Module 3: Heat production

Module 3.4
Economic and Environmental Assessment

SHaKE – Sharing Heat and Knowledge on Energy Communities
Erasmus+ KA220-HED Cooperation Partnerships in Higher Education
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SHaKE
Sharing Knowledge on Energy Communities

3.1. INTRODUCTION

District Heating

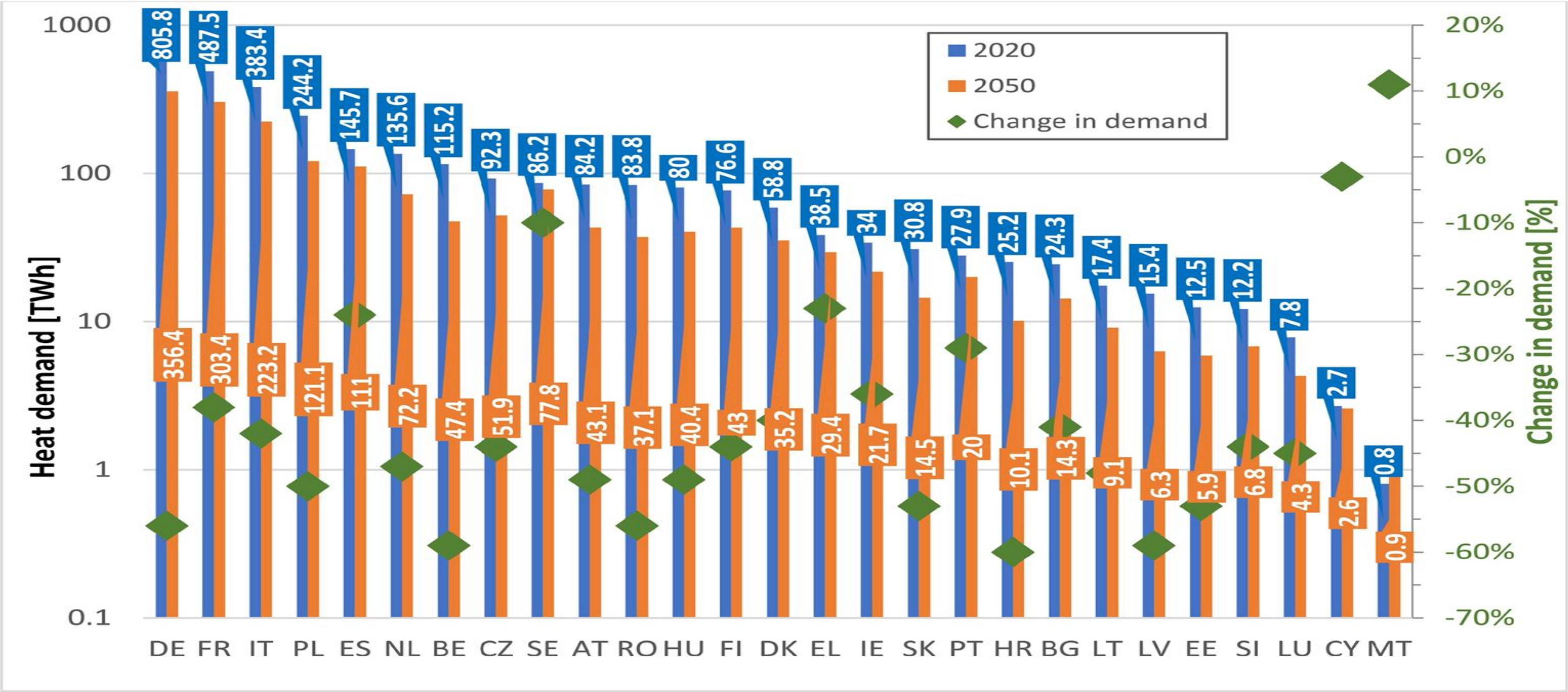

Fig. 1. Useful heat demand levels (TWh) in 2020 and 2050, and the relative changes in residential and tertiary sectors (secondary Y-axis) based on the best-case scenario.

