



Heat pump and future in Europe

Y.Sen^{1,a}, S.Keskin²

¹Duzce University, Faculty of Engineering, Duzce, Turkey

²Duzce University, Institute of Science, Duzce, Turkey

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Abstract

The most energy consumed worldwide in heating and cooling applications. Most of the energy consumed in our country is used for heating. Considering the problems in energy resources, two factors direct the developments in the heating sector. These are the problem of energy costs arising from the depreciation of fossil fuels and the environmental pollution caused by energy consumption and increased CO₂ emissions. These negativities in energy sources have brought renewable energy sources and renewable energy technologies to the forefront. Heat pump systems are one of the most important renewable energy technologies. The most important expenses of these systems are electrical energy. In this study, general characteristics and working principles of heat pumps are examined. Renewable energy sources in the world and in Europe and their future in Europe are discussed. working principles, The current situation in Europe and future perspectives are examined.

Keywords: renewable energy, energy sources, heat, cooling, heat pump.

1. Introduction

The need for energy resources in the world continues to increase day by day. Especially in developing countries, demand for energy will be more intense in the coming years in parallel with population growth, industrialization, increasing people's welfare level and technological developments.[1] Renewable energy is defined as "a renewable energy source, equal to the energy received from the energy source or faster than the rate of depletion". In another definition, renewable energy is defined as "the source of energy that can exist in nature's own evolution, the very next day." Renewable energies, like other types of energy (coal, oil, natural gas, etc.) have no risk of exhaustion, they are endless. We can also call this type of energy "energy for our grandchildren". Furthermore, the advantage of renewable energy sources over fossil fuels is that it does not pollute the environment and is environmentally friendly. However, there are disadvantages. Geographically, they are not abundant everywhere; they also have to collect from large areas because they are not intense forms of energy.

Especially in developed countries, renewable energy sources such as hydraulic, wind, geothermal, solar, biomass, wave, hydrogen and so on. energy sources are utilized in various ways, especially electricity production. Despite all these developments, the superiority of fossil energy resources in world primary energy consumption continues undisputed and will continue to maintain this advantage in the short term. Heat pump is one of the renewable energy sources. The heat pump is an electrically powered system based on the principle of transferring heat energy from one area to another. When the necessary conditions are met, large amounts of energy can be used at low costs. For most people, the heat pump is a new term. However, in our houses, devices such as refrigerators, air conditioners and freezers, which are the product of the same logic as the working principle of heat pumps, are used. Since the operating logic of these devices is based on the principle of carrying heat, these devices can be collected under the heat pump head.

2. Carbondioxide effect of fossil resources and future of available reserves

As of 2017, various energy resources have been used in the world, and they are used in natural gas, oil and coal etc. with 85.5%. fossil resources. (Figure 1).

^a Corresponding author; yasarsen@duzce.edu.tr

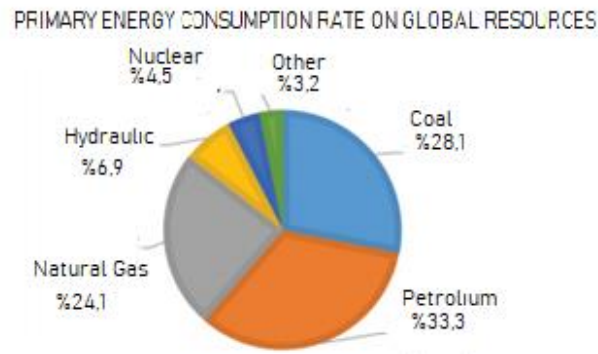
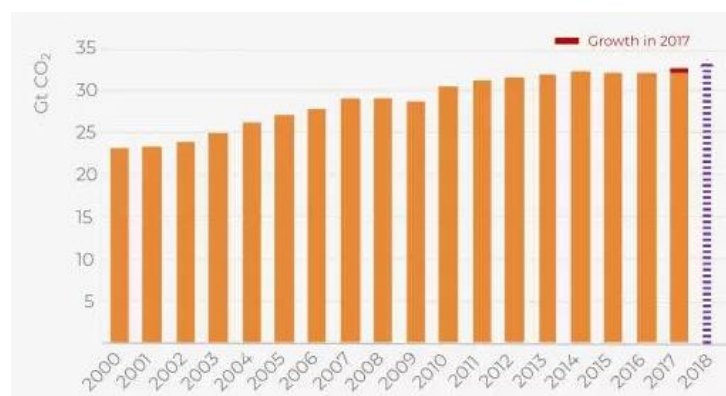


Figure 1: Primary Energy Consumption Rates Worldwide (source: Mühendis ve Makina).

