Fraunhofer IEG

Sector Collaboration Workshop – Chemicals

Chemicals 21.01.2026

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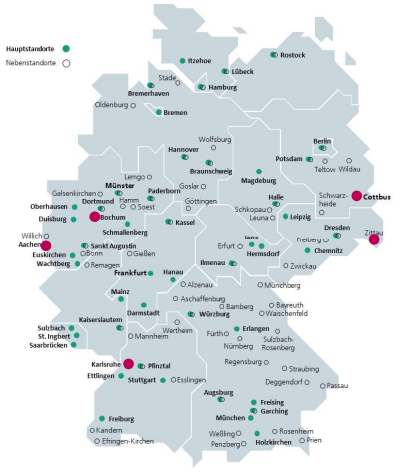
Fraunhofer at a glance



Impact-Goals

- Affordable healthcare
- Digital transformation
- Security and a resilient society
- Complete energy transition
- Fully circular economy

Fraunhofer Strategic Research Fields

- Bioeconomy
- Digital Healthcare
- Artificial Intelligence
- Next Generation Computing
- Quantum Technology
- Resource Efficiency and Climate Technologies
- Hydrogen Technologies

Lead markets

- Plant, mechanical and vehicle engineering
- Construction industry
- Digital Economy
- Energy Sector
- Health care
- Mobility
- Chemical industry
- Agricukture and food industry

Fraunhofer Groups

- Cluster of Excellence
- Flagship projects
- Research factories
- High-Performance Centers

Lead markets orientated Alliances

30.000 employees in 76 Fraunhofer institues

  Offen Fraunhofer IEG

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"We design the climate-neutral energy systems of the future"

- Integrated **energy infrastructures**
- Transmission and **distribution networks**
- Integrated **district supply** (Open District Hub)
- **Hydrogen** infrastructures (grids and storage)
- System transformation and technology transfer

- Exploration and exploitation of **georesources**
- **Geothermal energy**, shallow to deep geothermal systems
- **Geotechnologies**, drilling techniques and methods
- **Underground storage** for materials and heat, post-mining utilisation

- Development of **thermal energy systems** that work **grid-balancing**
- 4th and 5th generation **heating/cooling networks**
- **Overground storage** for energy and **integration** of sector-coupled energy systems
- Efficient redesign of **chemical production processes** and **carbon capture**

- **Control, automation & operational management** of energy systems
- Decentralised, **smart and digital grids** and systems
- **Large-scale demonstrators / field scale laboratories**

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Competence Center Thermal energy systems

The Fraunhofer IEG offers industrial clients, in addition to participation in research projects, a wide range of services for technology transfer from research in the field of thermal energy systems

1. Joint technology development and testing with manufacturers of large-scale heat pumps, direct electric processes, hydrogen combustion systems, and above-ground thermal storage systems through simulation and experimentation.
2. Investigation of flexible operating modes of large electrified heat generators to reduce average electricity costs and stabilize the grid
3. Support for investment decision-making through market analyses, evaluation of business cases, and due diligence support
4. Erarbeitung von Transformationskonzepten zur Integration innovativer Technik sowie Durchführung oder Koordination von Umsetzungsprojekten für das produzierenden Gewerbe und den Fernwärmesektor

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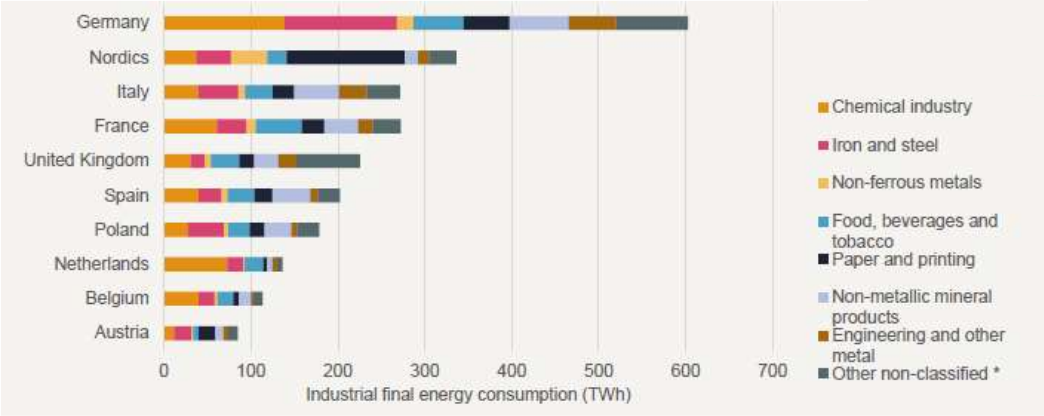
Final energy demand in Europe by sectors