3.1. INTRODUCTION

District Heating in Europe

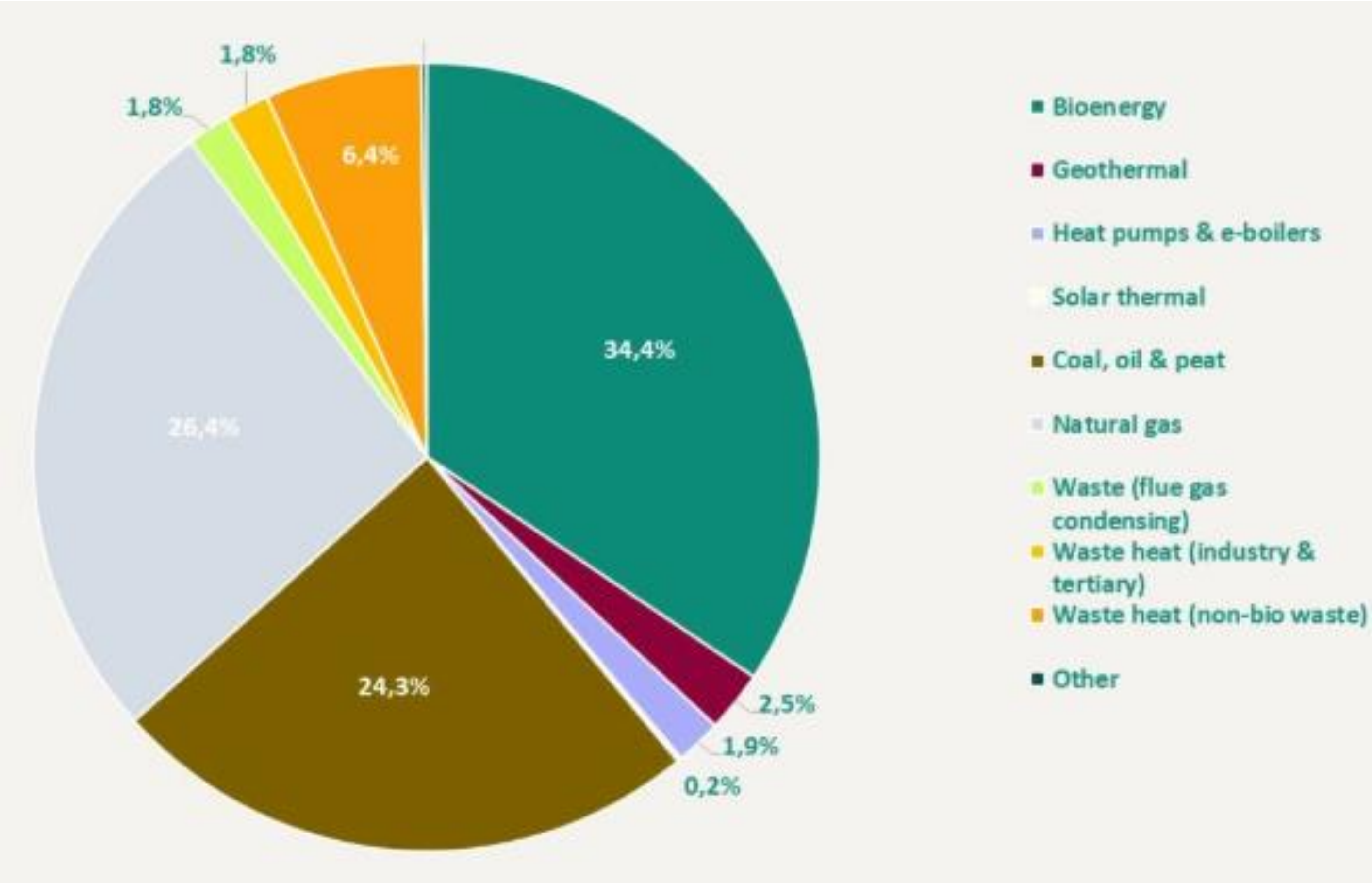

Fig 2. Energy sources in European district heating in 2022. (source: Euroheat & Power)

3.2. IN-DEPTH ECONOMIC ANALYSIS OF HEAT PRODUCTION SYSTEMS

Economic Analysis - Introduction:

Definition:

Economic analysis in heat production evaluates different technologies' cost-effectiveness, financial viability, and long-term sustainability.

- **Key Metrics:**

Capital Expenditure (CAPEX)
Operational Expenditure (OPEX)
Levelized Cost of Heat (LCOH)
Return on Investment (ROI)
Payback Period

3.2. IN-DEPTH ECONOMIC ANALYSIS OF HEAT PRODUCTION SYSTEMS

Capital expenditure (CAPEX):

Capital Expenditure (CAPEX) refers to investments made by a company in long-term fixed assets, such as buildings, machinery, and technology, which are essential for its operations and growth. These investments can be classified into two main categories:

- Maintenance CAPEX: Investments aimed at maintaining or repairing existing assets to ensure proper functionality.
- Expansion CAPEX: Investments focused on acquiring new assets or upgrading existing ones to increase production capacity or enter new markets.

