



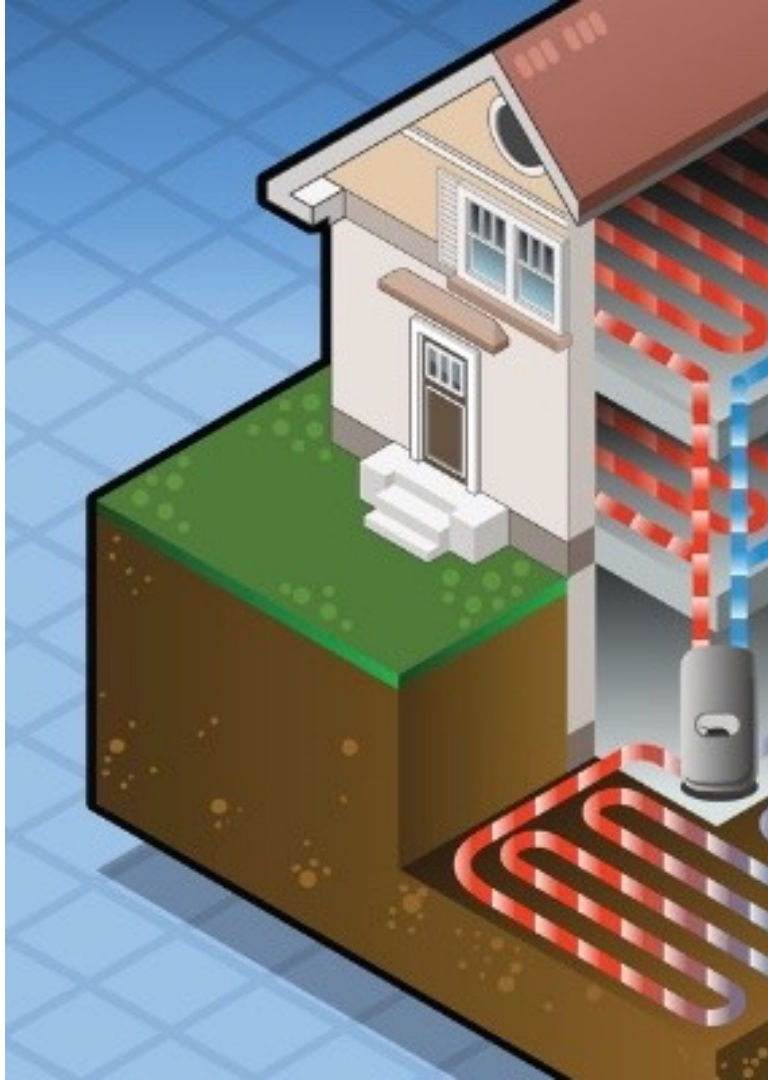
Cogeneration

Tuong-Van Nguyen
EPFL – IPESE

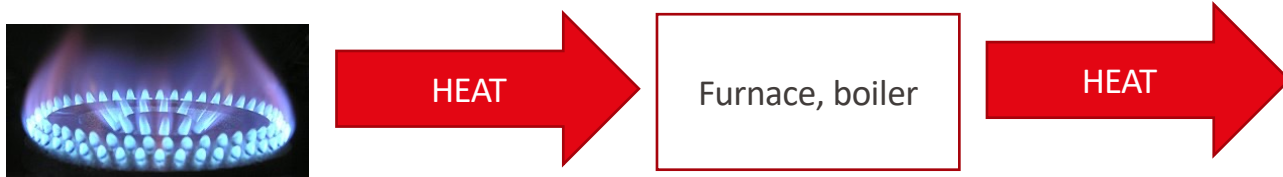
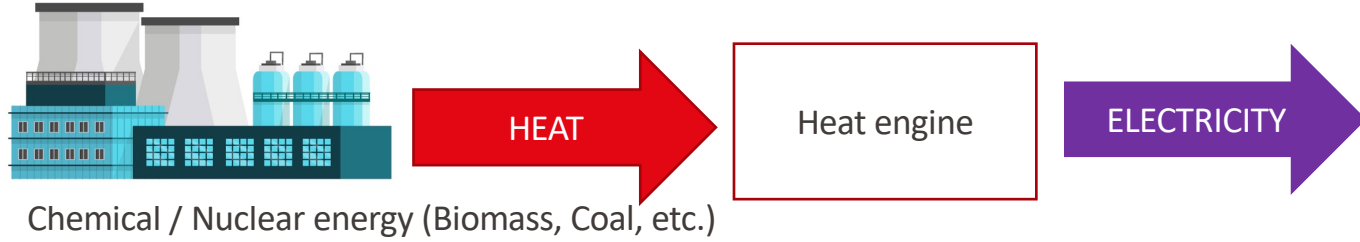
Lausanne, 28/10/2024