According to the information obtained in 2017; petroleum is the highest in energy consumption worldwide with 33.3%. Following petroleum, coal ranked second in energy consumption, 28.1% in natural gas, 24.1% in natural gas, 6.9% in nuclear power, 4.5% in nuclear power, and lastly in renewable energy resources. 3.2 of them are consumed. [2] CO₂ emissions resulting from the use of fossil fuels in electric power generation vary depending on the type of fossil fuel used. Most of the greenhouse gas emissions in the world are due to the energy sector due to the burning of fossil fuels, and CO₂ emissions from electricity generation have a significant share in the energy sector.

The world's high share of fossil fuels in energy production leads to greenhouse gas emissions and climate change. In the world, which has a rich potential in terms of renewable energy sources, this potential should be evaluated more and its share in electricity generation should be increased.

The Intergovernmental Panel on Climate Change (IPCC) report, published this year, says that the world must achieve net zero greenhouse gas emissions in the shortest time in 2050 to prevent global average temperatures from exceeding 1.5 °C. Emissions should not only fall; should be dropped quickly. [3]



Graph 1: Annual Change of CO₂ Emissions Worldwide (source: IEA).

As stated in the graph above, the CO₂ emission rate has increased by 47 percent since 2000 and in 2017 a result of over 30 ct was observed. Fossil resource consumption increases this rate and shows the importance of shifting to alternative sources for the future.

Fossil fuels, which meet most of the energy need, are the biggest triggers of CO₂ emissions and fossil resources are decreasing day by day. Due to the

intensive use of fossil fuels such as oil, coal and natural gas in the 20th century, the effects of ozone depletion, acid rains and global warming have left the world in a difficult environment. Furthermore, it is known that these fuels will be completely exhausted in the coming years due to the fact that fossil fuels have a finite reserve.

Fossil fuel reserves are rapidly decreasing, and especially oil and natural gas reserves are

approaching critical levels. Figure 2 provides information on world coal, natural gas and oil reserves.

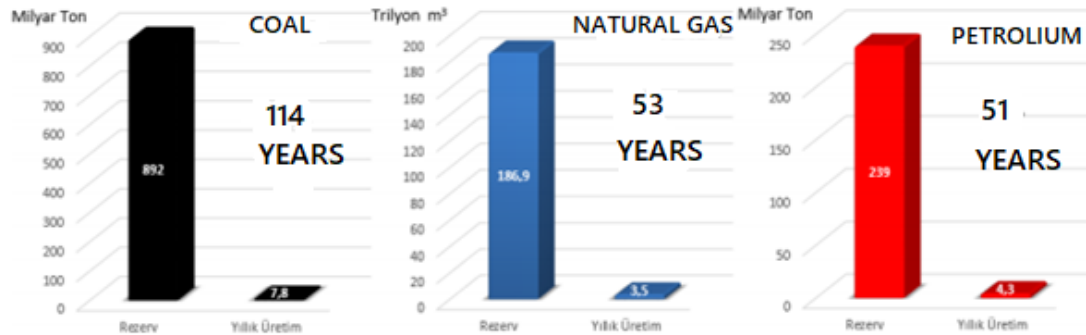


Figure 2 - Future perspective of fossil resources in the world (source: Ministry of Energy).

Total oil reserves in the world are around 1.7 trillion barrels, which corresponds to a consumption of 51 years. World natural gas reserves were determined as 187 trillion m³ at the end of 2015 and this amount is sufficient to cover global production for a period of

53 years. Global production of world coal reserves is sufficient for 114 years and has the highest reserve production rate among all fuels. America has the highest local reserves, followed by Russia and China. [4].