Typical CAPEX components include:

- **Equipment**
- **Installation**
- **Infrastructure**
- **System Integration Costs**

3.2. IN-DEPTH ECONOMIC ANALYSIS OF HEAT PRODUCTION SYSTEMS

Operating Expenditure (OPEX)

OPEX includes recurring costs for efficiently operating and maintaining a DHC system. The key components are:

- **Energy/Fuel:** Costs are a significant expense influenced by fuel price fluctuations. Renewable sources offer more stable long-term costs.
- **Maintenance:** Covers inspections, repairs, and unexpected interventions to ensure reliability.
- **Labor Costs:** Salaries and benefits for operational staff, typically 30–50% of total OPEX.
- **System Monitoring:** Software, analytics, and training for real-time performance tracking, improving efficiency and reducing costs.

3.2. IN-DEPTH ECONOMIC ANALYSIS OF HEAT PRODUCTION SYSTEMS

Levelized cost of heat (LCOH):

The Levelized Cost of Heat (LCOH) is a metric that evaluates the average cost of producing heat over a heating system's lifetime. It contains all relevant expenses, including initial capital investment, operational and maintenance costs, and fuel expenditures, normalized over the total heat output. This metric enables a consistent comparison across different heating technologies and systems.

Definition & Formula:

The LCOH is calculated using the following formula:

$$\mathrm{LCOH} = \frac{\sum_{t=1}^{n} \left(\frac{I_t + O_t + F_t}{(1+r)^t} \right)}{\sum_{t=1}^{n} \left(\frac{Q_t}{(1+r)^t} \right)}$$

Where:

I_t = Investment expenditures in year t
O_t = Operations and maintenance costs in year t
F_t = Fuel costs in year t
Q_t = Heat produced in year t
r = Discount rate
n = Expected lifetime of the system

3.2. IN-DEPTH ECONOMIC ANALYSIS OF HEAT PRODUCTION SYSTEMS

ROI and Payback period

In the context of District Heating and Cooling (DHC) systems, evaluating efficiency metrics such as Cost per MWh of Heat Produced and Return on Investment (ROI) with Payback Periods is essential for assessing their economic viability and performance.

Cost per MWh of Heat Produced:

The cost per megawatt-hour (MWh) of heat produced in DHC systems varies based on factors such as energy sources, system efficiency, and regional economic conditions. For instance, a study on efficient DHC systems in the EU highlighted that the cost per MWh can differ significantly depending on the combination of heat sources and generation technologies.

Return on Investment (ROI) and Payback Periods:

Initial capital expenditures, operational costs, and revenue streams influence the ROI and payback periods for DHC systems. A report on cost drivers in district heating systems noted that Dutch DHC systems, for example, exhibit variations in cost per MWh produced, which can impact the overall ROI and payback periods.

3.2. IN-DEPTH ECONOMIC ANALYSIS OF HEAT PRODUCTION SYSTEMS

Points – Case Studies and Economic Comparison

South Korea:

- Larger district heating systems reduce average costs due to economies of scale.
- Cost efficiency improves with increased system size.

CHP vs. Heat Pumps – Economic Performance:

- **CHP:** ~70% efficiency, lower operational costs, but high capital costs ($1,250–$3,300/kW).
- **Heat Pumps:** Lower operational costs, efficiency depends on COP and electricity source, but also high upfront costs.

Europe:

- District heating enables large-scale low-carbon energy integration.
- Expansion increases flexibility, efficiency, and cost-effectiveness.

Conclusion:

- Scaling up DHC systems improves efficiency and reduces costs, supporting sustainable urban heating and cooling.

Fig. 3. South Korea district heating.

3.2. IN-DEPTH ECONOMIC ANALYSIS OF HEAT PRODUCTION SYSTEMS

Comparative cost analysis:

Cost Drivers in Each System

CHP Systems:

Fuel Costs: The price and availability of the primary fuel (ex, natural gas) directly impact operational expenses.

Capital Expenditure (CAPEX): High initial costs due to equipment, installation, and infrastructure requirements.

Maintenance Costs: Regular upkeep is necessary to ensure optimal performance, adding to operational expenses.

Heat Pumps:

Electricity Costs: Operational costs are influenced by electricity prices and the system's efficiency.

Installation Costs: Expenses related to equipment and setup can be considerable, especially for systems requiring extensive ductwork or ground-source installations.

Performance Variability: Efficiency can decrease in extreme temperatures, potentially increasing operational costs.

