SCOoPE Webinar – CHAPTER 7
ENERGY EFFICIENCY IN FOOD INDUSTRY AND COMBINED HEAT AND POWER (CHP)

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PART I. SOME DATA OF THE FOOD SECTOR

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SOME DATA OF EUROPEAN FOOD SECTOR

Structural overview of the food supply chain, 2011

		Agricultural holding	Food and drink industry	Wholesale of agricultural and food products	Food and drink retail
Turnover	€ billion	392	**1,016**	1,100	1,110
Value added	€ billion	204	**206**	93	156
Number of employees	million	11.9	**4.2**	1.8	6.1
Number of companies	1,000	11,757[1]	**286**	250	839

(1) 2010 data

Structural overview of the food supply chain in Europe, 2011. Source: Data & Trends of the European Food and Drink Industry 2013-2014 - Food Drinks Europe 2014

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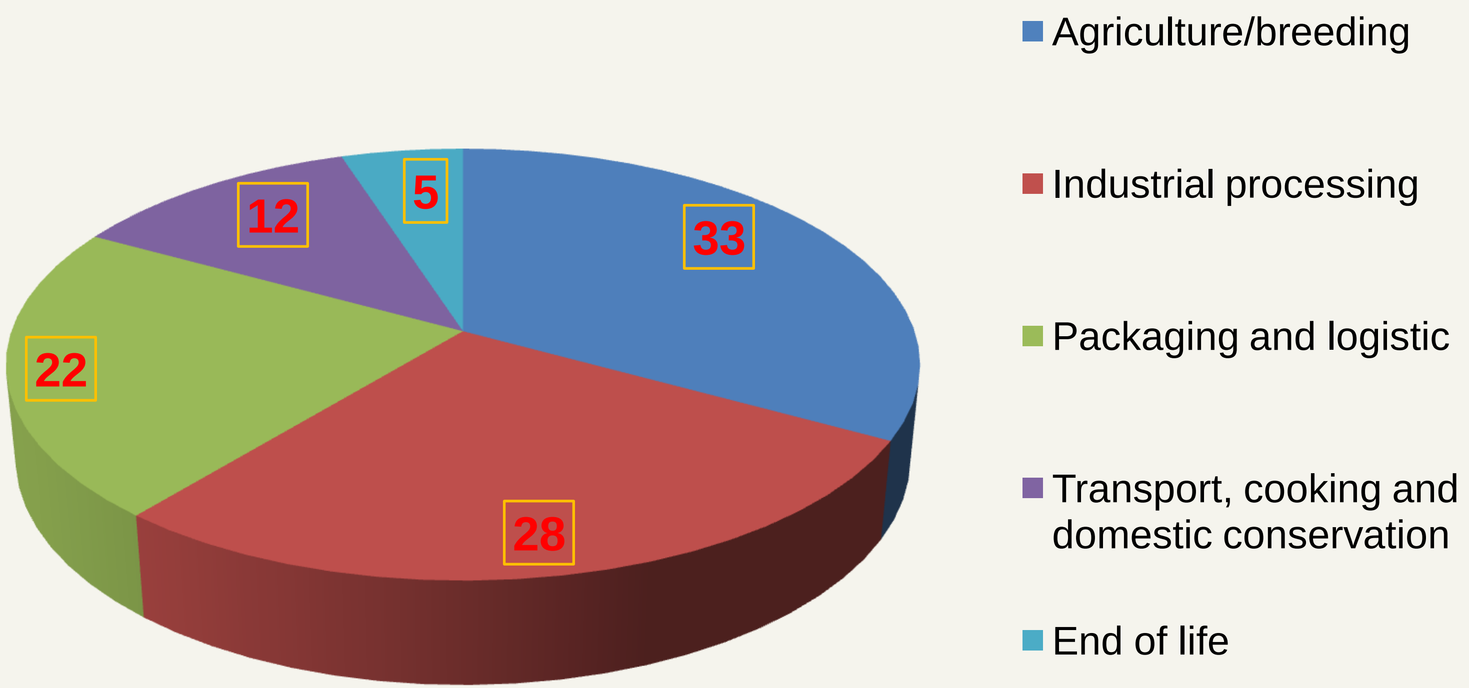
SOME DATA OF EUROPEAN FOOD SECTOR

Accounts of EU's energy consumption in the food chain (285 Mtoe in 2013, 26% of total UE energy consumption)



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FOOD INDUSTRY FEATURES: VARIETY OF INVOLVED PROCESSES

The amount of energy for 1 Kg of food can vary from a minimum of 0.5 KWh (vegetable) to a maximum of 61 KWh (processed meat, cooked food, etc.)

Production parts	Production stages
Agriculture/breeding	• Cultivation of crops • Animal rearing • Food waste management (relevant part)
Industrial processing	• Processing of ingredients • Slaughtering, processing and storage of meat • Chilled or frozen storage • Food waste management (relevant part)
Logistics	• International transport of imports • Transport to manufacturer • Transport to regional distribution centre • Distribution • Transport to retailer • Retail • Food waste management (relevant part)
Packaging	• Manufacture of packaging • Final disposal of packaging
Use	• Transport of the products from retailer to consumer's home • Refrigerated storage at home • Cooking of the meal
End of life	• Final disposal of food waste • Wastewater treatment

Production parts and stages of food production chains. Source : Authors of "Energy use in the EU food sector: State of play and opportunities for improvement" 2015 European Commission, JRC SCIENCE AND POLICE REPORT

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FOOD INDUSTRY FEATURES: INDUSTRIAL PROCESSES OF FOOD CHAIN

FEEDSTOCK ⇨

Reception and preparation of feedstock Handling and storage of food, Sorting / Selection, Classification, Cleaning and Treatments; Peeling, washing, thawing.
Processes for reducing dimensions, mixing, shaping Cutting, Slicing, Crushing, Grinding, Pressing. Mixing, Homogenizing, Grinding and Crushing, Shaping and Pressing
Separation processes Extraction; Ionic exchange, Purification, Centrifugation and sedimentation, Filtration; Membrane separation, Crystallization, Removal by neutralization of free fat acids; Bleaching, Removing odors by stripping steam, Decolorization, Distillation;
Treatment processes Soaking, Dissolution, Solubilization, Fermentation, Coagulation, Germination, Brine process, Drying, Pickling, Smoker process, hardening, sulphate treatment, Carbonation, Covering and coating operations, Aging.
Baking processes Fusion, Roasting, Baking and Boiling, Baking in oven, Frying, Curing, Pasteurization, Sterilization, UHT
Heat-concentration processes Evaporation, Drying, Dehydration
Heat removal processes Cooling, Cold Stabilization, Freezing
Post-Process Operations Packaging, Storage in artificial atmosphere
Service processes Cleaning and Disinfection, Generation and Energy Consumption, Water Use, Vacuum Generation, Refrigeration, Compressed Air Generation, Solid Waste Treatment, Sewage Treatment

⇨ PACKAGING AND LOGISTIC

List of possible processes of food and beverage industry

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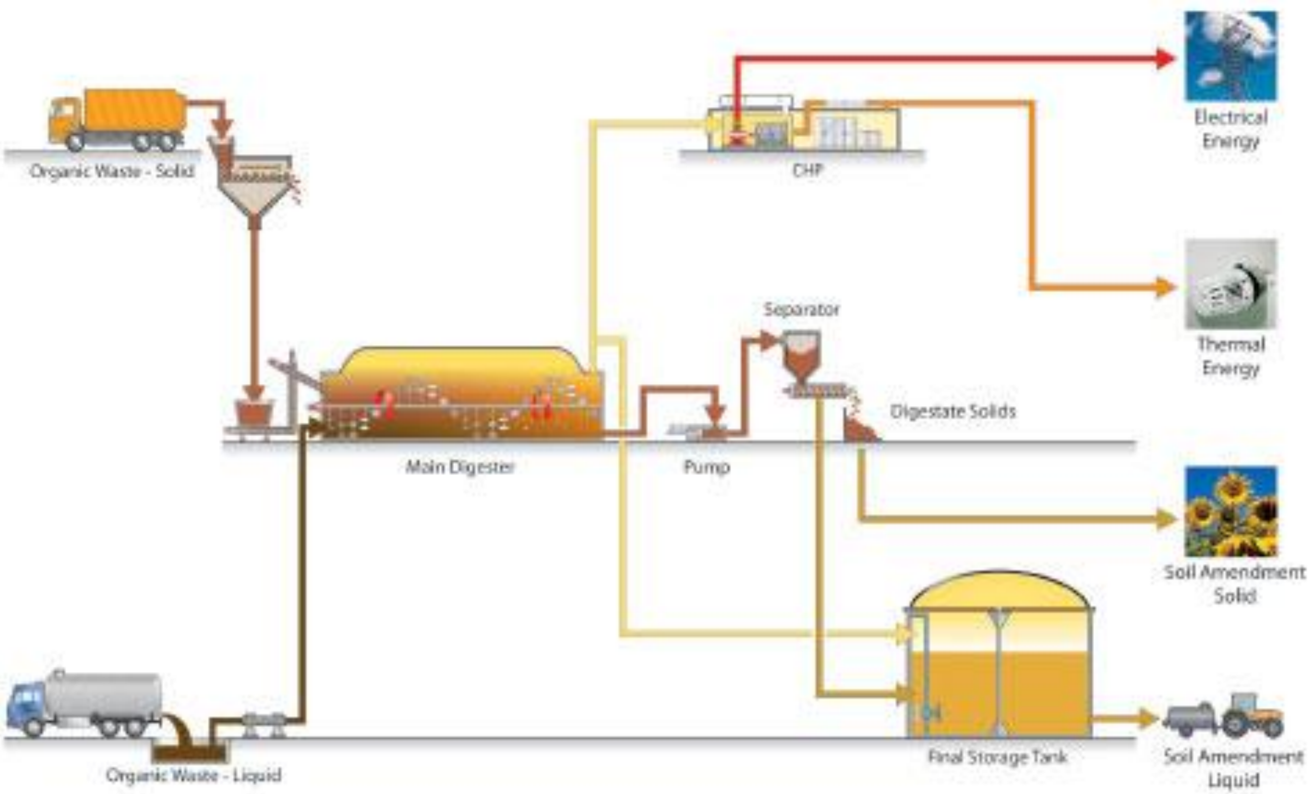
FOOD INDUSTRY FEATURES: ENERGY MIX REQUIRED AND PRESENCE OF ORGANIC WASTES



Organic wastes go through a digester and become one of two types of energy or one of two types of soil amendments.

