Heat Pump Systems

Technical Introduction and Implementation

Interreg Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

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
- CO_2 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

- Best Practice I
- Best Practice II

Interreg Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

1. Technical Introduction

General Function

Different Heat Pump Systems

Technical Introduction

General function

- Heat pumps extract energy from a heat source and rise it to a higher temperature level
- Heat is being extracted from the environment (e.g. groundwater, air) and then transferred to a heat distribution system
- To do so an additional energy input is required in the form of mechanical or thermal energy
- Conventional heat pump systems are designed as compression heat pumps with electrically driven compressors
- Heat pumps can be used for heating <u>and</u> cooling, the process is reversible

Figure 1: Different heat pump models. Source: Viessmann [1]

Technical Introduction

The heat pump cycle step by step

1. Extraction of heat from nature
   → this heat is used to evaporate a refrigerant

2. Compression of gas that is produced in the process

3. Heat exchanger transfers energy to the heating system

4. Pressurized refrigerant is being liquified again

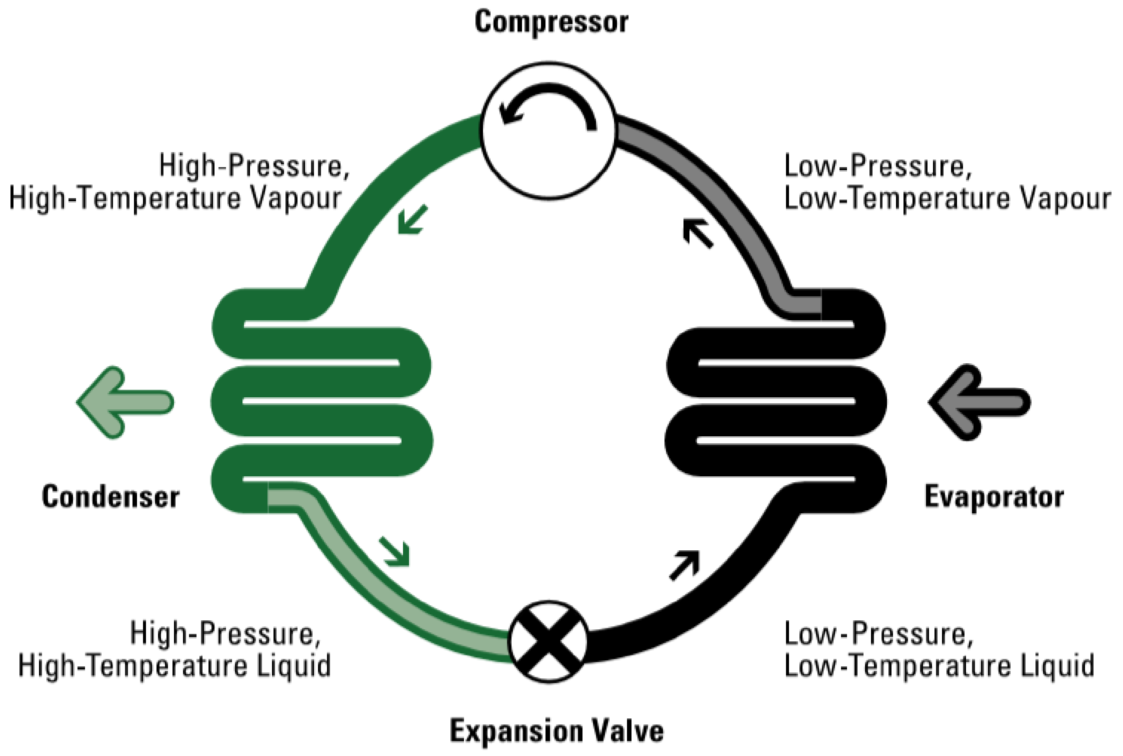

Figure 2: Ener Guide, Heating and Cooling with a Heat Pump. Source: Natural Resources Canada [2]

Technical Introduction

Heat pump components

- Evaporator (Outdoor coil): A fluid medium absorbs the temperature of the environment and then evaporates at low temperatue levels
- Compressor: Medium is compressed by the energy input
- Condensator (Inside Coil): Condensation and subcooling of the medium at high pressure, temperature and heat dissipation
- Expansion: Medium is relaxed and partially evaporated
- Refrigerant: working medium, which circulates heat pump circuit
- Reversing valve: For active cooling as well as for the de-icing of the evaporator, the direction of the refrigerant circuit is reversed.

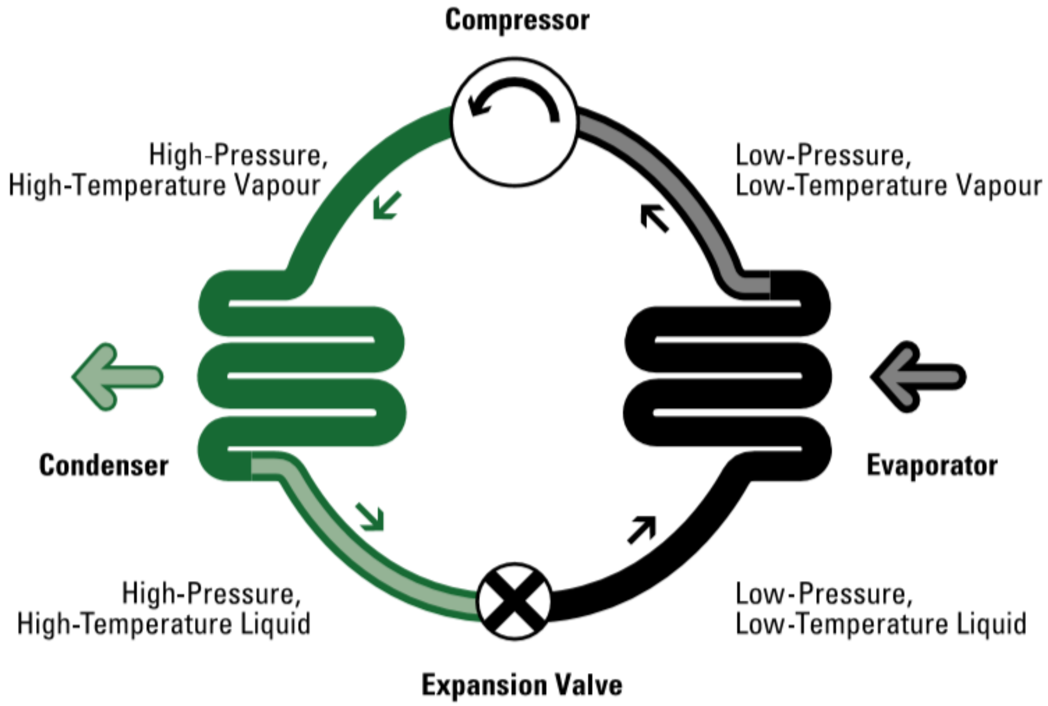

Figure 3: Ener Guide, Heating and Cooling with a Heat Pump. Source: Natural Resources Canada [2]

