Combined Heat & Power (CHP)

Heat production & applications within DH-systems

LowTEMP training package - OVERVIEW

Introduction

- Intro Climate Protection Policy and Goals
- Intro Energy Supply Systems and LTDH
- Energy Supply Systems in Baltic Sea Region

Energy Strategies and Pilot Projects

- Methodology of Development of Energy Strategies
- Pilot Energy Strategies – Aims and Conditions
- Pilot Energy Strategy – Examples
- Pilot Testing Measures
- CO2 emission calculation
- LCA calculation

Financial Aspects

- Life cycle costs of LTDH projects
- Economic efficiency and funding gaps
- Contracting and payment models
- Business models and innovative funding structures

Technical Aspects

- Pipe Systems
- Combined heat and power (CHP)
- Large Scale Solar Thermal
- Waste & Surplus Heat
- Large Scale Heat Pumps
- Power-2-Heat and Power-2-X
- Thermal, Solar Ice and PCM Storages
- Heat Pump Systems
- LT and Floor heating
- Tap water production
- Ventilation Systems

Best Practice

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Content

LowTEMP

- Introduction to Combined Heat and Power
- Basic operating principles of CHP
- CHP-units
- Future prospects of CHP-technology

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1. Introduction to Combined Heat and Power (CHP)

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Introduction to Combined heat and power (CHP)

„It generates **heat** and **power**" **or**

„It generates **power** and **heat**"

- The simultaneous generation of power and heat is increasing the energy efficiency as well as reducing CO2-emissions
- CHP has several opportunities to reduce dependencies on fossil fuels
- does not contradict with the general goal of integrating renewable energies into the heating sector
- CHP is applicable independent of the energy source
- Primary energy saving potentials are up to 30% – regarding the heating market even up to 70%

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Introduction to Combined heat and power (CHP)

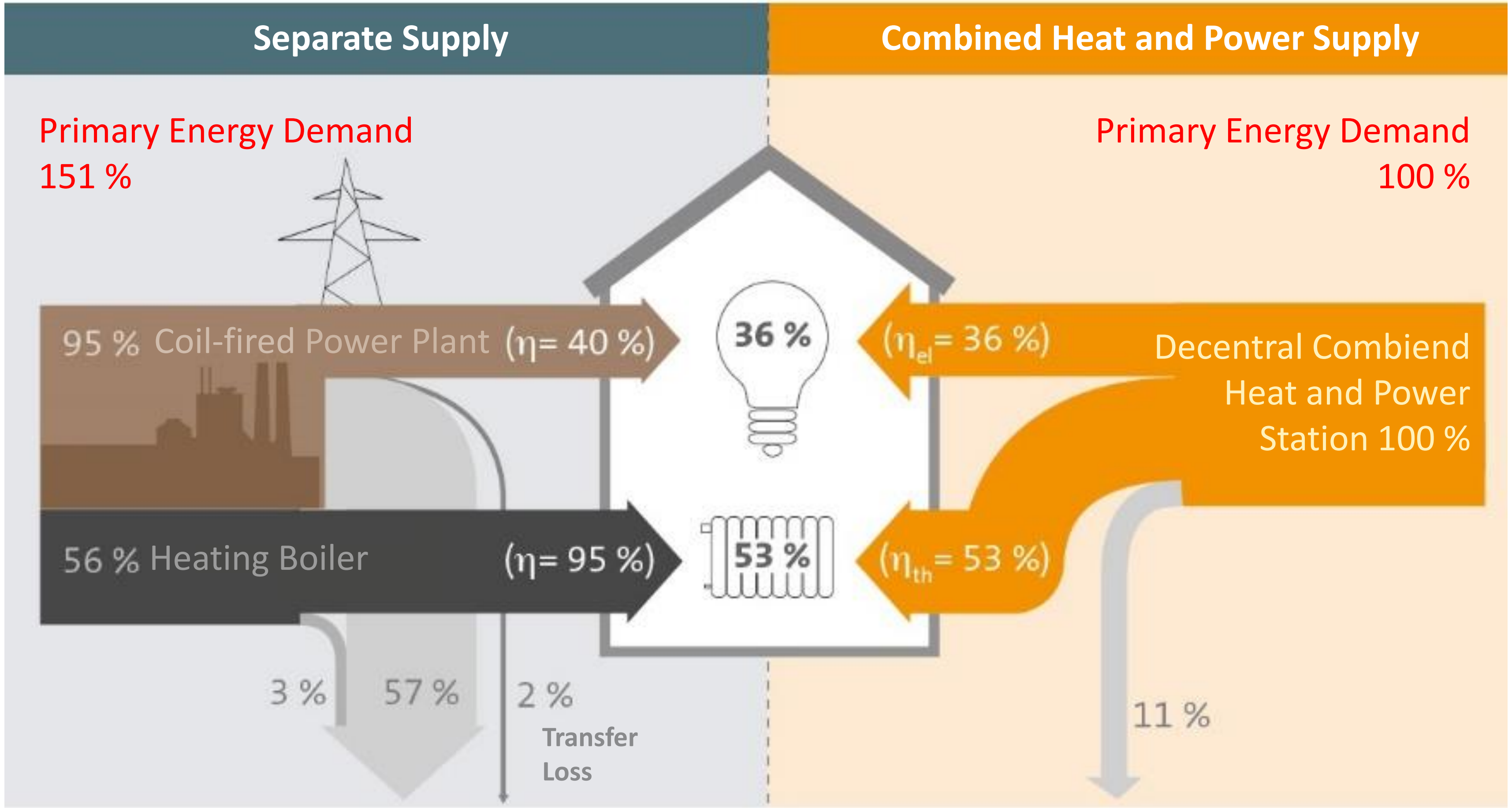


Figure 1: Benefit of CHP - Comparison of conventional energy supply and CHP regarding primary energy consumption (Source: ASUE20; translated [1])