Source: LCP Delta 2025

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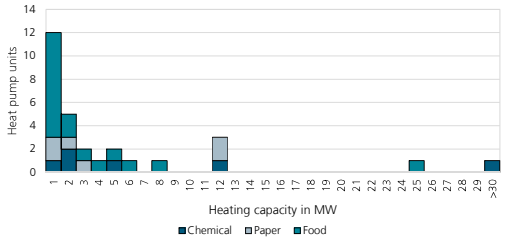
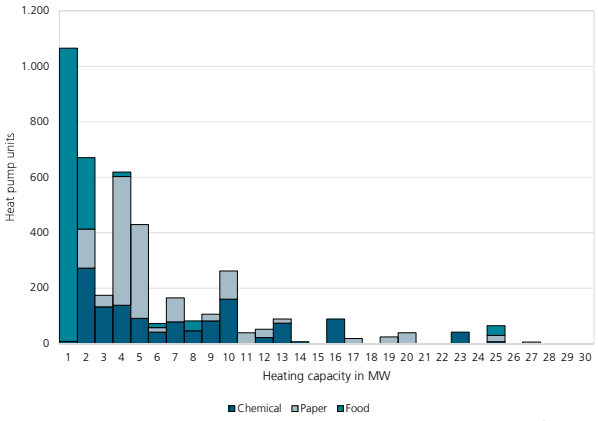
Market potential

- Food industry: Main market potential for plants with 1 to 2 MWth; larger plants are also possible.
- Paper industry: Main market potential for heat pumps with an estimated 2 to 10 MWth; larger plants are also possible.
- Chemical industry: Main market potential for plants with 2 to 10 MWth; potential also exists for plants with more than 10 MWth.

Heating outputs of the recorded projects (a total of 29)



Estimated market potential for the European market



Source: Marina 2021

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Market overview

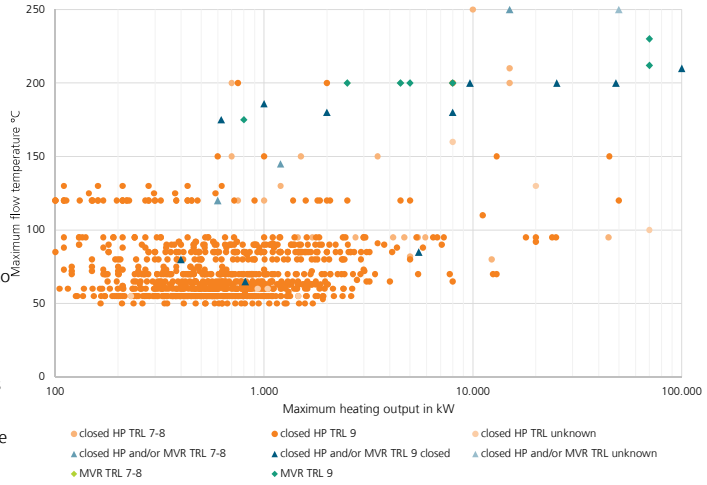
[Eigene Recherche]

High performance range:

- The distinction between large heat pumps and high-performance systems is not uniformly defined.
- Large heat pumps start at approximately 500 kW. High-performance systems start at 10 MW.

High temperature range:

- Limit in the literature at 100°C (Arpagaus HTWP, 2019)
- Market overview shows a gap in the supply from 180°C to 200°C
- Maximum temperature range from approx. 200°C
- Many manufacturers with customized and standard solutions are represented on the market for temperatures up to 120°C
- Few manufacturers offer solutions for temperatures above 120°C, often using open vapor compression (MVR)



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Online tool for efficient market analysis

Current situation:

- Extensive research in data sheets and static lists (BAFA)
- Planning and selecting the right HTWP requires high expertise and continuous analysis of new releases on the market.

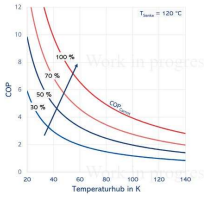
In Future:

- Dynamic database query on the LEA Hessen website
- (Detailed information on suppliers, TRL, refrigerants, potential sources and sinks, compressors, etc.)
- Contact information for manufacturers and suppliers
- Generic COP and CO_2 calculators
- Important background information for all stakeholders

LEA HESSEN LANDESENERGIEAGENTUR

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages



www.grosswaermepumpen-info.de

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Online tool for efficient market analysis

