SCOoPE Webinar – CHAPTER 5

Thermal Energy Efficiency in Industry

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Thermal Energy Efficiency in Industry Chapter 5

Saving Cooperative Energy

UNITÀ TECNICA EFFICIENZA ENERGETICA

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1. What is energy?

“It is important to realize that in physics today, we have no knowledge what energy is.”

R. Feynman

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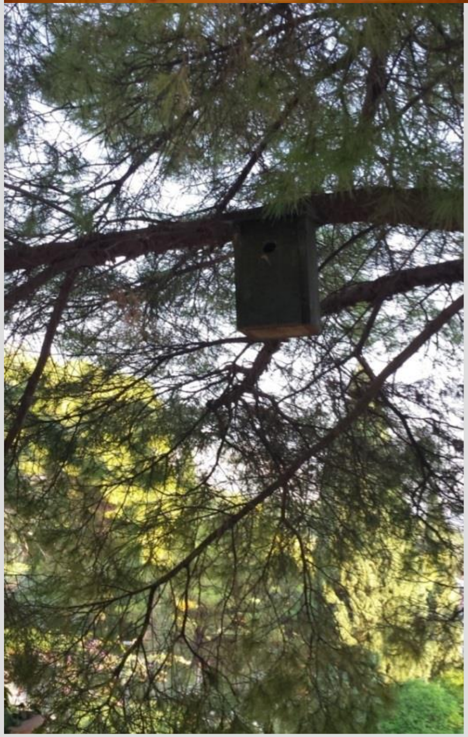
Saving Cooperative Energy

Energy is defined as the ability or the capacity for doing work.



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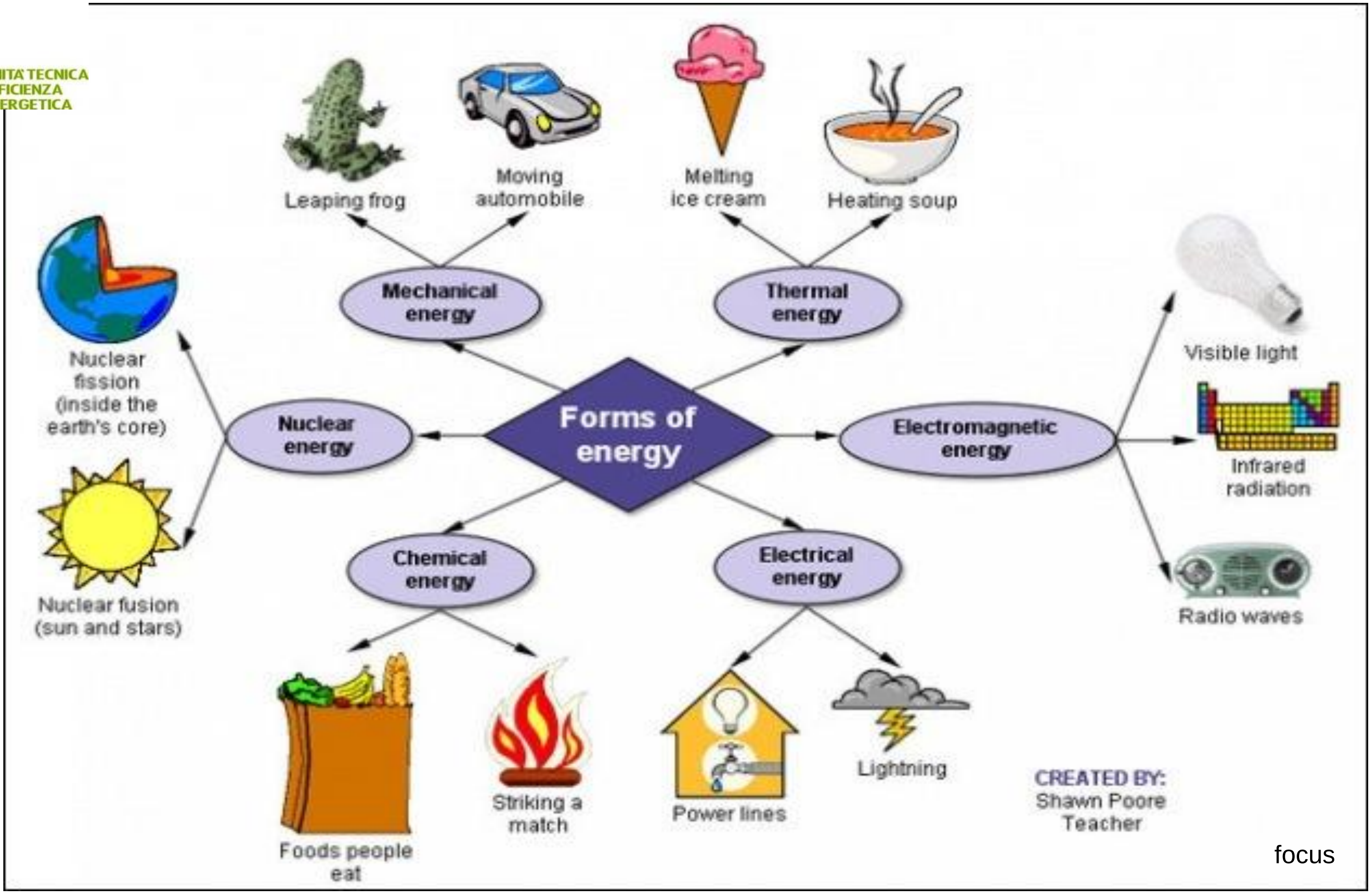
2. Forms of energy



focus

"Energy cannot be created or destroyed, it only can be transformed from one form into another."

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2.1 Thermal Energy

ENERGY and HEAT

Heat is one of the most important forms of energy: first of all, maintaining a precise body temperature is of vital importance to us. From the point of view of technology, heat is involved in many energy transformations.

Heat is a form of energy
(first principle of thermodynamics):
Thermal Energy

Thermal energy is connected to random oscillations of atoms and molecules, whose macroscopic manifestation is **temperature**
For a body of mass "M" the transfer (loss or gain) of the amount "Q" of T.E. causes a temperature variation

$$Q = M\,c\,\Delta T$$

Specific heat "c" is a property of the substance that constitutes the body

Thermal Energy cannot be entirely converted into mechanical energy (second principle of thermodynamics): any **heat engine** that transforms *heat into work* has an **efficiency** less than 1.