2. Basic operating principles of CHP

Basic operating principles

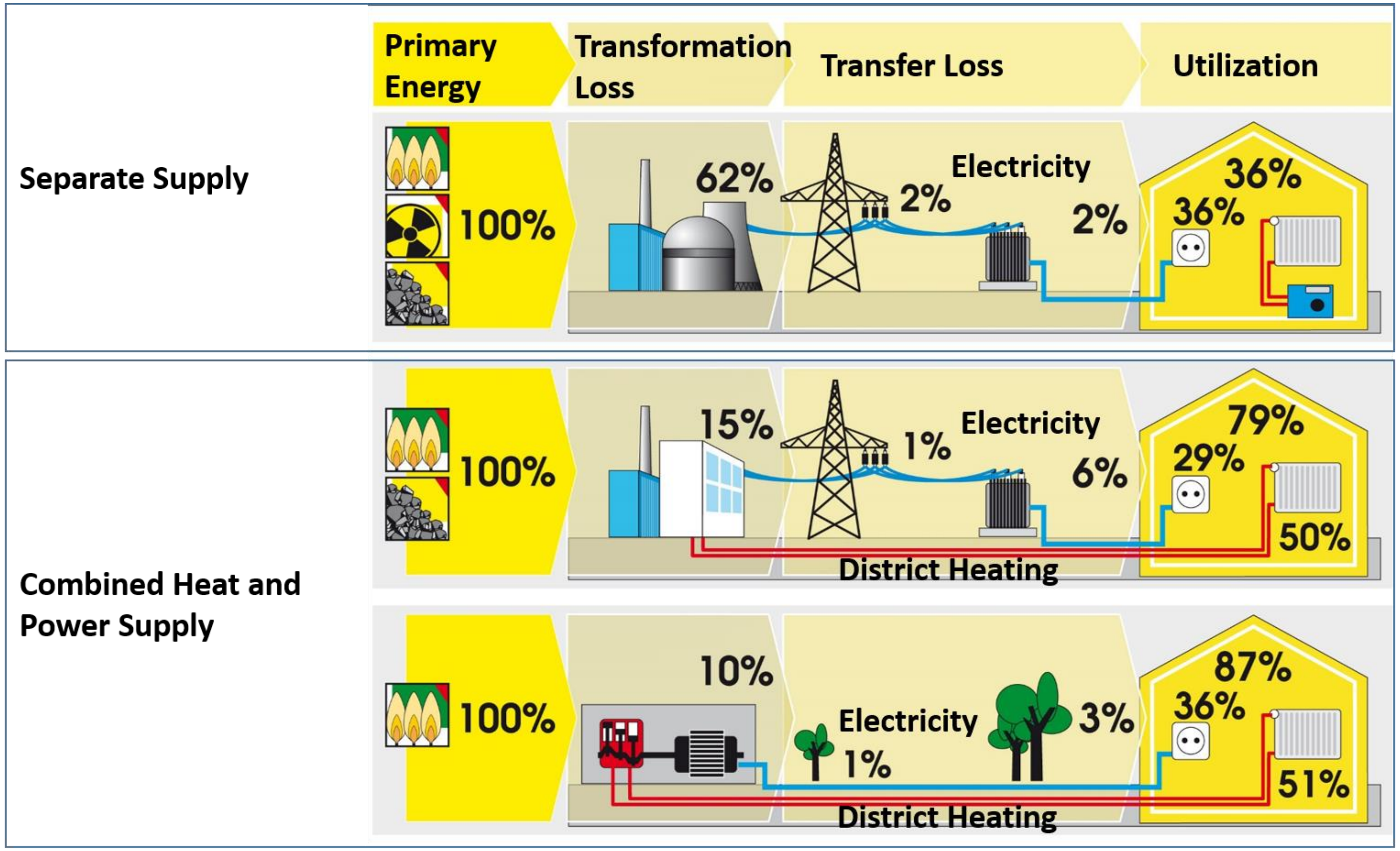


Figure 2: The energy flow in the pure energy supply as well as in the central and decentral CHP-generation (Source: ASUE99) [2]

- 100 % fuel energy input can be converted into more than 90 % effective energy
- the utilization of conventional power plants is only of about 35-59% efficient

Basic operating principles

- Simoultaneous generation of heat and electricity
  - Fixed ratio of heat and electricity generation
- By Utilization of heat and electricity
  - efficiency increases up to 90 % compared to conventional power generation
- Operation principles
  - Power-led controlled,
  - Heat-led controlled,
  - line-commutated controlled