3.3. ENVIRONMENTAL IMPACT OF HEAT PRODUCTION SYSTEM

Environmental Impact-Introduction:

Key Factors Analyzed

An EIA typically examines a range of factors to assess a project's environmental footprint:

- **Project Scale and Nature.**
- **Site Characteristics.**
- **Potential Environmental Impacts.**
- **Cumulative Effects.**
- **Mitigation Measures.**
- **Regulatory Framework.**

3.3. ENVIRONMENTAL IMPACT OF HEAT PRODUCTION SYSTEM

Greenhouse Gas Emissions (GHG):

Low/Zero Emissions with Heat Pumps

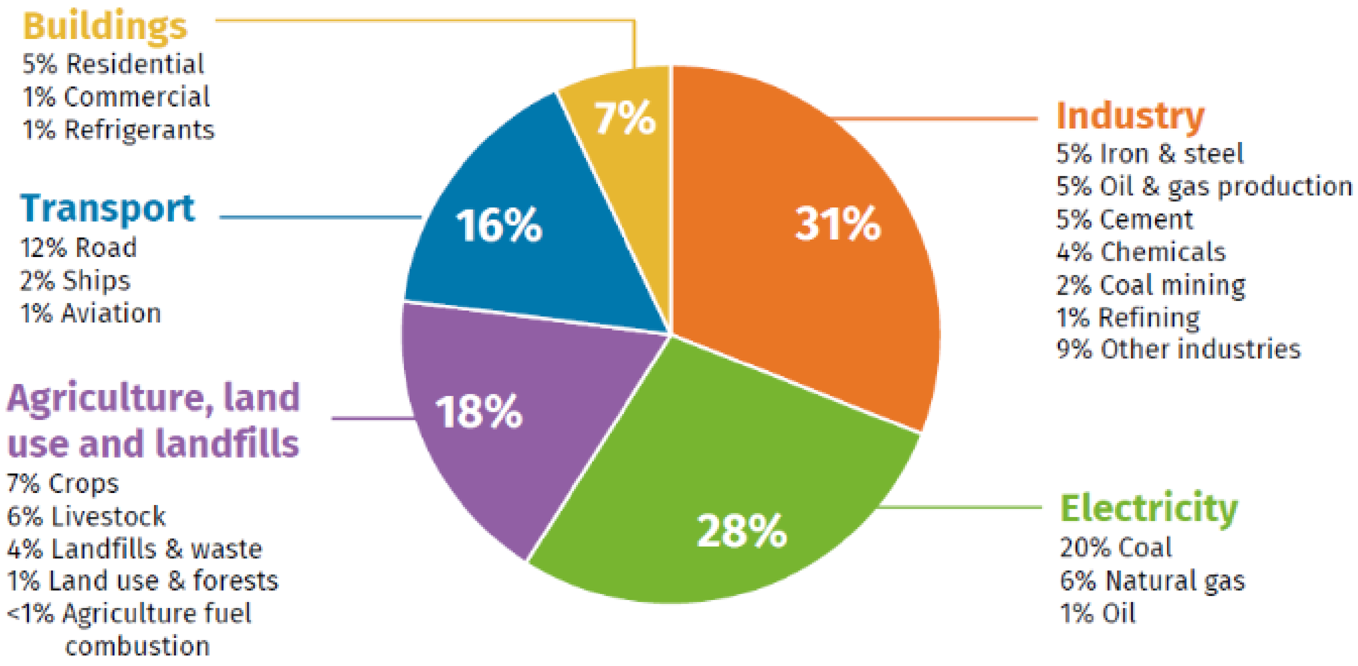

Fig. 4. Greenhouse gas emissions distribution by sectors.