Technical Introduction

Renewable energy

- Heat pumps can be used in combination with renewable energies to cover the electrical input.
- The heat sources for the heat pump itself are renewable (air, geothermal energy or water)
- Heat pumps can cover the complete heat load with renewable energies and very low CO2 Emissions

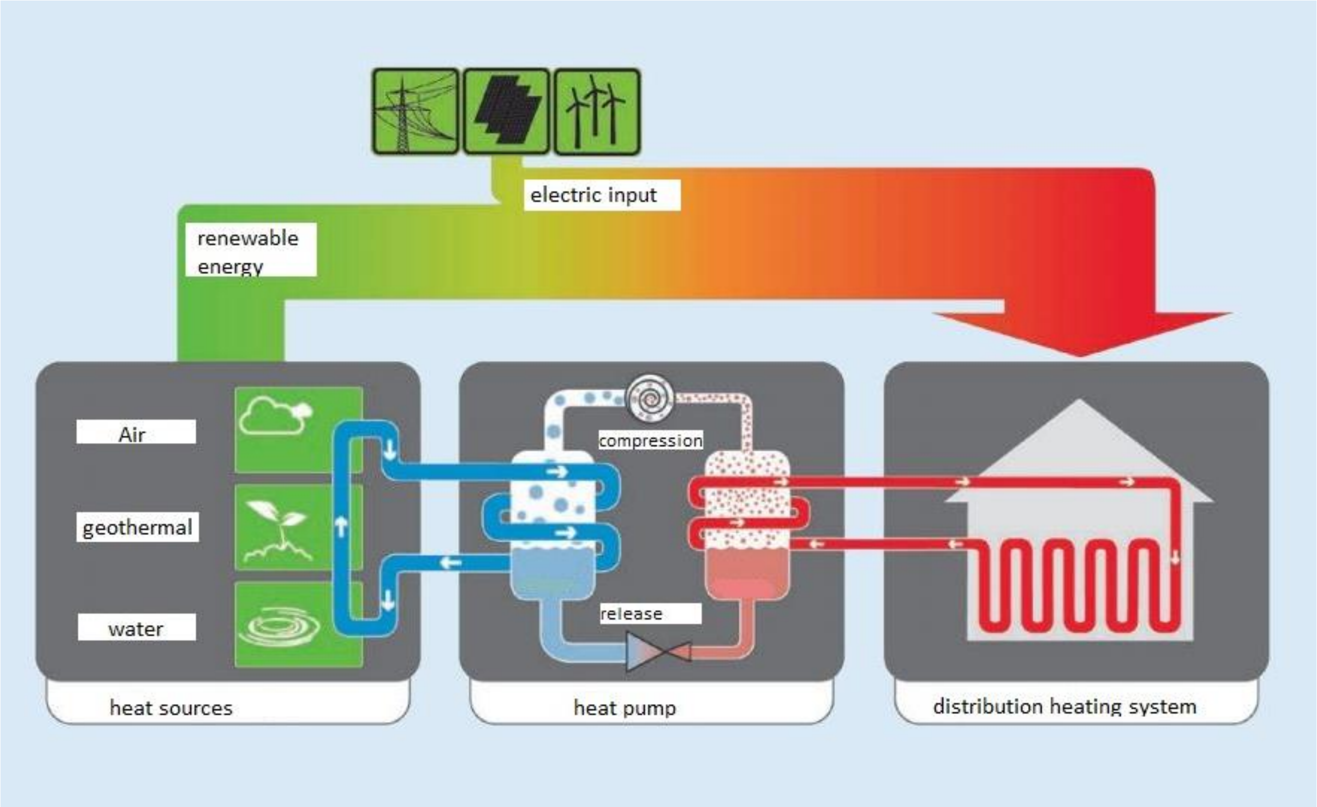

Figure 4: Energy flow in a heat pump system. Source: Energie Agentur NRW [3]

Technical Introduction

Different types of heat pumps

- Sole-to-water heat pump
  Geothermal heat source
- Air-to-water heat pump
  Air temperature heat source
- Water-to-water heat pump
  Groundwater heat source
- Hybrid heat pumps
  „Duel-fuel-Systems“

Technical Introduction

Sole-to-water heat pump – earth probes

- Geothermal collectors are vertical (as drillings)
- Use geothermal heat at depths of 5 to 100 m.
- The deeper the earth probes reach, the more heat can be transferred
- A soil survey must precede