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2.2 Measures of energy

- **Energy** (***electrical, thermal and mechanical***) **is measured in joules (J).**
- **Thermal energy is also measured in calories: 1 cal = 4.184 J.**
- **Power is the rate at which we do work.**
- **It is measured in watts (W): 1 W = 1 J per second.**

  Other units of power include
- **BTU per hour (BTUs/h) ≈ 0,3 W**
- **Horsepower (hp) = 746 W**
- **Calories per second (cal/sec)**
- **kilowatt (kW) = 1000 watts**

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General Energy Conversion Factors

TO	TJ	Gcal	Mtoe	MBtu	GWh
FROM	Multiply by				
Terajoule (TJ)	1	2.388×10^{2}	2.388×10^{5}	9.478×10^{2}	2.778×10^{-1}
Gigacalories (Gcal)	4.187×10^{-3}	1	1.000×10^{-7}	3.968	1.163×10^{-3}
Million tonnes of oil equivalent (Mtoe)	4.187×10^{4}	1.000×10^{-7}	1	3.968×10^{7}	1.163×10^{-4}
Million British Thermal Units (MBtu)	1.055×10^{-3}	2.520×10^{-1}	2.520×10^{-8}	1	2.931×10^{-4}
gigawatt hour (GWh)	3.600	8.598×10^{2}	8.598×10^{-5}	3.412×10^{3}	1

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3. Sources of energy

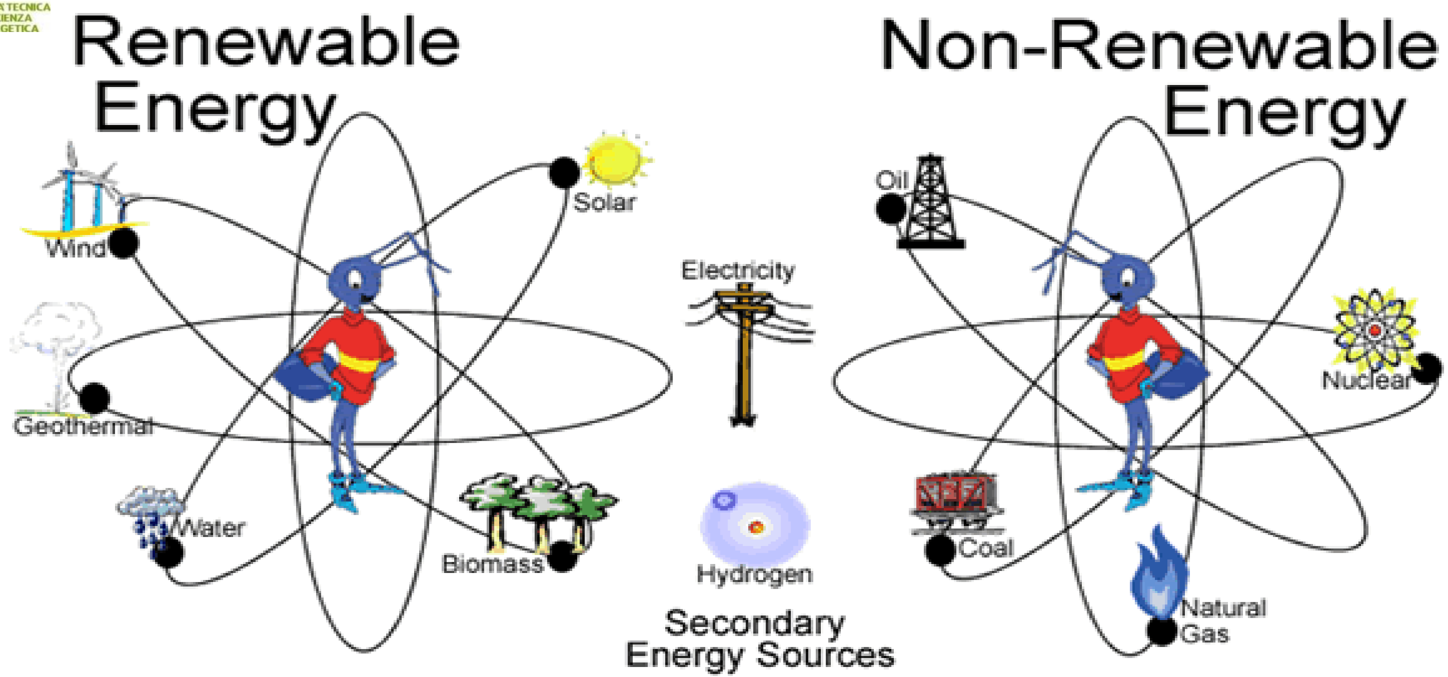

Image: http://greenplanetethics.com

Non renewable energy: *Energy sources that we are using up and cannot produce in a short period of time.*

Renewable energy: *Energy sources that replenish on a time scale compatible with our needs.*

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Advantages of renewable energy use

- **Less dependence on fossil fuels.**
- ***"The Coal will be able to meet demand for 100 years, while oil will start to be insufficient already in 40 years"* (International Energy Agency).**
- **Less greenhouse gas emissions.**

Climate and energy package 20 20 20

Cutting:

- **20% of greenhouse gas emissions (compared to 1990 levels)**
- **20% of the energy needs derived from renewable sources**
- **20% improvement in energy efficiency.**

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4. ENERGY EFFICIENCY

- Energy efficiency is key to ensuring a safe, reliable, affordable and sustainable energy system for the future. It is the one energy resource that every country possesses in abundance and is the quickest and least costly way of addressing energy security, environmental and economic challenges

- (IEA, 2016)

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Major factors that drive energy efficiency are:
population growth, uneven distribution of energy resources, climate changes.

We can summarize in the "energy trilemma":
energy security, energy equity, environmental sustanaibility at worlwide level.

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Multiple benefits of energy efficiency

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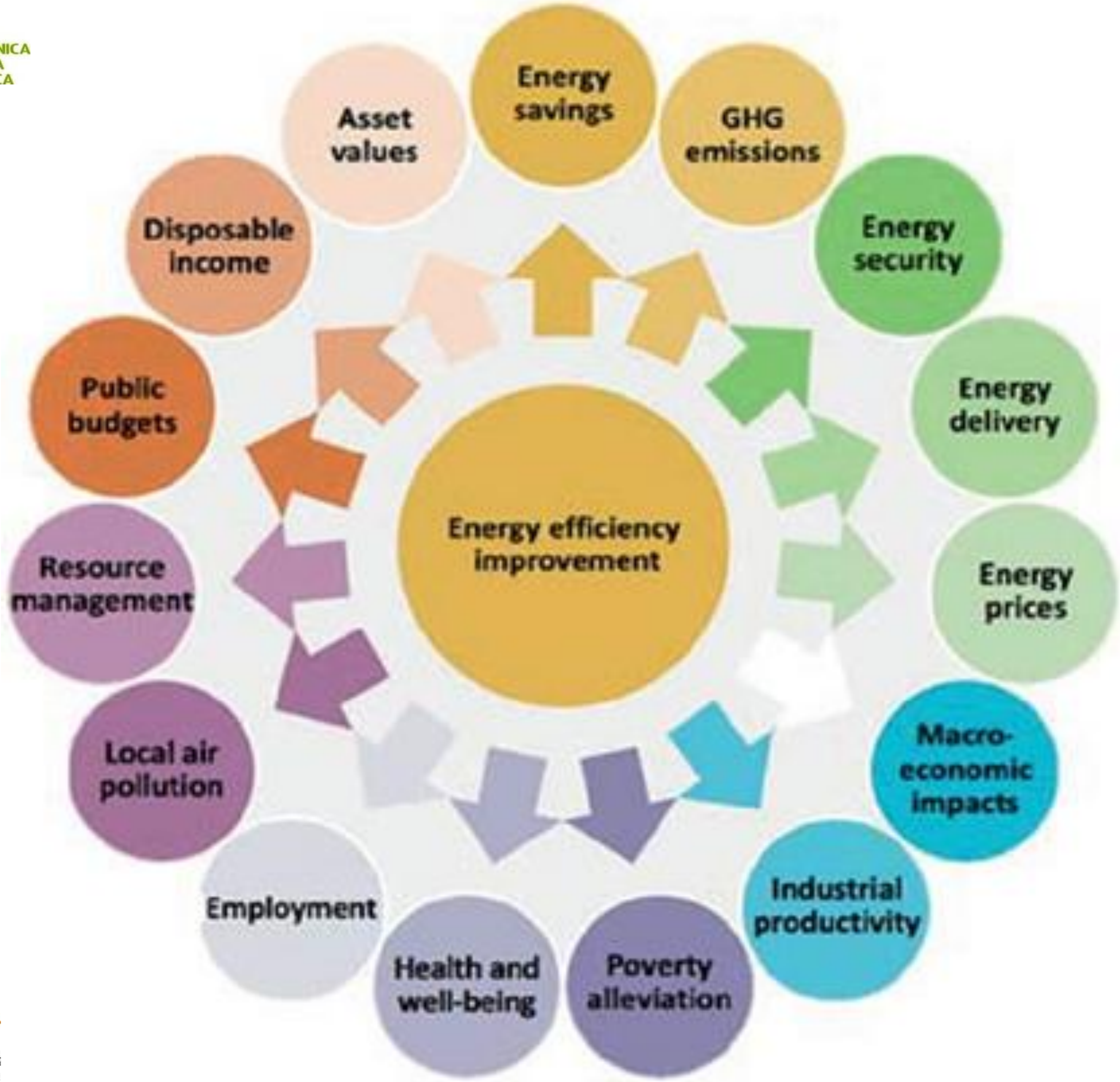