3.3. ENVIRONMENTAL IMPACT OF HEAT PRODUCTION SYSTEM

Resource utilization

Efficiency & Sustainability

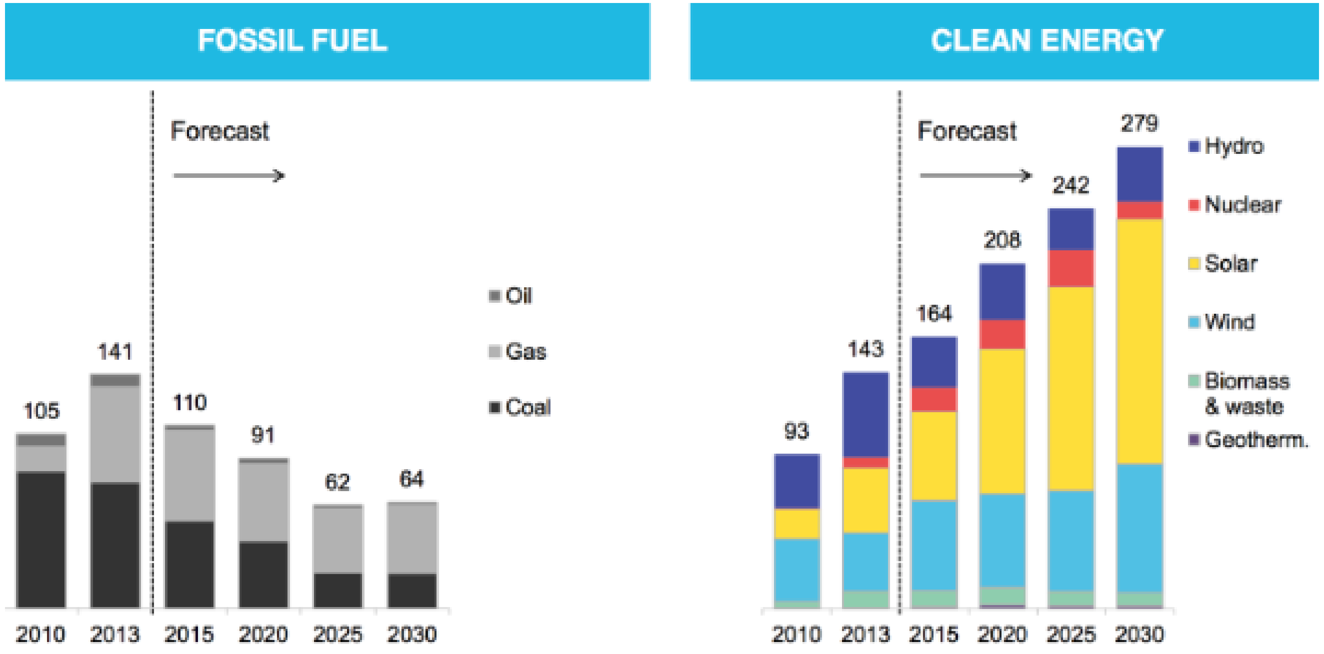

Fig. 5. Fossil fuel vs clean energy generation capacity forecast.

3.3. ENVIRONMENTAL IMPACT OF HEAT PRODUCTION SYSTEM

Emissions from CHP vs. Heat Pumps

CHP Systems:

- Emit NO_x, SO_x, and particulates, especially when using fossil fuels.
- More efficient than separate systems, but still contribute to air pollution.
- Emissions vary by fuel type and technology.

Heat Pumps:

- Almost no on-site emissions (NO_x, SO_x, particulates).
- Environmental impact depends on electricity source.
- Cleaner as grids shift to renewable energy.

3.3. ENVIRONMENTAL IMPACT OF HEAT PRODUCTION SYSTEM

Lifecycle Assessment (LCA)