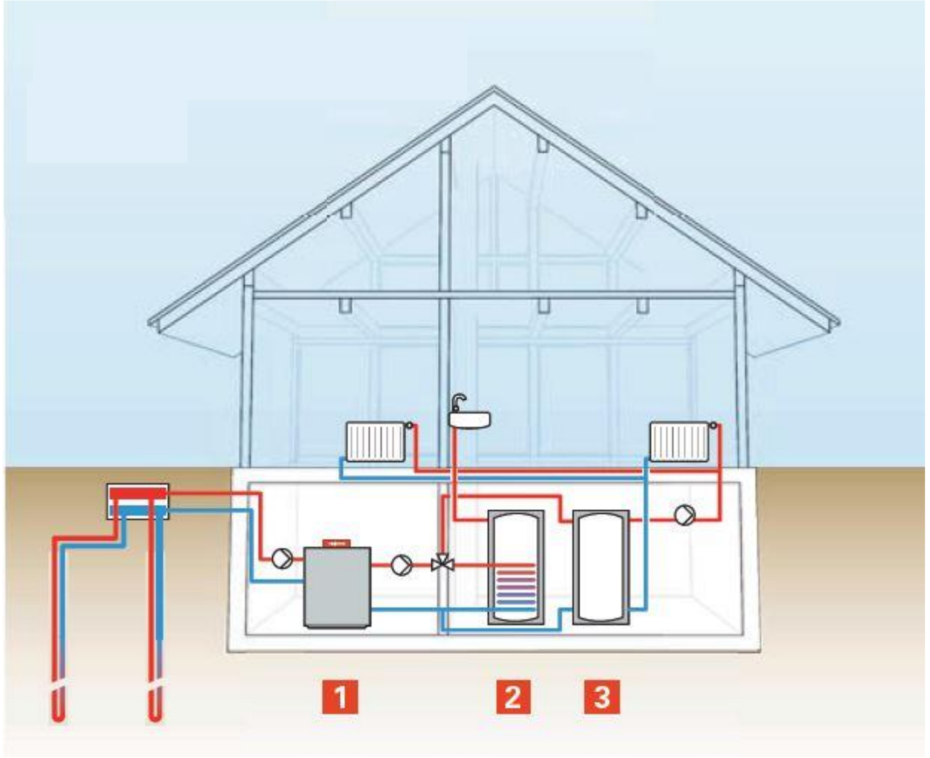

Figure 5: Ground-source heat pump. Source: Viessmann [1]

LowTEMP

Sole-to-water heat pump – earth collector

- Geothermal collectors are horizontal (as loops)
- Horizontal collectors are installed at >1,5m depth
- The pipes on the heat side are only implemented as a meandering surface or as a geothermal basket
- No drilling is required

Figure 6: Collector Baskets. Source: Noventec [4]

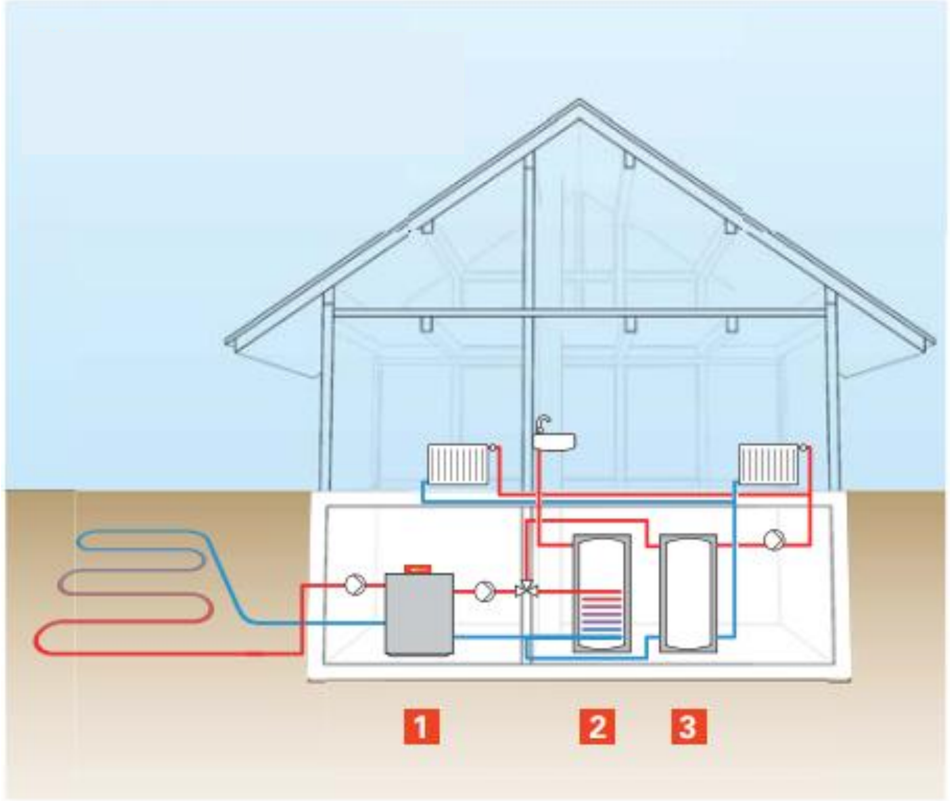

Figure 7: Ground-source heat pump. Source: Viessmann [1]

