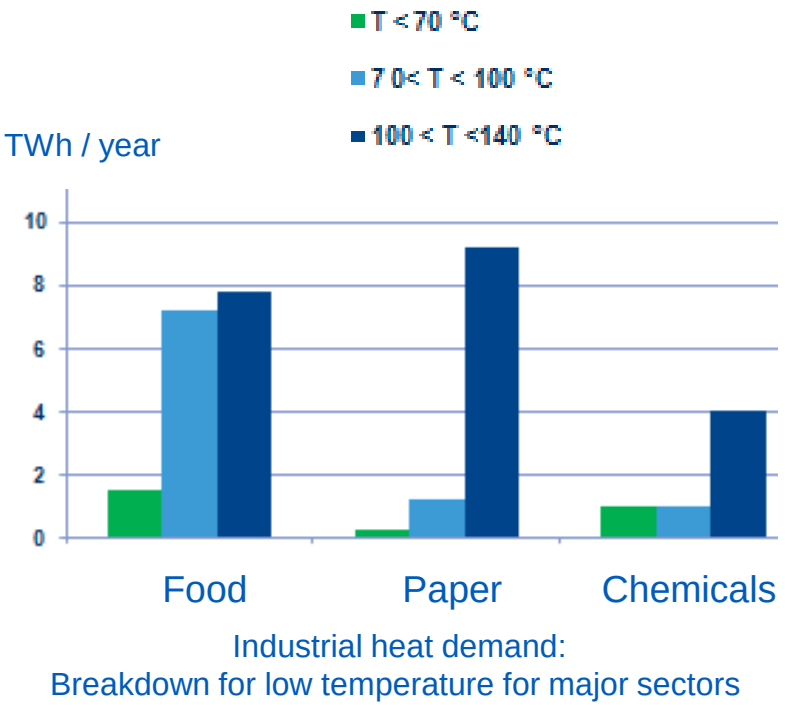
French Industrial Heat Pump Developments Applied To Heat Recovery, May 2014

Low temperature heat recovery has a big potential, e.g. in France

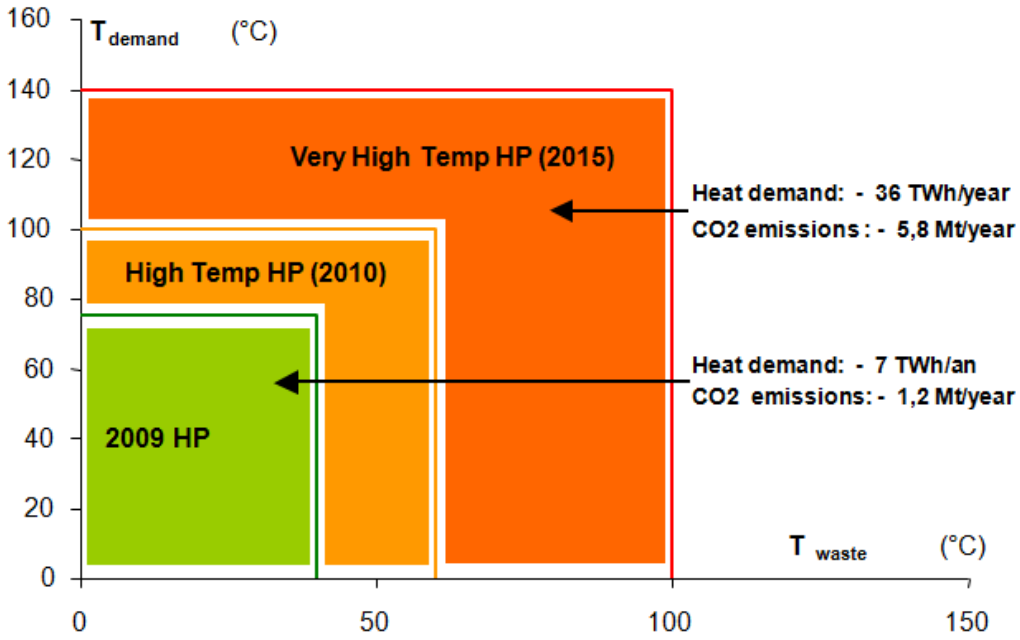


Yearly flux

Technical potential of heat pumps is double when reaching an output temperature of 140°C instead of 100°C



Industrial heat demand:
Breakdown for low temperature for major sectors

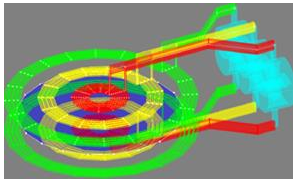


Source : EDF R&D analyses

Focus 2: induction heating and melting, a premium solution for high tech industries

- Originally used for steel and metal production, it's now in development in many other sectors (food, paper, chemicals, …)
  - Fast, precise, clean, easy to control

- Relevant new applications in the last decade:
  - Metallic strip heating, heating before forging
  - Local heat treatments, etc.
- Numerous R&D efforts (e.g. new configurations of coil conductors to reduce Joule losses)



- Barriers
  - Risk in changing to new process, lost production time in upgrading
  - Capital cost, benefits are insufficiently understood

Focus 3: microwave, rather a niche technology but offering peculiar properties well suited for specific needs

- Common applications are heating and drying of food, rubber vulcanization, welding of plastics, and drying textiles
  - Heating products from inside maintaining their flavors without degradation, with good organoleptics properties
- Advantages: rapid and selective heat transfer, energy efficient, speed of switching on and off, compactness of equipment…

Photo Credit : SAIREM

3.2 Electrolytic hydrogen production: a disruptive electrotechnology to save fossil feedstocks

Disruptive

- Nowadays, water electrolysis contributes only a low fraction of the world global hydrogen production (< 5%), the rest being produced from fossil fuels by steam reforming or partial oxidation of methane and coal gasification

- Intense research is conducted on that technique wich has many advantages:
  - It gives no carbon emission (no dependence to hydrocarbon sources)
  - It produces very pure H_2
  - It can be operated in small scale plants

4. A FINAL FOCUS ON A DISRUPTIVE TECH TO PRODUCE GREEN STEEL

Electrolysis may one day provide green iron…

Disruptive

Technology	Expected potentials for direct CO_2 mitigation effects	Soonest expectations (from a purely technical perspective)
Top Gas Recycling Blast Furnace (ULCOS-BF)	15% without CCS 60% with CCS	Laboratory: done Pilot: done Demonstrator: tbc Deployment: > 2020 onwards
Bath smelting (Hlsarna)	20% without CCS 80 % with CCS	Laboratory: done Pilot: 2011-2013 Demonstrator: 2020 Deployment: > 2030
Direct reduction (ULCORED)	5% without CCS 80% with CCS	Laboratory: done Pilot: 2013 Demonstrator: 2020 Deployment: > 2030
Electrolysis (ULCOWIN)	30% with today's electricity generation mix 98% with CO_2 free electricity generation	Laboratory: ongoing Pilot: 2020 Demonstrator: 2030 Deployment: > 2040

Source: EUROFER steel roadmap for a low carbon Europe 2050

Electrowinning cell demonstrator (ULCOwin, 2011)

ulcos

5. CONCLUSION

Key findings

- Electrotechnologies and decarbonised electricity are key solutions for industry decarbonisation
- R&D efforts are intense and need to be continually supported
- Environmental reglementation and energy prices will be crucial regarding the pace of industry electrification in the world
- Heat recovery is a major concern and heat pumps should play a big role
- Energy players will have a central role in the optimisation of energy consumptions of their industrial customers

Thank you for your attention