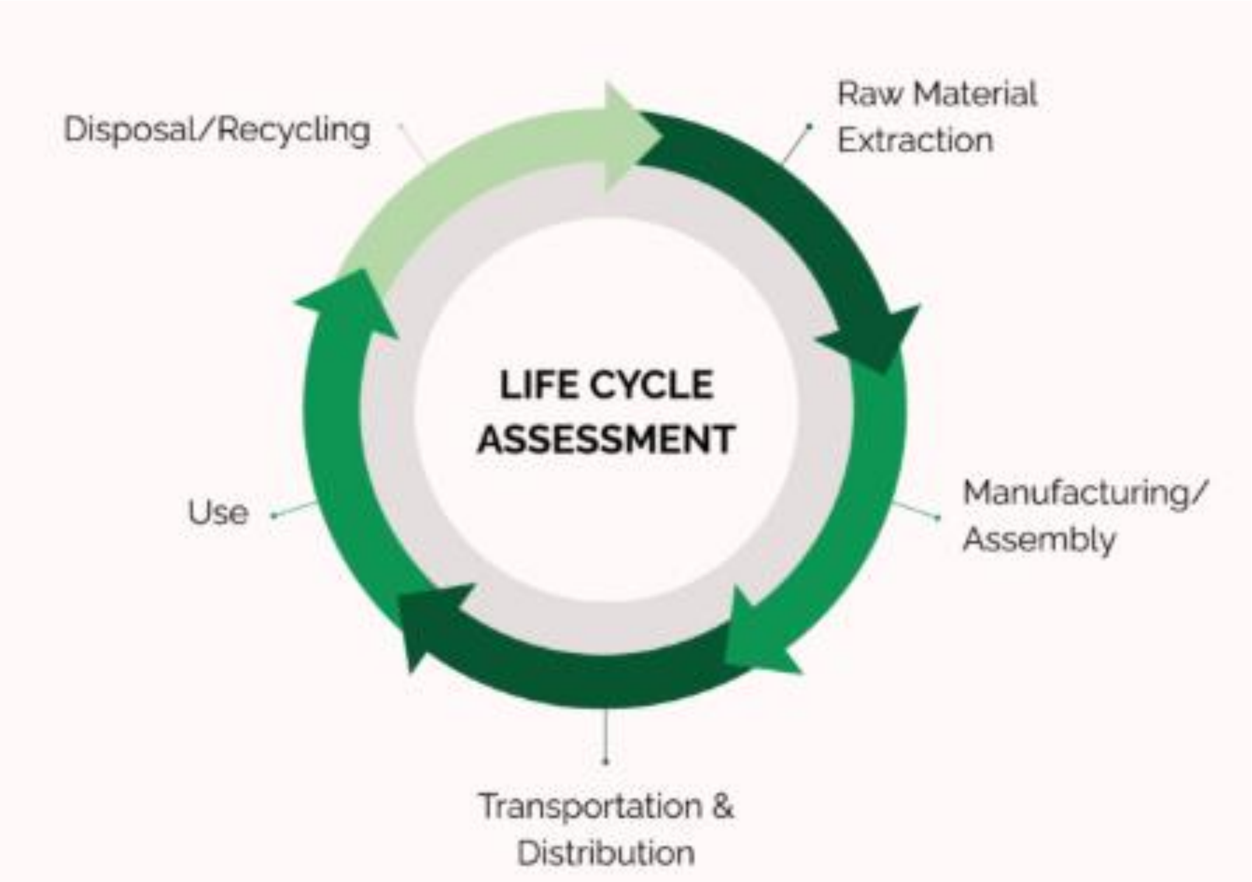

Fig. 6. LCA production cycle.

3.4. MARKET AND INDUSTRY TRENDS, PRICING, AND MARKET COMPETITION OF CHP AND HEAT PUMPS

Market Trends – Introduction

Evolution of Heat Production and Heat Pumps

Evolution of Heating:

- Transition from coal-fired systems to efficient, modern technologies.
- Steam and electric heating improved control and efficiency.
- Recent shift toward sustainable systems, especially heat pumps.

Heat Pumps:

- Accounted for ~10% of global space heating in 2021.
- Growth driven by high efficiency and use of renewables.
- In 2024, European sales dropped 23% due to political and economic factors.
- UK sales rose 63%, showing regional variation in adoption.

3.4. MARKET AND INDUSTRY TRENDS, PRICING, AND MARKET COMPETITION OF CHP AND HEAT PUMPS

CHP VS HP

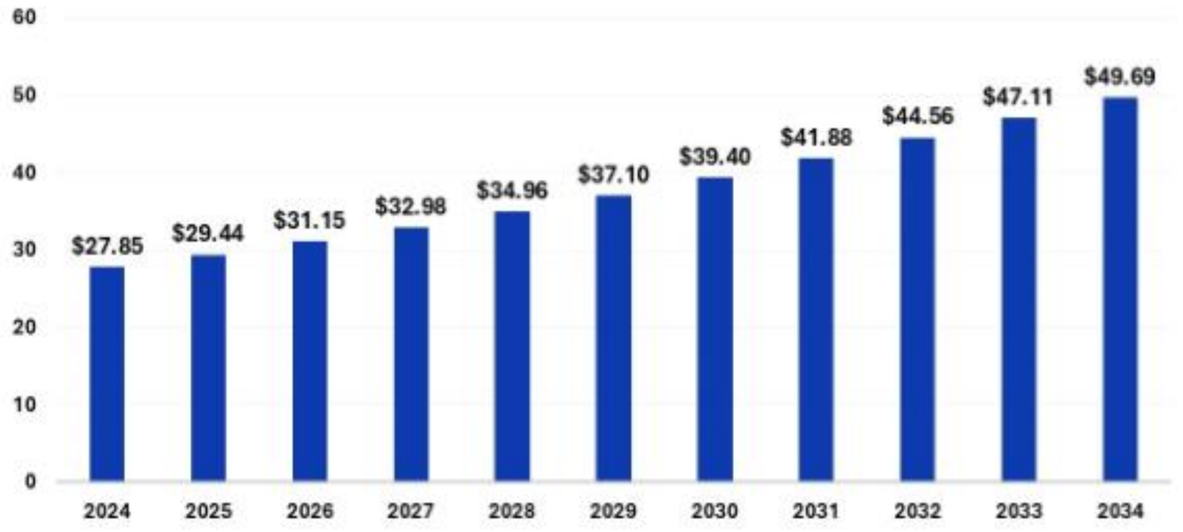

Fig. 8. CHP market size 2024 to 2034 (USD Billion)