Technical Introduction

Terms of use of geothermal energy in Hamburg, Germany

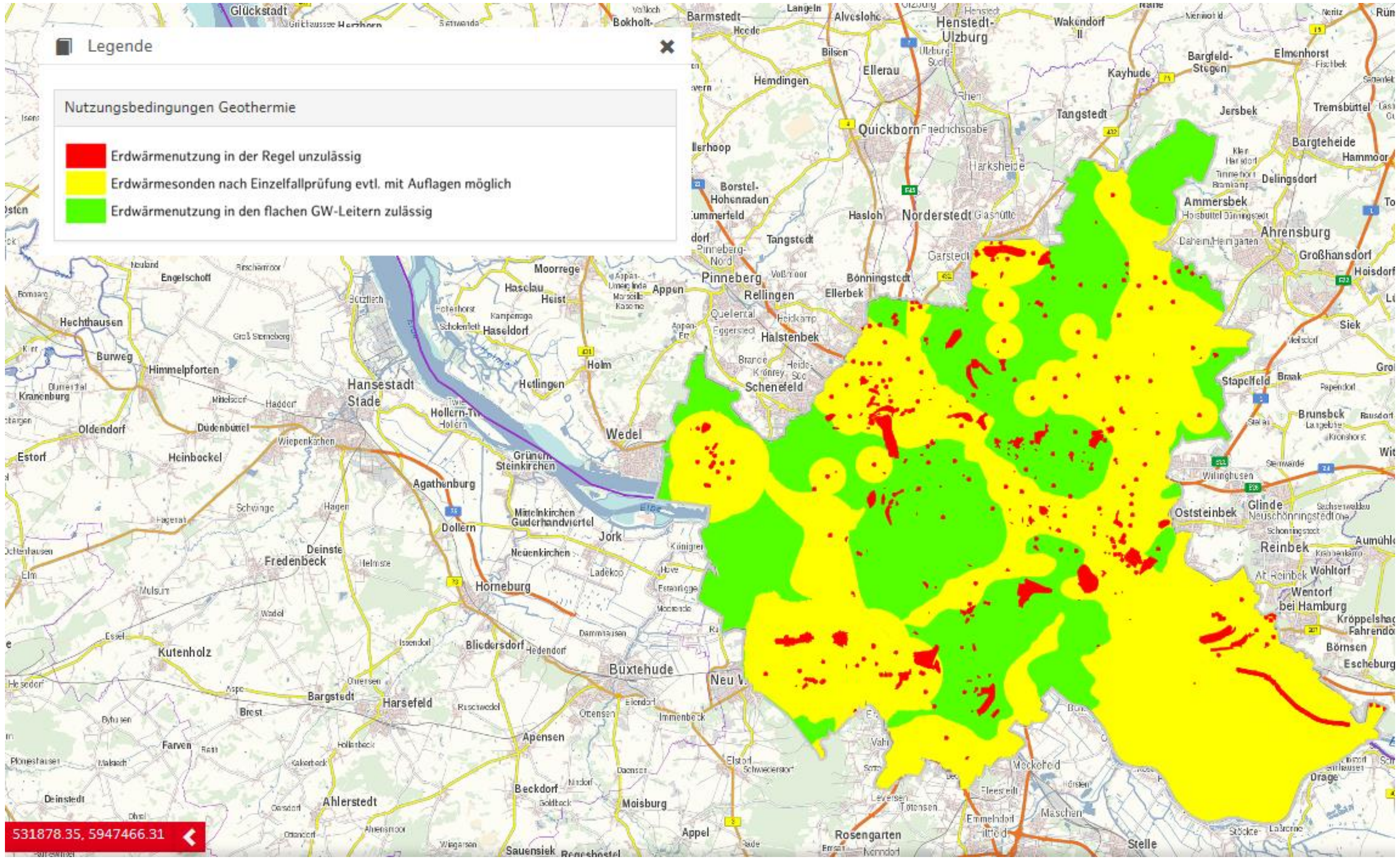

Figure 8: Conditions of use of geothermal. Source: LGV Hamburg [5]

Technical Introduction

Borehold register and extraction performance in Hamburg, Germany

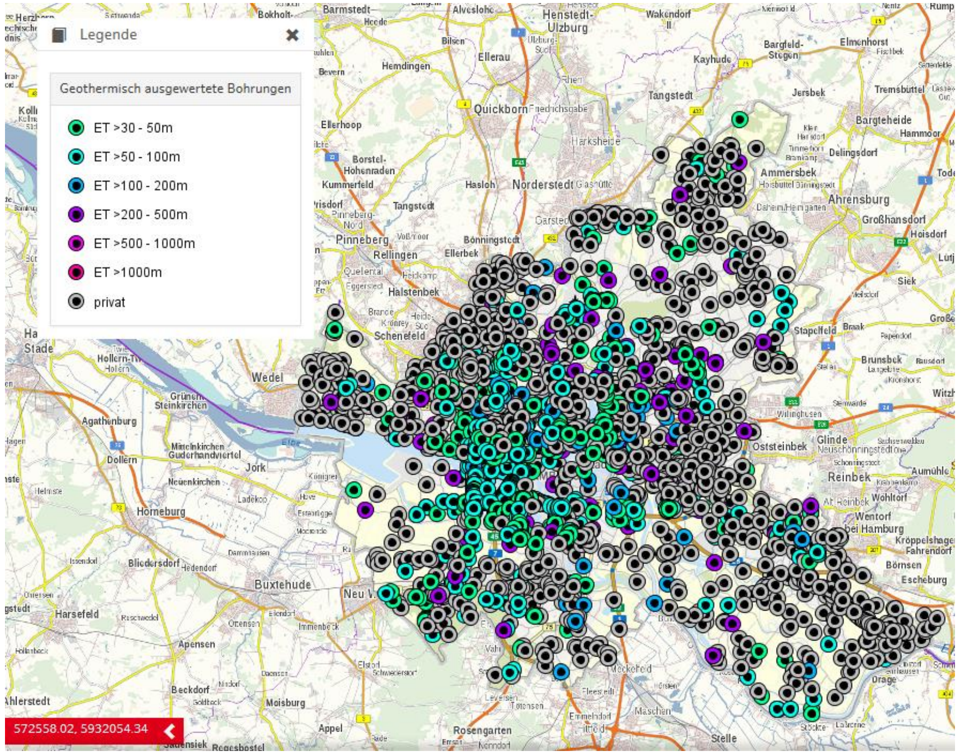

Figure 9: borehole register. Source: LGV Hamburg [5]

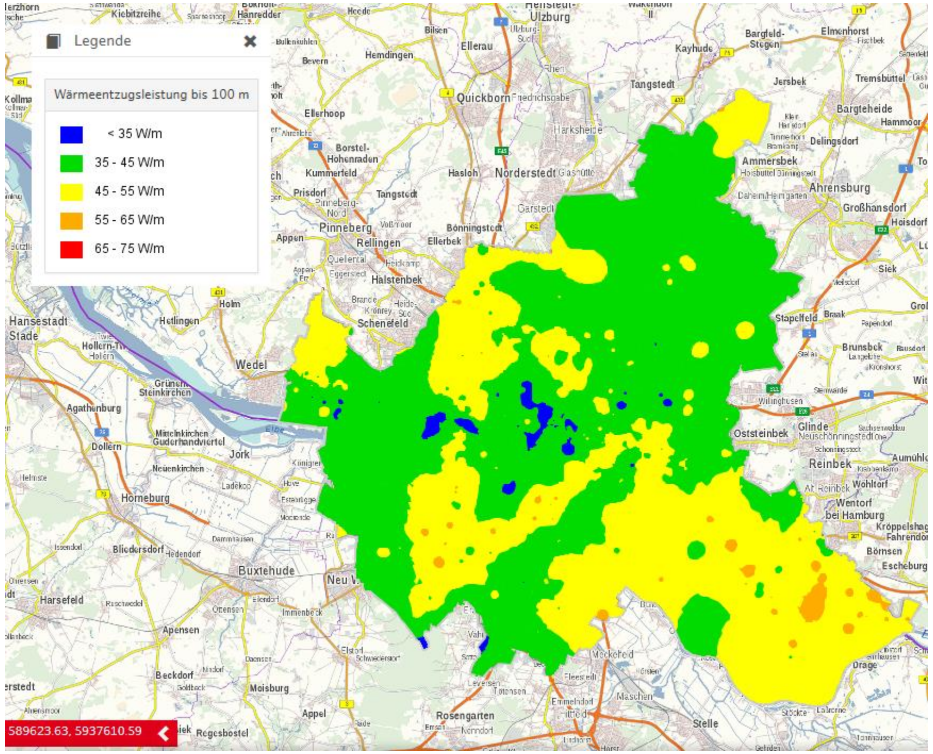

Figure 10: extraction performance. Source: LGV Hamburg [5]