- **Describe** the working principle of *cogeneration*
- **Explain** how cogeneration can replace conventional technologies
- **Estimate** the potential savings (energy, costs and environmental)

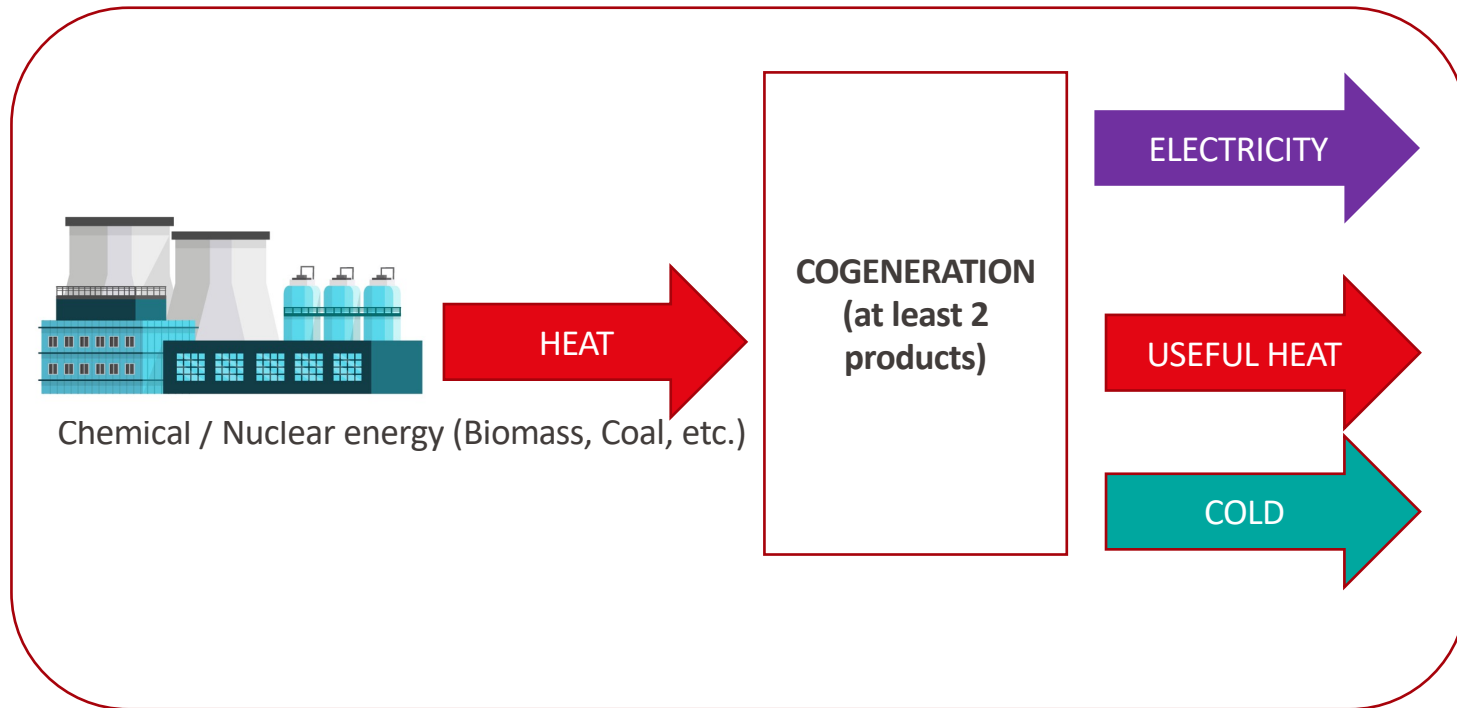




Principle



- Cogeneration : production of two useful energy outputs instead of one



Principle

A standard power plant

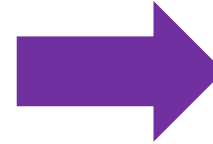
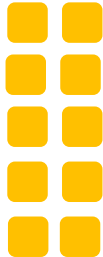
- Power generation

$$\eta = 40\%$$

FUEL

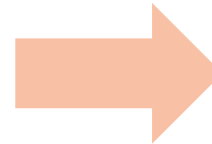
(Coal, uranium...)