Gefördert durch: Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages

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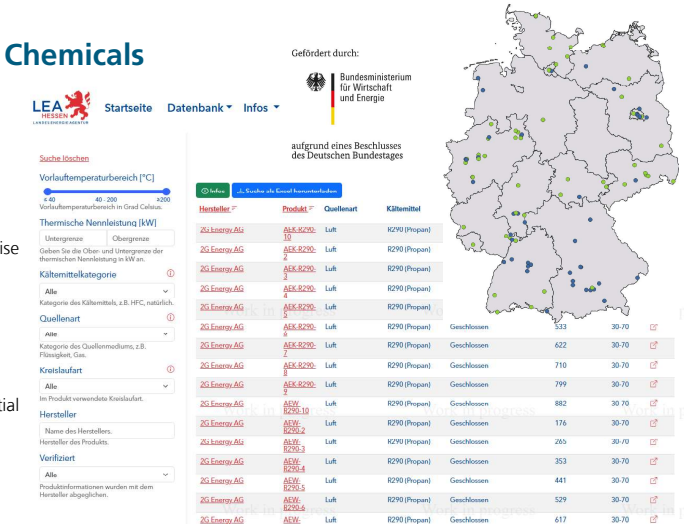

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Natural gas dependence

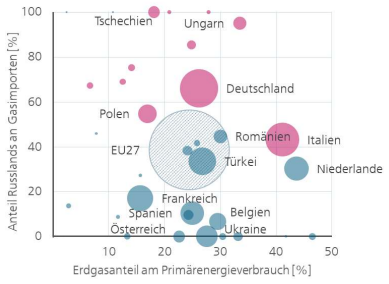
The share of Russian natural gas imports and the relevance of natural gas to the energy system differ for European countries.

- There is a great need for action in countries like Germany, Italy, Hungary, Poland, and the Czech Republic.
- Other countries with high consumption can also contribute to European independence by reducing their consumption.

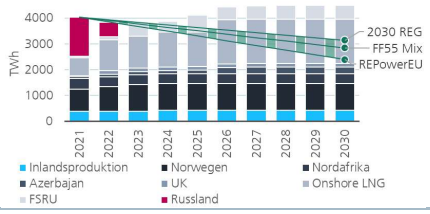
Alternative supply options are expected to be sufficient in 2 to 3 years to meet demand on a balance sheet basis

- Ambitious efficiency measures help to avoid supply bottlenecks.
- A detailed analysis of the gas networks is necessary to guarantee security of supply everywhere and at all times.

Erdgasabhängigkeit der europäischen Länder 2020[1]



Projektionen zur Entwicklung von Angebot und Nachfrage nach Erdgas in Europa[2]



[1] Eurostat (2021): nrg_bal_c, nrg_ti_gas
[2] McWilliams, B., G. Sgaravatti, S. Tagliapietra and G. Zachmann (2022) 'A grand bargain to steer through the European Union's energy crisis', Policy Contribution 14/2022, Bruegel

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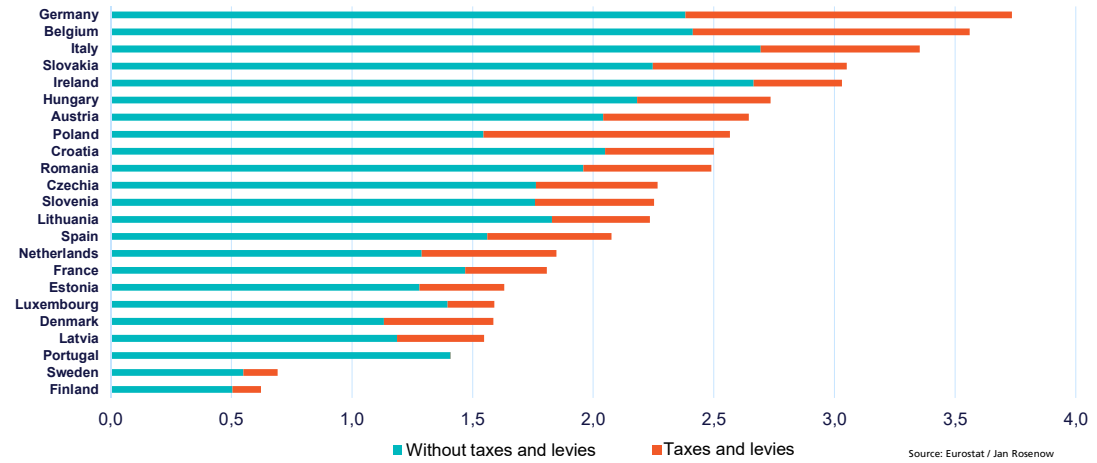
Ratio of electricity to gas price (industrial prices 2022)



Source: Eurostat / Jan Rosenow

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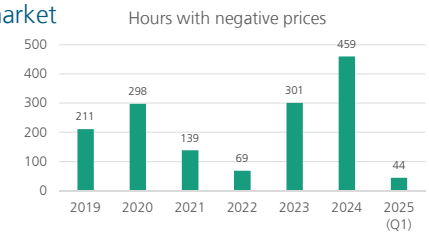
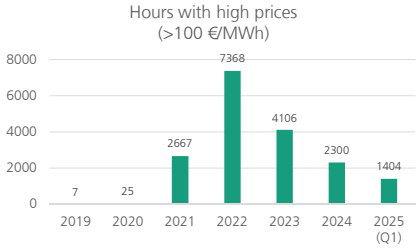
Electricity price volatility 2019-2025 GER, day-ahead market

- Hours with negative prices are steadily increasing due to more weather-dependent generation.
- Average market prices are not a sufficient indicator.
- The system must be resilient to price fluctuations and able to capitalize on them.
- Use heat storage and inertia to avoid high prices and take advantage of low ones.