Technical Introduction

LowTEMP

Design and Planning

- Earth probes must be installed by specialist companies
- They are not possible everywhere, depending on geological conditions
- Drillings must be approved by the respective authorities
- The pipe system should have low pressure losses for an economic operation
- Drillings with 3 or more probes need a distributor for hydraulic adjustment
- For flat earth collectors, a maximum of 100 m pipe lenght is favourable
- The heat transfer medium used in the circuit is mixed with anti-freeze to withstand temperatures up to -15°

Interreg Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Technical Introduction

Air-to-water heat pump

- extracts thermal energy from the outside air and transfers it to the buildings heating system.
- The system is subject to high fluctuations in temperature, depending on climate zones
- It might not be able to produce enough heating during cold outdoor temperatures -> dual systems

Figure 11: Air-to-water heat pump (device)
Source: Viessmann [1]

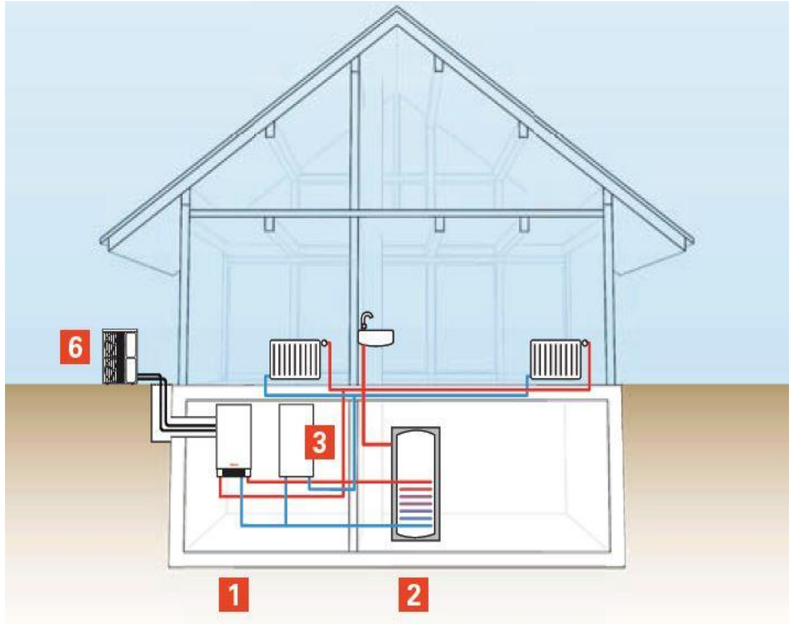

Figure 12: Air-to-water heat pump. Source: Viessmann [1]

Design and planning

- Fans are needed to extract the air

  →This causes noise pollution and must be assessed during planning
- The system can be used with controlled or uncontrolled compressors, depending on demand and stability of temperature level
- Because of the high temperature fluctuations, air pumps are usually run bivalently, to avoid oversizing of the system
- The system should be designed to function until at least -3 to -10 °C outdoor temperature, to cover large parts of the heat load

Technical Introduction

Water-to-water heat pump

- Uses near-surface groundwater as a source for thermal energy
- Only small seasonal fluctuations – constant heat output
- Operation as open loop system with two wells
- Well pump accesses water from ~20 m depth
- Efficiency depends on quality, temperature and height of the ground water

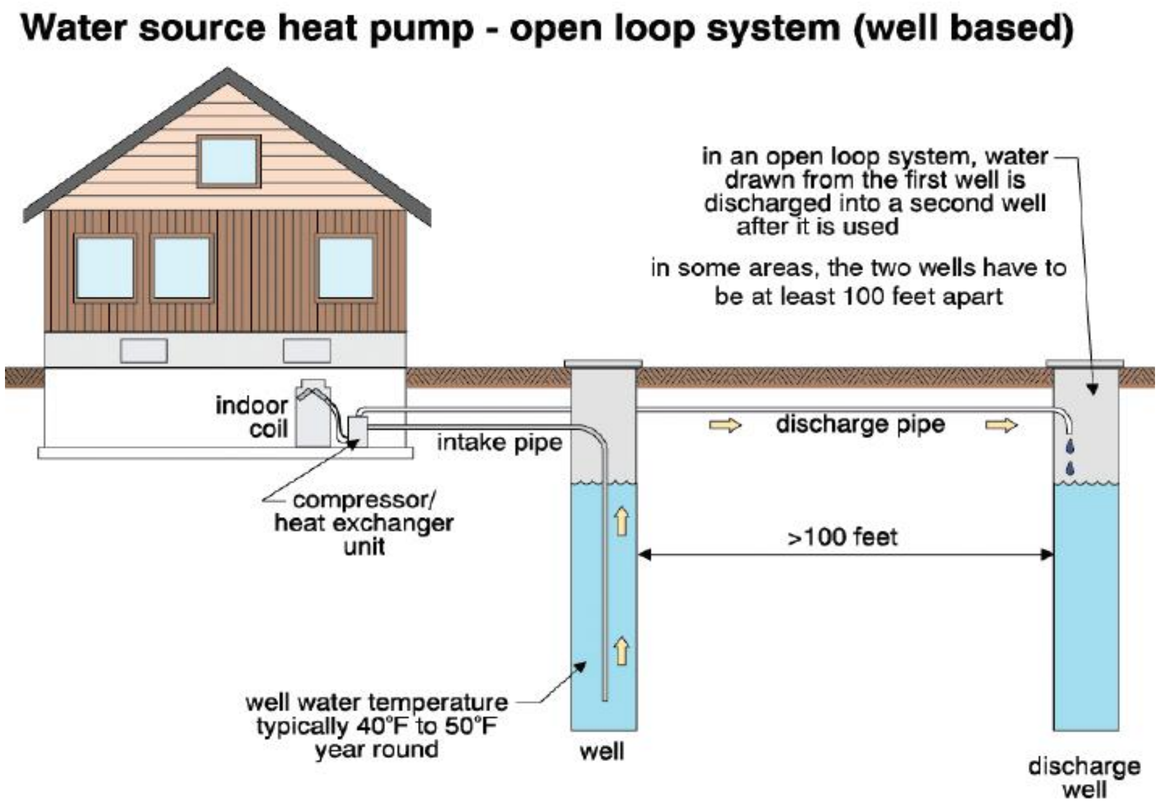

Figure 13: Water-source heat pump. Source: ASHI [6]