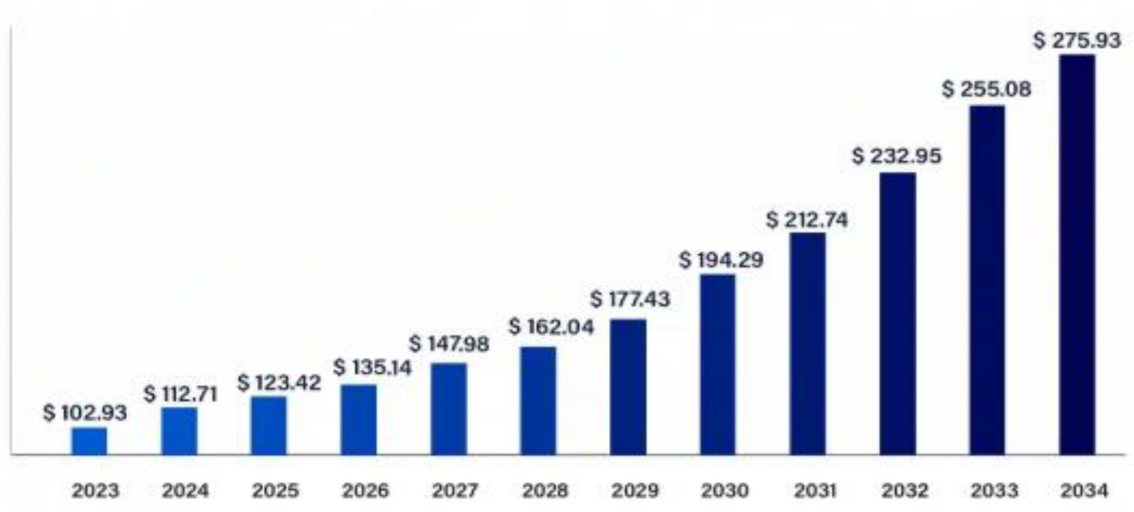

Fig. 7. Heat pump market size 2023 to 2034 (USD Billion)

3.4. MARKET AND INDUSTRY TRENDS, PRICING, AND MARKET COMPETITION OF CHP AND HEAT PUMPS

Industry Leaders, Pricing Dynamics & Technology Impact

Key Market Players

GE – Major CHP provider with high-efficiency, reliable systems.

Siemens Energy – German leader offering CHP solutions for diverse industries.

Veolia – French company delivering integrated energy and CHP services.

Wärtsilä – Finnish innovator with strong CHP market presence.

2G Energy – German specialist in advanced CHP technology.

Pricing & Market Dynamics (2019–2022)

Energy price increases:

- Electricity: +6–14% | Natural gas: +22–46%
- Heating oil: +35% | Propane: +33–50%

Rising gas prices → lower CHP profitability.

Stable/falling electricity → boosts heat pump adoption.

Integration of micro-CHP + heat pumps + thermal storage + PV → >130% fuel efficiency.

Improved performance reduces operating costs.

Heat pumps: Payback up to 16 years, supporting long-term market growth.

3.5. POLICY INSTRUMENTS AND REGULATORY FRAMEWORKS OF CHP AND HEAT PUMPS

Policy Instruments & Global Framework

Global Context

- Policies aim to limit global warming to 1.5°C through heat decarbonization.
- Implementation varies by region, depending on economic and political conditions.

EU Initiatives

- REPowerEU Plan:
    - 20 million heat pumps by 2026
    - 60 million by 2030 → reduce fossil fuel dependency.

Global South Challenges

- High borrowing costs slow clean energy projects.
- COP29 & G20: emphasize climate financing (carbon taxes, debt swaps).
- Policies must be region-specific to ensure sustainable adoption.

Regulatory Frameworks (EU)

- RED II: ≥ 32% renewable energy by 2030.
- EED: +32.5% energy efficiency by 2030.
- National Standards: Adapt EU goals locally (e.g., Germany's *EnEV* for buildings).

