



Technical analysis of cogeneration projects

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Contents

- **What is Cogeneration?**
- **Available Cogeneration Technologies**
- **Steps of Technical Analysis of Cogeneration Projects**
- **Assessment of Energy Demands (Power, Heat, Cooling)**
- **Assessment of the Available Fuels**
- **Selection of Suitable Cogeneration Technologies**
- **Identification of the Alternative Cogeneration Systems**
- **Sizing of Cogeneration Systems**

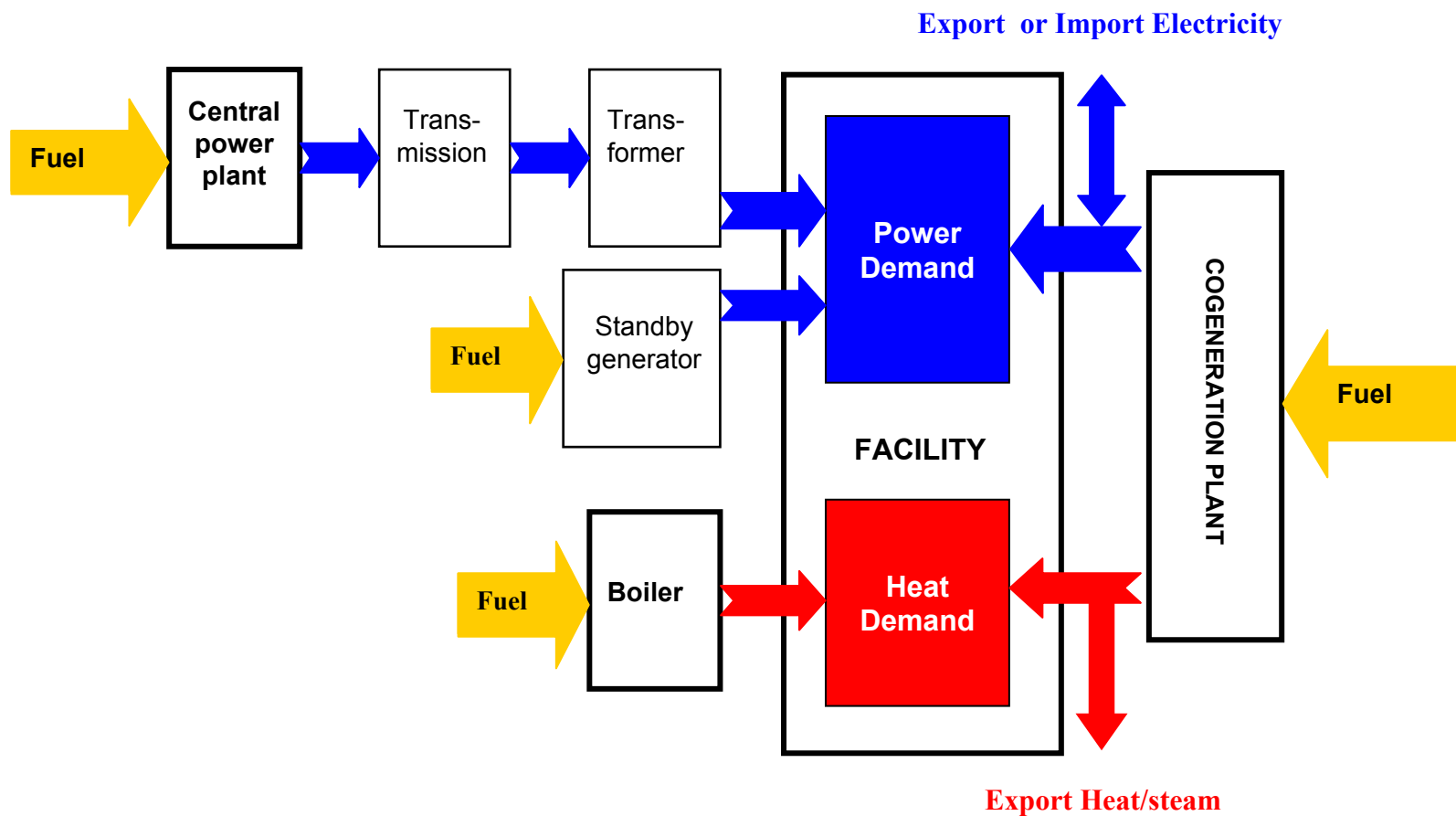


What is cogeneration?

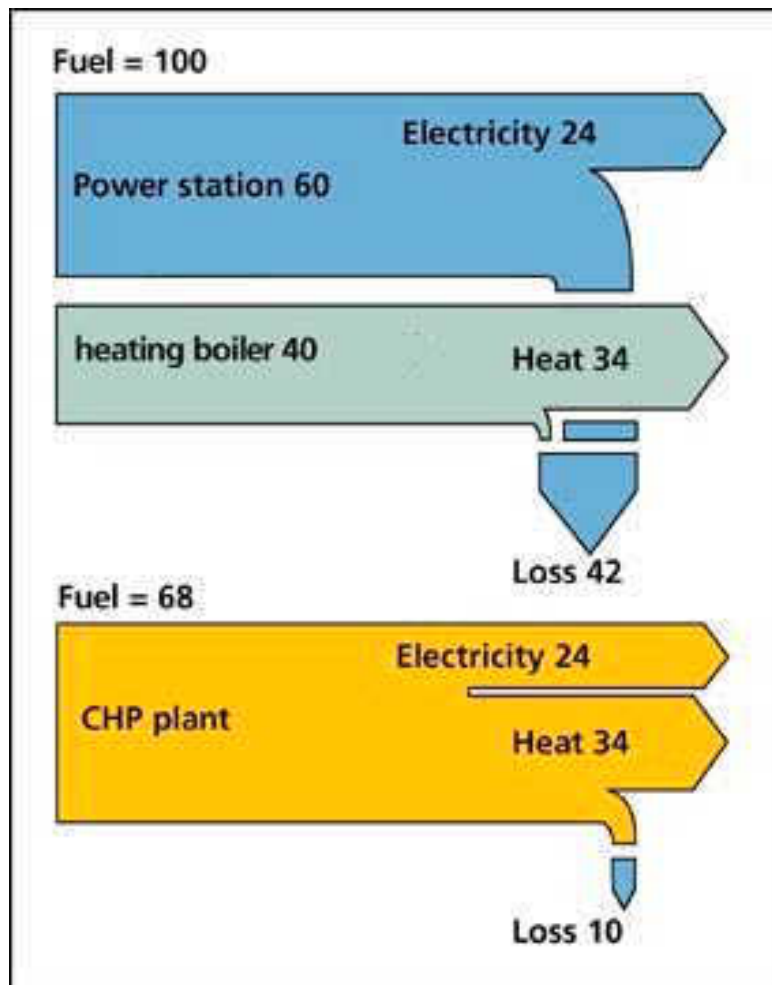
- Cogeneration is the sequential generation of **two** different forms of useful energy in a **single** technology process
- The sequences of generation can be **any** combination of two different forms of useful energy (electricity & heat, mechanical energy & heat, electricity & cooling, etc.)
- **Tri**generation (electricity, heat & cooling)



What is cogeneration?



What is cogeneration?



Benefits of Cogeneration (for the end-users):

1. Saving 30-40% input fuel energy
2. Reducing facility's energy bills
3. Increasing security of energy supply
4. Reducing environmental pollution



Driving Forces for Cogeneration

Why is cogeneration considered & implemented?