Technical Introduction

LowTEMP

Design and planning

- The depth of groundwater is especially important for the economy of the heat pump
- Water-water heat pumps are a good option, if a groundwater well is already in place!
- The wells must be constructed by a specialist company, the use of this system must be approved according to the Water Resource Act
- The maximum fluctuations in temperature should not exceed 6 Kelvin
- The chemical constitution of the water should be taken into account
    - Risk of corrosion and deposits on the pipes and plant components
- Stainless steel plates are favourable to the common copper plates to avoid damage

Interreg Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Technical Introduction

Hybrid heat pump

- Heat pump system combined with another non-renewable heat source, usually gas boilers
  - Also known as dual fuel system
- Usually used in existing buildings with a traditional system already in place
- A control unit monitors and manages the operation and switches between the systems for intelligent use
  - It even considers aspects like market price for grid energy
- Flexibility and efficiency, independant from exterior circumstances
- Disadvantage: Fossil fuels are part of the system
- Significantly higher CO_2 emissions than other heat pump systems

Technical Introduction

Low temperature district heating networks

- Low temperature heat networks are innovative heat infrastructures based on heat networks with low temperatures at **20 to 95 degrees**
- Heat is provided under criteria of climate protection and predominantly on the basis of renewable energies such as solarthermal energy, industrial waste heat and application of technologies of storage.

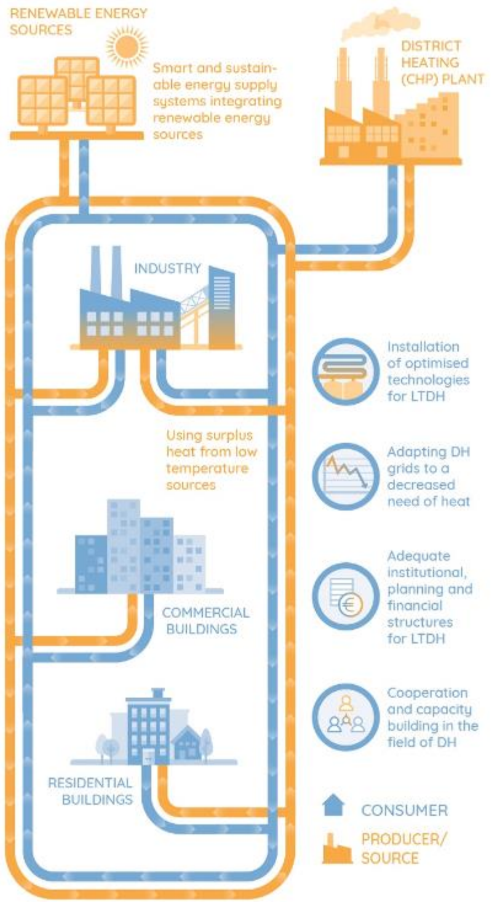

Figure 14: LTDH (Low Temperature District Heating). Source: LowTEMP project [7]

Technical Introduction

Cold heating networks

- Cold local heating networks are operated at a low temperature level of **8 to 20 degrees**
- Groundwater is distributed through an uninsulated cold heating network to the consumers
- It is then used to operate decentralised heat pumps
- Advantages of cold local heating:
  - lower heat loss of the heat distribution
  - possibility of using less expensive materials
  - the possible transport over longer distances
  - interesting for new building areas

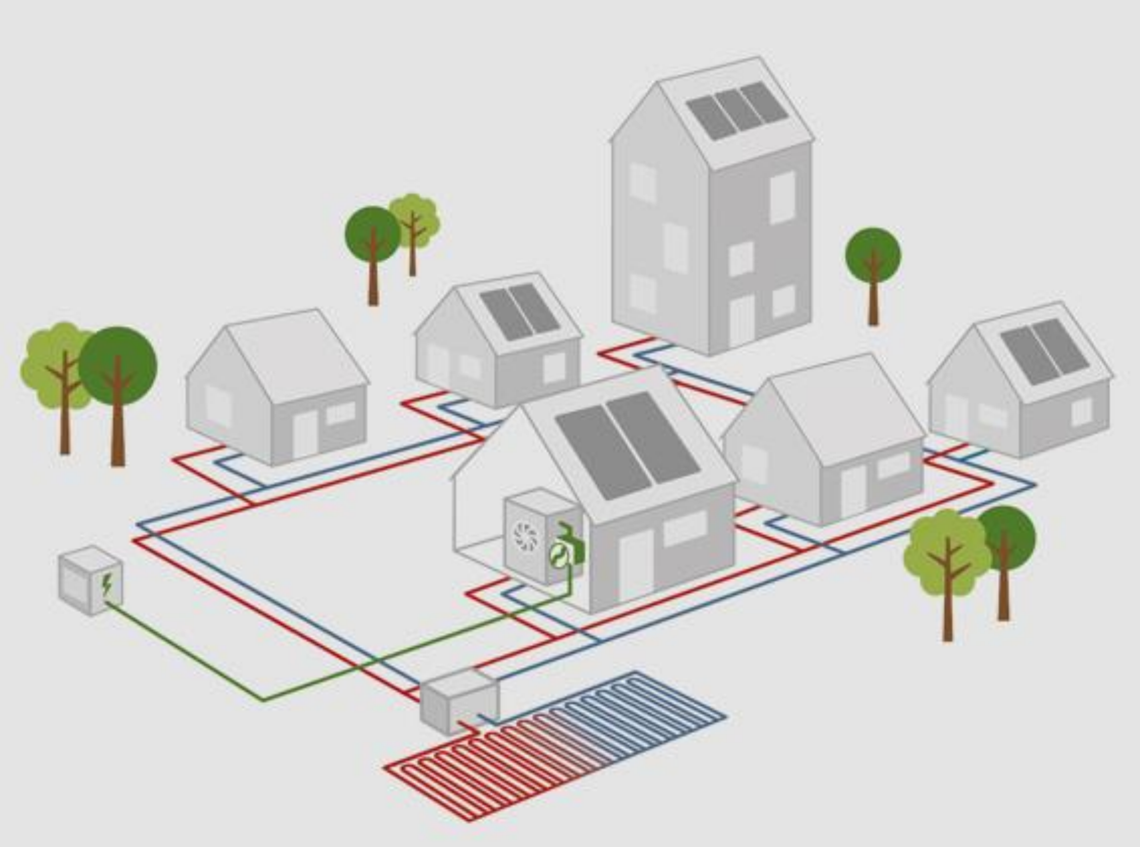

Figure 15: Cold heating network. Source: Naturstrom [8]