100%



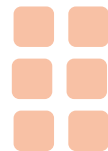
ELECTRICITY

40%



WASTE HEAT

60% (40°C)



Principle

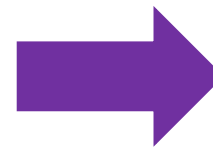
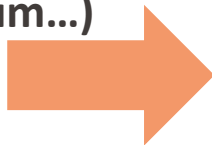
A power plant with cogeneration

- Combined heat and power generation

FUEL

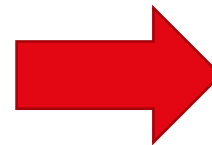
(Coal, uranium...)

100%



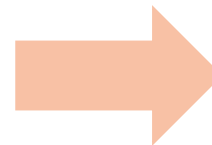
ELECTRICITY

35%



USEFUL HEAT

45% (150°C)



WASTE HEAT

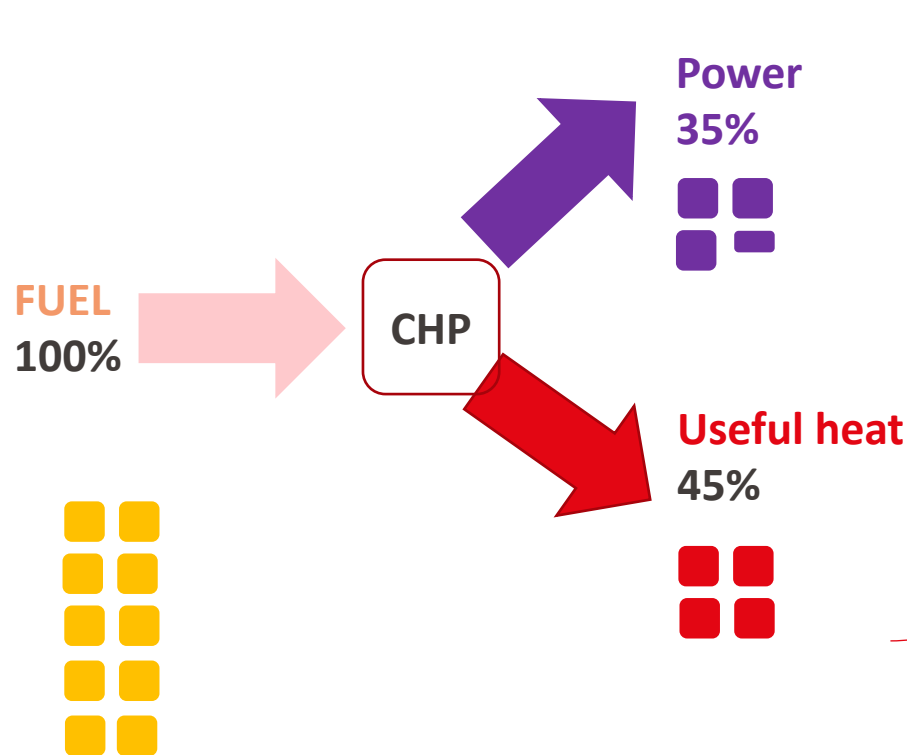
20% (40°C)



Principle

Performance indicators

- Combined heat and power generation



$$\eta_{el} = \frac{W^-}{Q^+}$$

$$\eta_{th} = \frac{Q_{useful}^-}{Q^+}$$

$$\varepsilon = \eta_{th} + \eta_{el}$$

Electrical efficiency: 35-60%

Heat production efficiency: 35-45%

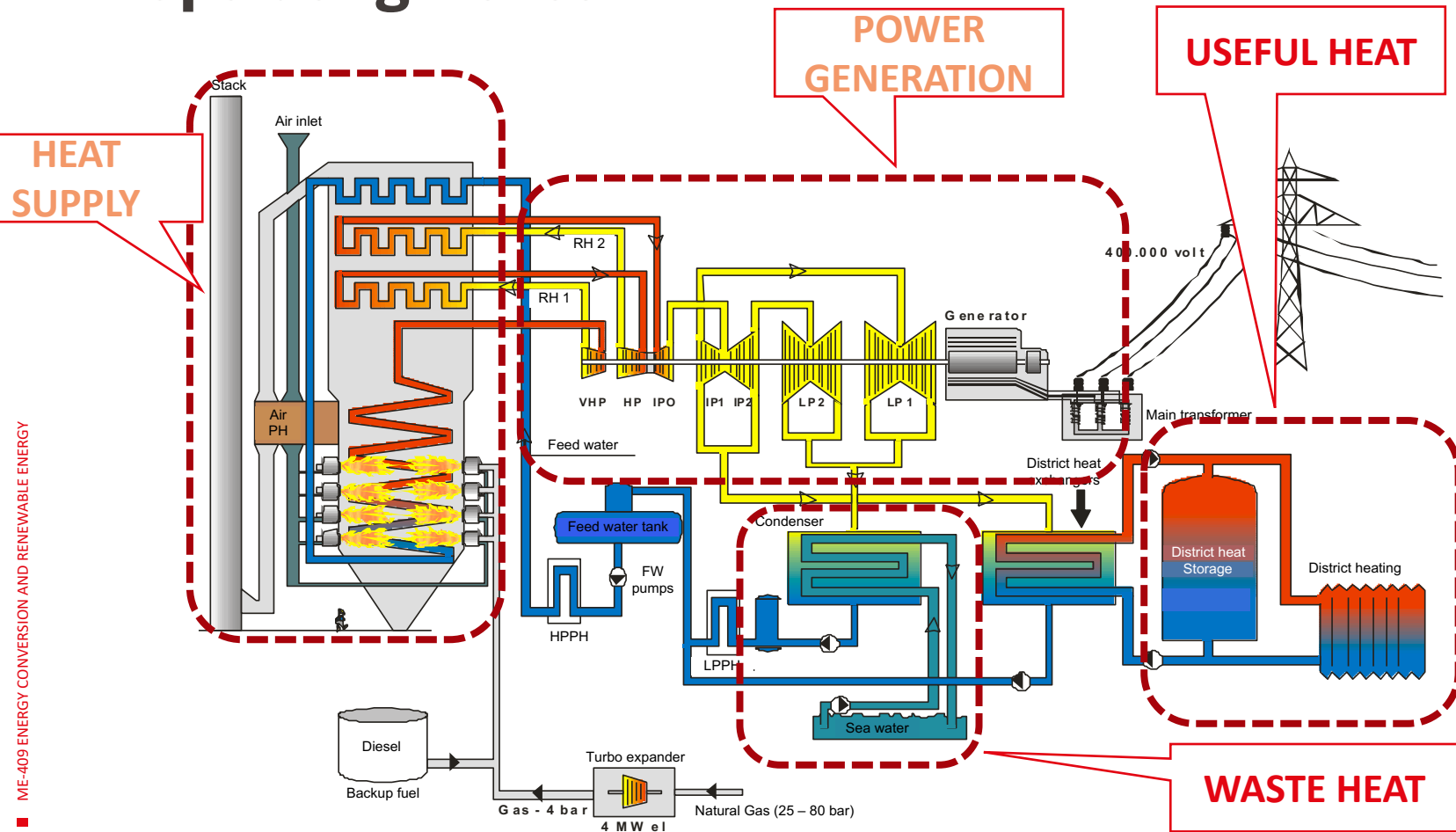
Utilization factor

$$\varepsilon = 80\%$$

Work
output

Useful
heat
output

Operating modes



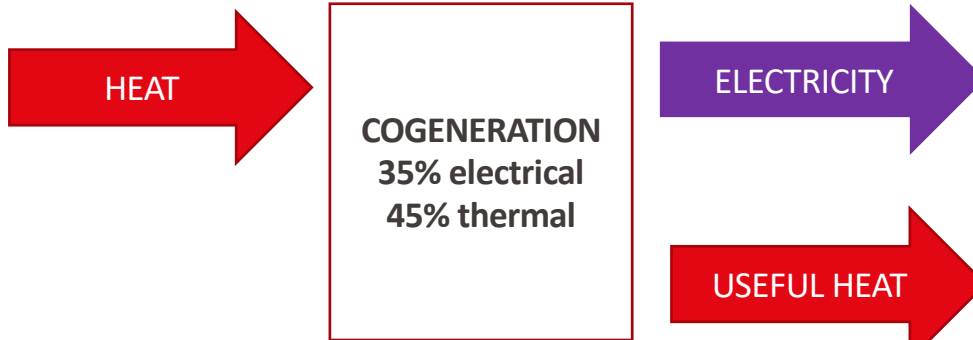
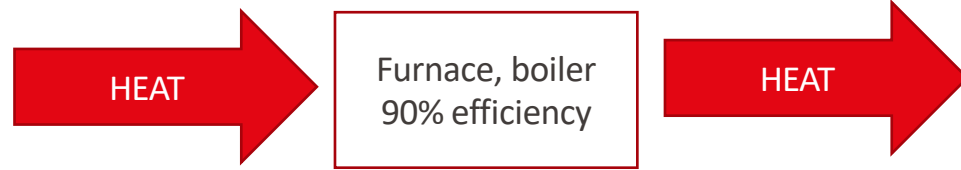
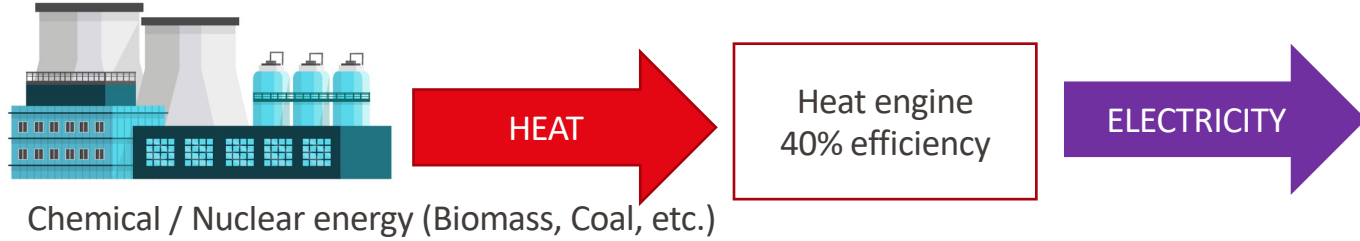