➢ Optimum effiencies only achieved during heat-controlled operation

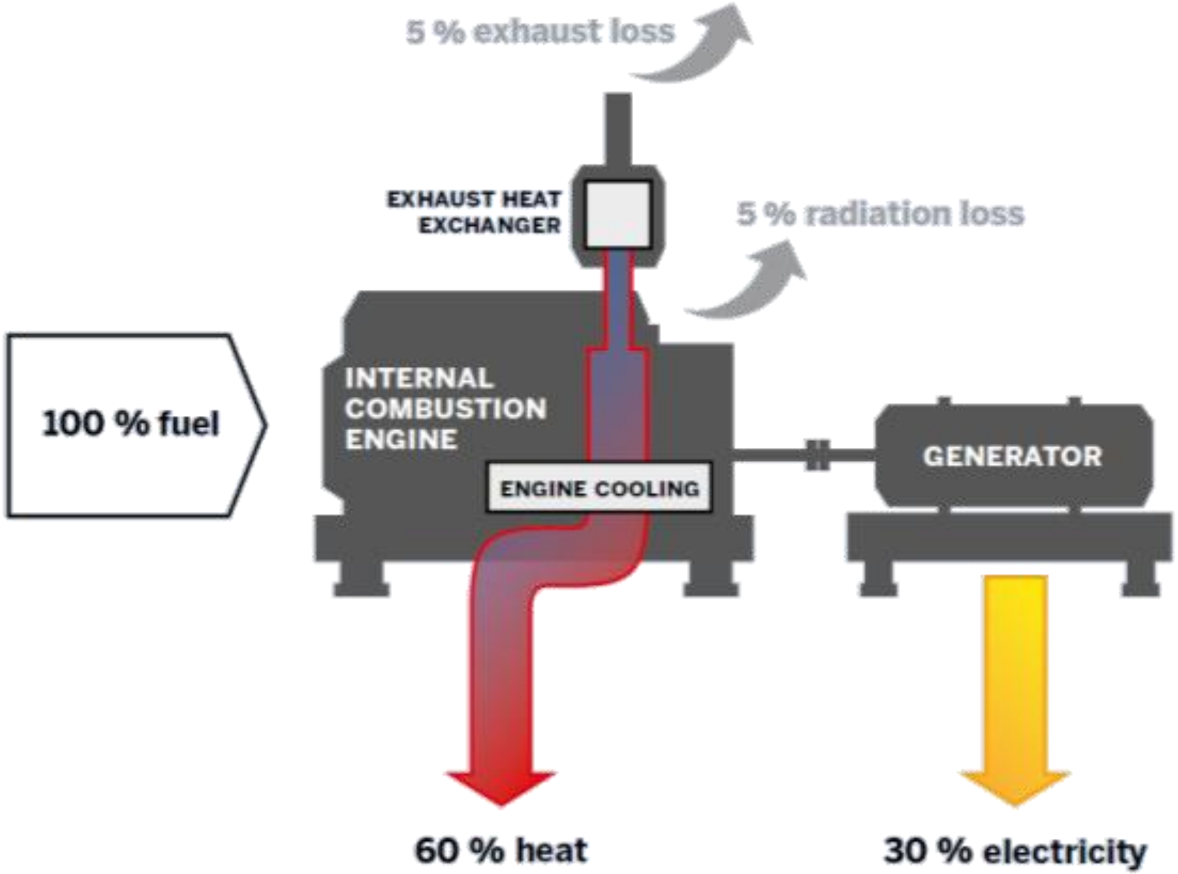
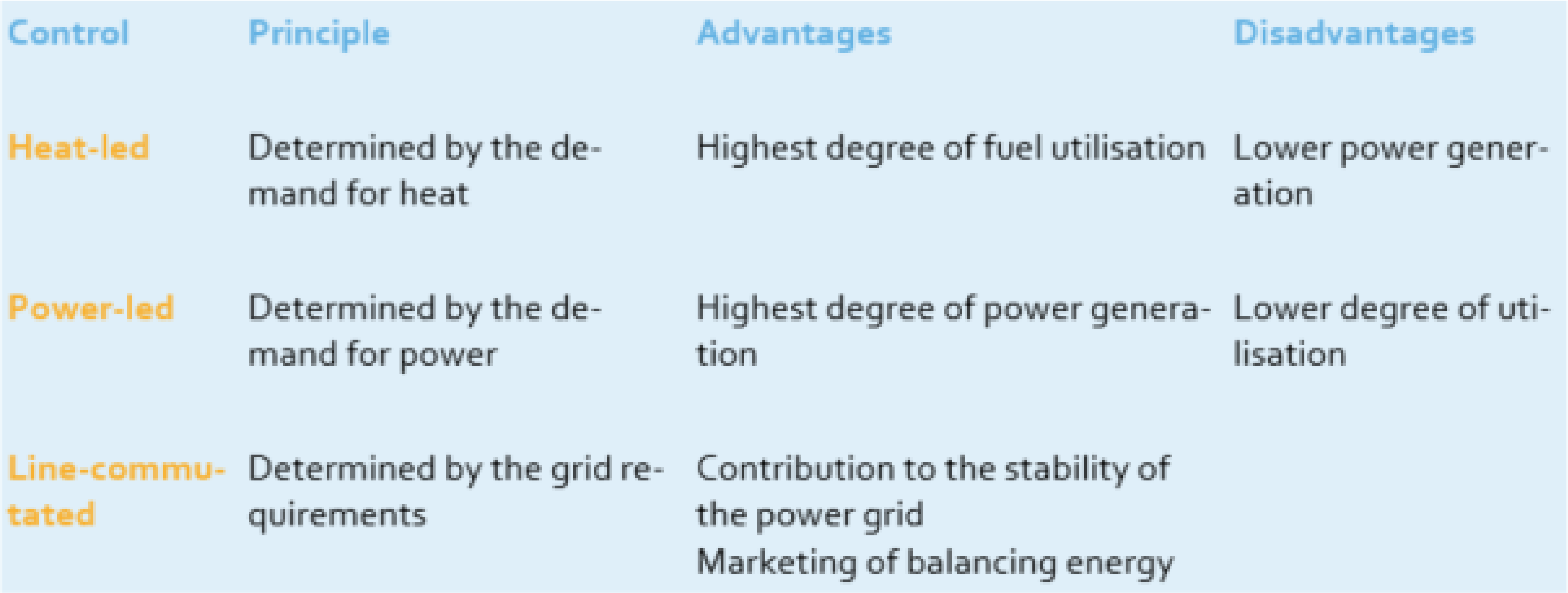


Figure 3: Energy consumption of coupled heat and electricity production (Source: EnergieAgentur.NRW GmbH: 2016; translated [3])

Overview CHP operation designs



Control	Principle	Advantages	Disadvantages
Heat-led	Determined by the demand for heat	Highest degree of fuel utilisation	Lower power generation
Power-led	Determined by the demand for power	Highest degree of power generation	Lower degree of utilisation
Line-commutated	Determined by the grid requirements	Contribution to the stability of the power grid Marketing of balancing energy	

Table 1: Overview of different CHP-control designs (Source: Getec 2020 [4])

CHP-applications - Classification of power ranges

	POWER RANGE	FUELS
Steam or condensing turbine	500 MW < P_{el} < 1100 MW Nuclear power plant: P_{el} < 1600 MW	Coal (oil, gas, bio mass, waste nuclear power)
Gas turbine	1 MW < P_{el} < 545 MW Micro turbines: P_{el} < 100 kW	(natural) Gas, fuel oil
Combustion / reciprocating engine	1 KW < P_el < 10 MW	(natural, biomass) Gas, (biomass) fuels
Fuel cells	125 KW < P_{el} < 1,4 MW (59 MW prototype)	Methanol, natural gas, hydrogen, synthetic gas (coal gas)

Table 2: Classification of several CHP-units [7]