Performance of a heat pump

- For the evaluation of heat pumps, the COP (coefficient of performance) is determined under fixed test conditions and is defined as follows according to DIN EN 14511:
- COP = $\left|\frac{Q_{WP,Heiz}}{W_{el,WP}}\right|$

→ The larger the number, the more efficient the heat pump

→ A heat pump with a COP of 4 indicates that you can generate a total of 4 kWh of heating energy with the electrical input of 1 kWh

Heat Pump	COP
Water-source heat pump	~ 5,0
Ground-source heat pump	~ 4,0
Air-source heat pump	~ 3,0

Sewage heat pump with heat exhanger

- Innovative production technology: gas absorption heat pump
- Conducting hot water to a sewage system
- By using waste water heat, 75 percent carbon dioxide can be avoided
- Used for heating as well as hot water preparation
- Condensing boilers to cover peak demand

Figure 16: Waste water heat exchanger
Source: Hamburg Wasser [9]

Figure 17: Sewage pipe. Source: Hamburg Wasser [9]

2. Implementation

Current state in the Baltic Sea Region

Implementation

- Most new heat pumps are installed in new buildings
- Access to the heat sources usually requires extensive ground works and assessments prior to construction
- When designing a new heat pump system, it is important, that all components work well together to assure economic and efficient operation
- Air-to-water heat pumps are easier to install, especially during a renovation to improve energy efficiency, so they are most common in old buildings
- Funding programs for energy efficiency should be used to shorten the amortisation period

Implementation

Sales development

- The sales figures for four different types of heat pump in Germany from 2000 to 2018.
- The highest increase took place in 2006, when a total of 32,000 heat pumps was added.

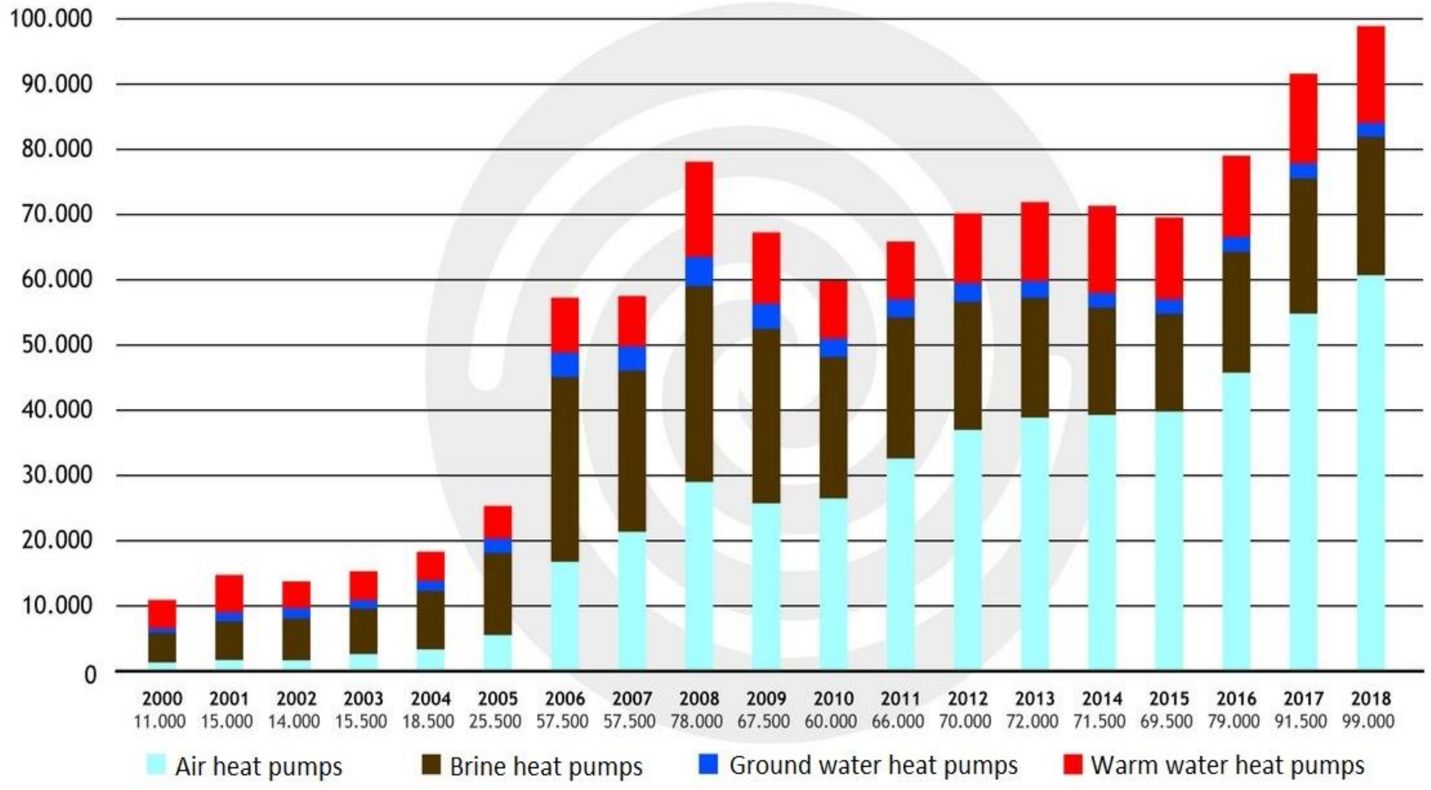

Figure 18: Sales development of heat pumps in Germany. Source: BWP [10]

Implementation

Current state in the Baltic Sea Region

- The price ratio is the quotient of electricity price to oil price for an equivalent amount of thermal energy