IEA, 2014

Co-funded by the Hori: Horizon 2020 research

4.1 EU Strategy on Heating and Cooling 2016

Heating and cooling consume half of the EU's energy and much of it is wasted

Developing a strategy to make heating and cooling more efficient and sustainable is a priority for the Energy Union. It should help to reduce energy imports and dependency, to cut costs for households and businesses, and to deliver the EU's GHG reduction goal and meet its commitment under the climate agreement reached at the COP21 climate conference in Paris.

Heating and cooling sector is moving to clean low carbon energy

At the moment, 75% of the used fuel still comes from fossils (nearly half from gas).

Security of supply remains a priority, especially in Member States that rely on a single supplier.

Heating and cooling and the electricity system can support each other in the effort to decarbonize.

This strategy provides a framework for integrating efficient heating and cooling into EU energy policies by focusing action on stopping the energy leakage from buildings, maximizing the efficiency and sustainability of heating and cooling systems, supporting efficiency in industry and reaping the benefits of integrating heating and cooling into the electricity system.

Industry can move in the same direction, taking advantage of the economic case for efficiency and new technical solutions to use more renewable energy.

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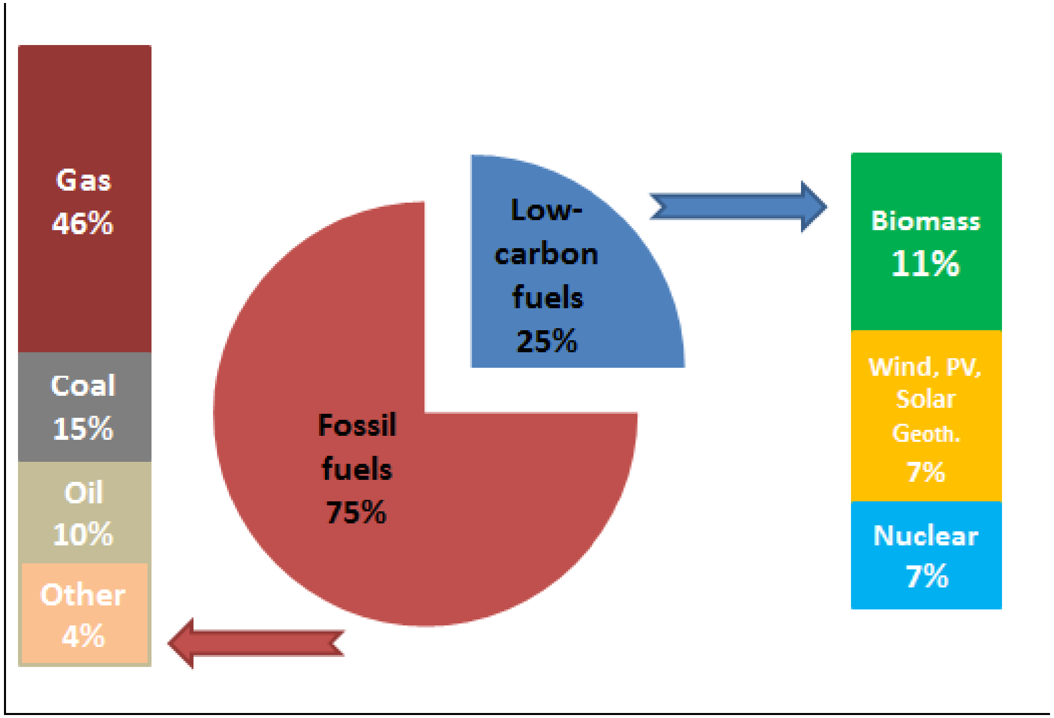
Primary energy for heating and cooling, 2012
(EU strategy for heating and cooling 2016)



Due to EU targets for 2020, renewable energy is growing. Most member States are on the right way to achieve these targets (according to the National Renewable Energy Action Plans).

The Commission will propose at the end of 2016 a **bioenergy sustainability policy**, which will take into account the impact of bioenergy on the environment, land-use and food production.

Biomass is the most widely used renewable energy for heating today, representing some 90%.

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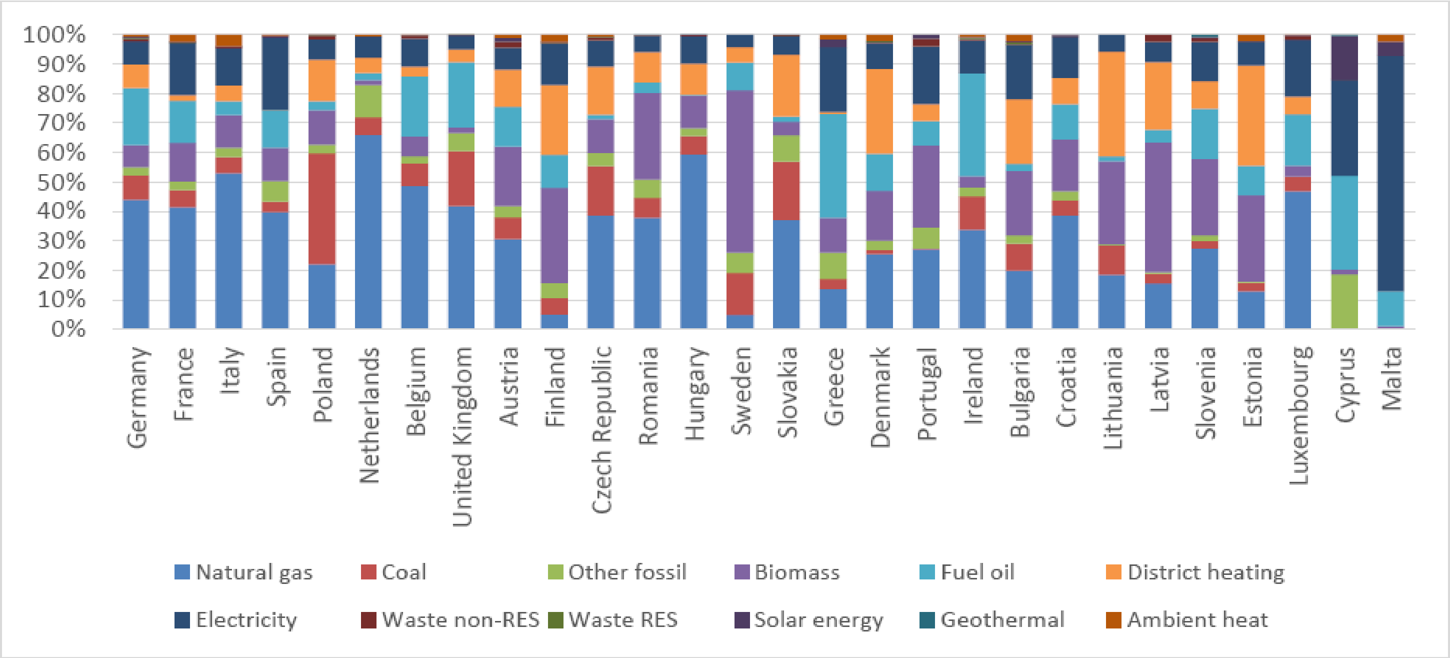
Final energy consumption for heating and cooling in the EU 28 (2012)



Energy for heating and cooling in the EU is:

- 45% is used in the residential sector,
- **37% is used in industry**
- 18% is used in services

a quarter of the EU's final energy consumption in 2012 was in industry

73% of this is used for heating and cooling

European industry has cut its energy intensity twice as fast as the US since 2000. The improvement rate is steeper in energy intensive sectors: i.e. The chemical sector halved its energy intensity over the last 20 years. The reason is clear: energy is an important cost. By putting a price on CO_2 emissions, the EU Emissions Trading Scheme has provided an incentive to use low carbon fuels and to invest in energy efficiency.

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“The measurement of the energy efficiency of a system or process is an essential step towards the control of the energy consumption and energy costs”

(Giacone and Mancò, 2012).

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Energy Efficiency

Energy Input

Energy Conversion Device

Useful Energy Output

Energy Dissipated to the Surroundings

$$Efficiency = \frac{Useful\ Energy\ Output}{Total\ Energy\ Input}$$

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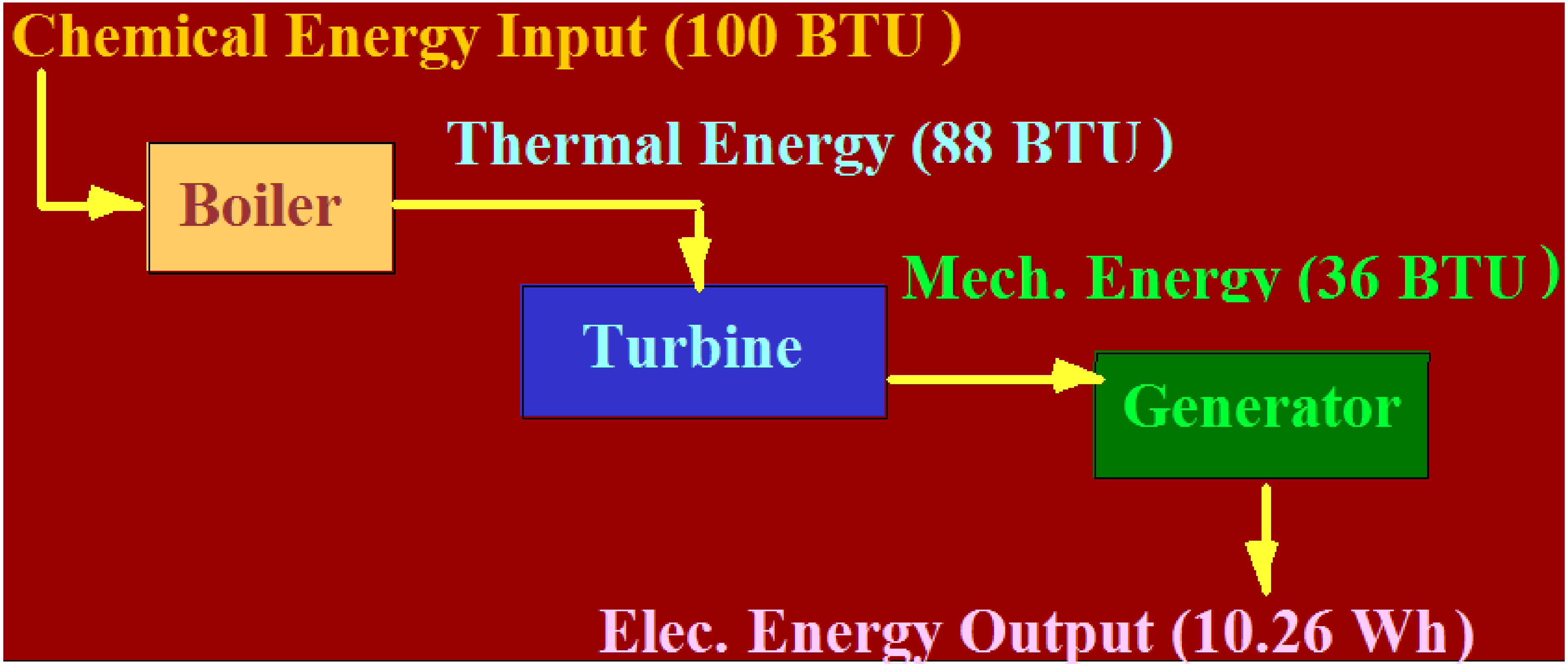
POWER PLANT ENERGY FLUX



Just an example

10.26 Wh= 35 BTU

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1) THERMODYNAMICS INDICATORS

(The input and output is measured in thermodynamic units).

Three different indicators are described:

A) Enthalpic efficiency indicator (also referred to as thermal efficiency or first-law efficiency) presents energy efficiency as shown in equation:

Useful energy output/Total energy input

The heat content is measured in terms of enthalpic change values.

The difference between energy input and energy output is the energy that has been lost.

B) A second indicator is used to adjust for energy quality in order to support comparisons.

For example, when we want to compare two technologies using different types of energy inputs with different properties, the energy input is converted to common quality units representing work potential.

C) A third approach, called second-law energy efficiency, is obtained by dividing the actual enthalpic efficiency by an ideal efficiency. Therefore, the most efficient possible process has an efficiency value of 1.

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ENERGY EFFICIENCY EVALUATION IN INDUSTRY

- **2) PHYSICAL-THERMODYNAMIC INDICATORS**
- **The input is measured in thermodynamic units and the output is measured in physical units (e.g. tonnes of product). These indicators are the most commonly used in industry comparison and benchmarking. For example, in milk industry, pasteurization of 1000 L uses 25 kg of steam.**
- **3 Economic-thermodynamic indicators: the input is measured in thermodynamic units and output is measured in terms of market prices.**
- **4 Economic indicators: entirely economic indicators where input energy and output service are both measured in monetary terms according to market values. They relate to the economic productivity of energy.**

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AGRO-FOOD INDUSTRIAL PROCESSES REQUIRING THERMAL ENERGY

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- **IN AGRO-FOOD INDUSTRY, THERMAL PROCESSES ARE AMONG THE MOST ENERGY INTENSIVE ONES.**

- **THE PROCESSES THAT REQUIRE THERMAL ENERGY INCLUDE:**
    - **Hot water or steam demand processes**
    - **Drying and dehydration processes**
    - **Preheating**
    - **Concentration**
    - **Pasteurization, sterilization**
    - **Washing, cleaning**
    - **Chemical reactions**

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AVERAGE THERMAL ENERGY CONSUMPTION IN AGROFOOD INDUSTRY *(for orange juice production)*

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PROCESS	THERMAL ENERGY CONSUMPTION (MJ)	ELECTRICITY CONSUMPTION (MJ)	TOTAL ENERGY CONSUMPTION (MJ)	% ENERGY CONSUMPTION
SORTING and WASHING		8	8	0.54
EXTRACTION		52	52	3.53
FILTRATION		12	12	0.82
CENTRIFUGATION		17	17	1.15
PASTEURIZATION	1177	34	1211	(79.96 + 2.31) 82.27
ASEPTIC FILLING and PACKAGING		147	147	9.99
AUXILIARY PROCESSES		25	25	1.70
TOTAL	***1177***	***295***	***1472***	***100.00***

Thermal and electrical energy consumption for processes in the ***orange juice*** *manufacturing (elaboration from a sample of specific enegy audits and from Waheed, 2008).*

D.3.6 Extended Value Stream Maps of NACE 10.3: Fruit juices and purees and tomato concentrates (www.scoope.eu).

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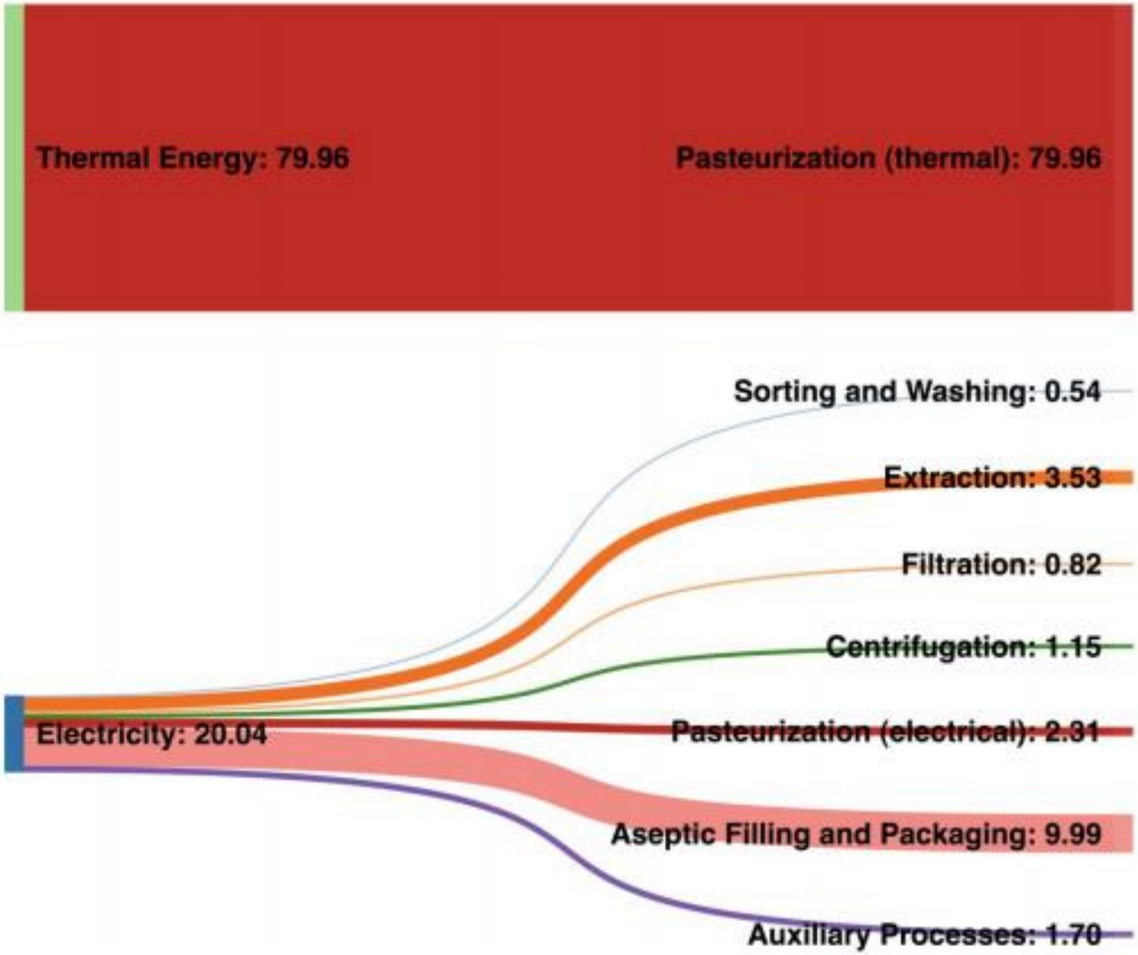

***AVERAGE CONSUMPTION FLOWS OF THERMAL ENERGY IN THE UPPER PART OF THE GRAPH AND ELECTRICITY IN THE LOWER ONE, IN ORANGE JUICE PRODUCTION*.**

D.3.6 Extended Value Stream Maps of NACE 10.3: Fruit juices and purees and tomato concentrates (www.scoope.eu).