CHP-applications - Classification of power ranges

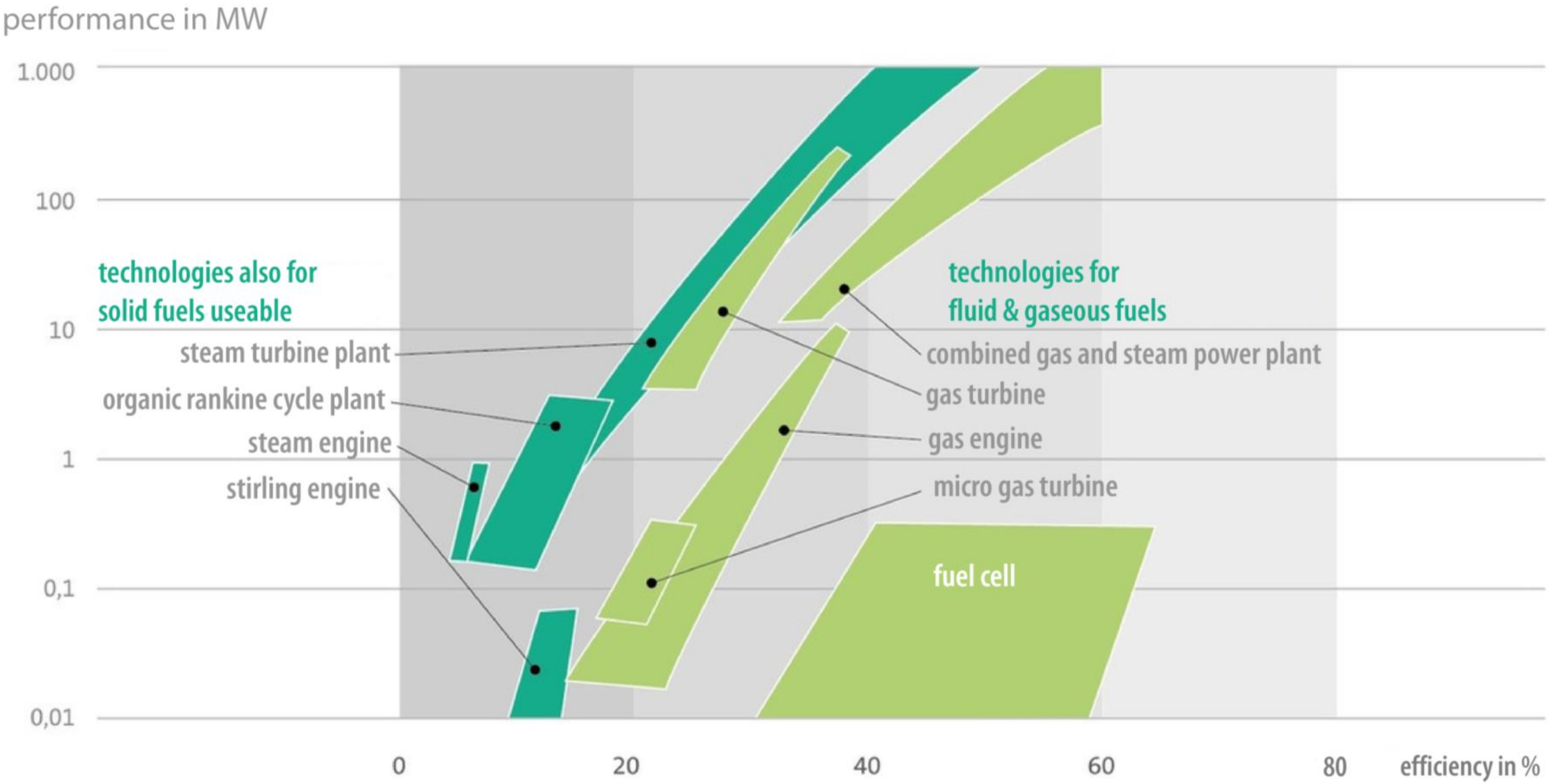
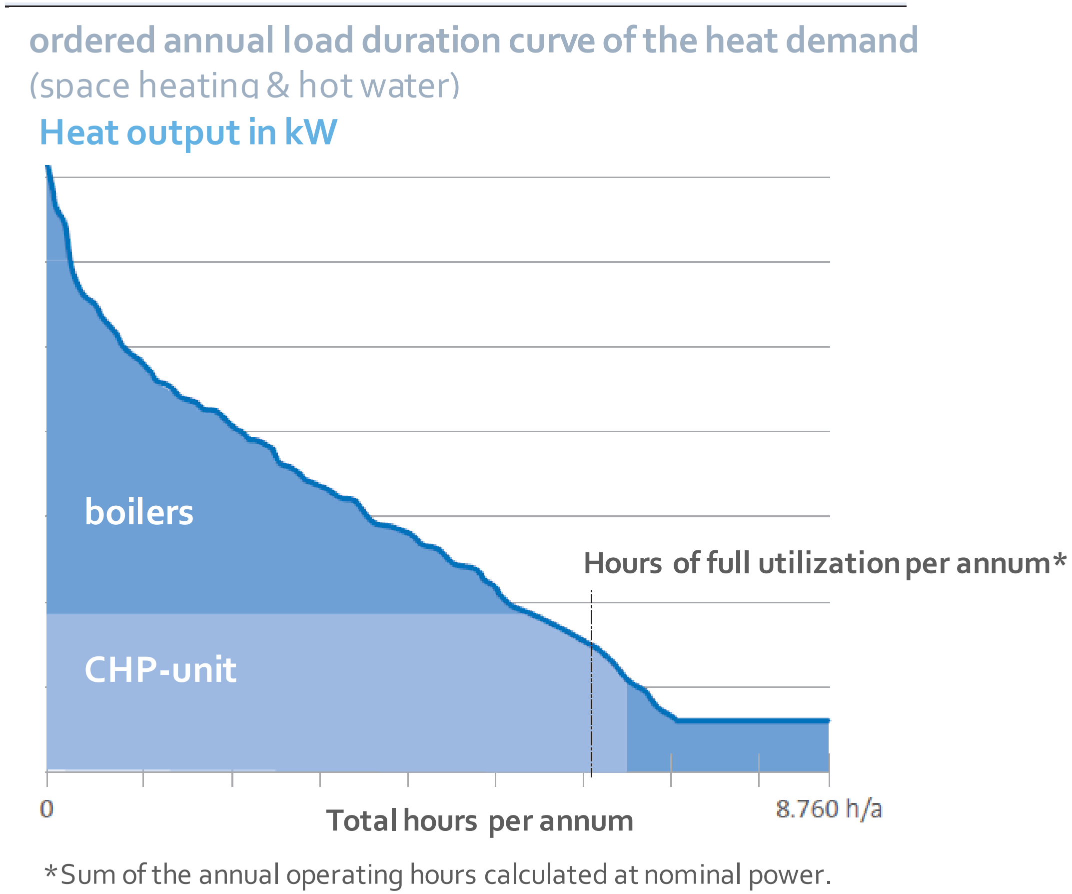