- It can indicate the COP necessary for a heat pump operate ensure economically compared to fossil fuel heat supply (Interpretation)

- The ratio is high especially in Germany and Belgium, but lower in the Scandinavian countries, France, Italy and Portugal, and especially low in Hungary

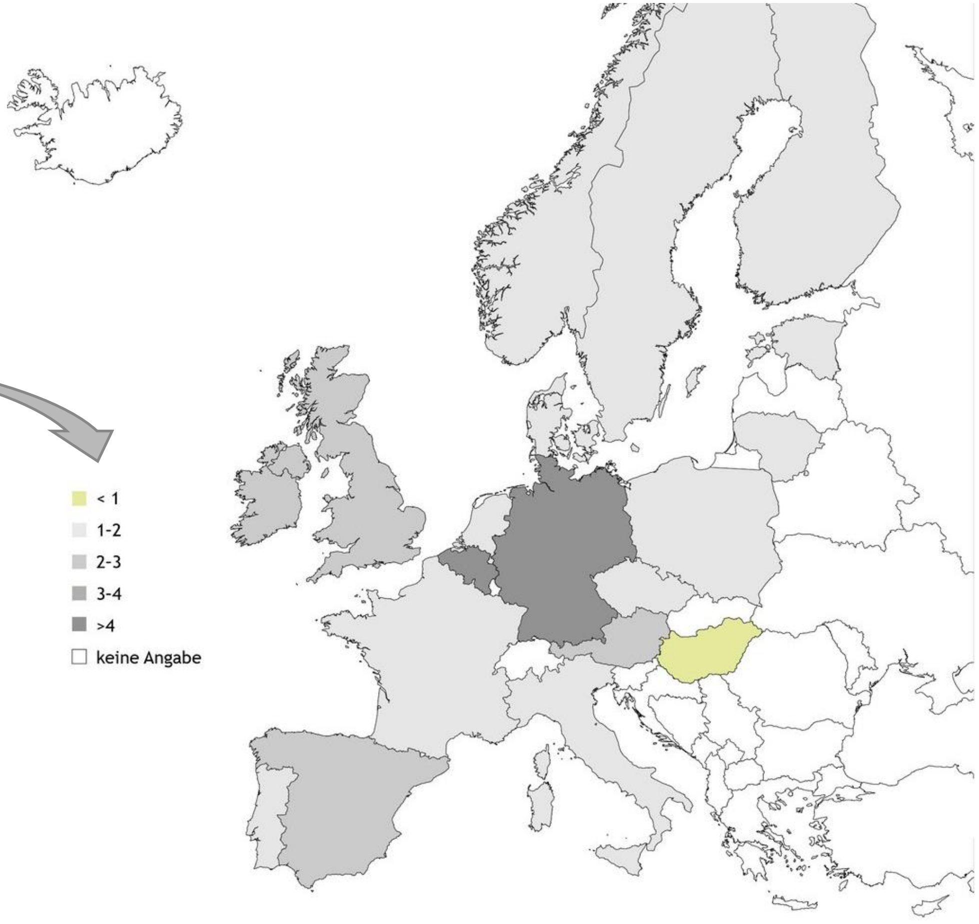

Figure 19: Price ratio heat pump energy to oil. Source: BWP [10]

Implementation

Current state in the Baltic Sea Region

- Despite their benefits, heat pumps are still being implemented below their potential rates in large parts of Europe
- But: Heating and Cooling (H&C) account together for approximately 50% of Europe's total energy consumption, considering residential, service and industrial sectors
- Heat pumps are an important instrument to achieve the renewable energy goals by the EU
- → Political framework for the BSR:
  Heat pumps are defined as renewable energy technologies in the *EU Renewable Energy Directive* and in the *Energy Efficiency Directive*

3. Conclusion

Disadvantages and Benefits of heat pumps

Benefits of heat pump systems

LowTEMP

+

Short ammortisation times

If a heat source with high temperature levels is available and can be accessed cost-effectively, the investment will pay off quickly

High flexibility

Especially in combination with photovoltaic and storage systems

Integration of renewable energies → improved environmental balance

As 4 kWh heat can be generated from 1 kWh electricity

Heating and cooling function

In comparison to a conventional heating system

−

Relatively high investment costs

costs depend on different factors (e. g. environmental surrounding)

large expenditures for earthworks

Economic dependency on the electricity price

If the heat pump is not combined with a photovoltaic system, it depends on the electricity price set by the market

Variable environmental balance

Life cycle assessment depends on the electricity consumption and source of the electric input

Interreg Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

References

- [1] Viessmann. https://www.viessmann.de/de/wohngebaeude/welche-heizung/waermepumpen.html
- [2] Natural Resources Canada. https://www.nrcan.gc.ca/energy-efficiency/energy-star-canada/about/energy-star-announcements/publications/heating-and-cooling-heat-pump/6817
- [3] Energie Agentur NRW. https://www.waermepumpe.nrw/uploads/datapool/Dokumente/Energieagentur_NRW_Planungsleitfaden_Waermepumpen.pdf
- [4] Noventec. https://www.noventec.de/produkte/erdwaerme/erdwaermekorb/
- [5] LGV Hamburg. Landesbetrieb Geoinformation und Vermessung Hamburg. https://geoportal-hamburg.de/geo-online/
- [6] ASHI. American Society of home inspectors. http://www.ashireporter.org/HomeInspection/Articles/Warming-Up-to-Heat-Pumps/15064
- [7] LowTEMP project. http://www.lowtemp.eu/downloads/
- [8] Naturstrom. https://www.naturstrom.de/kommunen/kalte-nahwaerme
- [9] Hamburg Wasser. https://www.hamburgwasser.de/fileadmin/hhw-privatkunden/downloads/broschueren/hamburgwasser-waerme-aus-abwasser.pdf
- [10] BWP. Bundesverband Wärmepumpe e.V.. https://www.waermepumpe.de/presse/zahlen-daten/

Interreg Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Contact

LowTEMP

ZEBAU GmbH
Centre for Energy, Construction, Architecture and the Environment

Jan Gerbitz
Andreas Broßette
Merle Petersen

Große Elbstraße 146
22767 Hamburg
Germany

E-mail: info@zebau.de
Tel: +49 40 - 380 384 - 0
www.zebau.de

Interreg Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND