Module 3: Heat production

Module 3.3
Combined Heat and Power

SHaKE – Sharing Heat and Knowledge on Energy Communities
Erasmus+ KA220-HED Cooperation Partnerships in Higher Education
Developing institutions: Universitat Jaume I de Castellón
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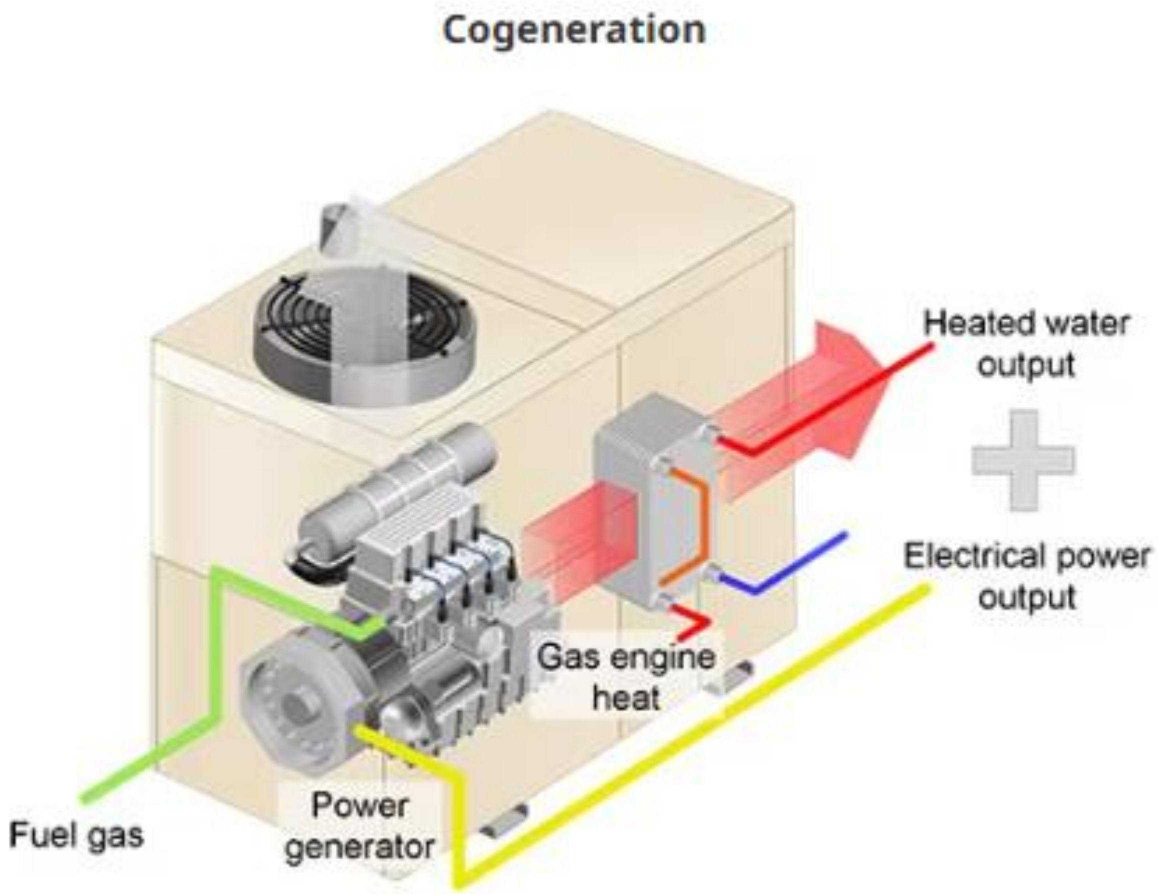
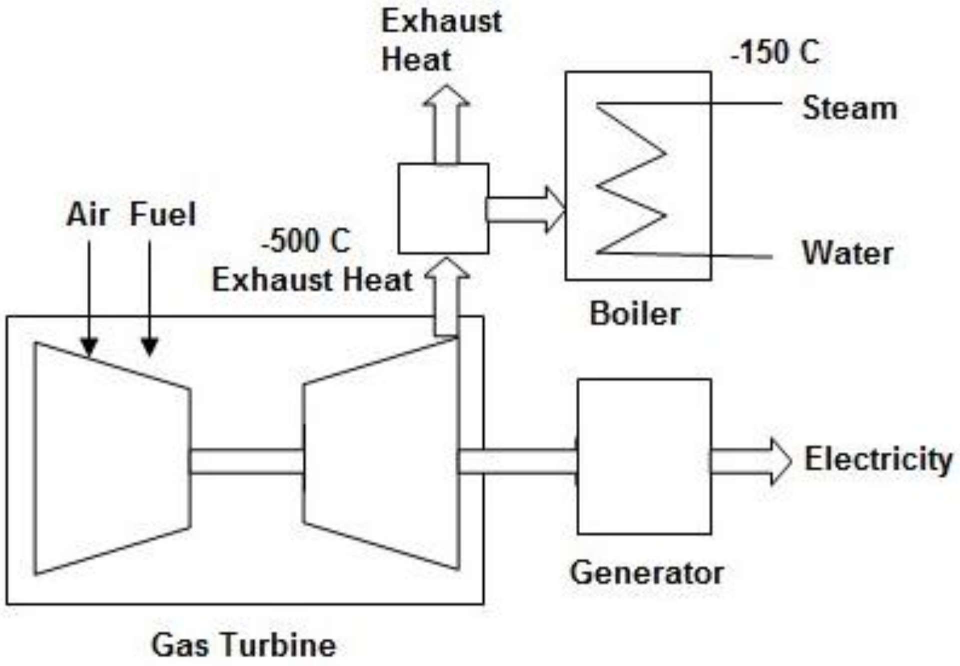
SHaKE
Sharing Knowledge on Energy Communities

2.1. INTRODUCTION TO CHP SYSTEMS

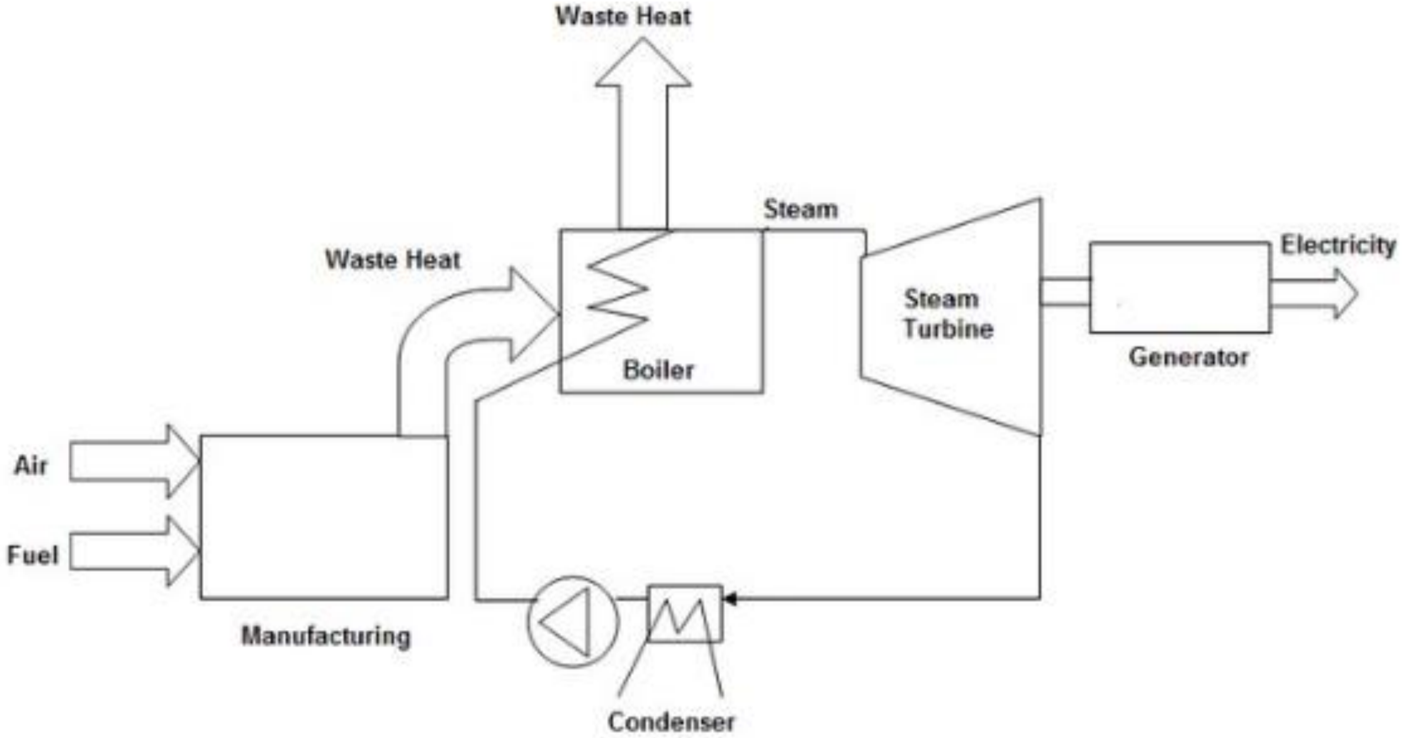


Source: Yanmar

2.1. INTRODUCTION TO CHP SYSTEMS



Head-End Cogeneration Cycle (Topping Cycle)



Tail-End Cogeneration Cycle (Bottoming Cycle)

Source: Jahanzaib et al. (2010)

2.1. INTRODUCTION TO CHP SYSTEMS

Various CHP technologies have been developed, categorized into two main groups:

1. **Flexible Units**:

These systems can adjust their power-to-heat ratio based on heat demand. These units can operate in:

Full cogeneration mode: Maximum heat generation.

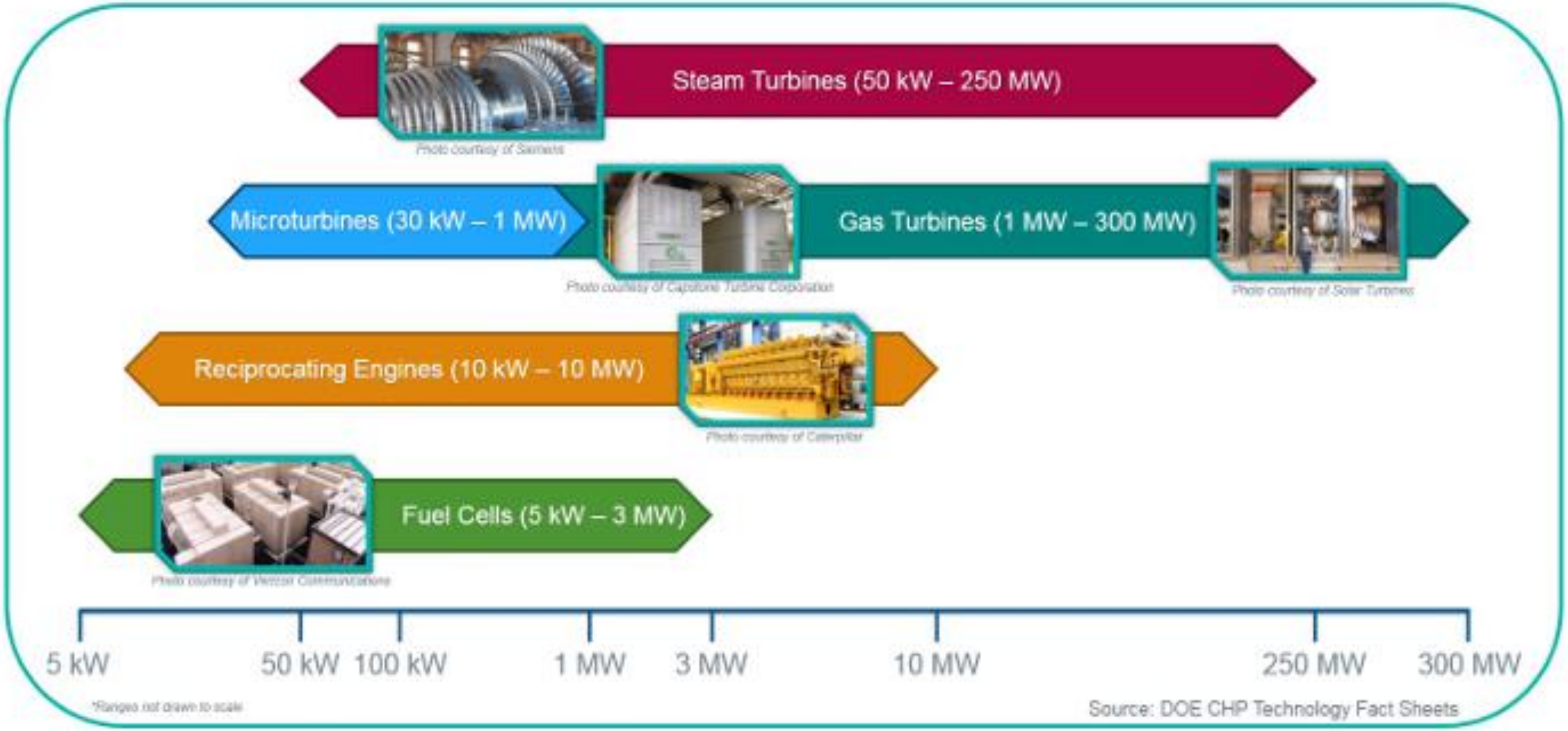
Full condensing mode: Maximum electricity generation with no useful heat.
Operation depends on the specific heat demand.

1. **Fixed Heat Production Units**:
   These systems produce heat at a constant rate, regardless of demand. If heat is not needed, the excess is released into the environment.

Source: European Commission

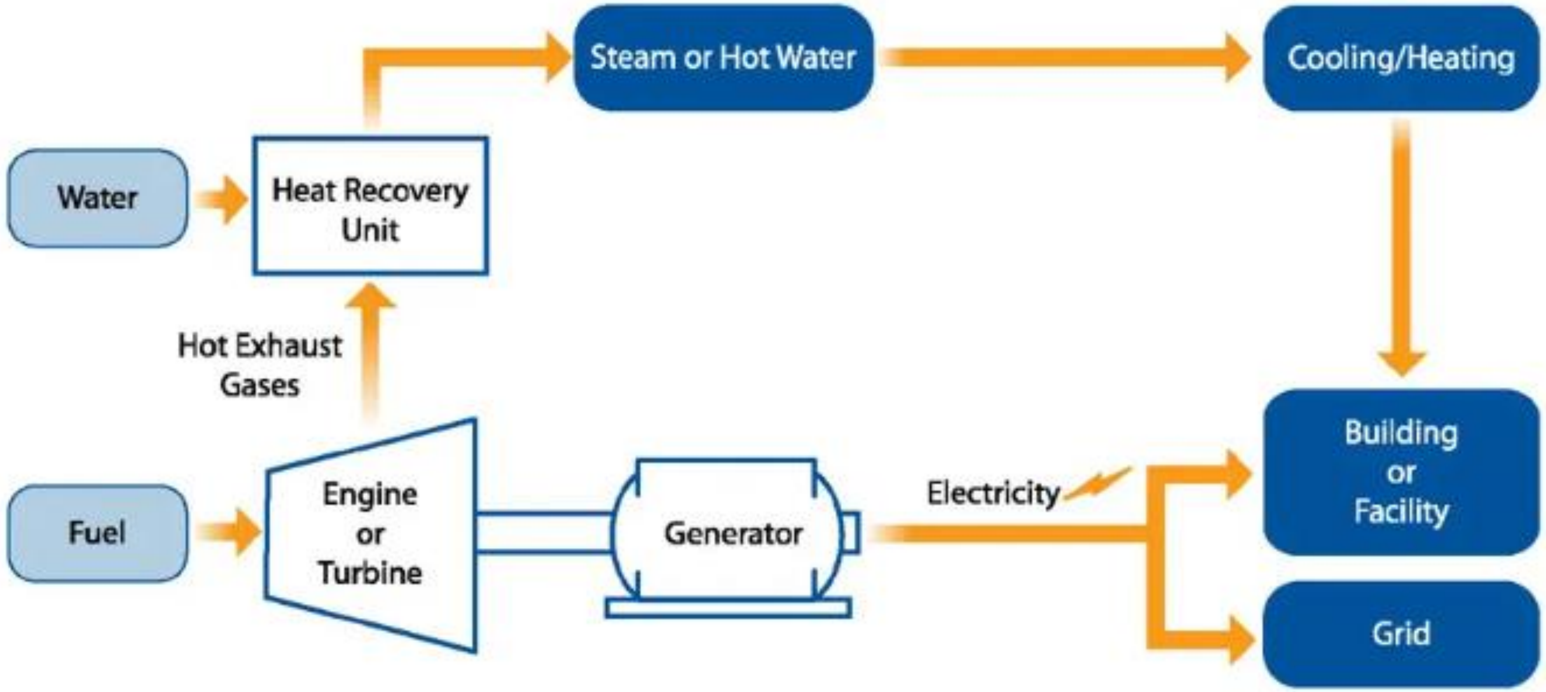
2.1. INTRODUCTION TO CHP SYSTEMS

Different CHP technologies:



Source: Epperson & Jane

2.1. INTRODUCTION TO CHP SYSTEMS



Source: EnergyLink

2.1. INTRODUCTION TO CHP SYSTEMS

- Main parameters

Electrical power (P_e): $P_e = \dfrac{Q_{\text{fuel}} \times \eta_{\text{generator}}}{\text{Inlet temperature of fluid}}$

Thermal power (P^t): $P^t = m \times C_p \times (T_{\text{out}} - T_{\text{in}})$

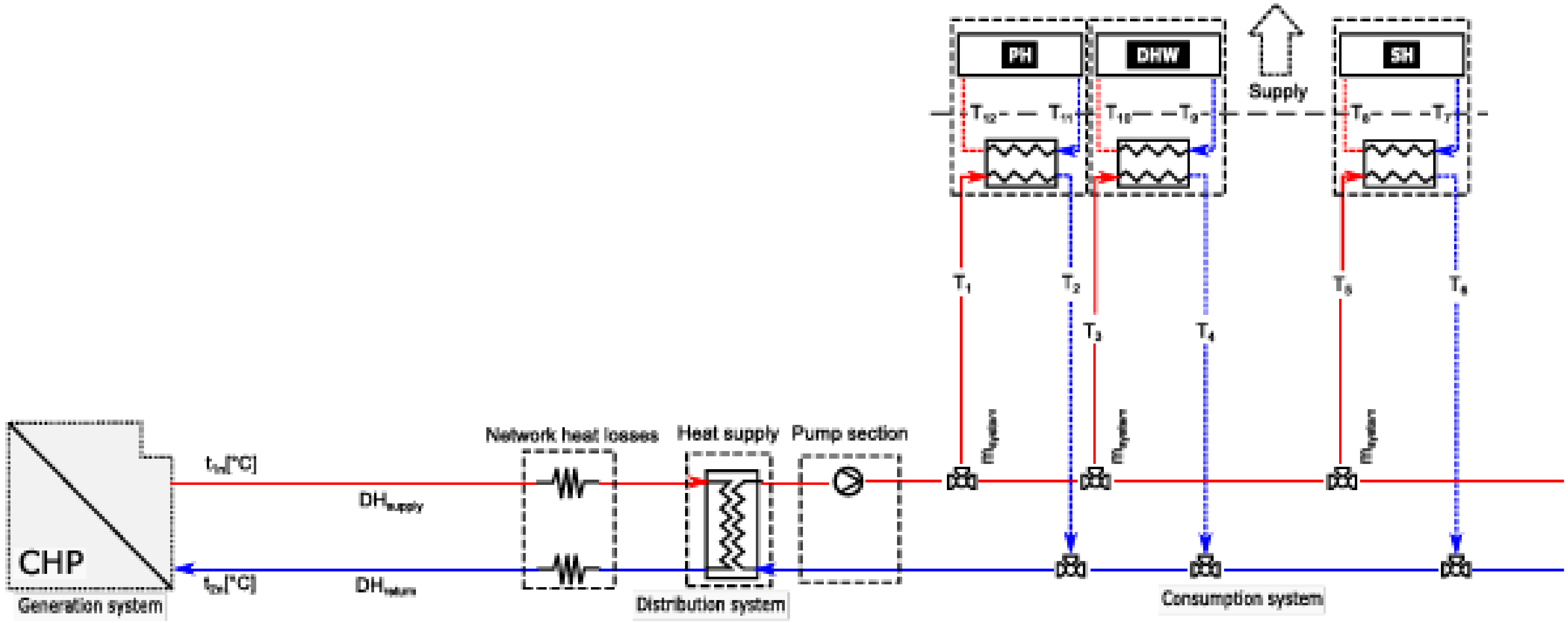
Overall efficiency (η_x): $\eta_x = \dfrac{P_e + P^t}{Q_{\text{fuel}}} \times 100$

Heat-to-electricity ratio (C/E): $\dfrac{C}{E} = \dfrac{P^t}{P_e}$

Load factor: $FL = \dfrac{P_{\text{average}}}{P_{\text{max}}}$

2.2. THE ROLE OF CHP SYSTEMS IN HEAT PRODUCTION AND THEIR INTEGRATION INTO VARIOUS TECHNOLOGIES SUCH AS DHN

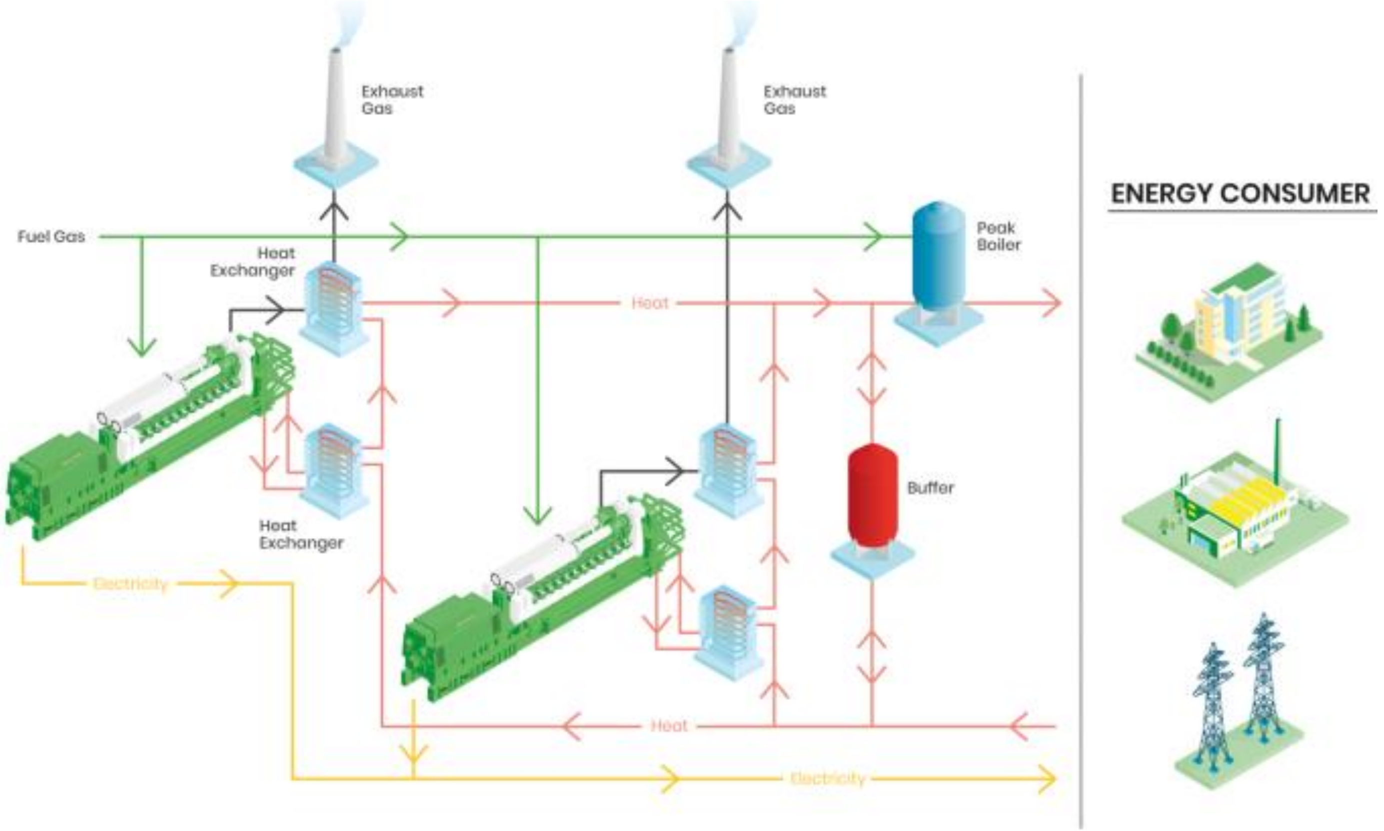
CHP integration into DHN



Source: barco burgos et al. (2022)

2.2. THE ROLE OF CHP SYSTEMS IN HEAT PRODUCTION AND THEIR INTEGRATION INTO VARIOUS TECHNOLOGIES SUCH AS DHN

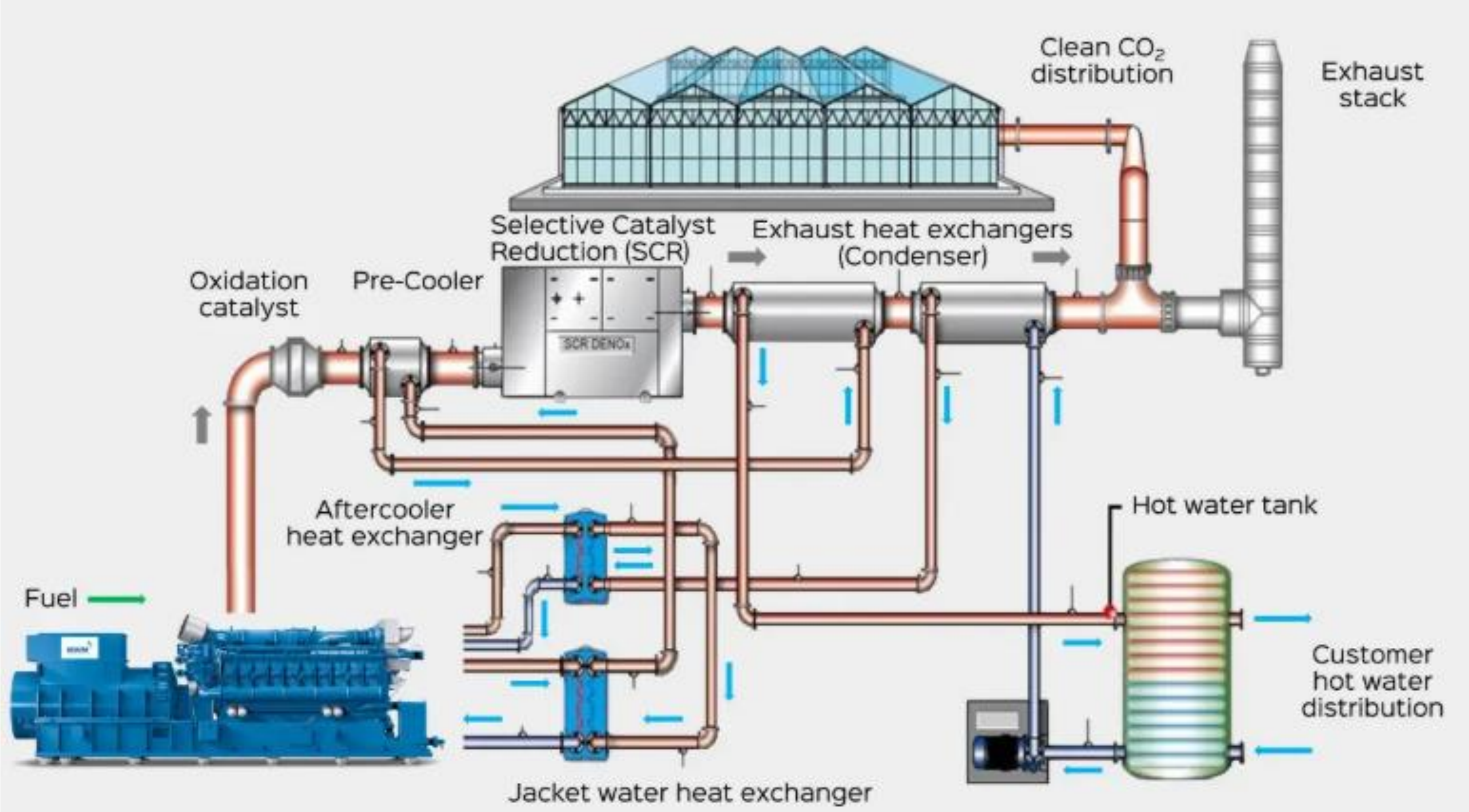
CHP integration into Commercial and Institutional Buildings



Source: JENBACHER

2.2. THE ROLE OF CHP SYSTEMS IN HEAT PRODUCTION AND THEIR INTEGRATION INTO VARIOUS TECHNOLOGIES SUCH AS DHN

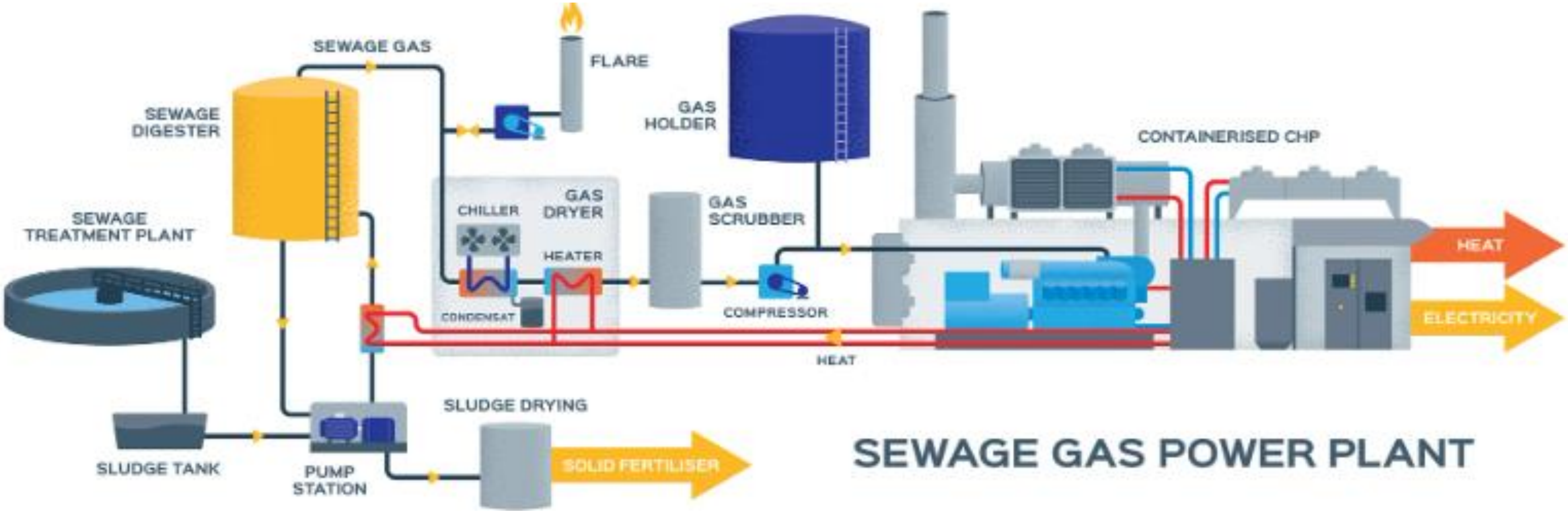
CHP integration into Greenhouses



Source: Edina

2.2. THE ROLE OF CHP SYSTEMS IN HEAT PRODUCTION AND THEIR INTEGRATION INTO VARIOUS TECHNOLOGIES SUCH AS DHN

CHP integration into Wastewater Treatment Plants



Source: Edina

2.2. THE ROLE OF CHP SYSTEMS IN HEAT PRODUCTION AND THEIR INTEGRATION INTO VARIOUS TECHNOLOGIES SUCH AS DHN

Types of Heat Produced by CHP Systems

- Hot Water: For space heating and domestic use.
- Steam: Used in industrial processes or district heating.
- Low-Grade Heat: For pre-heating, drying, or absorption cooling.
- Process Heat: Direct heat application in industrial systems.
- Thermal Energy for Absorption Chillers: For trigeneration (heat, power, and cooling).

2.3. ADVANTAGES OF CHP TECHNOLOGY

General Advantages of Cogeneration:

1. **Energy Efficiency**
2. **Emission Reduction**
3. **Flexibility**
4. **Energy Security**
5. **Reduced Operating Costs**

2.4. OPERATIONAL AND TECHNICAL CHALLENGES OF INTEGRATING CHP TO DHN

- **Operational Flexibility**

Demand variability: DHNs have fluctuating heat demand; CHP prefers steady full-load operation → needs advanced control and backups.

Grid interaction: CHP must balance heat and electricity demand → complex, especially with renewables.

- **Infrastructure Integration**

Retrofit challenges: Upgrades to pipes, exchangers, and tanks often needed.

Temp/pressure matching: Mismatches require extra equipment → higher cost and complexity.

- **System Reliability**

Dual dependency: CHP failure affects both heat and power → requires high maintenance.

Backups needed: Storage or auxiliary systems increase costs but ensure continuity.

- **Fuel & Emissions**

Fuel supply: Steady fuel access critical (natural gas, biomass).Emissions control: Must meet CO_2, NOx, PM limits → needs scrubbers, filters, or clean combustion.

Renewables integration: Biogas or waste heat need fuel quality and emissions planning.

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2.5. ENERGY EFFICIENCY, ECONOMY, AND ENVIRONMENTAL IMPACT OF CHP IN HEATING PRODUCTION

CHP Type	Electrical Efficiency (%)	Thermal Efficiency (%)	Total Efficiency (%)
Gas engine	35–42 %	45–50 %	80–90 %
Gas turbine	25–35 %	40–50 %	70–85 %
Combined cycle (GT + ST)	45–55 %	30–40 %	80–90 %
Micro-CHP (residential)	12–20 %	60–70 %	80–85 %
Biomass CHP	20–30 %	40–50 %	60–80 %
Steam CHP (industrial)	10–15 %	60–75 %	70–85 %

2.5. ENERGY EFFICIENCY, ECONOMY, AND ENVIRONMENTAL IMPACT OF CHP IN HEATING PRODUCTION

Economy

Case example:

Gas turbine operates 7,800 hour/year

Total Annual Savings	**1,650,000$**
Estimated Capital Cost	**9,075,000$**
Simple Payback	**5,5 years**

(Epperson & Jane, n.d.)

$$\text{Payback time} = \frac{\text{Initial investment}}{\text{Annual savings}}$$

2.5. ENERGY EFFICIENCY, ECONOMY, AND ENVIRONMENTAL IMPACT OF CHP IN HEATING PRODUCTION

Environmental Impact

$$E_{CO_2} = \frac{Q_{\text{fuel}} \times \text{Emission factor}}{\text{Calorific value of the fuel}}$$

Source: ICF

Thank you!

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https://www.shakeproject-dhc.eu/

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