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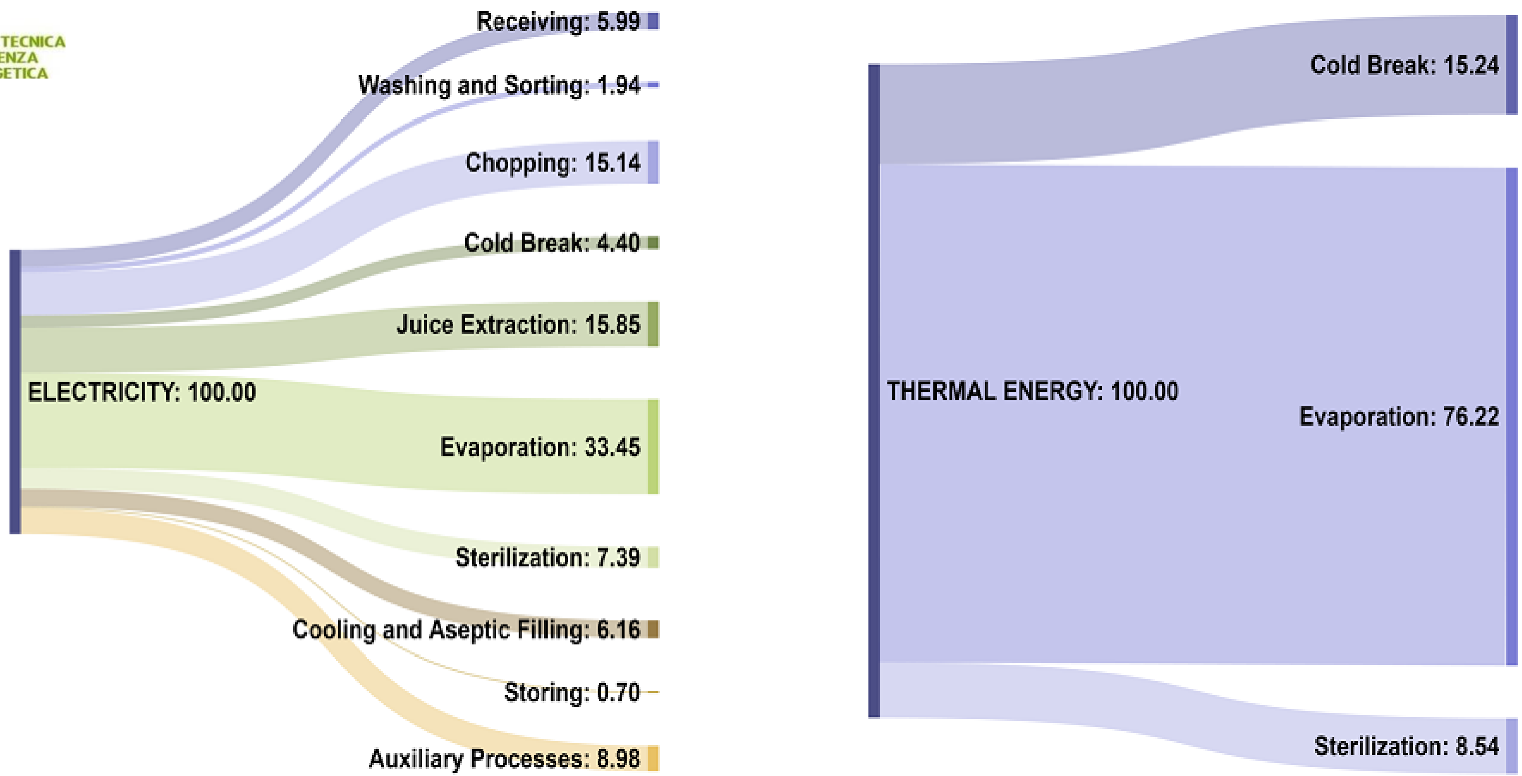

Average consumption flows of thermal energy (on the right) and electricity (on the left) in ***tomato concentrate*** *production (data elaboration from specific energy audit information*

D.3.6 Extended Value Stream Maps of NACE 10.3: Fruit juices and purees and tomato concentrates (www.scoope.eu).

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PASTEURIZATION

PASTEURIZATION

Multitubular heat exchanger (from HRS heat exchangers). Tubular (or plate) heat exchangers are available in various configurations.

Nominal capacity	Production capacity depending on the model
Installed power	Depending on the model production capacity

Pasteurizator tubular
for fruit juice, milk, wine and beer
Flow rate from 500 to 30,000 lt/h

http://www.etaitaly.com

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Triple effect FC evaporator with dual output at two different concentrations
(from Ing. A. Rossi, mod. 3t2600).

Evaporation capacity: 26.000 L/h.
In a triple effect evaporator up to 3.2 kg of water are evaporated for each kg of live steam used.
Nominal capacity: up to 1.200 t fresh tomato/day

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AGROFOOD ENERGY EFFICIENCY IN ITALY

(*SOME CASE*)

USING BEST AVAILABLE TECNOLOGIES (BAT)

(years 2005 – 2015)

Source : RSE S.p.A.

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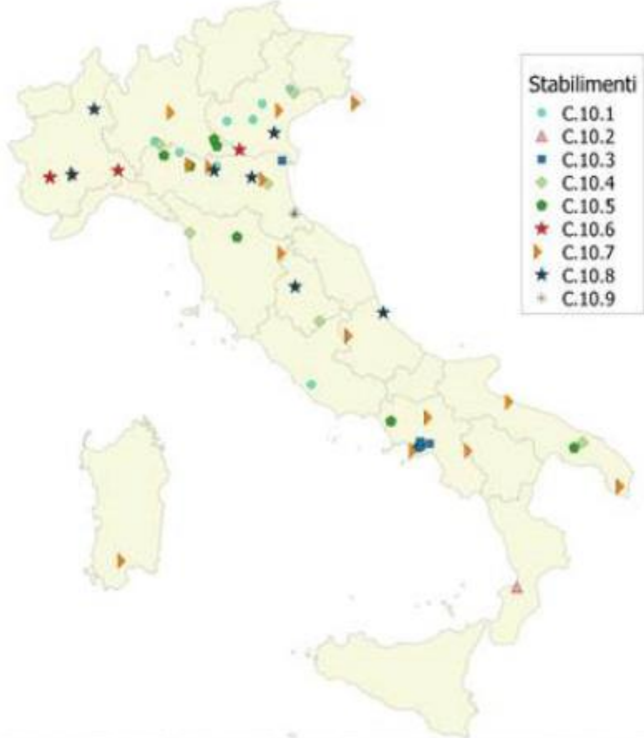
Energy Efficiency in italian agrofood industry per sectors (years 2005-2015)

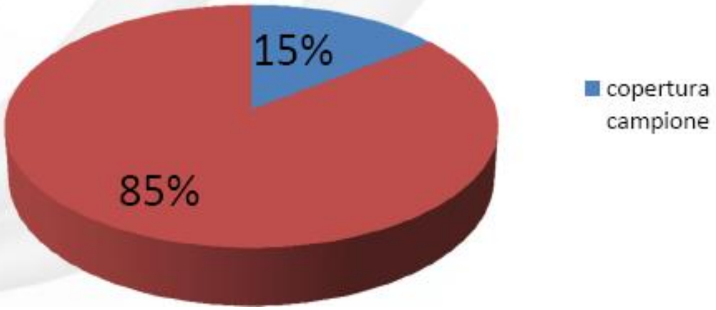
139 interventi di efficienza energetica (di seguito riferiti come "casi") relativi al periodo 2005-2015, realizzati in Italia presso gli stabilimenti del settore.



58 stabilimenti, di cui:

carne e prodotti a base di carne	pesce, crostacei e molluschi	frutta e ortaggi	oli e grassi vegetali e animali	Industria lattiero-casearia	granaglie, produzione di amidi e di prodotti amidacei	prodotti da forno e farinacei	altri prodotti alimentari	alimentazione degli animali
C10.1	C10.2	C10.3	C10.4	C10.5	C10.6	C10.7	C10.8	C10.9
9	1	8	7	6	3	16	6	2

produzione industria alimentare per i sottosettori considerati



Ricerca di Sistema Elettrico, RSE S.p.A

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Statistics of 139 energy efficiency initiatives in italian agro - food industry (2005-2015)

n°	Interventi di efficienza Energetica	Percentuale di realizzazioni
1	Recupero di calore da fluidi da impianto termico **Waste heat recovery**	21,9%
2	Installazione di un impianto cogenerativo **Co-generation**	17,5%
3	Sostituzione caldaia tradizionale con caldaia più efficienti **High efficiency boiler**	5,8%
4	Inverter - Regolazione della potenza elettrica dei motori per pompe	5,1%
5	SGE (Sistemi di Gestione dell'Energia)	5,1%
6	Sostituzione compressori rotativi convenzionali con compressori ad alta efficienza	4,4%
7	Sostituzione di refrigeratori con macchine frigorifere più efficienti	4,4%
8	Sostituzione forno di linea di produzione	4,4%
9	Sostituzione motori elettrici con motori più efficienti di classe IE3 (esclusi compressori)	2,9%
10	Miglioramento dell'efficienza delle linee produttive	2,9%
11	Aria compressa - Riduzione delle perdite di aria	2,2%
12	Recupero di calore da fluidi della linea di produzione	2,2%
13	Installazione di un impianto di concentrazione a compressione meccanica del vapore	2,2%
14	Installazione di un concentratore con maggiore numero di effetti	2,2%
15	Impianto termico esistente alimentato da biogas proveniente dalla digestione anaerobica	2,2%
16	Refrigerazione - Installazione sistemi accessori alle macchine frigorifere per aumentarne l'efficienza (free-cooling, pannelli adiabatici,...)	1,5%
17	Installazione di bruciatori a biomassa o CSS in sostituzione di bruciatori a combustibile fossile su caldaie esistenti	1,5%
18	Recupero di calore dai fumi	1,5%
19	Installazione di concentratori a termocompressione	1,5%
20	Aria Compressa -motori più efficienti Classe IE3	0,7%
21	Inverter sui motori dei compressori	0,7%
22	Sostituzione caldaie a combustibile fossile con caldaia a biomassa	0,7%
23	Refrigerazione - isolamento ad alta efficienza	0,7%
24	Refrigerazione - uso di apparecchiature efficienti (motori elettrici)	0,7%
25	Illuminazione (LED + SAP)	0,7%
26	Recupero di calore da cascami termici	0,7%
27	Installazione di un preriscaldo in testa ad un concentratore	0,7%
28	Sistema di ossigenazione a microbolle negli impianti di depurazione	0,7%
29	Realizzazione di un impianto di digestione anaerobica per la produzione di biogas per il suo utilizzo nell'impianto termico	0,7%
30	Misure di efficientamento energetico nel settore della distribuzione idrica	0,7%
31	Nuova linea di produzione	0,7%

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EXPECTED ENERGY SAVINGS

TIPOLOGIA	INDICATORE	RISPARMI POTENZIALI TOTALI
TERMICO	ktep risparmio ener. primaria	160
	% sui consumi termici (ener. primaria)	12%
ELETTRICO	ktep risparmio ener. primaria	75
	% sui consumi elettrici (ener. primaria)	5%
TOTALE	ktep risparmio ener. primaria	235
	% sui consumi primari totali	8%

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AGRO-FOOD INDUSTRY
investment costs

SOTTOSETTORE	CLUSTER	COSTO SPECIFICO DI INVESTIMENTO [Euro/tep annuale primario risparmiato]	TEMPO DI RITORNO [anni] ROI (y)
Lavorazione e conservazione di carne e produzione di prodotti a base di carne	Elettrico	192	0,4
	Processo	1'275	3,5
	Termico	845	2,3
Lavorazione e conservazione di frutta e ortaggi	Termico	1'413	3,8
Produzione di oli e grassi vegetali e animali	Processo	508	1,4
	Termico	588	1,6
Industria lattiero casearia	Processo	240	0,7
	Termico	1'503	4,1
Lavorazione delle granaglie, produzione di amidi e prodotti amidacei	Processo	604	1,6
	Termico	844	2,3
Produzione di prodotti da forno e farinacei	Elettrico	2'938	5,6
	Processo	1'615	4,4
	Termico	719	2,0
Produzione di prodotti per l'alimentazione degli animali	Termico	1'176	3,2

04-05-2018

Ricerca di Sistema Elettrico, RSE S.p.A

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Field of application	Alternative technologies
Waste heat recovery	- **Exhaust water heat exchanger, washing and drainage cycles** - **Heat exchangers for exhaust gas of dryers and boilers** - **Heat recovery from vapour condensate** - **Heat recovery from workplace ambient air**
More rational use of process and service machines	- Use of more efficient electric motors - The use of more efficient transformers - Inverter installation for electric motors - Automatic /centralized control of users
Interventions on plant (sustainable technologies) and structure (thermal containment)	- **Solar cooling in air conditioning** - **Photovoltaic power generation** - **Use of biomass boilers for heating** - **Thermal insulation of the storage spaces and the heat distribution system** - **Improving energy performance of the building envelope** - **Supervision through energy management, software for machineries, processing and storage units**

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8.

Saving Cooperative Energy

Example of intervention for improving energy efficiency

UNITÀ TECNICA EFFICIENZA ENERGETICA

Cogeneration plant in rice production

- **The company produces energy from biomass: dedicated energy crops and agricultural residues (mainly from the rice factories of the group.**
- **(The cogeneration plant went into operation in year 2003).**
- **Recovered heat is used for the rice production process while electricity is sold to the public network.**
- **The production process is a large state-of-the-art high-tech plant which concentrates the most modern and efficient solutions in the food industry.**

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A case of plant cogeneration applied to rice processing

- **The entire process minimises the production of wastes; all the by-products of the rice manufacturing process present a further utilisation:**
  - **rice husks and straw as biofuel for the cogeneration plant;**
  - **rice chaff, which is composed by the fatty external layers of the raw rice**
  - **grain, are the raw material for rice oil production;**
  - **the white rice broken grains are used to produce puffed rice grains**
- **The by-products amount is nearly 40% (in mass) of the input raw material.**
- **Through a strict quality and efficiency control of every production phase and a totally new production lay out, the industry is able to run a "zero waste" operation.**

The input biomass comes from the rice production process (rice husks and straw); this biomass is integrated by wood chip fuel from dedicated energy crops (white poplar).

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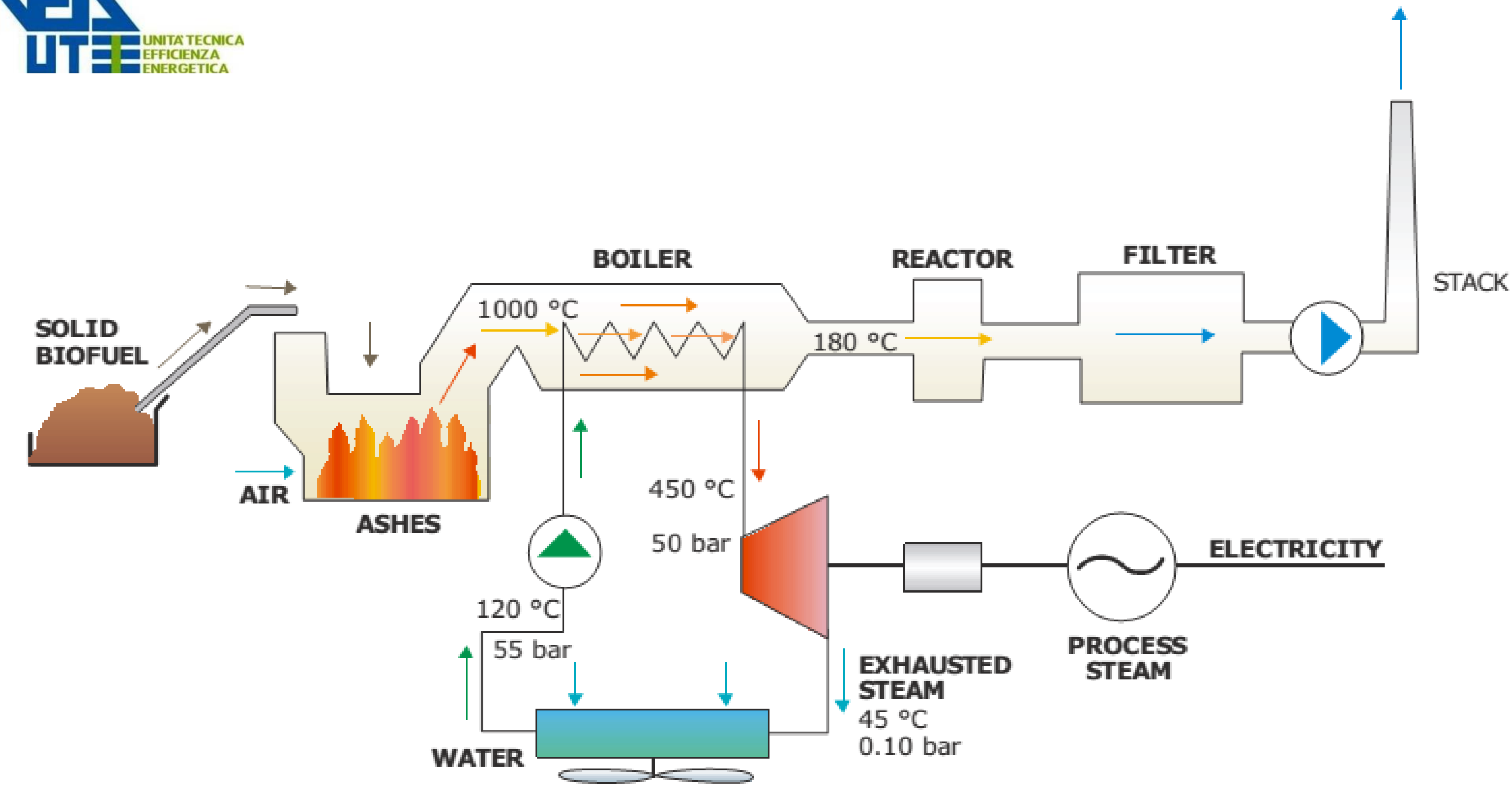
Plant scheme



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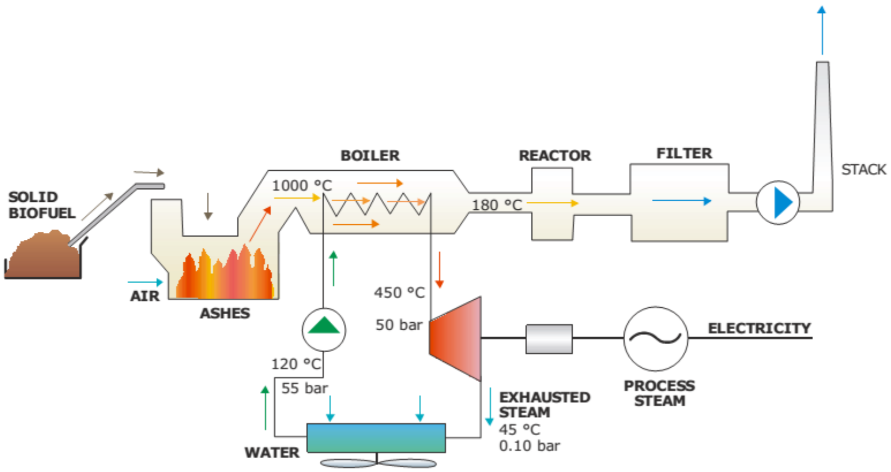
Main plant components/areas

- Storage area (*the area where the biofuel is stored and pre-processed*);
- plant feeder;
- boiler and steam generator;
- fumes treatment and filter
- steam turbines;
- automatic monitoring and



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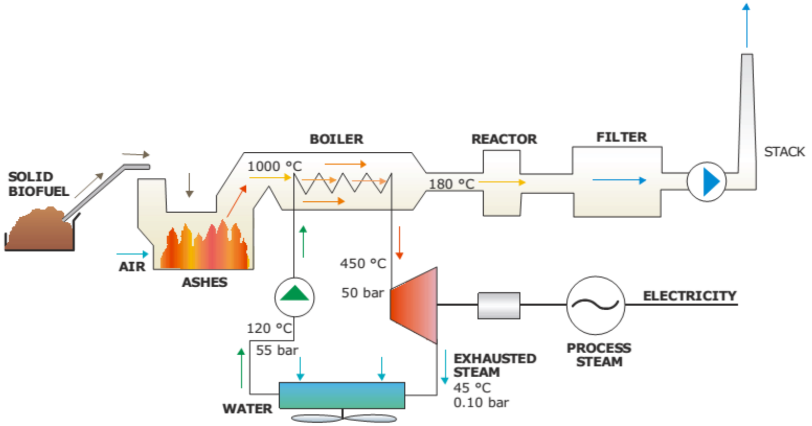
Plant Design Data

- The plant burns nearly 80-90,000 tons of biomass per year.
- The plant power unit is composed by two impulse steam turbines: one of 5.6 MW electrical nominal power at 8,200 rpm, the other of 2.0 MW electrical nominal power at 7,450 rpm.
- Thus the total nominal electrical plant power is 7.6 MW.



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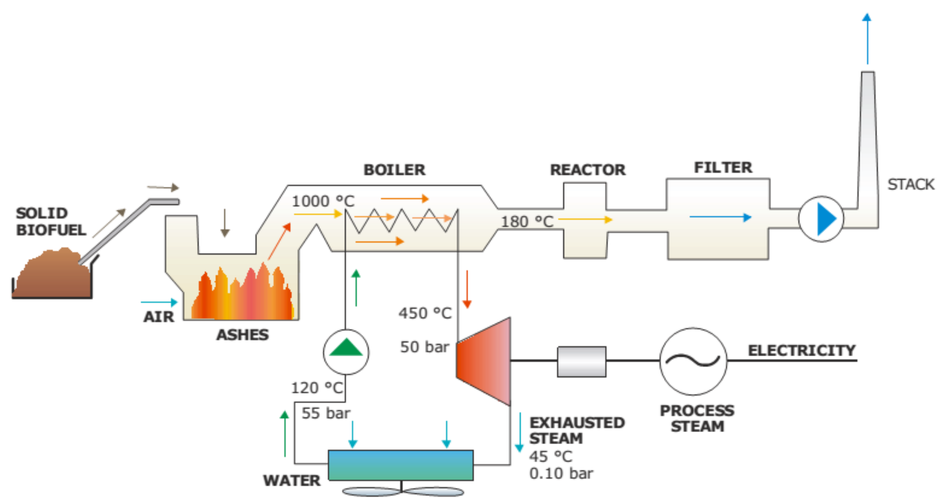
Improvement

- The cogeneration plant produces nearly 45 GWh electricity per year; this electricity is sent to the public grid under the incentive system.
- Moreover, nearly 10 t/h of steam are extracted from the steam turbine and used for the rice manufacturing process.
- For this plant a fossil fuel saving of nearly 30,000 t/y has been evaluated, thus avoiding CO_2 emissions of about 130,000 t/y



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Thank you for your attention!

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