- **Electricity requirements: Availability, reliability, quality & cost**
- **Thermal energy requirements: Reliability, quality & cost**
- **Market deregulation: Electricity sale opportunities**
- **Incentives (IPP, SPP, CDM etc.)**
- **Solve waste problems**
- **Environmental requirements**
- **Environment-friendly image**



Available cogeneration technologies

Proven, commercially available cogeneration technologies

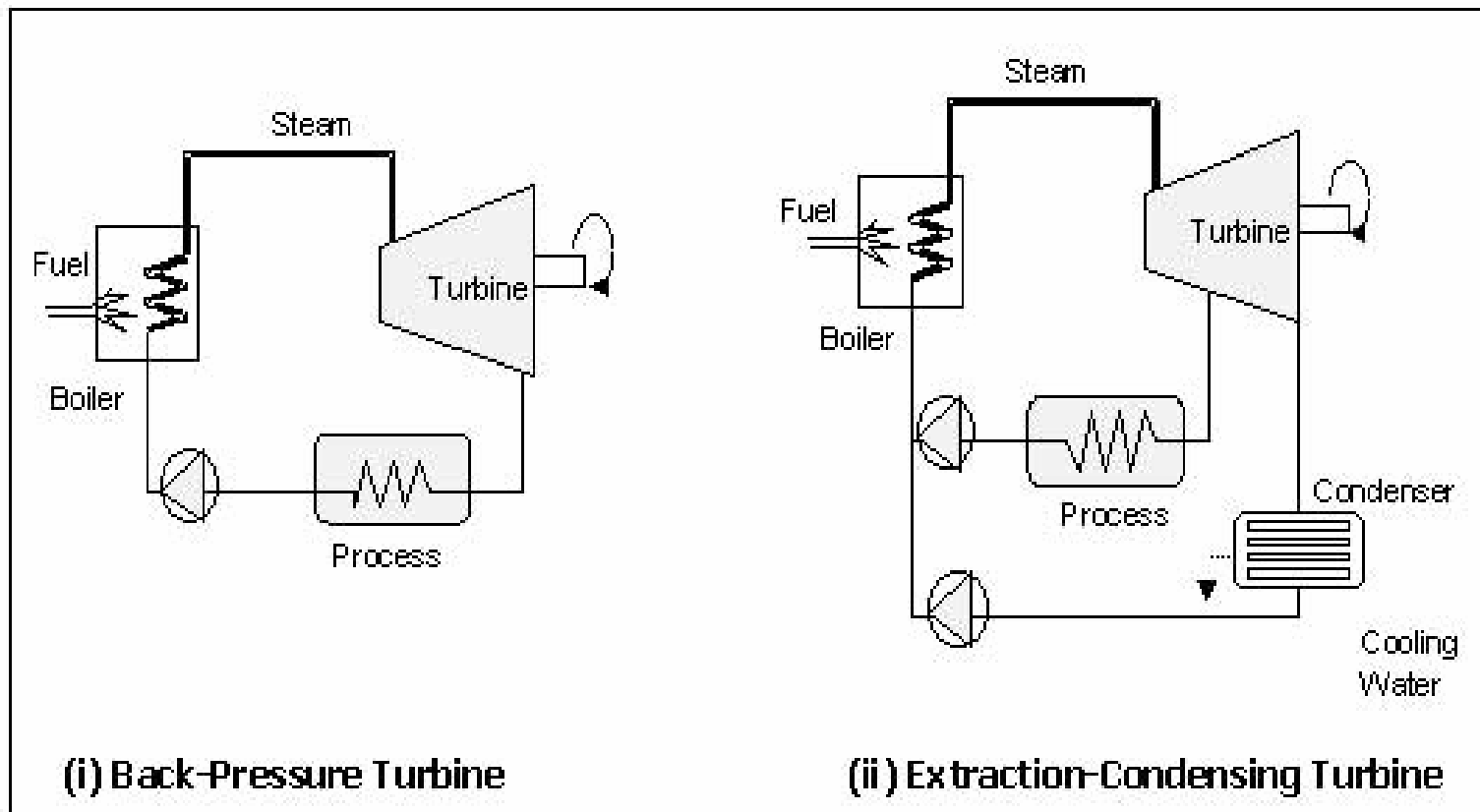
- Steam turbine (ST) cogeneration system
- Gas turbine (GT) cogeneration system
- Combined cycle gas turbine (CCGT) cogeneration system
- Internal Combustion Engine cogeneration system
- Steam Engine cogeneration system

Other “less” commercially available cogeneration technologies:

- Integrated Gasification Combined Cycle (IGCC)
- Micro-turbines
- Fuel cells
- Stirling Engines

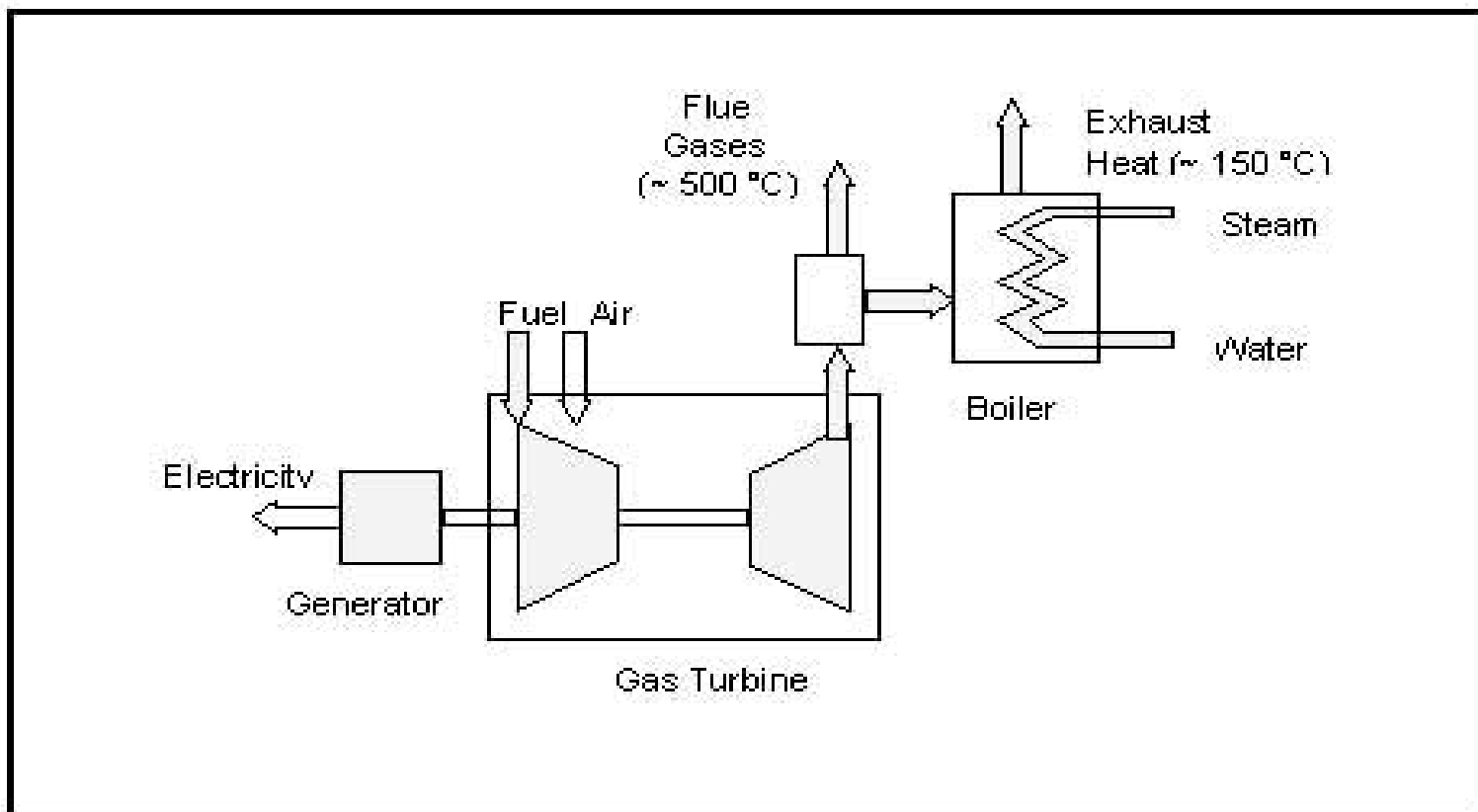


Available cogeneration technologies



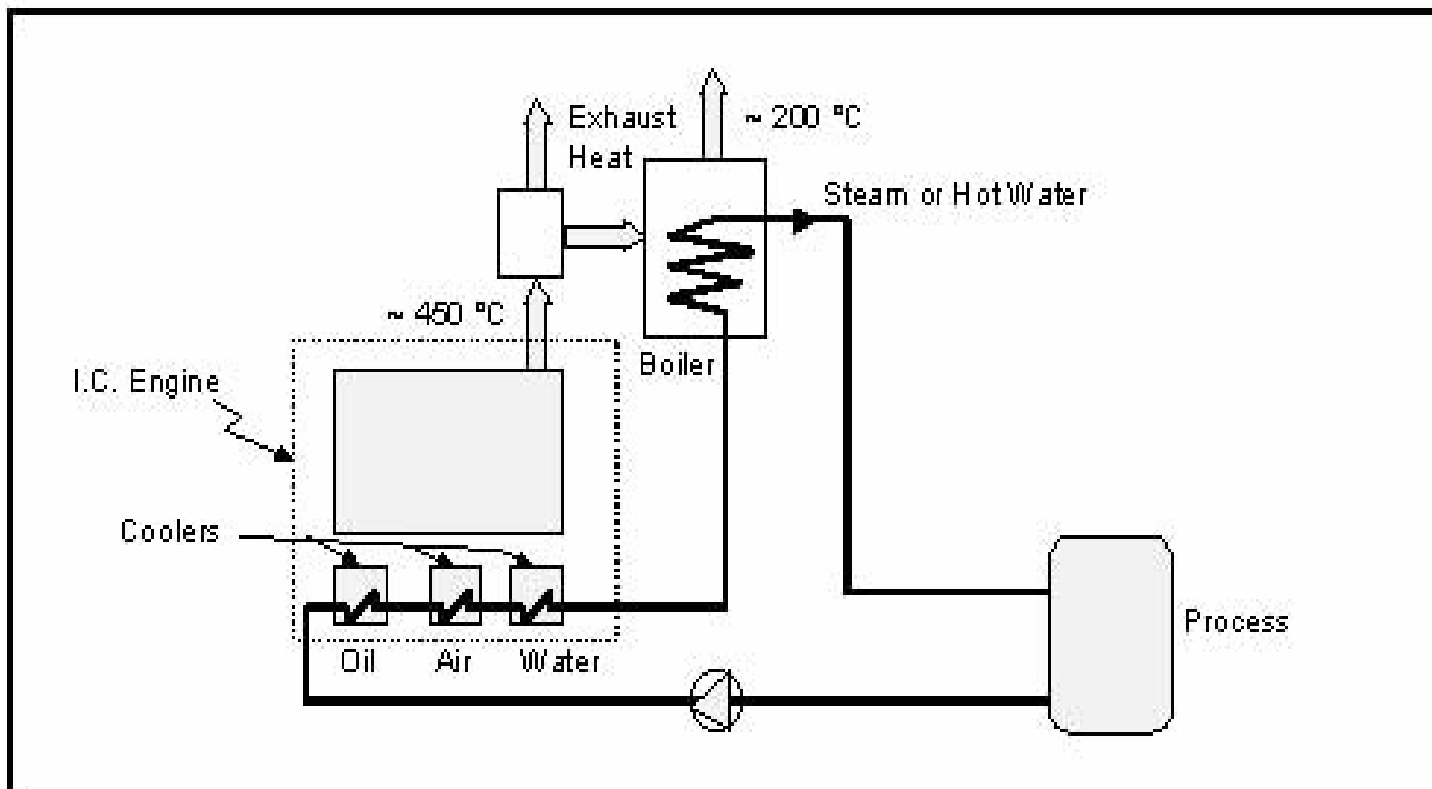
Schematic diagrams of steam turbine cogeneration systems

Available cogeneration technologies



Schematic diagram of gas turbine cogeneration system

Available cogeneration technologies



Schematic diagram of internal combustion engine cogeneration system



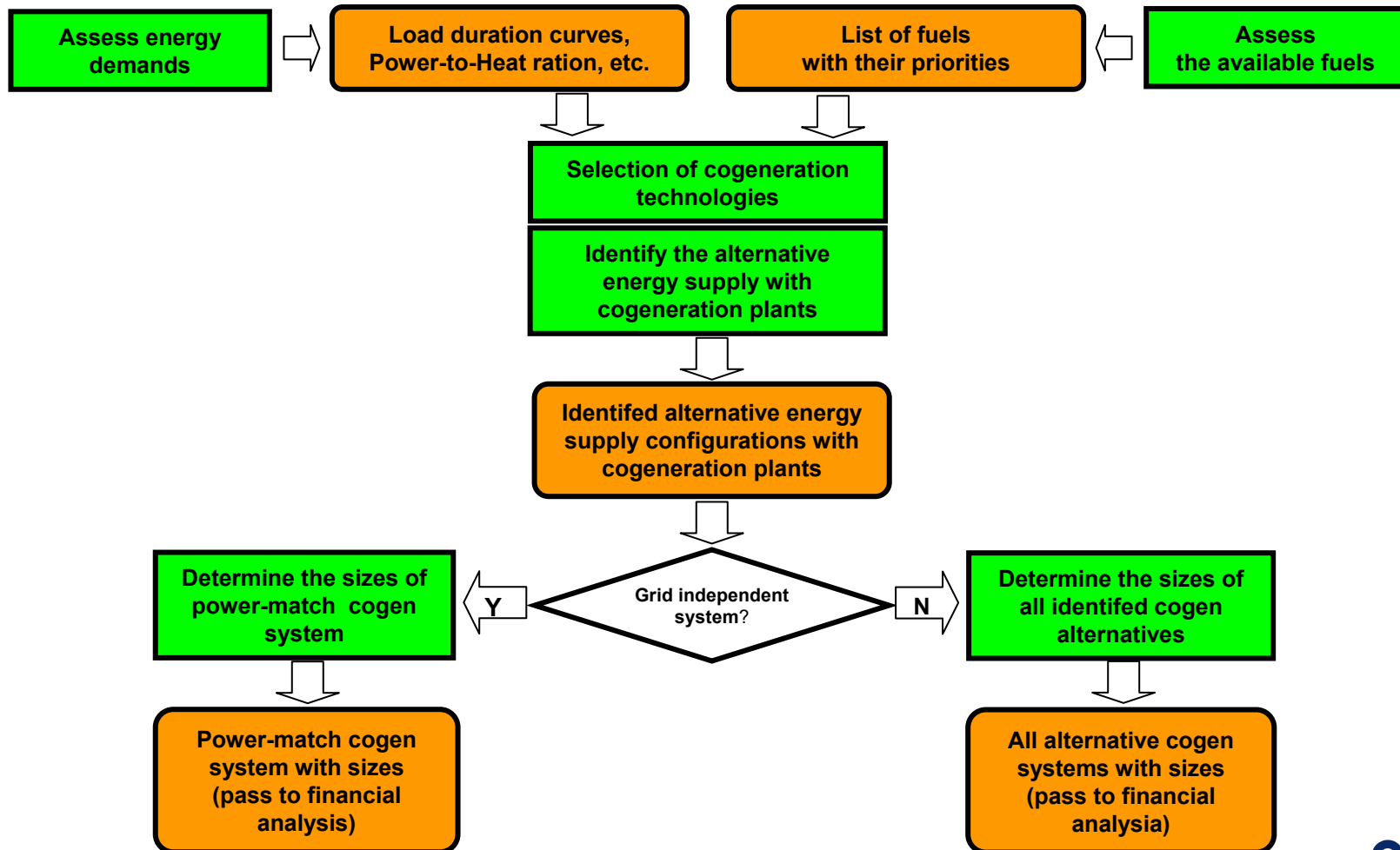
Steps of Technical Analysis

The tasks of Technical analysis of cogeneration projects:

- To select the suitable technologies for your proposed cogeneration plant
- To identify the possible alternatives of energy supply systems with cogeneration plant
- To determine the sizes of the selected cogeneration plants, i.e. the main technical input data needed for further financial analysis of cogeneration project



Steps of Technical Analysis





Assessment of energy demands (1)

Energy Demands: how much? and when?

What should be defined?

- Electricity demand
- Thermal energy/steam demand
- Cooling demand

How to define the energy requirements?

- Energy audit done by consultant
- Own mapping and prediction

Should be considered:

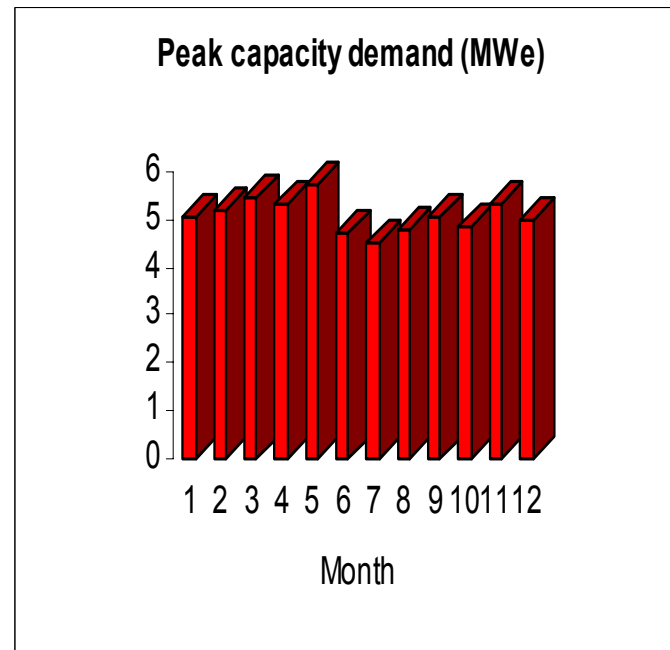
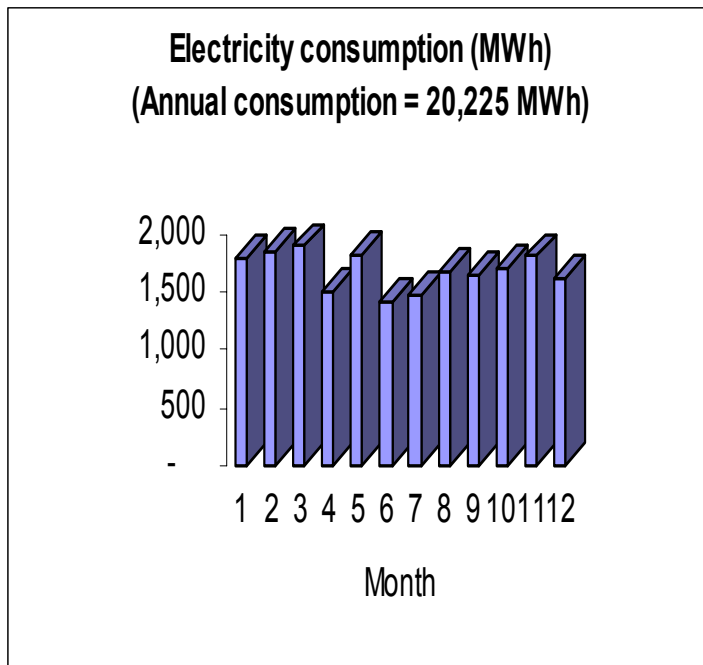
- Possible savings, process changes, process integration etc.
- Future energy requirements





Assessment of energy demands (2)

Electricity Demand



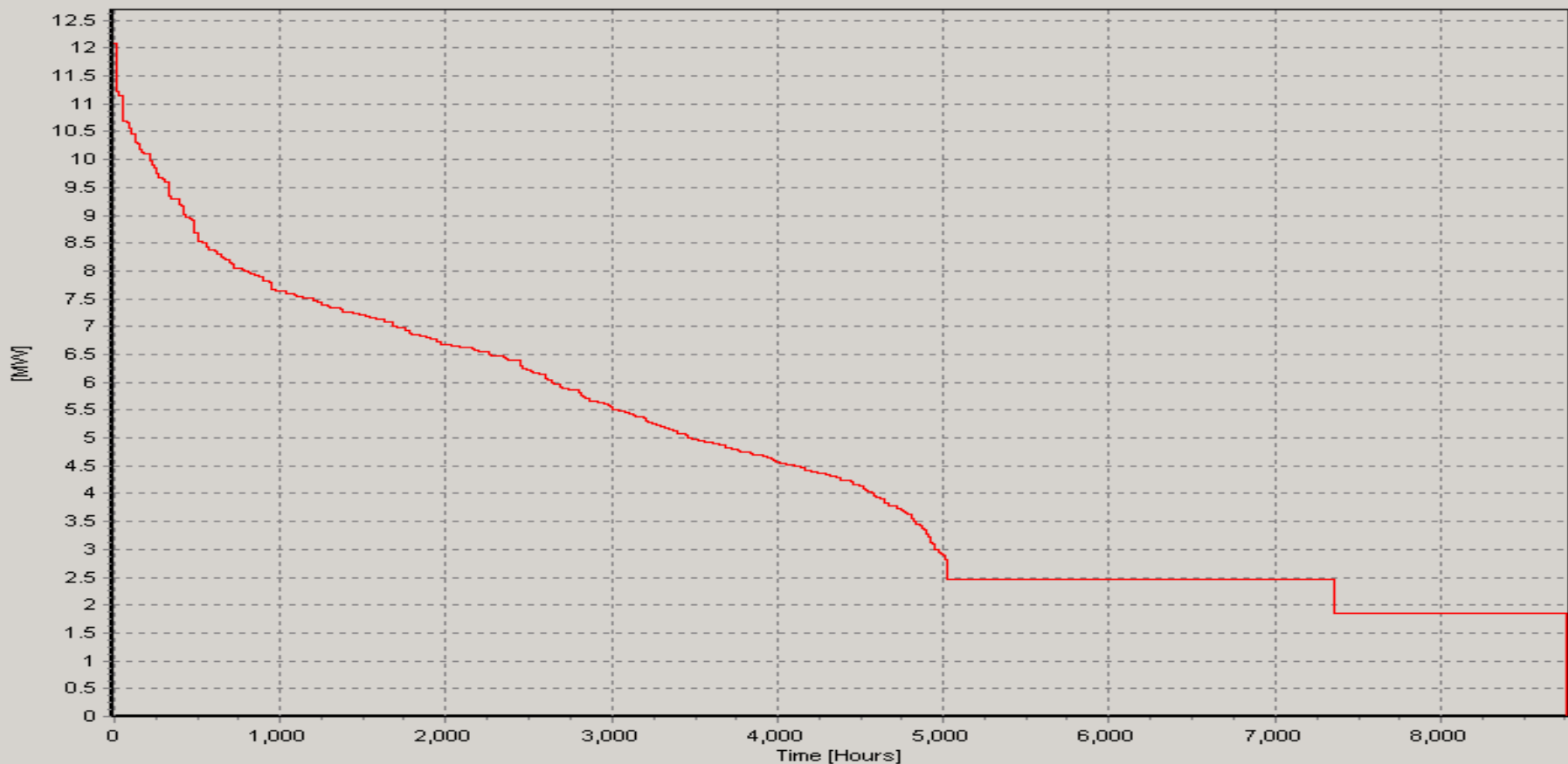


Assessment of energy demands (3)

ory, Income statements for an energy plant, ACCOUNTS (Modified) (Calculated)

Show heat productions

Duration curve for heat demand
(January 1, 2003 to January 1, 2004)





Assessment of available fuels

The assessment is mainly based on:

- Long term availability of fuel
- Adherence to the local environmental regulation
- Fuel price and its expected escalation

The result of fuel assessment is a list of the available fuels and their relative priorities





Selection of cogeneration technologies

Sector	Plant size	Coal + products	Gas	Heavy fuel oil	Light fuel oil	Biomass	Wastes	Biogas
Domestic	< 15 kW _e		GE		GE			GE
Commercial	15-100 kW _e		GE		GE	ST	ST	GE
	100kW _e -1MW _e		GE		GE	ST	ST	GE
	1-5 MW _e	ST	GT/GE	ST	GT/GE	ST	ST	GT/GE
Industry	1-5 MW _e	ST	GT/GE	ST	GT/GE	ST	ST	GT/GE
	5-50 MW _e	ST	OCGT	ST	OCGT	ST	ST	OCGT
	> 50 MW _e	ST	CCGT	ST	CCGT	ST	ST	CCGT

Notes: CCGT: Combined cycle gas turbine

GE: Gas engine

GT: Gas turbine

OCGT: Open cycle gas turbine

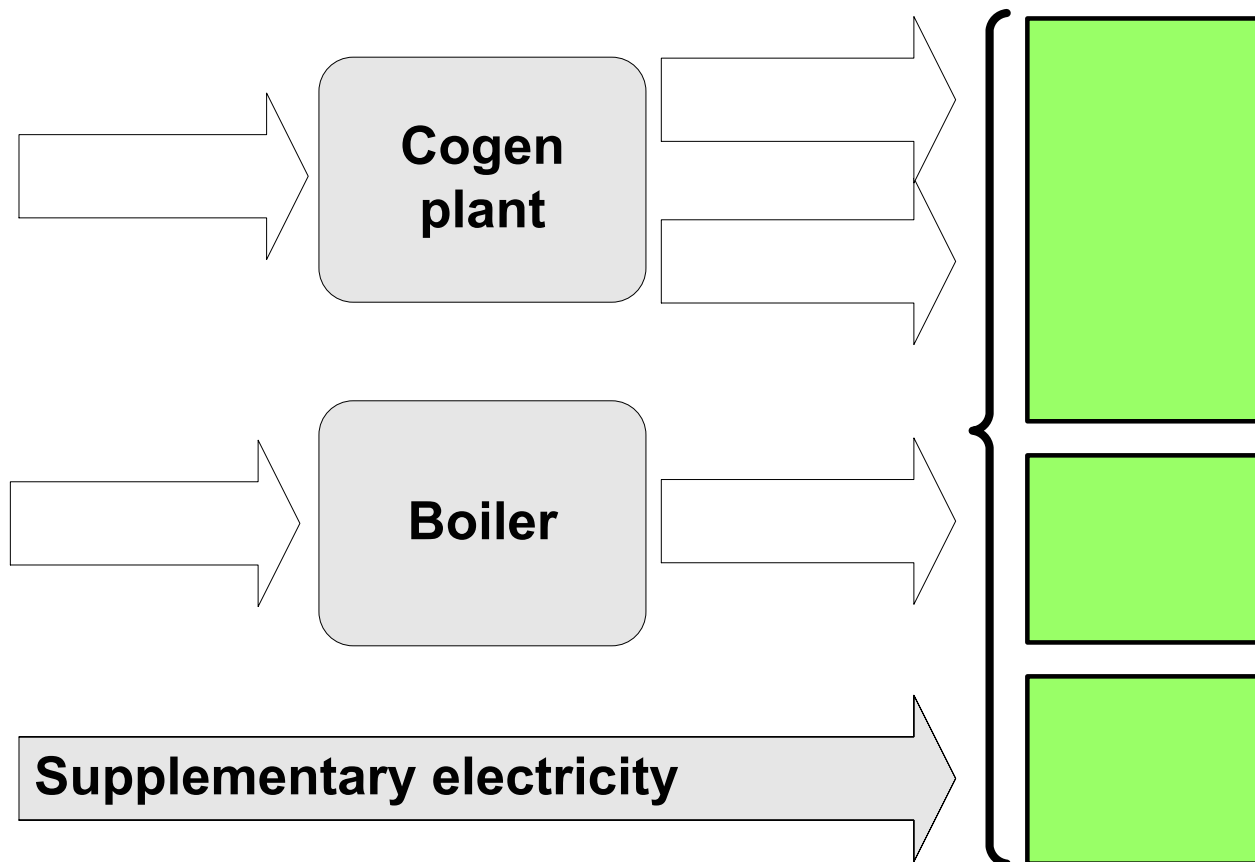
ST: Steam turbine

Source: The Future of CHP in the European Market – The European Cogeneration Study, SAVE/Future COGEN, May 2001





Alternatives of energy supply with cogeneration plant (1)





Alternatives of energy supply with cogeneration plant (2)

Baselines:

Current energy supply: Existing boiler with low efficiency and electricity from grid

Other baseline alternative: New boiler with high efficiency and electricity from grid

Cogeneration alternatives:

Alternative 1: Cogeneration covering host facility energy use

Alternative 2: Cogeneration covering partially host facility's energy use and supplementary energy supply

Alternative 3: Cogeneration covering host facility energy use and export

Systematic approach needed to find optimal solution!



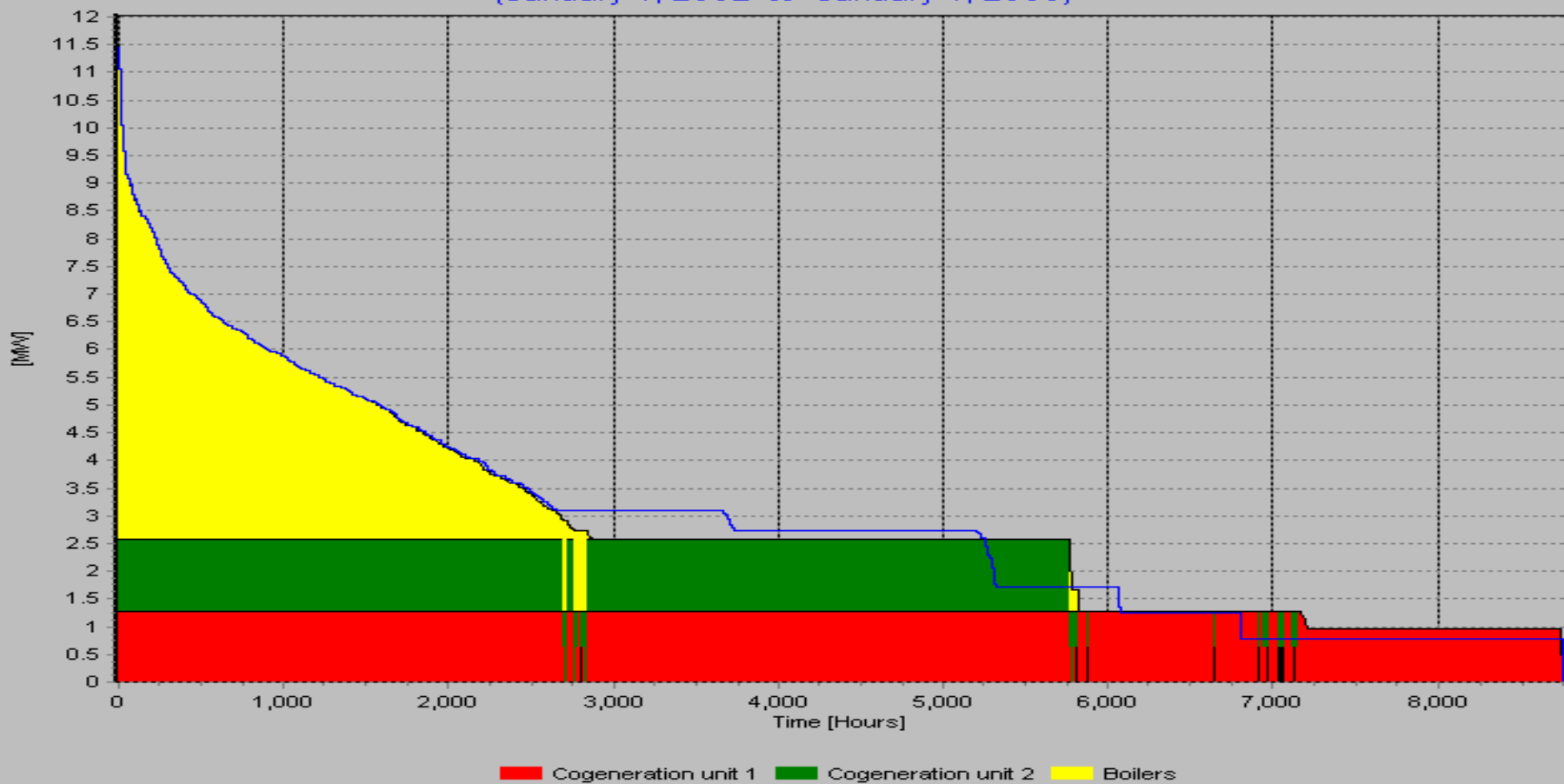
Example (1)

[Modified] [Calculated]

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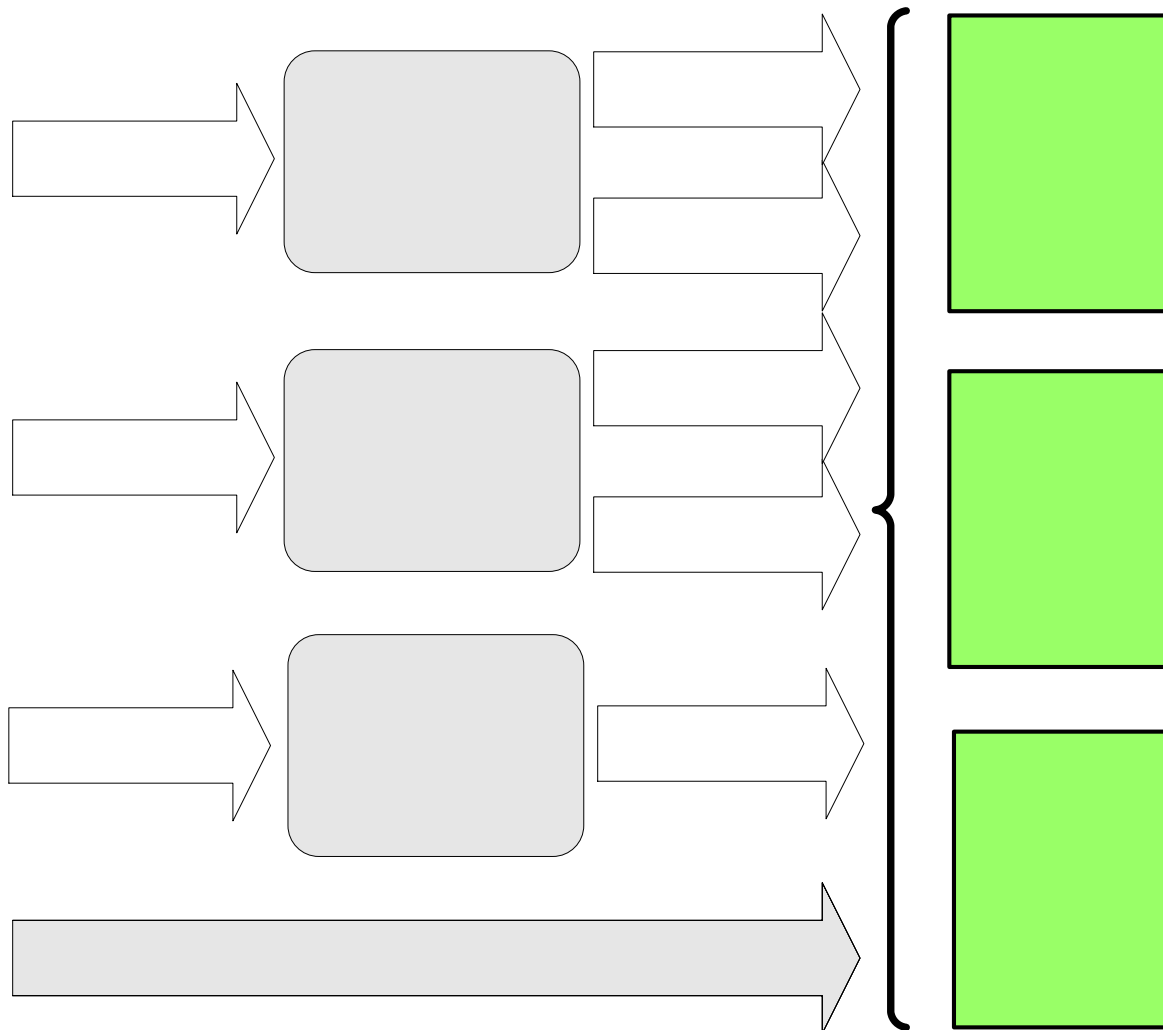
 Show heat productions

Duration curve for heat demand
(January 1, 2002 to January 1, 2003)





Example (2)



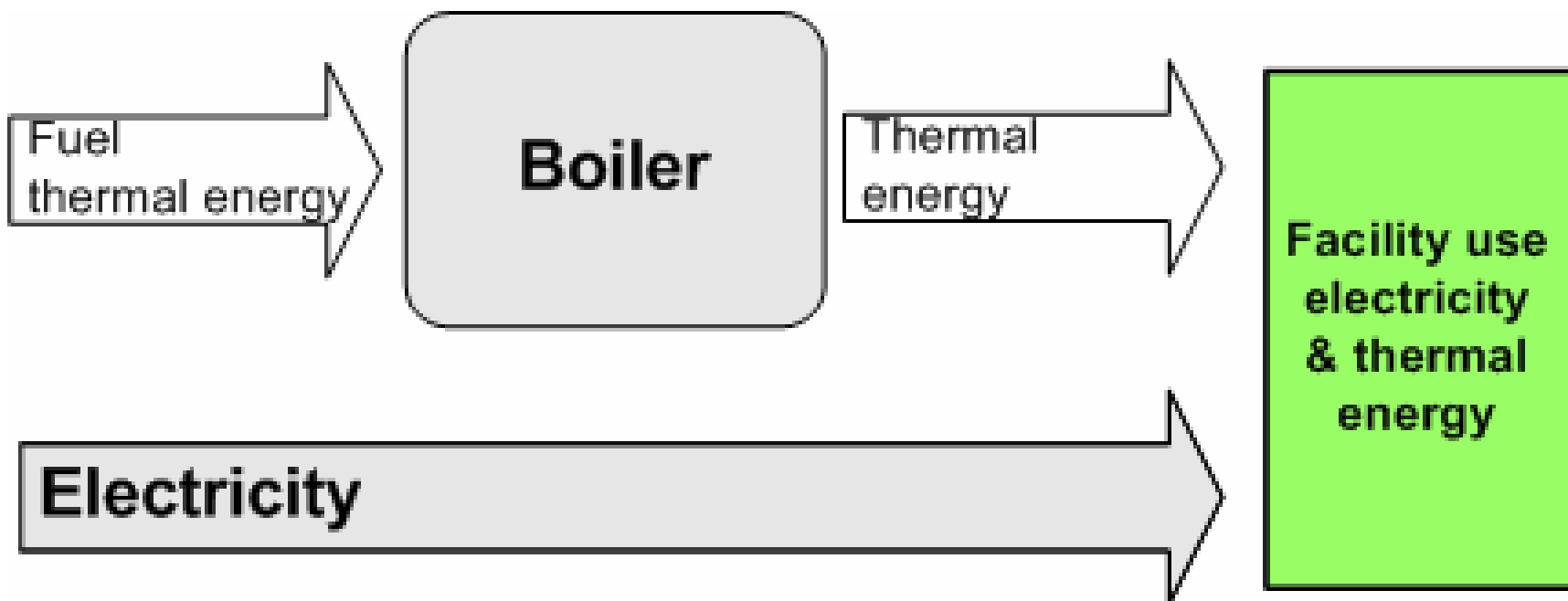


Sizing of cogeneration systems (1)

- Energy flows analysis
- Determination of the capacities of key equipment (steam boiler, turbines, engines, generator,...) of the cogeneration system
- Calculation of the fuel amount needed for cogeneration system

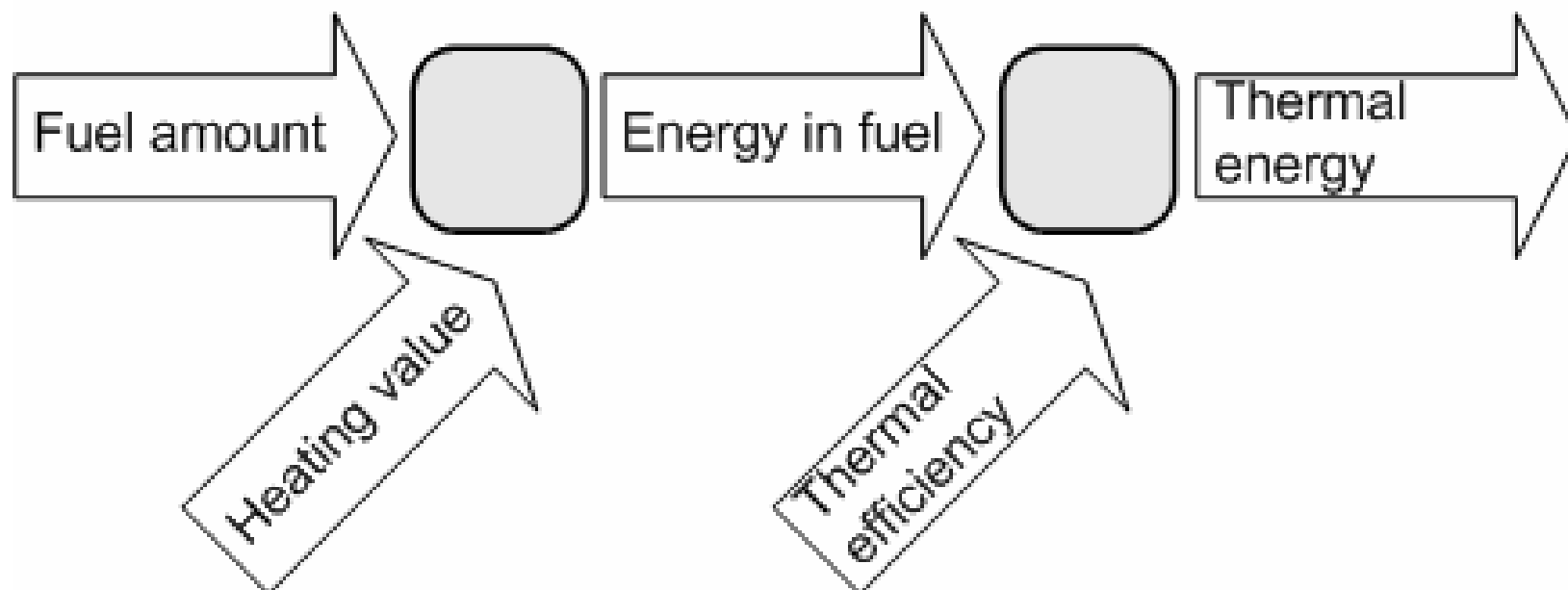


Sizing of cogeneration systems (2)



Sizing of cogeneration systems (3)

Boiler





Sizing of cogeneration systems (4)

How to calculate the energy flows:

$$\text{Energy in Fuel} = \frac{\text{Thermal Energy Output} - \text{Energy in Feedwater}}{\text{Boiler Efficiency}}$$

$$\text{Fuel Amount} = \frac{\text{Energy in Fuel}}{\text{Fuel Heating Value}}$$





Sizing of cogeneration systems (5)

Fuel type	LHV (MJ/kg)	Moisture content (%)	Mineral content (%)
Coal Anthracite	34.9	3	7-9
Bituminous	24.4-36.1	3-5	6-8
Sub-bituminous	19.3-26.7	15-30	3.5-5
Lignite	14.6-19.3	30 up	6-8
Peat	< 7.0	Up to 70	-
Natural gas	46.5-53.5 MJ/m ³		
Biogas	20.0-26.0 MJ/m ³		
Rice husk	13.2	12	20
Bagasse	7.8	50	3-4
Palm oil residues	7.2-17.3	10-60	
Wood Residues	11.4	30	1-2

Source: COGEN 3 Cogeneration Project Development Guide - 2002



Sizing of cogeneration systems (6)

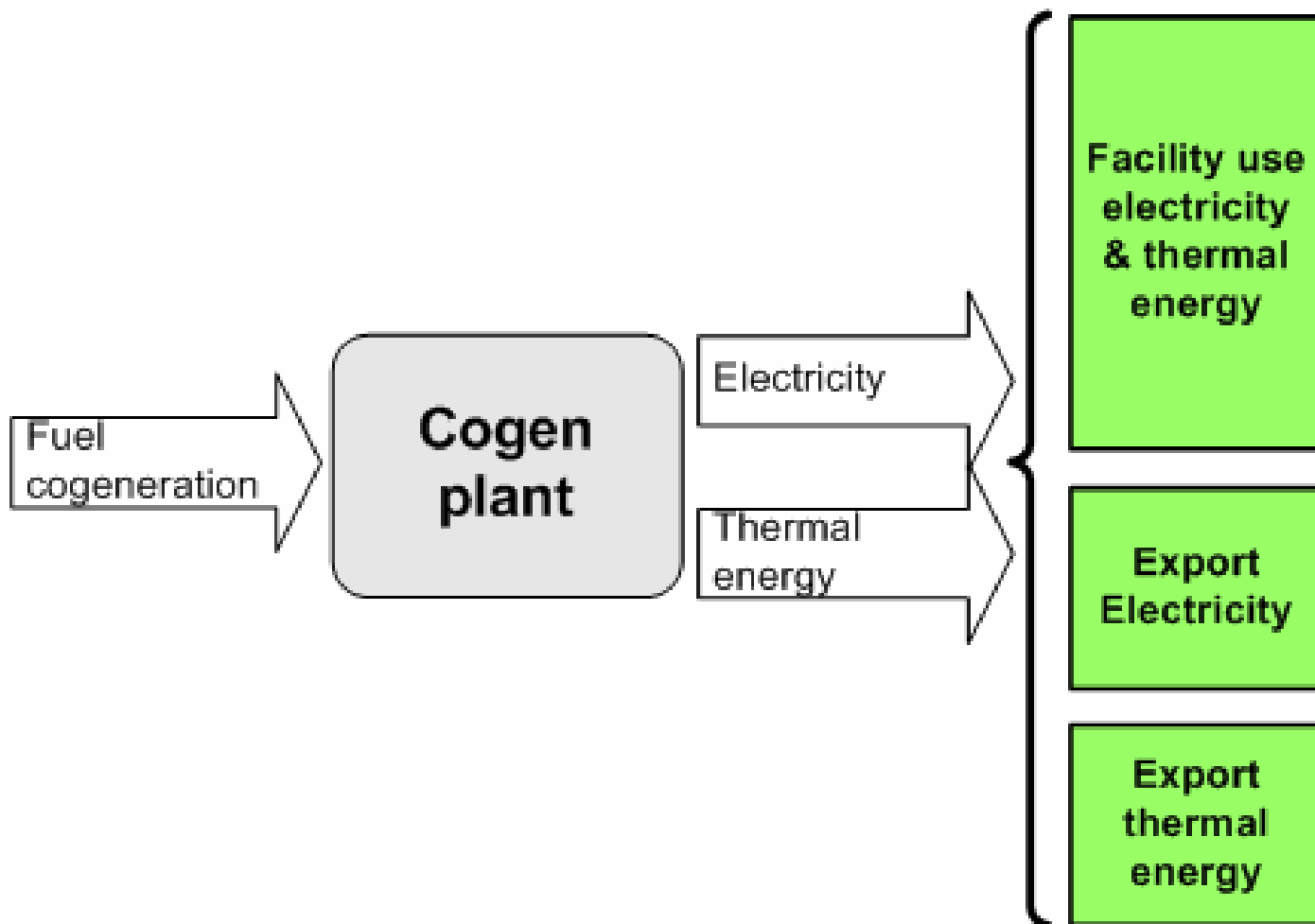
Fuel type	Boiler type	Typical Boiler efficiency (%)
Coal	Grate Boiler, Pulverized, Fluidized Bed	75 – 90
Gas Biogas		85 – 90 ⁺ 85 (*)
Biomass Palm oil wastes Rice husk Sugar bagasse Wood wastes	Grate Boiler, Fluidized Bed	65 – 85 80 – 85 (*) 76 – 85 (*) 80 – 90 (*) 73 – 80 (*)

(*) – Suppliers' data from Full Scale Demonstration Projects applications

Higher Steam Parameters (Steam pressure, temperature) → Lower boiler efficiency

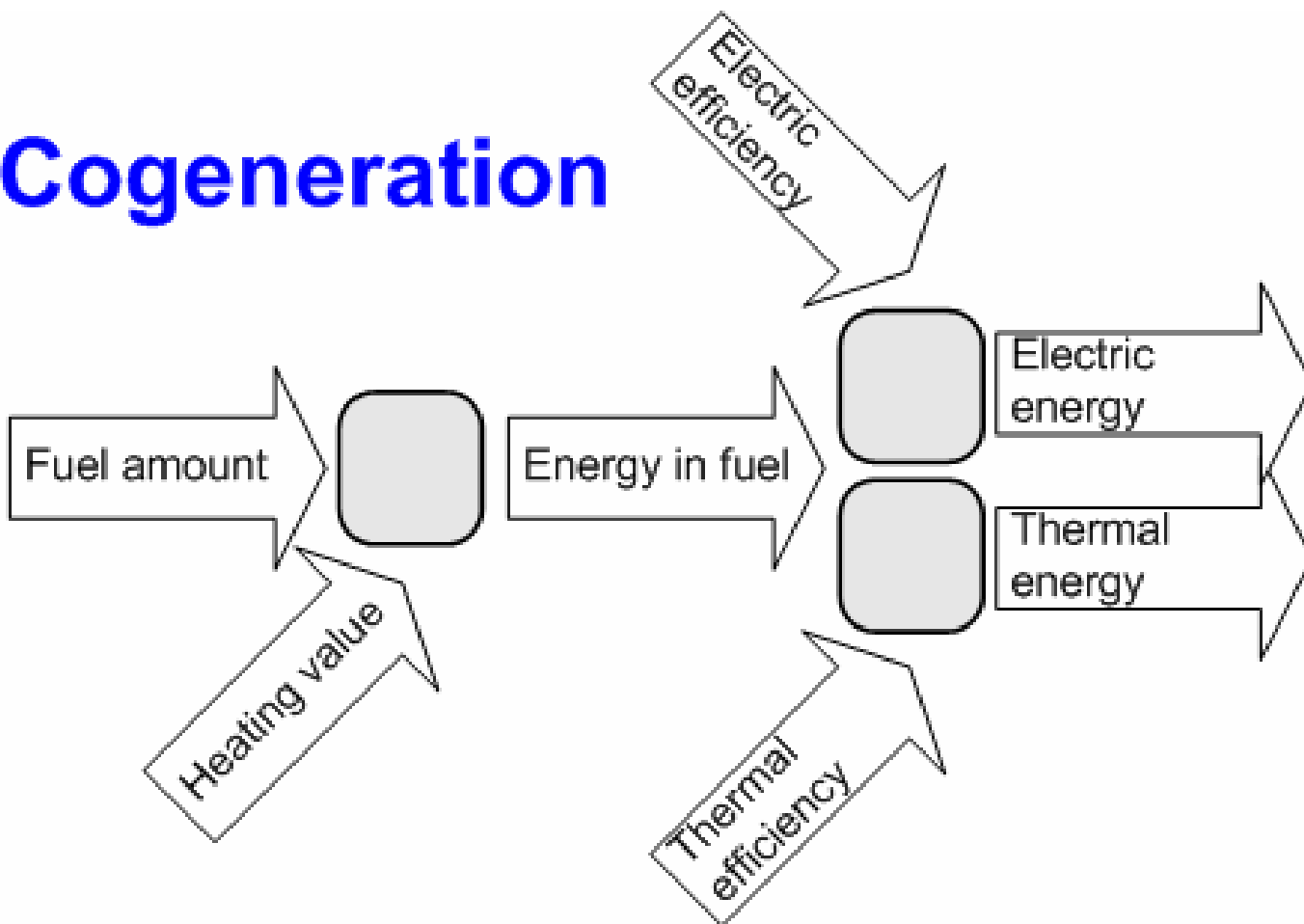
Higher steam capacity → Higher boiler efficiency

Sizing of cogeneration systems (7)



Sizing of cogeneration systems (8)

Cogeneration





Sizing of cogeneration systems (9)

How to calculate the energy flows:

$$\text{Energy in Fuel} = \frac{\text{Electric Energy Output}}{\text{Cogen Electric Efficiency}} = \frac{\text{Thermal Energy Output}}{\text{Cogen Thermal Efficiency}}$$

$$\text{Fuel Amount} = \frac{\text{Energy in Fuel}}{\text{Fuel Heating Value}}$$

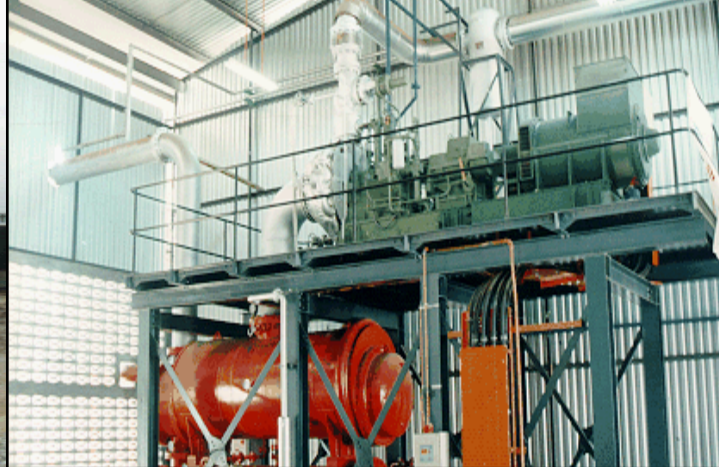
$$\text{Electric Efficiency} + \text{Thermal Efficiency} = \text{Overall Efficiency}$$



Sizing of cogeneration systems (10)

System	Range	Cogen Electrical Efficiency (%)	Typical Overall Efficiency (%)	Typical Power to Heat Ratio (PHR)
Steam turbine	0.4-300 MW _e	10-45	< 80%	0.15 – 0.75
Gas turbine	0.5-300 MW _e	25-40	65-90%	0.45 – 0.75
Combined cycle	10-300 MW _e	35-50	75-90%	0.75 – 1.70
Internal Combust Engine	1 kW _e -15 MW _e	25-45	65-85%	0.50 – 1.80
Steam engine	20 kW _e -2 MW _e	5-25	70-80%	0.10 – 0.45
Micro turbine	25-250 kW _e	25-30	50-80%	0.55 – 0.75

Source: COGEN 3 Technical Report – Available Cogeneration Technologies in Europe – Part I





For more information,
please visit COGEN 3 Website at:

<http://www.cogen3.net>

Thank You !