Source: Source: energy-charts.info (27.03.2025)

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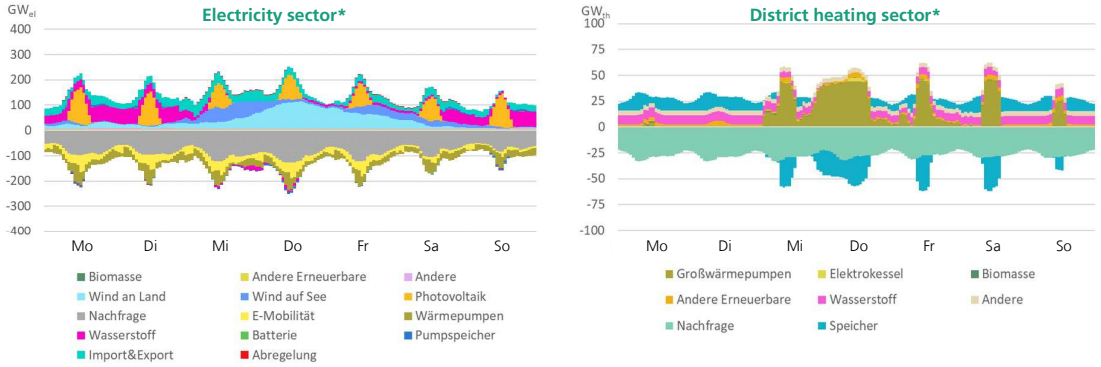
Development of electricity supply – Winter 2045 GER



- High renewable energy generation = high grid utilization & low electricity prices -> Heat pumps are in operation. Excess heat is stored.
- Low renewable energy generation = high electricity prices -> Heat demand is met by thermal storage & other technologies (e.g., hydrogen combined heat and power).

* Early Febuary 2045 according to T45-electric scenario; own representation based on Fraunhofer ISI (2022)

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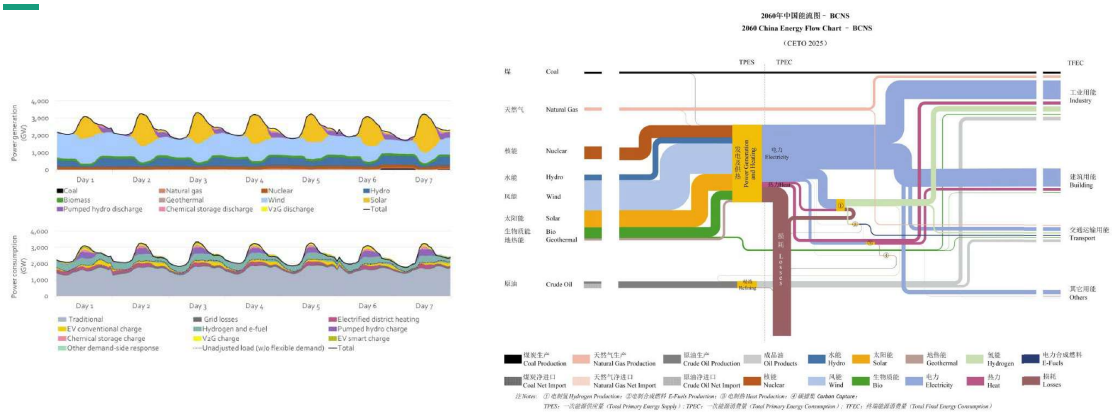
Simulation Winter Week 2060 - China



Source: China Energy Transformation Outlook 2025

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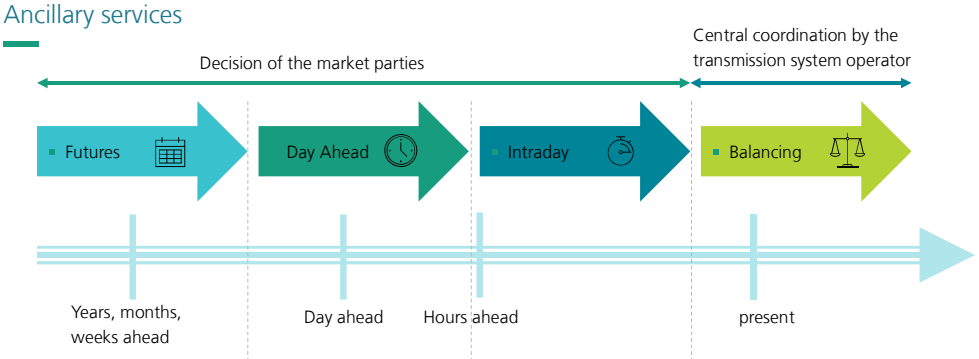
Ancillary services



- Long-term hedging
- Risk management
- Possibility of reselling energy

- 24 Hours Ahead
- Main Energy Trading Market
- Predictable Daily Patterns

- Hours to minutes in advance
- Fine-tuning of the energy balance
- Higher volatility

- Real-time
- System stability
- Higher volatility
- Various services

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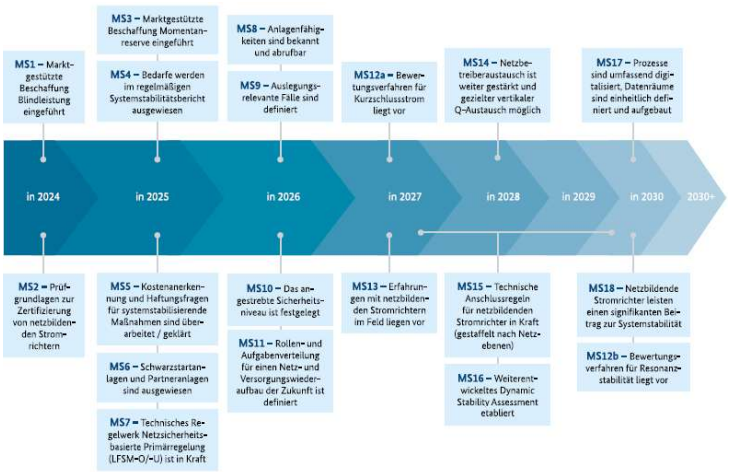
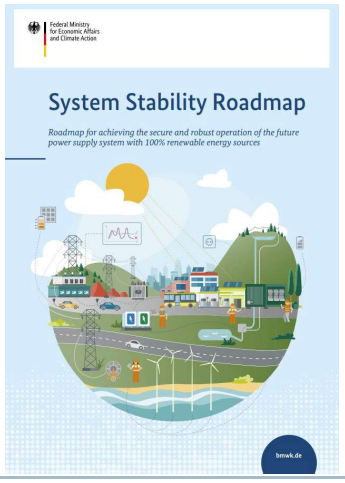
Roadmap Systemstabilität





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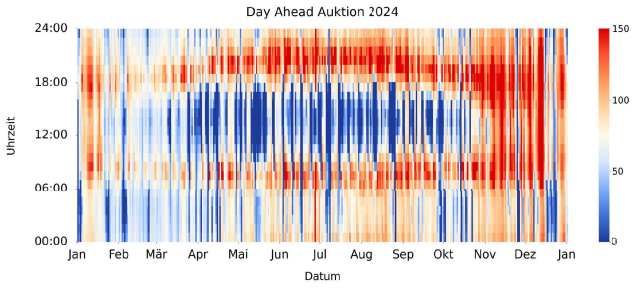
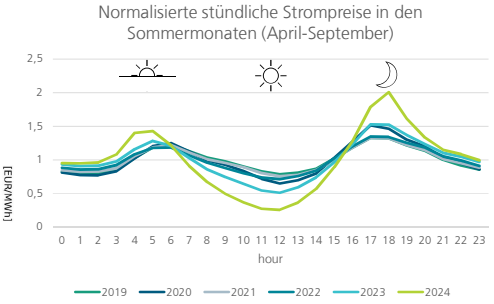
Volatility patterns of the electricity market - Day Ahead market

- Daily patterns with peaks in the morning and evening, most pronounced in summer
- Dark doldrums in late autumn
- Heatmap of electricity prices shows patterns and opportunities for control.



- Hourly prices on the spot market become more volatile year by year (duck curve).



Source: energy-charts.info (27.03.2025)

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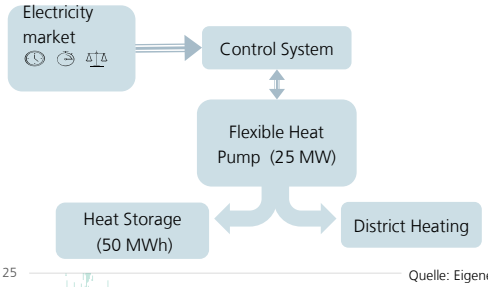
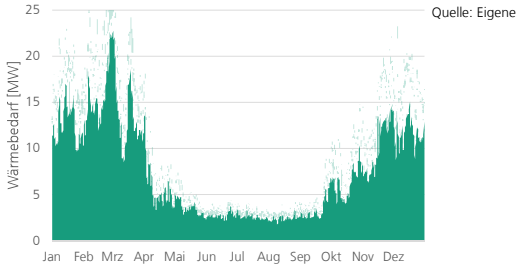
Model and test scenarios

- Model:
  - Large heat pump: 25 MW thermal output
  - Thermal storage: 50 MWh thermal capacity
  - Electricity market: Real 2024 price data from the day-ahead market
  - Heat demand: Real load profile on the right
  - Simulation duration is one year with hourly resolution
- Comparison of two operating scenarios:
  - Base scenario: Heat demand-oriented operation without market optimization
  - Flex scenario: Electricity market-oriented operation with heat storage utilization



Quelle: Eigene



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Result: 22% cost savings through intelligent operations management

Szenario	Basis	Flex
Total annual heating demand [MWh]	77687,25	
Total cost [€]	2.504.836,47	1.949.121,68
Savings	-	22,19%
Average electricity price [€/MWh]	80,61	62,72
Goal	Cover heating requirements	Meeting heating needs with cost optimization
Storage usage	only if necessary	optimal use to avoid high prices

The results were confirmed with data from other municipal utilities, and we obtained similar results +/- 4%.

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New Fraunhofer IEG Spin-Off

flex4grid GmbH

Engineering solutions for lower electricty costs

Fraunhofer IEG

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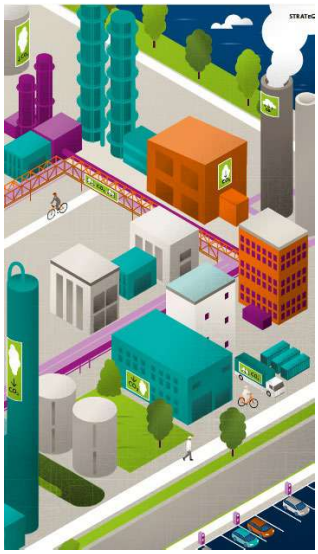
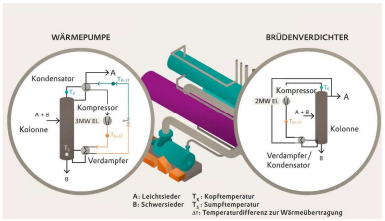
Process Heat Transformation at Evonik

The role of (high temperature) heat pumps for cost-effective defossilisation

Presenter: Daniel Murrenhoff

Evonik Operations GmbH / Process Technology / Sustainable and Environmental Technologies

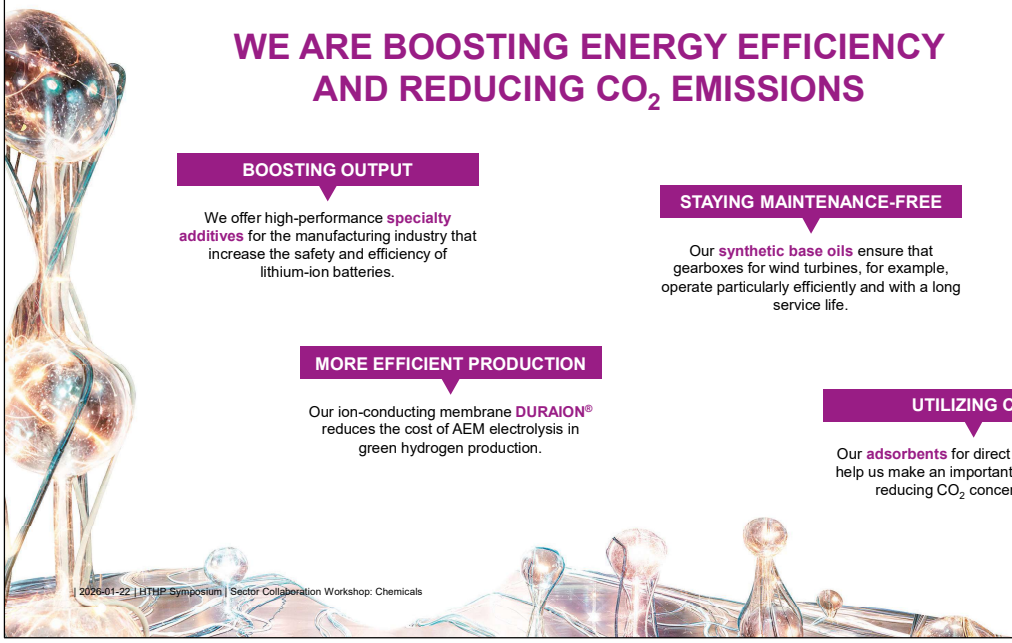




EVONIK Leading Beyond Chemistry

Short intro Evonik

EVONIK
Leading Beyond Chemistry



WE ARE BOOSTING ENERGY EFFICIENCY AND REDUCING CO_2 EMISSIONS

BOOSTING OUTPUT

We offer high-performance **specialty additives** for the manufacturing industry that increase the safety and efficiency of lithium-ion batteries.

STAYING MAINTENANCE-FREE

Our **synthetic base oils** ensure that gearboxes for wind turbines, for example, operate particularly efficiently and with a long service life.

MORE EFFICIENT PRODUCTION

Our ion-conducting membrane **DURAION®** reduces the cost of AEM electrolysis in green hydrogen production.

UTILIZING CO_2

Our **adsorbents** for direct air capture will help us make an important contribution to reducing CO_2 concentrations.

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Evonik in figures

FINANCES	BUSINESS	INNOVATION	PEOPLE
€15.2 billion in sales generated by our company in the 2024 fiscal year.	**9,200** products in our portfolio – from ABIL® to NANOPOX® and ZETASPERSE®.	**21,400** patents stand for Evonik's innovative spirit. Our first patent dates back to 1882/83.	**32,000** employees represent 110 nations. Plenty of potential to develop tailor-made solutions for every market in the world.
€2.1 billion was our adjusted EBITDA in 2024, with a corresponding EBITDA margin of 13.6%.	**104** production locations ensure close proximity to customers and markets, whether in North America, South America, Europe or Asia.	**€459** million invested in our company's research and development activities in 2024.	**60%** women on our executive board – no other company in the DAX or MDAX has a higher proportion.

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Sustainability goals and process heat transformation

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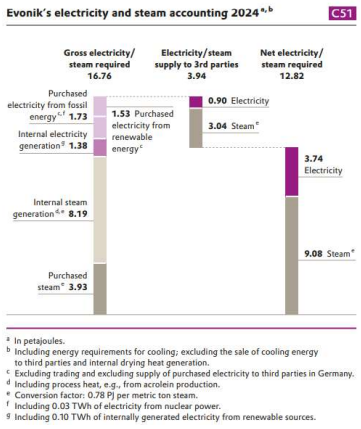
Energy balance of Evonik 2024
How do we transform approx. 9 TWh of steam/process heat worldwide?



Target: 100% green procurement by 2030

How does the steam or process heat become sustainable?

ESRS E1-5

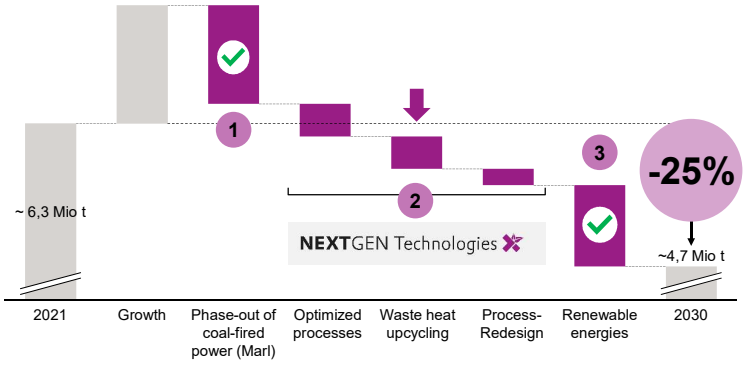
Energy consumption[a] and mix T39

in GWh	2024
Natural gas	9,901
Coal and coal products	931
Crude oil and petroleum products	1.1
Other fossil sources	1,424
Purchased or acquired electricity from fossil sources	1,705
Purchased or acquired steam	3,929
Total fossil energy consumption	**17,891**
Consumption from nuclear sources	**27**
Purchased or acquired electricity from renewable sources	1,534
Consumption of self-generated non-fuel renewable energy	101
Fuel consumption for renewable sources, including biomass[b]	44
Total renewable energy consumption	**1,679**
Total gross energy consumption	**19,597**
thereof share of fossil energy (in %)	91
thereof share of nuclear sources (in %)	0.1
thereof share of renewable sources (in %)	8.6
Sales in € billion[c]	15,157
Energy intensity ratio in GWh/€ billion	1.29

Source: https://www.evonik.com/content/dam/evonik/documents/Evonik_Finanz_und_Nachhaltigkeitsbericht_2024.pdf, S. 141f

Footprint: A clear roadmap to achieve Scope 1 and 2 targets by 2030
Three clusters with economically attractive measures defined

Absolute GHG emissions Scope 1 and 2



Reduction measures

1. **Phase-out of coal-fired power generation in Marl**
2. **Next Generation Technologies**
   Optimized processes, e.g. modern process control
   Innovative waste heat recovery, e.g. heat pumps
   Process redesign
3. **Renewable energies**
   e.g. Green PPAs

Concepts for alternative process heat generation
Green process heat can be produced by multiple sources / technologies

Biogenic Energies


Biogas


Biomethane-Certificates


Biomass combustion

Local Energies


Solar thermal heat (CST)


Geothermal energy

...

(Green-) Power


E-boiler
No public picture rights


Heat Pump, Mech. Vapor Recompression


Direct electrification


Green Hydrogen

DAC/CCU/CCS

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Why is heat integration essential for Evonik's heat transformation?
It allows electrification with low electricity consumption

Temperature profile Evonik processes up to 250 °C	Preferred technologies	estimated COP/efficiency*
T > 250 °C	Direct el. Heating, e-boiler, biogas / H_2 Usage	0,7
150 °C < T < 250 °C	HT**-Heat Pump **and** Mechanical Vapour Recompression	1-2
120 °C < T < 150 °C	HT**-Heat Pump **or** Mechanical Vapour Recompression	2-3
T < 120 °C	Industrial Heat Pumps **or** Mechanical Vapour Recompression	4-10

*) COP = Coefficient of Performance = Efficiency = Verhältnis thermischer zu elektrischer Energie
**) HT = High Temperature

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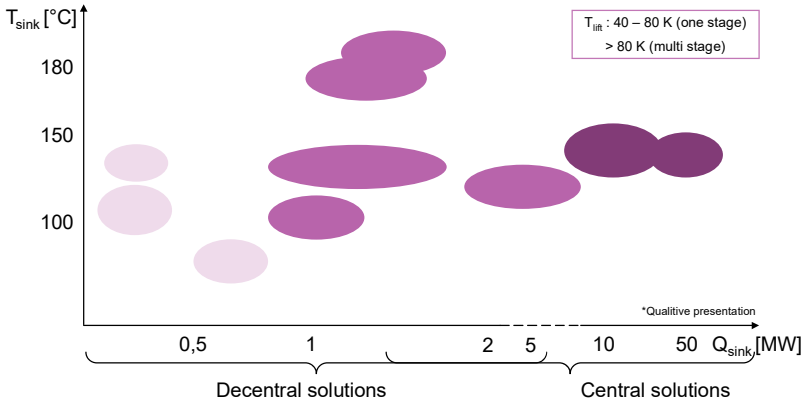
Relevant sink temperatures and heating capacities for heat integration



Key points for our projects

→ Steam generation is essential in most cases

→ High flexibility of the HP helps to adapt to production needs and energy market demand

→ Standardisation and scaling reduces HP and integration costs

Modular, steam generating HP-Packages with a high flexibility in heat capacity are important for Evonik

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What is the state of the market and technology?
Our previous experiences with tenders and tech scouting

	200 – 500 kW	500 kW – 2 MW	> 10 MW
Industry-HP < 100-130°C[1] / no steam	▪ Primarily screw compressors, partially piston ▪ Standardized series products ▪ TRL 9 available, partially new products with TRL < 9 ▪ Moderate specific costs	▪ Primarily screw compressors, partially piston ▪ Standardized series products ▪ TRL 9 available, partially new products with TRL < 9 ▪ Moderate specific costs	▪ Primarily turbo compressors ▪ „Standardized“ products available (district heating) ▪ Relatively many suppliers/products with TRL 9 ▪ Moderate specific costs
HTHP > 130° C or steam	▪ Primarily piston ▪ Only 1-2 manufacturers with marketable products ▪ **No HTWP with TRL 9 available in this area** ▪ Aggregates partially suitable for series production ▪ (still) high specific costs	▪ Primarily piston ▪ Only 1-3 manufacturers with marketable products ▪ **No HTWP with TRL 9 available in this area** ▪ Aggregates partially suitable for series production ▪ (still) high specific costs	▪ Primarily turbo compressors ▪ Only 2-3 manufacturers with marketable products ▪ **No HTWP with TRL 9 available in this area** ▪ Customer-specific solutions, scale effects questionable ▪ (still) high specific costs

1 depending on manufacturer, there are different definitions of HTHP and IHP temperature wise

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Key take aways for suppliers from heat integration at Evonik

Heat integration is essential to achieve Evonik's sustainability goals at acceptable costs

Majority of process temperatures at Evonik are < 250 °C
→ HP and HP + MVR suitable

Sustainability projects need to be economical
→ Lower integration and package cost reduction using modular concepts
→ Use of funding programs and other financial aids is mandatory

Technical and commercial risk needs to be moderate/low
→ Wide operational experience with HTHP is required
→ Market entry products/companies need a chance to grow

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