Figure 5: Divers CHP-device technologies. Performance subject to efficiency (Source: ASUE16 [8])

Seizing & dimensioning of CHP-units



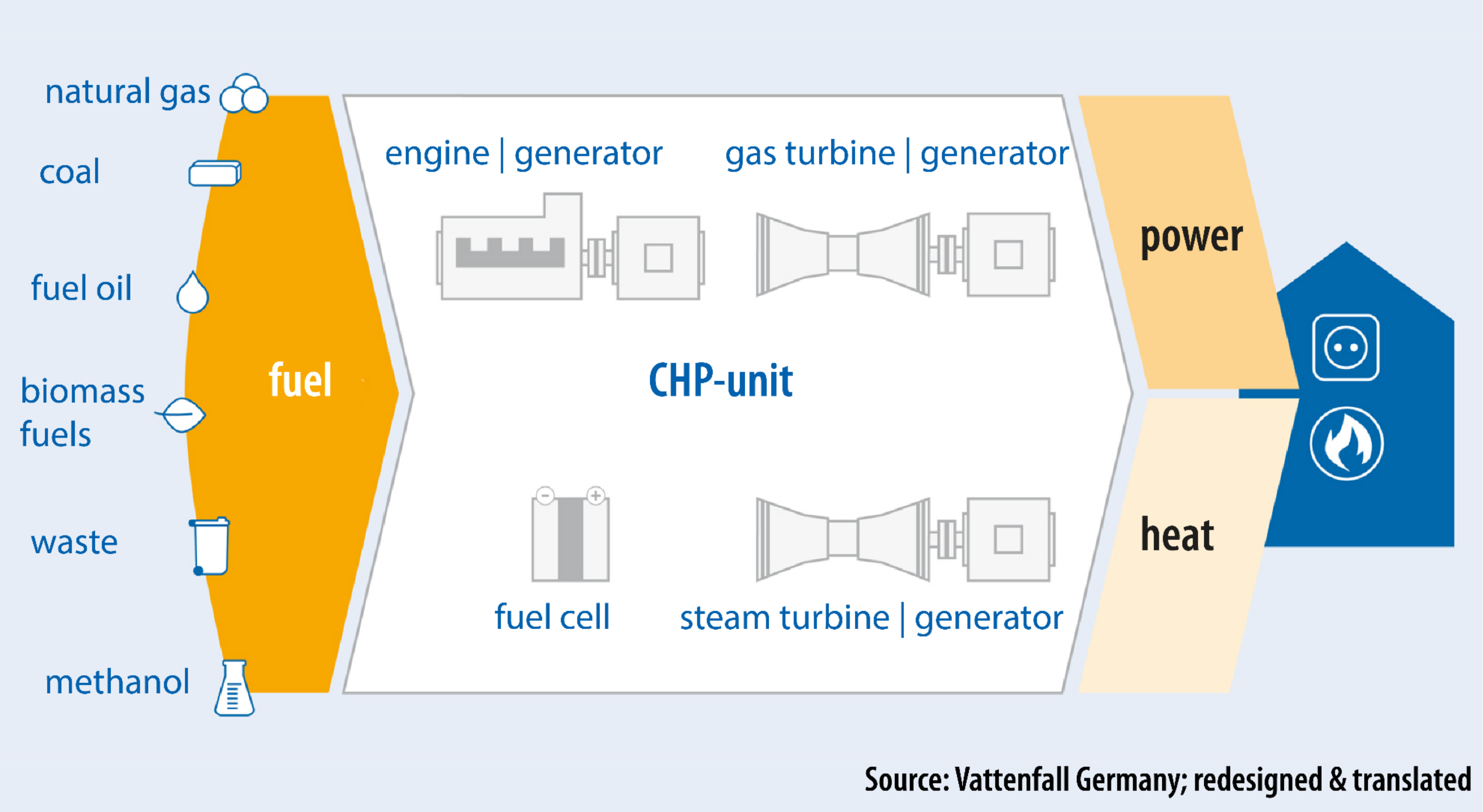
*Sum of the annual operating hours calculated at nominal power.

Figure 6: Exemplified operation hours and dimensioning of a CHP-unit (Source: ASUE, 2015 [9])

- Right dimensioning ensures long durations and a high amount of full utilization hours per annum
- Approx. 20 % of the thermal nominal capacity of the CHP-unit should be taken as a basis for calculation and planning
- Baseload is efficiently covered & 50 % of the required annual heat demand
- The remaining heat demand is uslly covered with boilers or additional heat sources

3. Overview of CHP-units

CHP differentiated in fuels and applications



Source: Vattenfall Germany; redesigned & translated

Figure 7: Supply chain of different incoming fuels to electricity and heat by utilize diverse CHP-devices (Source: Vattenfall Germany [10])

Combustion engines

- Standard combustion, usually supplemental boiler for peak loac
- Heat of cooling water and oil have temperature levels of 80-90°
- Exhaust gases temperature level high enough for steam generation

Operational characteristics

- Mostly rigid coupling between electricity and heat generation
- Engine modules generally operate at nominal load
- improvable with modern control systems and/or heat storages
- Operation without constant supervision possible up to 72 hours

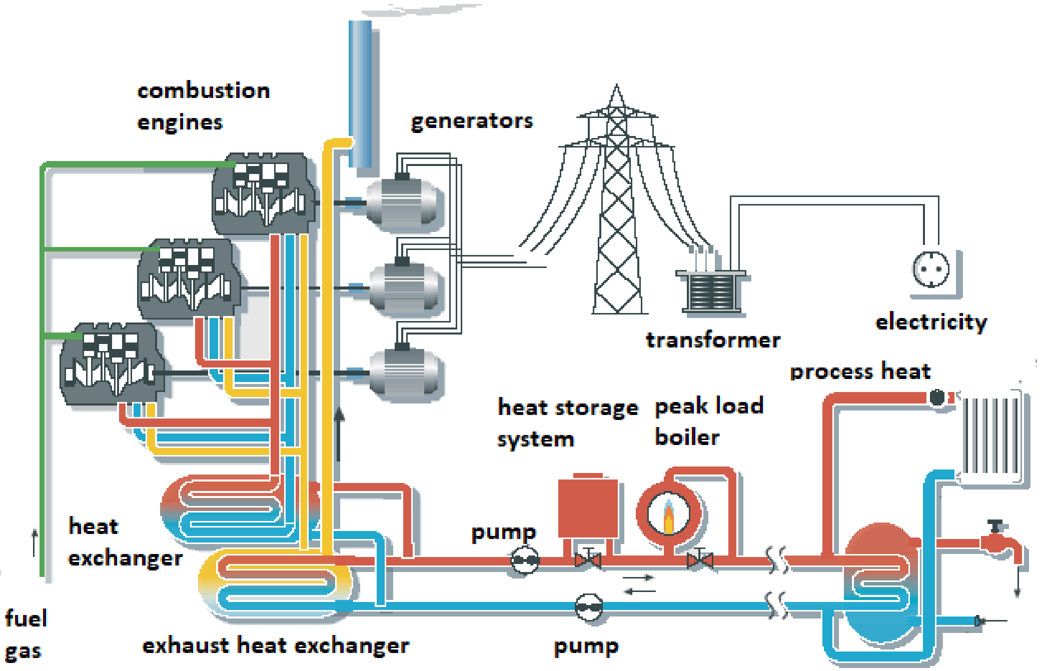


Figure 8: Common scheme of CHP-units working in a power plant. Several engines operates coupled for generation electricity and heat in case of huge demand (Source: AGFW11)

Gas turbines

- Systems consists of one or more gas turbines
- The heat utilization takes place in waste heat boiler with or without auxiliary firing
- Work related electricity values of 0,5 – 0,8 kWh_{el}/kWh_{th}
- Gas turbines use heat of 400-600°C from the exhaust gases
- The applications are highly developed, compact, very efficient

Essential characteristics:

- Cheap operating conditions (start-up behaviour, automation)
- Decoupling of electrical power for heat production
- Compact design
- Low investments
- Low personnel requirements due to high degree of automation

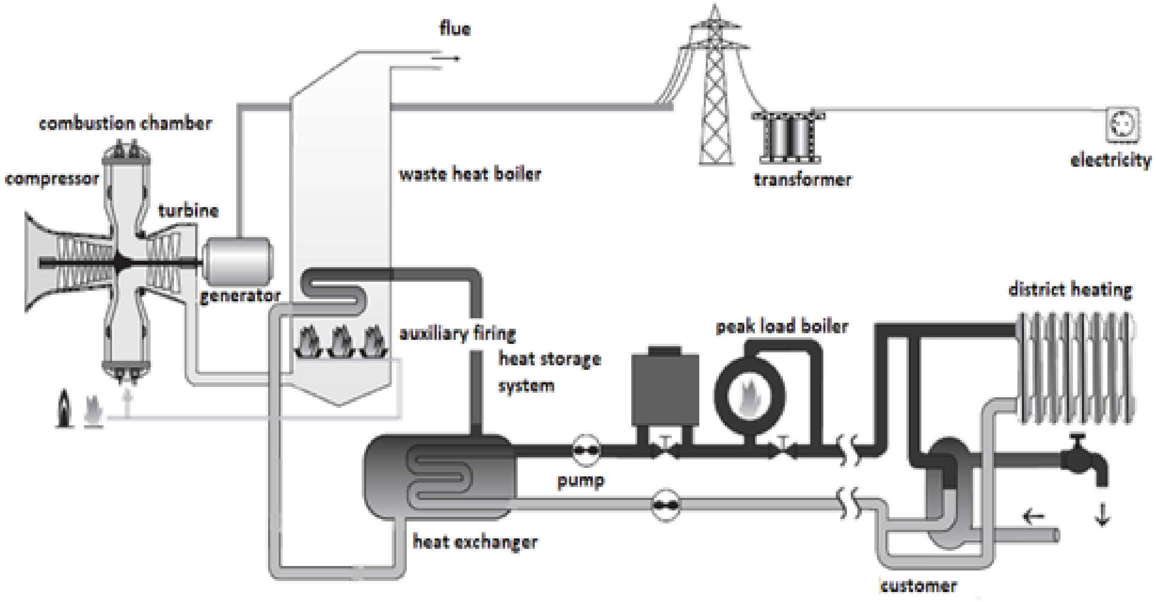


Figure 9: Example for decoupling District Heat from a gas turbine power plant (Source: AGFW11)

Steam / Condensing turbine

Operational characteristics

- Water is transformed into steam within a boiler system
- During expansion of the steam within a turbine the steam energy converts into motion which is transformed into electricity
- For **heat production** there are two different ways:
- **Decoupling heat from the power plant process**
- **Using the excess heat of the condensation process**