DIAGRAM COURTESY OF EISENMANN CORPORATION

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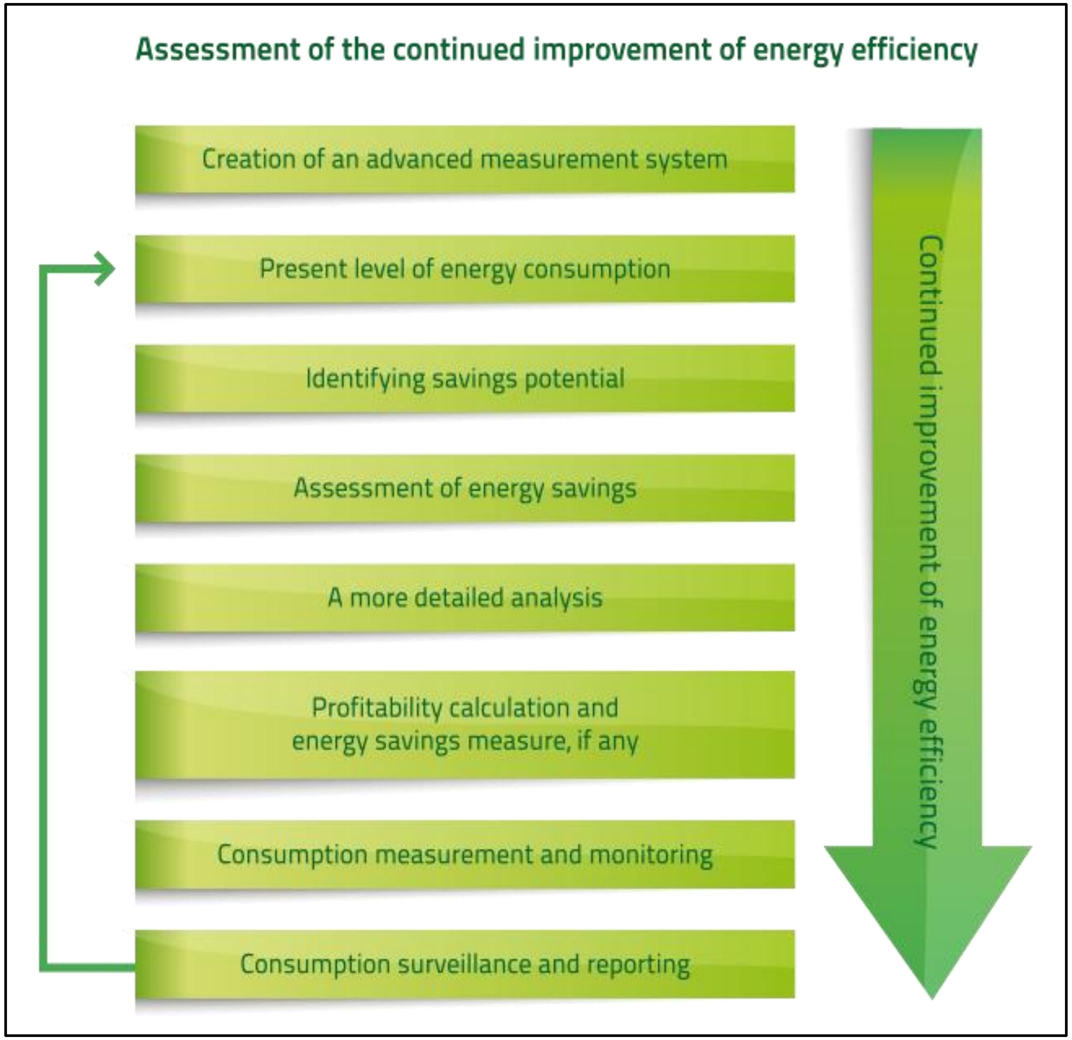
ENERGY EFFICIENCY IN FOOD INDUSTRY AND COMBINED HEAT AND POWER

A correct Energy audit is very important to identify losses of energy and potential optimization of industrial processes, and consequently know the real demand of energy (electricity, heat). This allows to procede at right choices and correct investments to pursue continuous improvements about energy efficiency.



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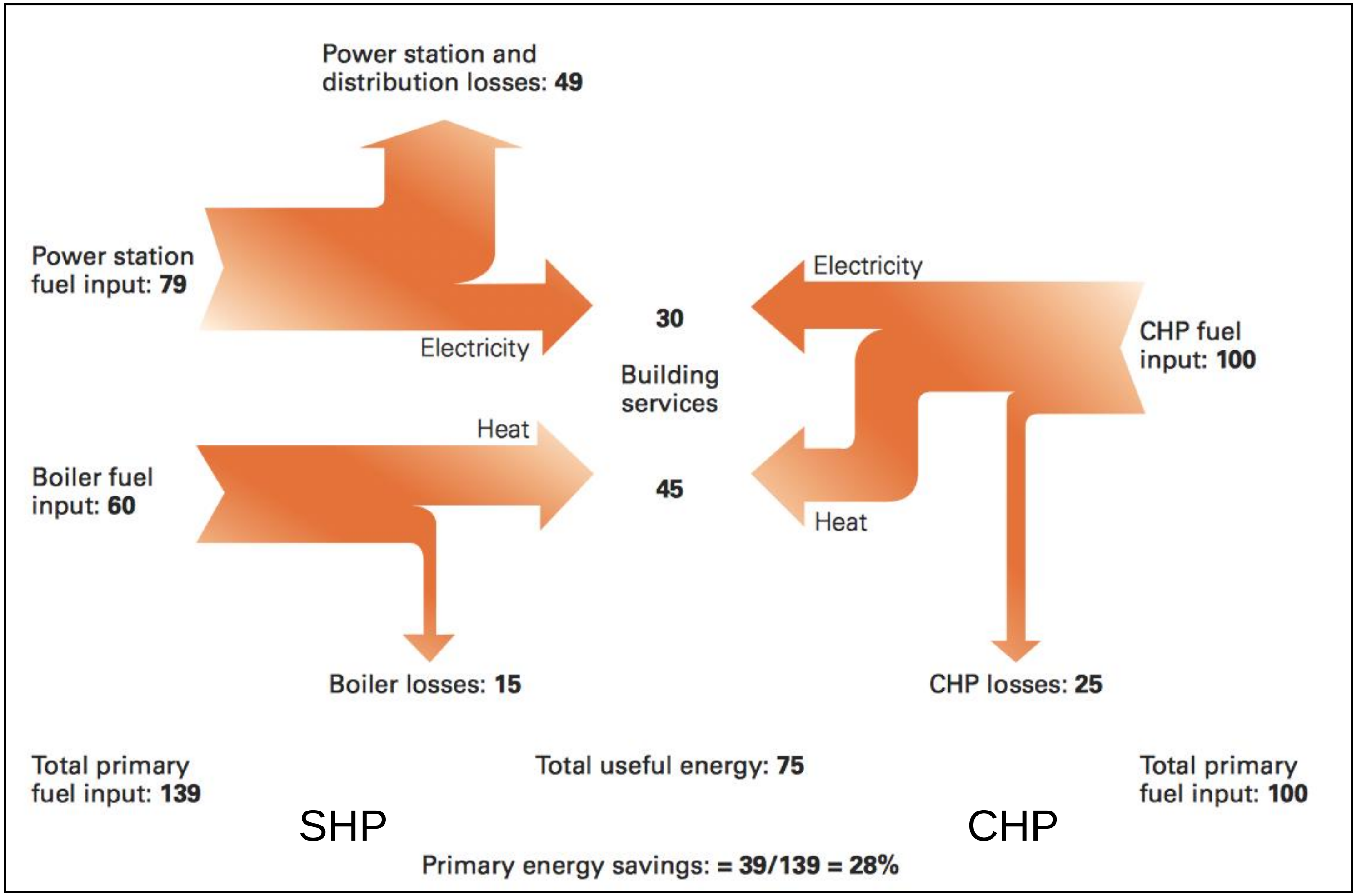
WHAT IS COMBINED HEAT AND POWER? HOW IT WORKS?



Comparison between conventional SHP (Separate Heat and Power) and CHP (Combined Heat and Power)
Source: Carbon Trust "introducing combined heat and power" technology guide

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MOST IMPORTANT PERFORMANCE INDEXES FOR A CHP PLANT

1) CHP electric efficiency *(η_{el})* indicates how much of the fuel energy (***Ec***) is converted into electric energy (***E_{el}***):

$$\eta_{el} = \frac{E_{el}}{E_c}$$

2) CHP heat efficiency *(η_t)* indicates how much of the fuel energy is converted into useful thermal energy (***Qr***):

$$\eta_t = \frac{Q_r}{E_c}$$

3) Energy Utilization Factor (*EUF*) indicates how much of the fuel energy is effectively used into electric or thermal form, and it can reach value of 0,8 or more in modern CHP plants:

$$EUF = (E_{el} + Q_r) / E_c = \eta_{el} + \eta_t$$

4) Power/Heat Ratio (Y) = CHP electrical energy output / useful heat output (it can vary from 0.6:1 to 10:1):

$$Y = E_{el}/Q_r$$

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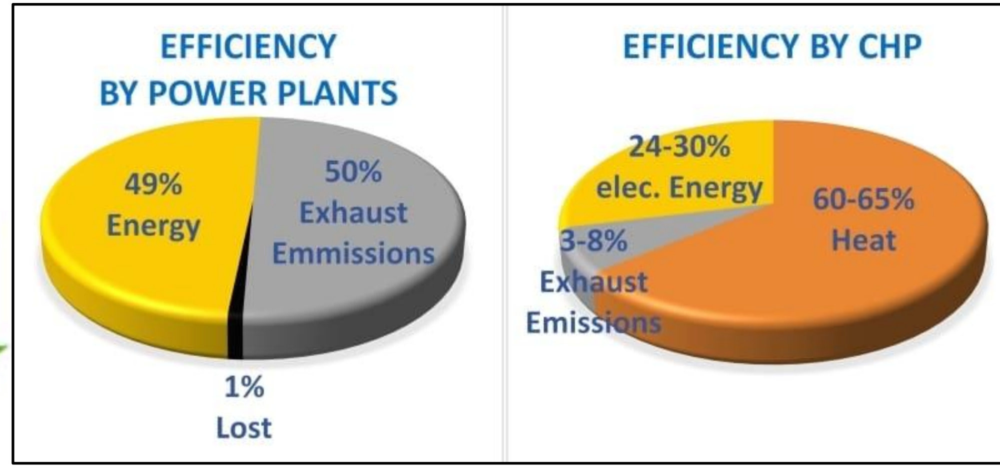
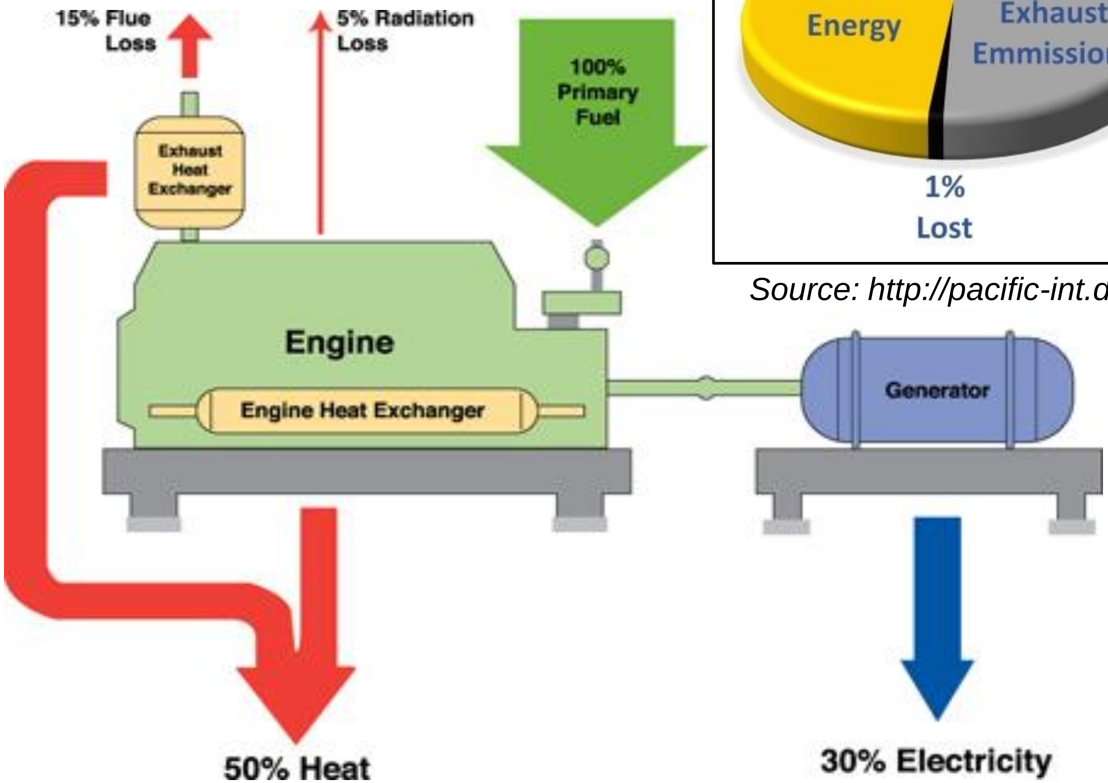
CHP PLANT SCHEME



Source: http://pacific-int.de/trade/energy/renewable-energy/chp



Source: https://www.cusw.ca

Technologies actually available in industry are:

1) Gas turbines
2) Steam turbines
3) Reciprocating engines
4) Fuel Cells (not yet mature)

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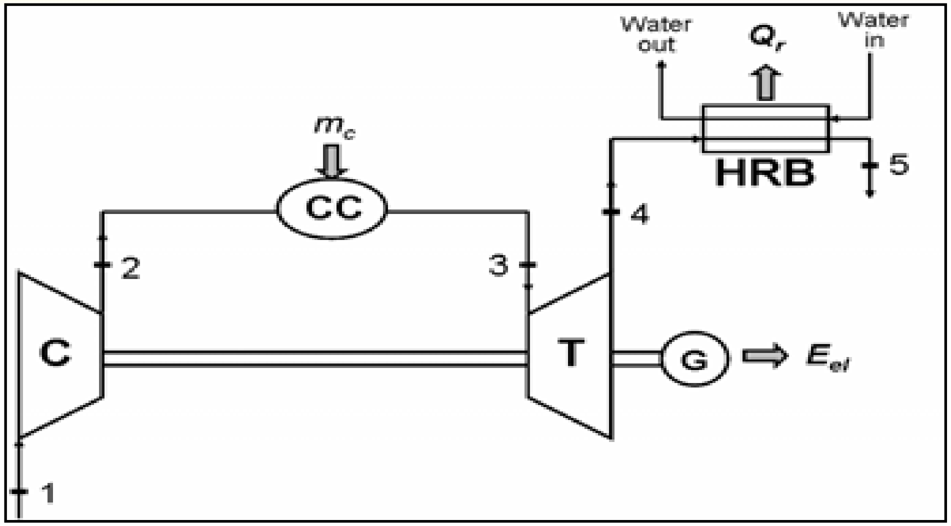
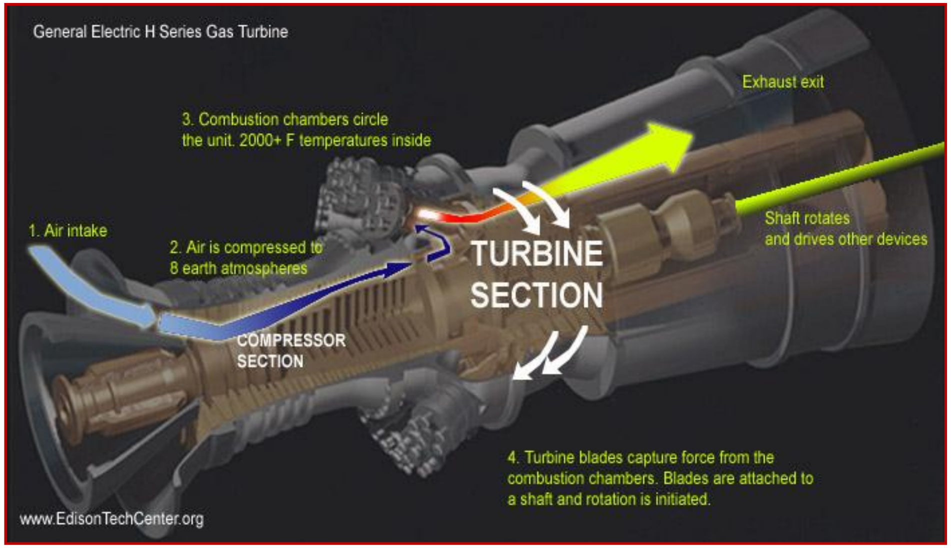
CURRENTLY USABLE CHP TECHNOLOGIES FOR INDUSTRIAL PROCESSES: GAS TURBINE



CHP unregenerated and open gas turbine plant layout. Source: RENAEL



The shaft of a gas turbine. http://www.utilities-me.com/ by SIEMENS

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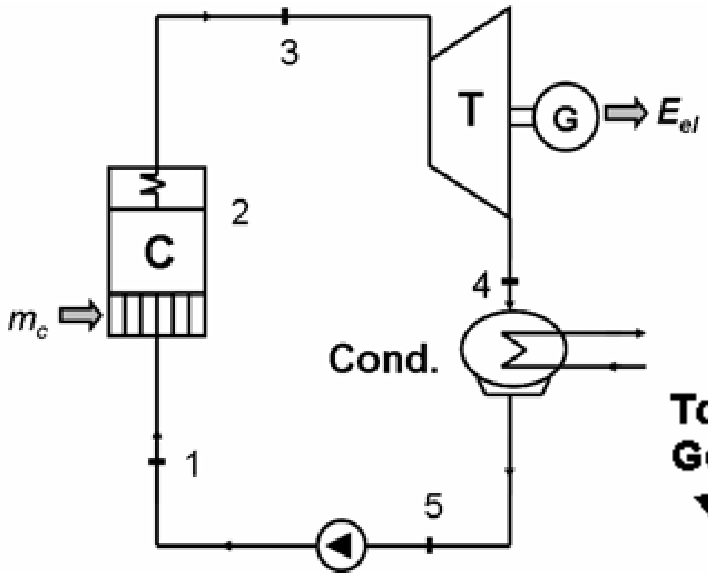
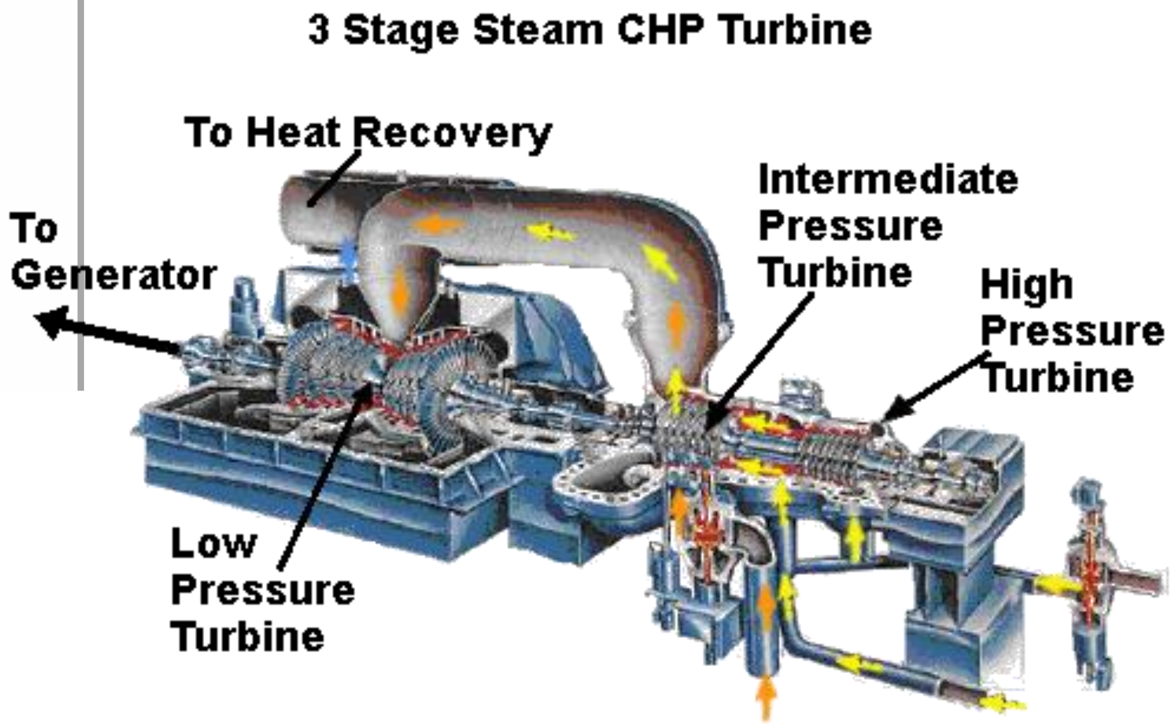
CURRENTLY USABLE TECHNOLOGIES IN CHP FOR INDUSTRIAL PROCESSES: STEAM TURBINE



Steam plant with heating. Source: RENAEL (Rete Nazionale delle Agenzie Locali per l'Energia)



Split of a single-shaft steam turbine with three stages. Source: www.renewableenergyhub.co.uk

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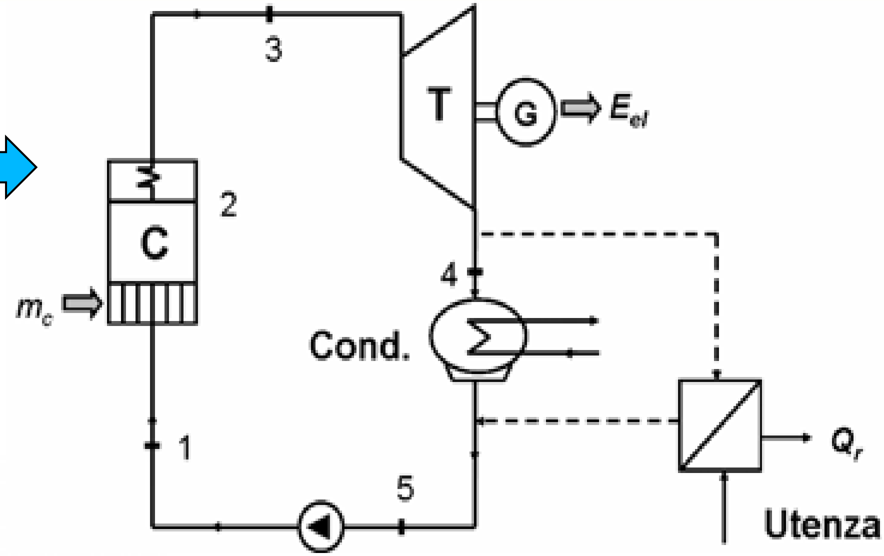
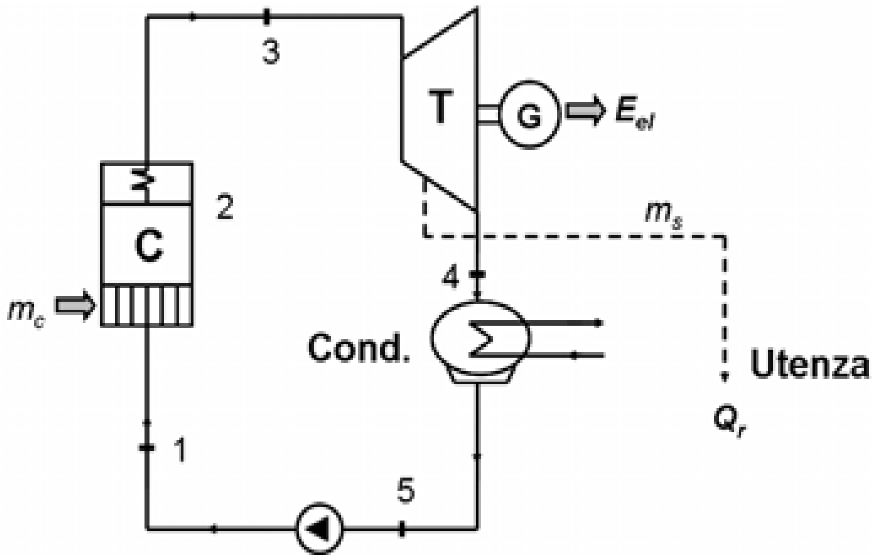
CURRENTLY USABLE TECHNOLOGIES IN CHP FOR INDUSTRIAL PROCESSES: STEAM TURBINE

Counterpressure plant



Steam escape plant



Source: RENAEL (Rete Nazionale delle Agenzie Locali per l'Energia)

Shaft of a steam turbine. Source: www.uralenergomash.ru

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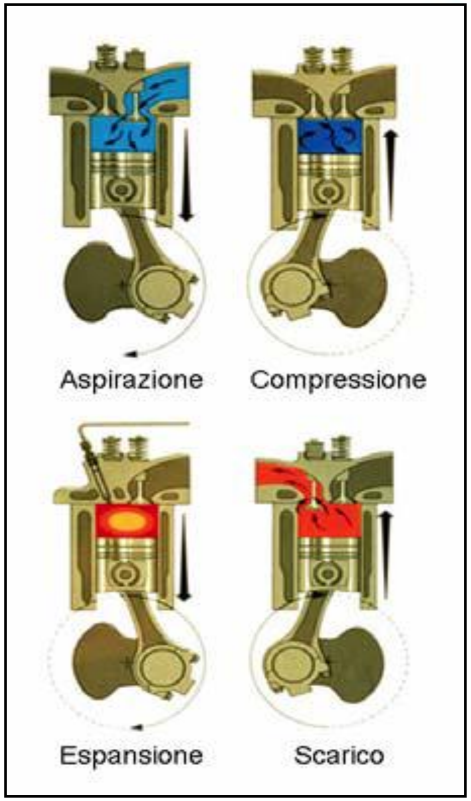
CURRENTLY USABLE TECHNOLOGIES IN CHP FOR INDUSTRIAL PROCESSES: RECIPROCATING ENGINES

Reciprocating engines for cogeneration. Otto or Diesel cycle. Source: www.rolls-royce.com



Four stroke engine. Note cooling compartments from which heat is recovered. Source: RENAEL

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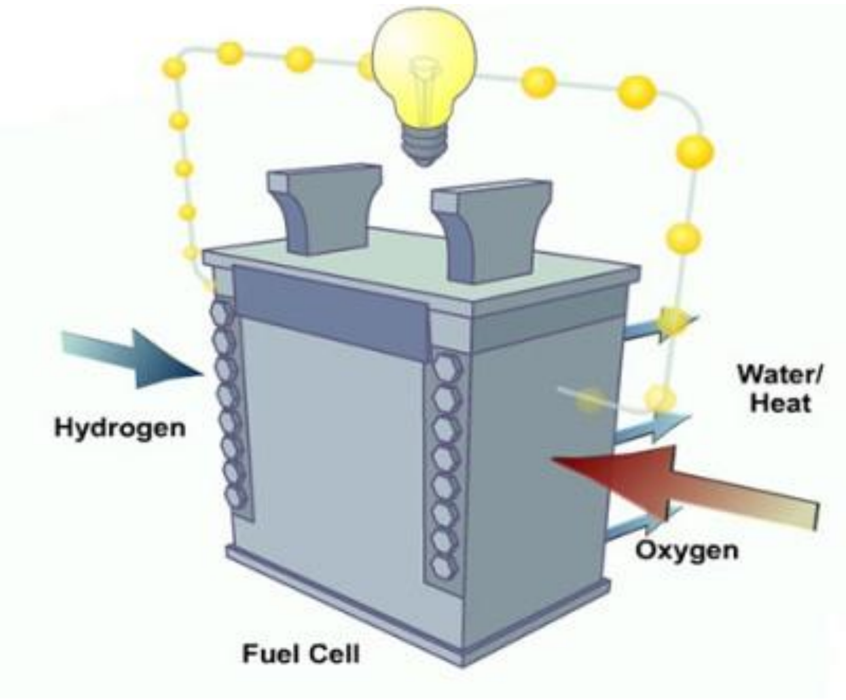
OTHERS USABLE TECHNOLOGIES IN CHP: STIRLING,MICROTURBINES, FUEL CELLS

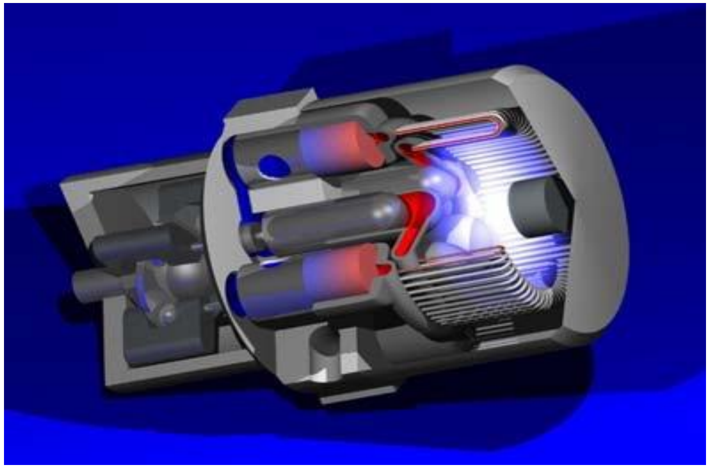
1) Stirling engines
2) Microturbines

Very compact, used in small plants (domestic, buildings), not in industrial processes where is required high power.

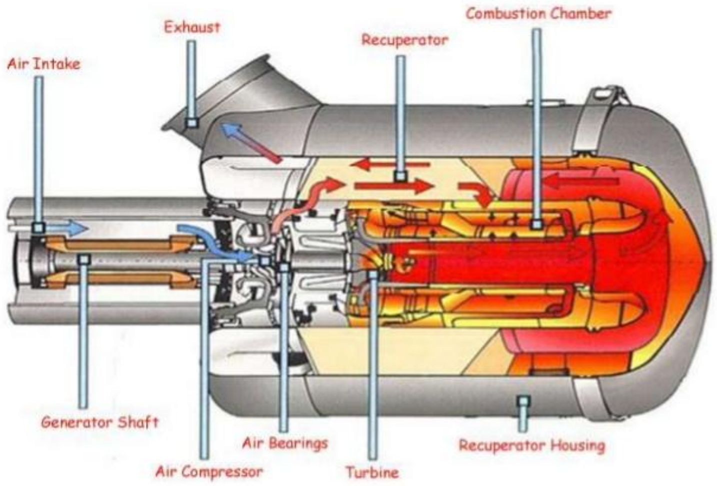
3) Fuel Cell



Fuel Cell. Source: www.iop.org



Stirling engine. Source:RENAEL



Microturbine. Source: www.slideshare.net

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COMPARISON AMONG DIFFERENT CHP TECHNOLOGIES

		Advantages	Constraints	Suitable industries	Cost Capital cost ($/kW) + O&M cost ($/kWh)	Overall efficiency
LARGE-SCALE	**Gas turbine** (500 kW to 350 MW)	• Low emissions • High reliability • No cooling required • High-grade heat available	• Poor efficiency at low loads • Output falls as ambient temperature rises • Requires high-pressure gas or in-house gas compressor	• Chemicals • District energy • Food processing • Oil recovery • Paper/pulp • Refining • Universities • Waste treatment	$1,000 to $1,300 /kW + 0.5 to 1 cent/kWh	75% to 85%
LARGE-SCALE	**Steam turbine** (500 kW to 350 MW)	• High overall efficiency • High reliability • Flexible fuel usage • Long working life • Variable power-heat ratio • Can meet more than one heat-grade requirement	• Slow start up • Cannot attain high power-heat ratio	• Agriculture • Ethanol plants • Lumber mills • Paper/pulp • Primary metals • Refining	$400 to $1,100 /kW + < 0.5 cent/kWh	85% to 90%
LARGE-SCALE	**Reciprocating engine** (100 kW to 5 MW)	• Low investment cost • High power efficiency • Good load following capability • Fast start-up • Easy maintenance	• High maintenance costs • Relatively high emissions • Cooling required • Limited to lower-temperature applications • Loud (low-pitch) noise	• Chemical processing • Dairy farms • Data centers • Food processing • Health care • Office buildings • Universities • Water treatment	$1,100 to $2,200 /kW + 1 to 2 cents/kWh	75% to 90%
SMALL-SCALE	**Fuel cell** (1 kW to 1,200 kW)	• Low emissions • High efficiency • Low noise • Modular design	• High costs • Fuels require processing • Low durability • Low power density	• Backup/portable power • Distributed generation • Material handling • Residential • Transportation	$5,000 to $6,500 /kW + 3 to 4 cents/kWh	60% to 90%
SMALL-SCALE	**Microturbine** (30 kW to 400 kW)	• Low emissions • No cooling required • Compact size	• High costs • Relatively low efficiency • Limited to lower-temperature applications	• Education • Health care • Lodging • Office buildings • Residential • Warehousing	$2,400 to $3,000 /kW + 1 to 2.5 cents/kWh	70% to 85%

Source: NRDC Issue paper Combined Heat and Power Systems:Improving the Energy Efficiency of Our Manufacturing Plants, Buildings, and Other Facilities

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COST AND BENEFITS FOR CHP TECHNOLOGIES

MAJOR BENEFITS OF CHP TECHNOLOGY ARE:

- cost savings for the energy consumer due to higher efficiency;
- lower CO2 emissions;
- reduced reliance on imported fossil fuels;
- reduced investment in energy system infrastructure;
- reduced loss of T&D of electricity due to local production and consumption;
- enhanced electricity network stability through reduction in congestion and ‘peak-shaving’;
- beneficial use of local and surplus energy resources (particularly through the use of waste, biomass,and geothermal resources in district heating/cooling systems);
- possibility to operate the cogeneration systems also in "Stand Alone" mode, reducing the risk of interruption of power supply for network disruption, a condition of fundamental importance in all those contexts where the continuity of the supply of electric energy.

MAJOR COSTS OF CHP TECHNOLOGY ARE:

- presence and closeness of heat users;
- contemporary users;
- flexibility of the system;
- cost of investment.

An example of CHP application

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SOURCES OF THE WEBINAR CONTENTS

- Combined Heat and Power Evaluating the benefits of greater global investment IEA 2008
- Report “L’efficienza energetica come driver per la competitività dell’Industria Alimentare” FEDERALIMENTARE 2015
- Preparatory study on food waste across EU 27 of the European Commission. October (33), 2010
- T. J. Bowser. Food Technology Fact Sheet. FAPC-142. Robert M. Kerr Food & Agricultural Products Center. Steam basics for food processors.
- FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies by the European Commission Framework Programme 2012-2016
- Combined Heat and Power Systems: Improving the Energy Efficiency of Our Manufacturing Plants, Buildings, and Other Facilities authors Vignesh Gowrishankar ,Christina Angelides, Hannah Druckenmiller, NRDC Issue paper, April 2013.
- others

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Thank you for your attention!

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