Benefits

Substitution

Marginal efficiencies

Substitution : how much *primary* energy do we save

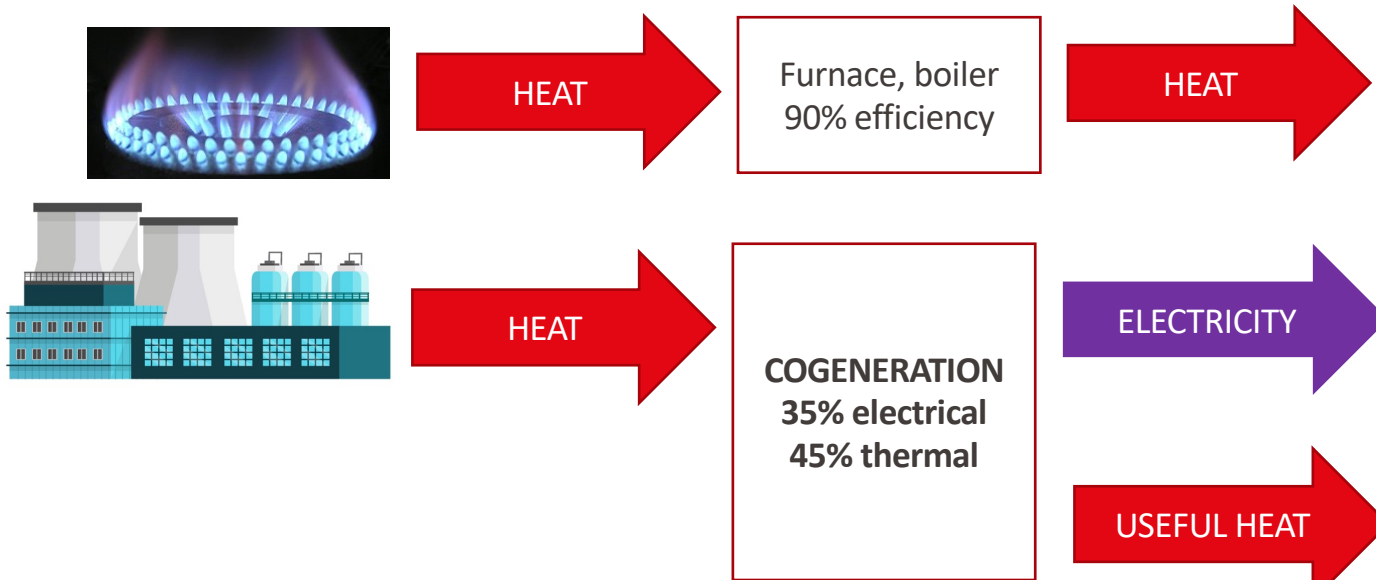


Marginal efficiencies

Electricity production

- How much extra primary energy do we spend with a cogeneration unit, compared to a boiler, for the benefit of **producing electricity** ?

Chemical / Nuclear energy (Biomass, Coal, etc.)



GROUP QUESTION (2 ppl., 10 mins)

A typical Swiss family living in an old building needs, per year, 4'000 kWh electricity and 18'000 kWh heat. It uses a gas boiler for heating with 90% efficiency and consumes electricity from the grid, produced with an average efficiency of 40%.

- *How much primary energy is required to satisfy the energy demand of the house?*



A small cogeneration unit with 35% electrical efficiency and 45% heat production efficiency is implemented in the building. It is designed to fully satisfy the heating needs (same heat production as the boiler).

- *How much electricity is produced in excess?*
- *How much primary energy is needed for the house?*
- *Considering that the produced electricity replaces some electricity on the grid, how much primary energy is saved in total?*



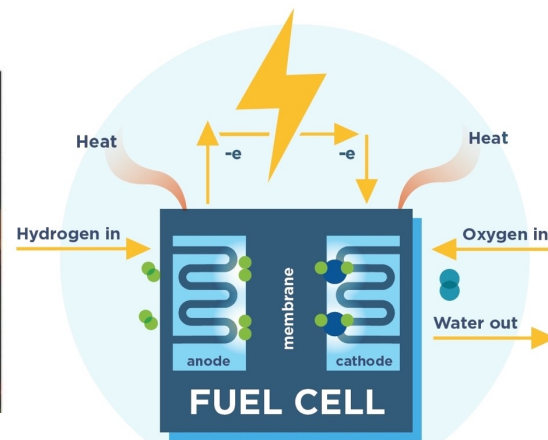
Types of plants

Applications

Uses

Types

- Gas turbines/engines
- Biofuel engines
- Advanced steam cycles
- Combined cycles (gas)
- Fuel cell systems



	Typical capacity	electrical	Suitable fuel types	Electrical efficiency (%)	CHP efficiency (%)	Power to heat ratio
Mature technologies						
ICE	5 kWe – 1 MWe		Natural gas, oil, biogas, bio-oil	25 – 45	80 – 95	1:1.1
Emerging technologies						
Fuel cells	1 kWe – 1 MWe		Natural gas, biogas	30 – 40	90 – 95	1:1
Micro gas engine	<5 kWe		Natural gas, oil, biogas, bio-oil	20 – 30	85 – 90	0.3 – 0.5
Micro gas turbine	1 – 100s kWe		Natural gas, oil, biogas, bio-oil	10 – 25	80 – 90	0.1 – 0.5
Stirling engines	1 – 100 kWe		Any	15 – 30	80 - 90	0.2 – 0.5

- Large-scale applications



Large-scale units and power plants
(> 10 MW) for cities and industries

- Small-scale applications



Internal combustion engines (5 kWe
– 1 MW) for households

- Electricity + **heat** for **district heating/industrial heat**



Nuclear and biomass power plants
(CH, DE, DK...)

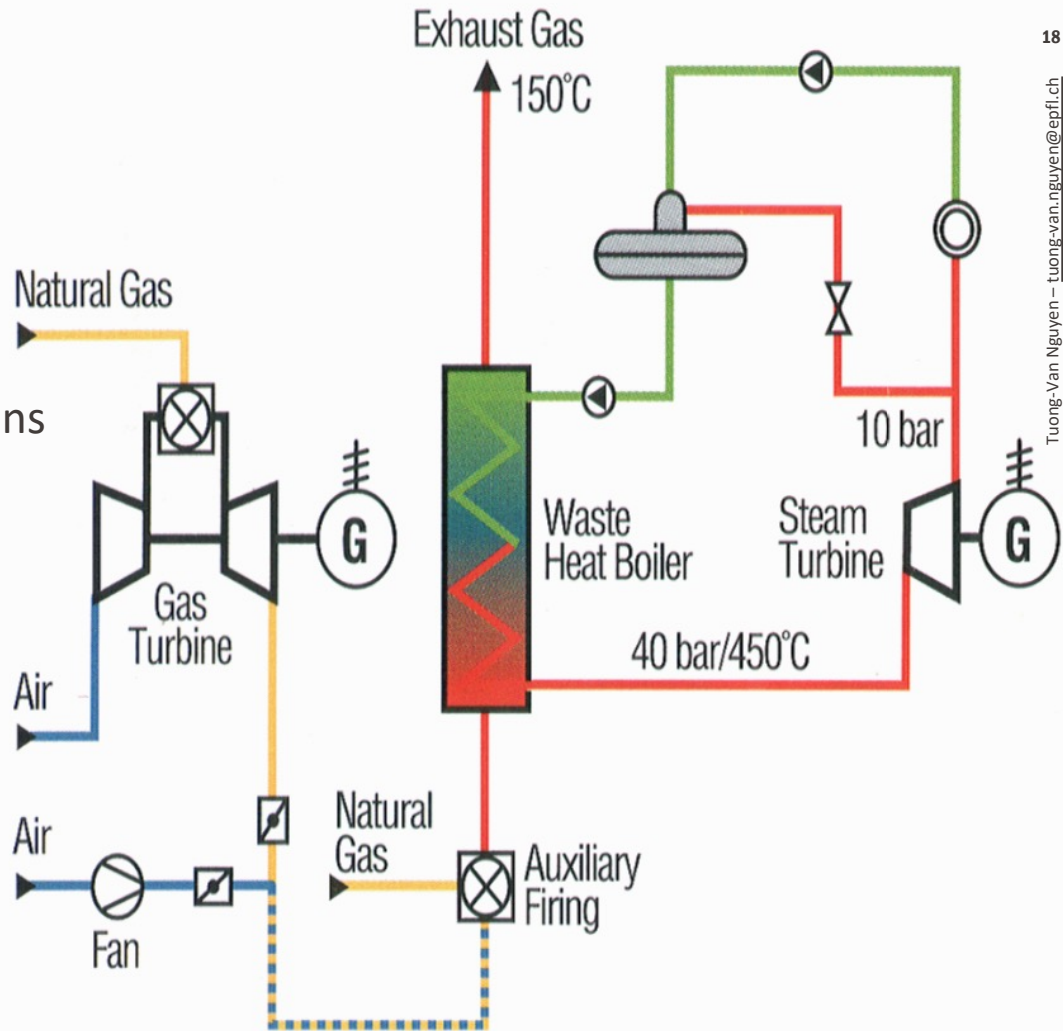
- Electricity + **heat** for **small households**



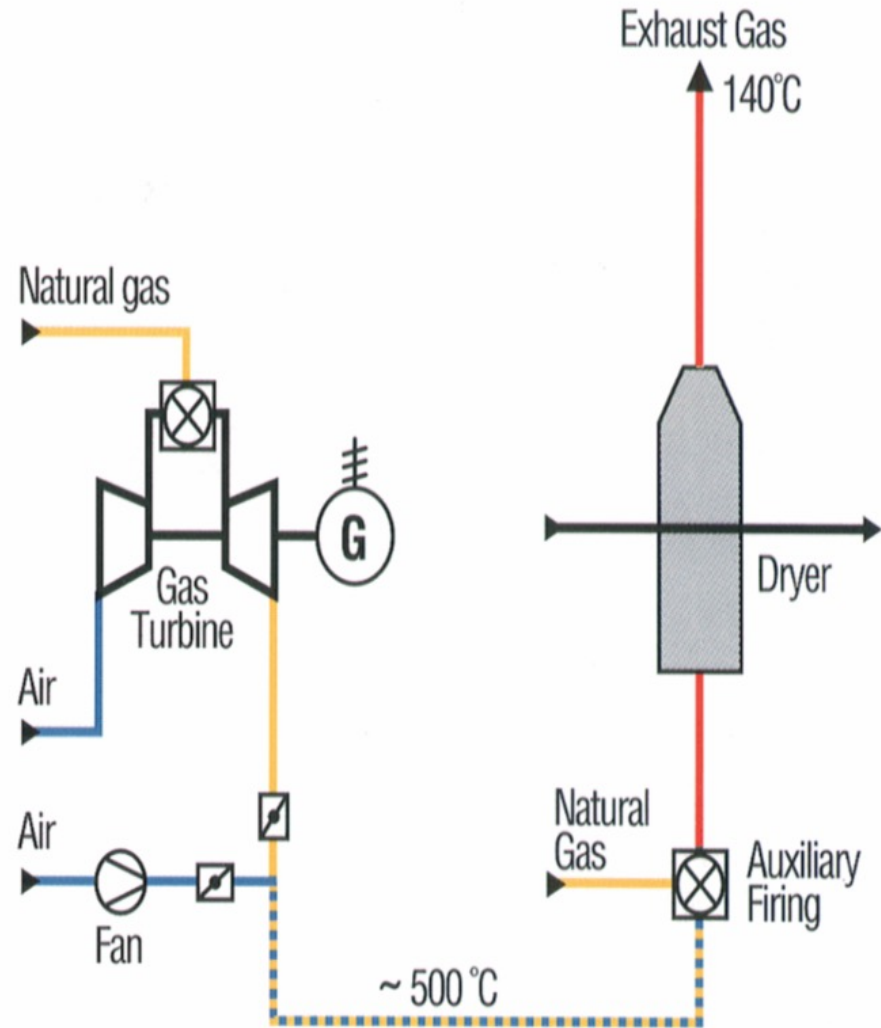
Micro gas turbines, fuel cells, etc.
(research)

Applications

- **Gas turbines/power plants**
- Mostly large-scale applications (cities/regions)
- Proven technology, high efficiencies
- High operational costs



- **Gas engines** (industries)
- Small-to-medium sizes
- Application to processes (air heating/drying)





Take-home message

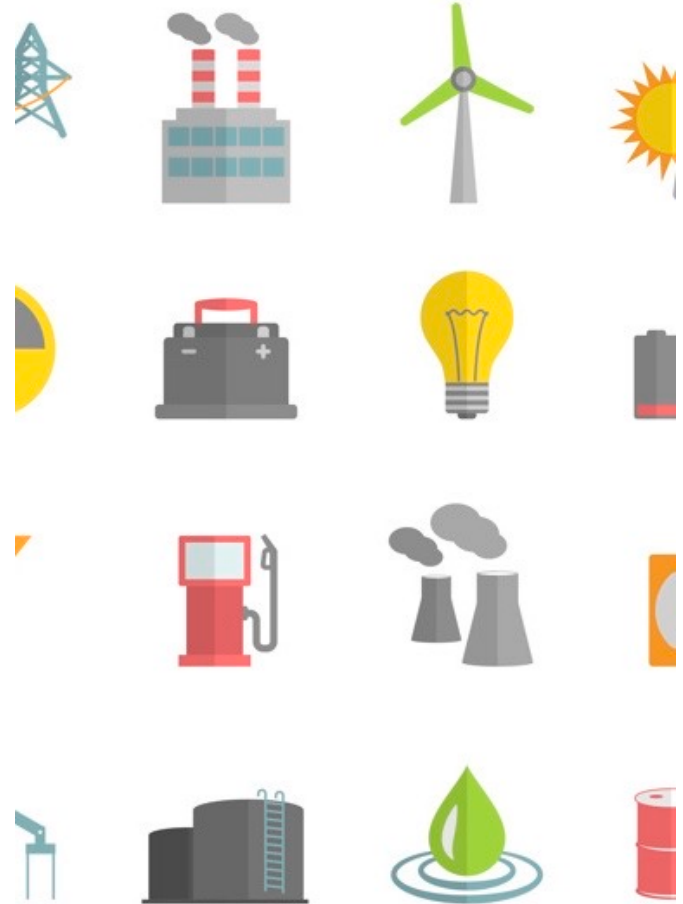
Take-home message

■ Cogeneration

- Electricity and heat
- Utilization factors > 90%

■ Substitution

- Which systems does it replace?
- Energy, cost and CO₂ savings





Questions?

**Tuong-Van
Nguyen**