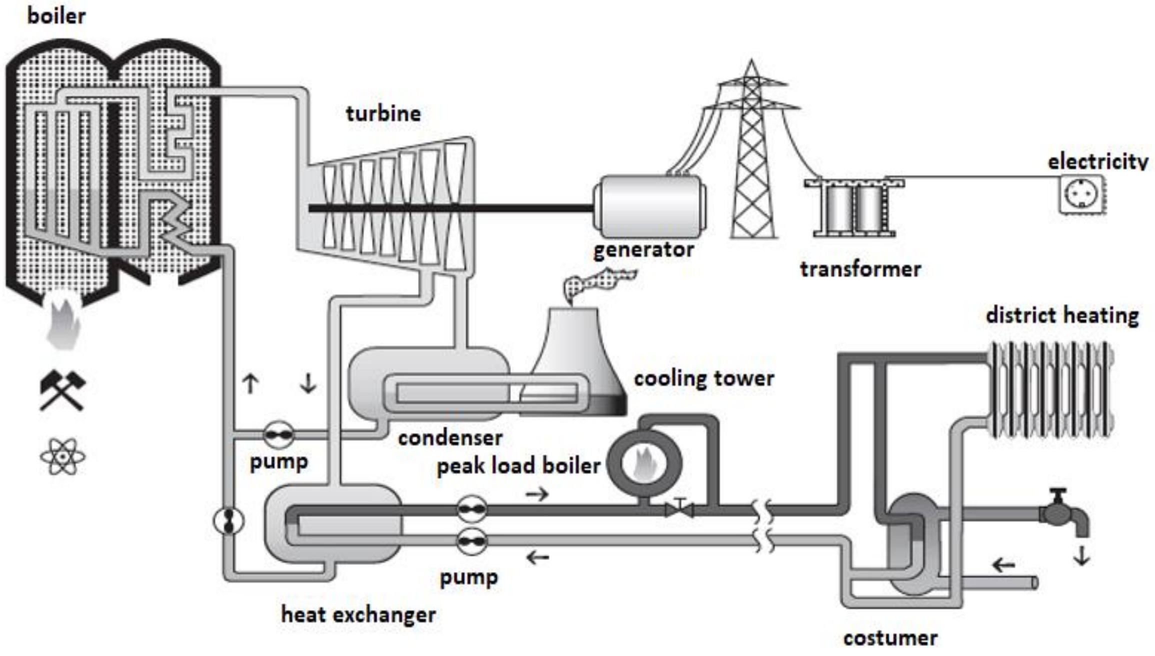


Figure 10: Main principle of a condensing power plant (Source: AGFW11)

Combined-cycle gas turbine (CCGT) plant

- Gas turbines focus on the power generation (65-80%)

- Utilization of the exhaust gas heat can happen at low temperature

➢ Mainly limited characterstics of the flue gas

- Work related electricity values of 0,8 – 1,2 kWh_{el}/kWh_{th}

- No additional heat source is required for the steam turbine process → high energy utilization

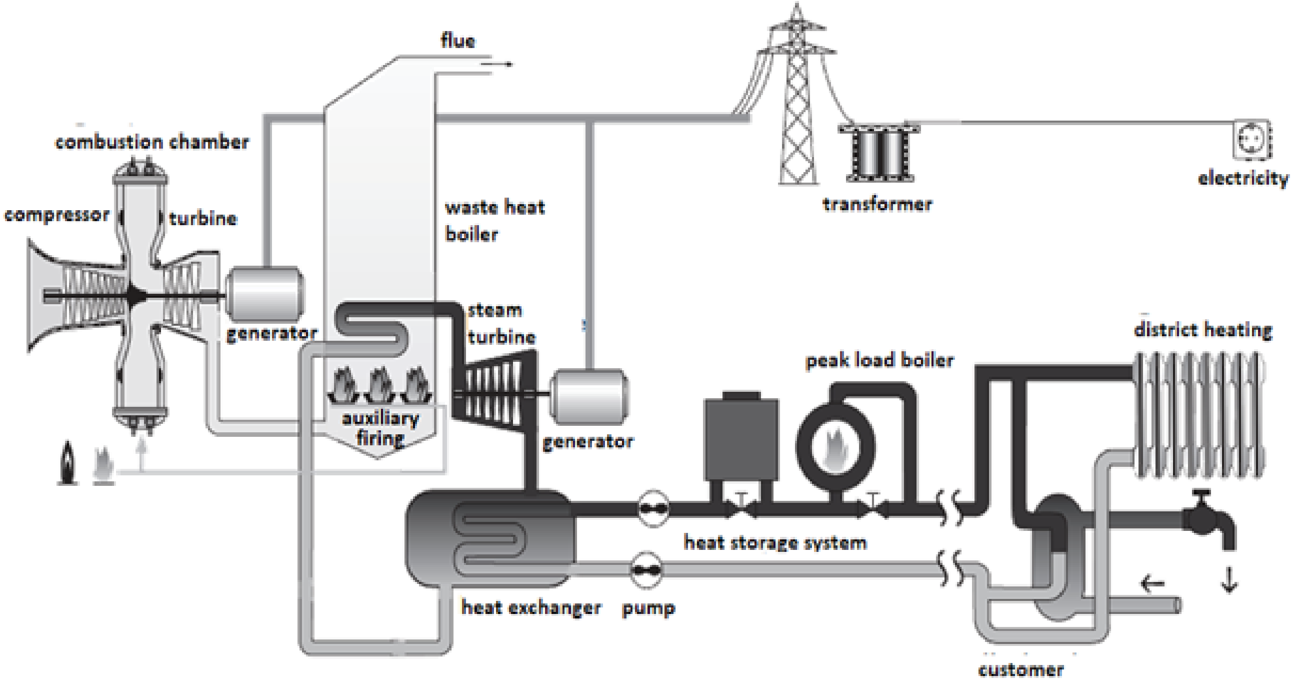


Figure 11: Decoupling District Heat from a gas and steam power plant (Source: AGFW11)

Combined-cycle gas turbine (CCGT) plant

Detailed explanation of the coupled gas turbine- and steam turbine processes

- Combination of one (or more) gas turbine(s) and one (or more) steam turbine(s)
- The 400-600°C of the exhaust gas produces live steam with 40-80bar/350-540°C
- The steam turbine is connected to heat exchangers and a DH network
- Auxiliary firing increases the electrical power of the steam turbine and/or DH

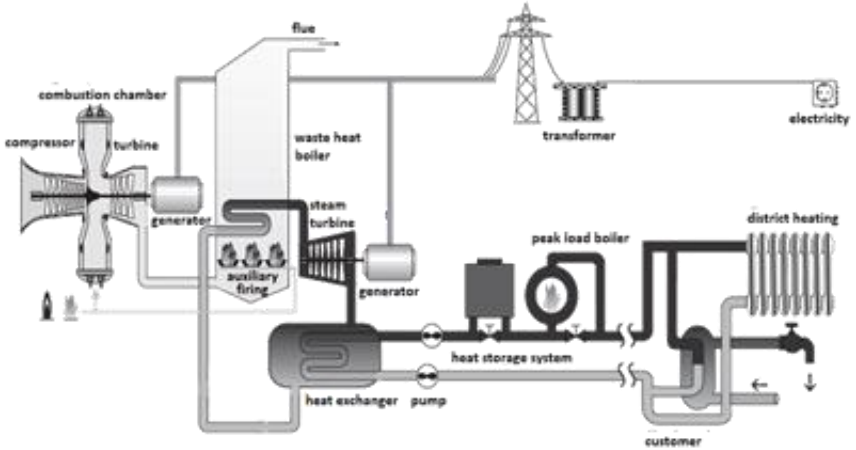


Figure 12: Decoupling District Heat from a gas and steam power plant (Source: AGFW11)

Characteristics of the waste heat process

- No additional heat source for steam turbine process required
- Low personnel requirements
- Relatively low investments
- Flat curve of the specific heat consumption in the electrical partial load area

Fuel cells

- Direct coupled generation of electricity and heat without mechanical energy
- Controlled reaction of hydrogen and oxygen to water
- Electricity generated highly efficient by this eletrochemical process and good controllable
- different temperature levels of utilizable waste heat - depending on the fuel cell technology
- Fuel cells are differentiated to their technology and/or operating temperature (low, medium, high)

Areas for improvement:

- Optimized material, cell lifetime, investment costs and peripheral costs

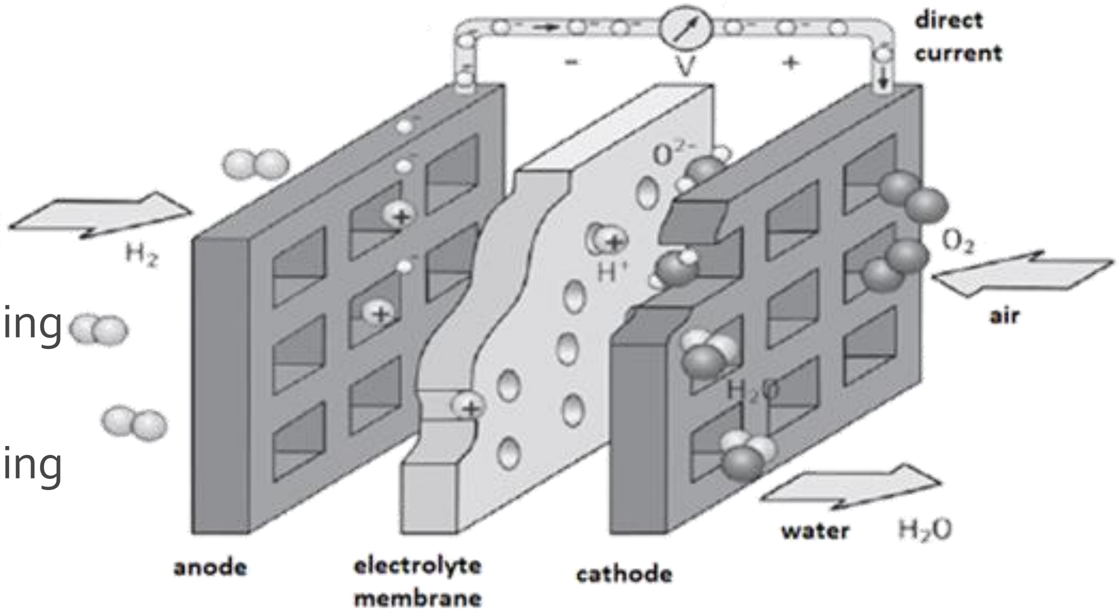


Figure 13: Principle operation of a hydrogen-based fuel cell (Source: Vaillant Remscheid [11])

4. Future prospects of CHP-technology

Future prospects of CHP-technology

Summary of recent CHP-technology & future potentials

- CHP-plants have experienced rapid development in recent years
- CHP-applications contribute to energy and heat transformation in several ways
- flexible solution for accommodating an increasing amount of renewable energy sources in future
- Important interface for the sectors power, gas & heating

Changes are necessary!

→ most CHP systems are still using fossil fuels

→ alternatives are necessary and implementable also in already existing plants

Future prospects of CHP-technology

Possible renewable energy sources

- Using biomass & sewage gas
- Using Hydrogen or methane produced by renewable energies (so called synthetic gas)

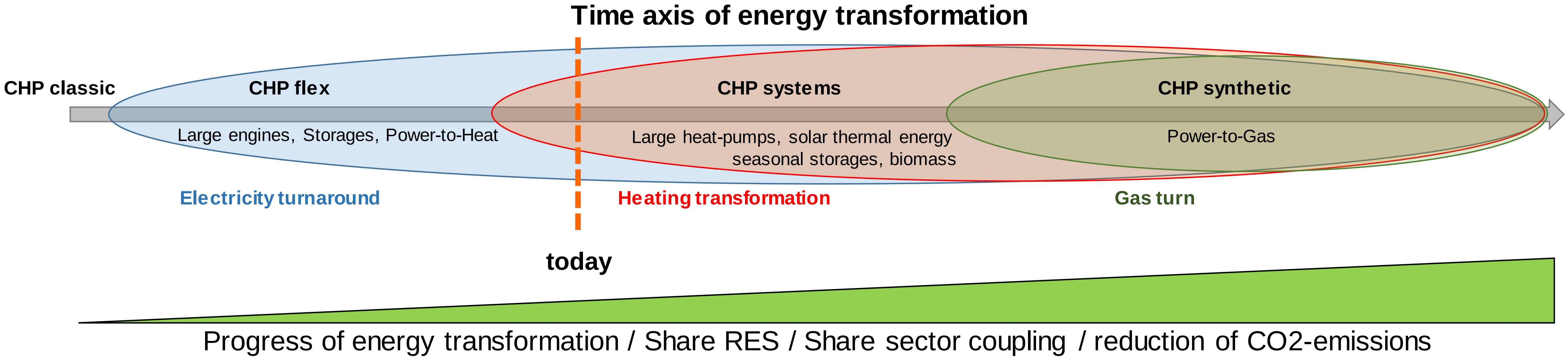


Figure 14: *Time axis of energy transformation and the role of CHP (Source: AGFW 2019)*

Sources

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- [11] Vaillant Remscheid. Quoted after https://www.bhkw-infozentrum.de/innovative/bz_gl.html
- [all others]. Own illustrations AGFW.

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