3.5. POLICY INSTRUMENTS AND REGULATORY FRAMEWORKS OF CHP AND HEAT PUMPS

Subsidies, Carbon Pricing & Market Impact

- Subsidies & Incentives
- Grants: Reduce upfront investment costs.
- Tax Credits (ITC, PTC): Encourage installation & operation of renewables.
- Feed-in Tariffs (FiTs): Guarantee income for renewable producers.

Impact on Market

- Higher adoption rates & market expansion through lower costs.
- Encourages innovation and long-term competitiveness.
- Gradual reduction of subsidy dependence as technologies mature.

Carbon Pricing Mechanisms

- Emission Trading Systems (ETS): Companies trade emission allowances; caps drive reductions.
  - Example: EU ETS – largest global carbon market.
- Carbon Taxes: Increase cost of fossil fuels → lower emissions.
  - Example: Sweden’s carbon tax → major emission cuts.
- Both instruments affect operational costs and promote cleaner innovation.

3.6. FUTURE CONSIDERATIONS

Future Energy Transitions: Decarbonization & Innovation

Decarbonization Challenges

- Transition to renewable heat sources (solar, geothermal, waste heat).
- Barriers: infrastructure, investment, and storage capacity.
- Example: Geothermal systems require advanced temperature control.

Innovation & Technology

- Advanced heat pumps, thermal storage, and low-carbon systems enable sustainable growth.
- Example: New-generation heat pumps improve integration with renewables.

Business Models & Financing

- Public–Private Partnerships (PPPs) and green bonds fund renewable transitions.
- Aim: reduce financial risks and promote sustainable district heating investment.

Net-Zero 2050 Goals

- EU & U.S. committed to net-zero emissions by 2050.
- Requires: large-scale renewable integration, energy storage, and smart grids.
- Example: EU Green Deal → –55% emissions by 2030, net zero by 2050.

3.6. FUTURE CONSIDERATIONS

Transition from Fossil-Based CHP

- Current: CHP plants use natural gas, coal, oil → major CO_2 sources.
- Future: shift to biomass, solar thermal, geothermal, green hydrogen.
- Example: Danish District Heating System moving to biomass & waste heat (carbon-neutral by 2030).

Technological Advancements

- Ultra-High-Temperature Heat Pumps (UHTHPs): operate >100°C for industrial/district use.
    - Example: *Energiepark Mainz* (Germany) – >100% efficiency.
- Advanced CHP with Biofuels & Hydrogen: low-carbon or zero-emission operation.
    - Example: *Hannover CHP Plant* using hydrogen fuel for carbon-neutral heat.

Grid Integration & Flexibility

- Demand-Side Management (DSM): consumers adjust usage by price/supply.
- Thermal storage: balances heat demand and grid fluctuations.
- Benefits: lower costs, prevent congestion, improve system efficiency.

3.6. FUTURE CONSIDERATIONS

Climate Resilience

- Weather variability affects heating demand (mild winters vs. cold extremes).
- Solutions: flexible operations, thermal storage, renewable backup (biofuels, H_2).
- Goal: reliable & adaptive district heating systems.

Economic Resilience

- Diversify energy sources, apply flexible pricing & smart grids for stability.
- Focus on long-term investment and life-cycle cost optimization aligned with decarbonization goals.

Future-Proof Heat Networks: Key Projects

- UK – Green Gas for London: Biogas + waste heat for zero-carbon district heating.
- Copenhill (Copenhagen): Waste-to-energy plant heating 150,000 homes; carbon-neutral goal by 2025.
- Amsterdam Smart Heat Network: Integrates solar, geothermal & thermal storage with digital control.

Impact

- Decarbonization: Combines renewables & innovation for low-carbon systems.
- Resilience & Flexibility: Stable supply under changing climate.
- Scalability: Designed for expansion and future technology integration.

3.7. CONCLUSIONS

Conclusions

- **Economic & Environmental Aspects:**
  - Economic: District heating systems reduce fossil fuel dependence, lower operational costs, and generate revenue via incentives and carbon credits.
  - Environmental: Adopting renewable technologies and waste heat recovery helps decarbonize heating and reduce carbon footprints.
  - Efficiency: Smart grids and advanced technologies improve system adaptability and energy efficiency.
- **Importance of Policies & Future Trends:**
  - Policies: Supportive policies like subsidies, carbon pricing, and energy standards are essential for accelerating adoption.
  - Future Trends: Ultra-high-temperature heat pumps, CHP with biofuels and hydrogen, and smart grids will shape the future of district heating.
  - Climate Resilience: Flexibility in system design ensures reliability in changing climate conditions.

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Thank you!

Module 3.4 – Economic and Environmental Assessment
SHaKE – Sharing Heat and Knowledge on Energy Communities

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