2. Heat pump and history

The theory that emerged in 1824 by Nicolas Leonard Sadi Carnot is the basic theory of the heat pump. The mechanical power generated by the steam engine can be supplied from outside to provide a hot - cold cycle. in this case the system is no longer a steam engine; It will operate as a cooling machine that

transfers energy from the hot environment to the cold environment or as a heating machine that transfers energy from the cold environment to the warm environment. This cycle, known as the Carnot cycle, is the basic principle for heat pumps and thermodynamics.

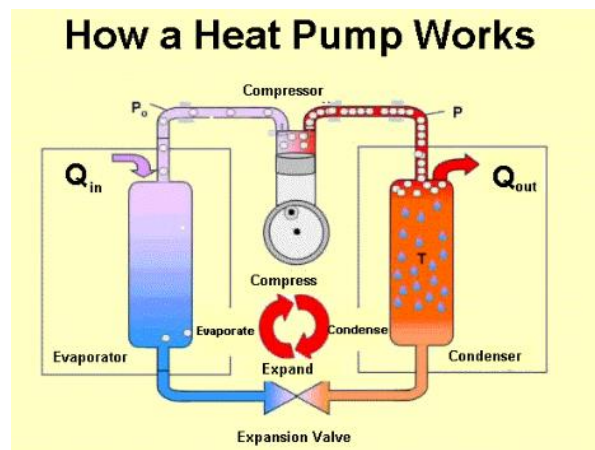


Figure 3 - Heat pump general diagram.

To be able to operate a heat pump system which heats as long as it cannot cool, the medium to be heated and the medium to be cooled together are required. Since the environment to be heated is usually your home, the environment to be cooled will be air, water or soil. 26 years later, in 1850, Lord Kelvin claimed that the cooling devices could be used for heating purposes. Before World War II,

many engineers and scientists made researches and studies in order to develop and make the heat pump usable. In the war years, these activities were interrupted because the industry directed the opportunities to more urgent problems and resumed after the war. Because of the potential of the heat pump industry in the 1950s, the high installed cost, and the cheapening of energy based on natural gas

and oil, the confidence in the heat pump decreased in the 1960s. Heat pumps gained importance after this pause after the energy crisis in 1973 and many studies have been done after this date. [5]. The confidence in the heat pump declined in the 1960s due to the potential of the heat pump industry in the

1950s, the high cost of installation, and the cheapening of energy based on natural gas and oil. Heat pumps gained importance after this pause after the energy crisis in 1973 and many studies have been done after this date.

3. Heat pump working system

The operating cycle of the refrigerant in a heat pump operating in heating mode (energy exchange with its

environment) can be explained by a Logp-h (pressure enthalpy) diagram as follows.

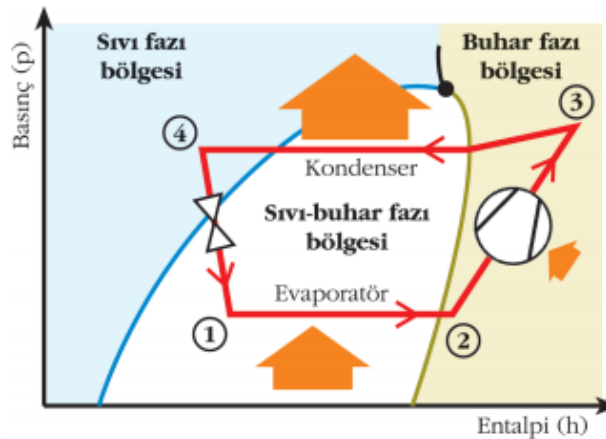


Figure 4. - Carnot Conversion h-P diagram.

Between points 2 and 3; The refrigerant is compressed in the compressor in the gas phase to increase its temperature and pressure and goes to the condenser in the gas phase. Between points 3 and 4: The refrigerant entering the condenser in the gas phase condenses into the liquid phase and transmits its resulting energy to the medium, for example, to the heating water. Between points 4 and 1: The refrigerant exits the condenser in the liquid phase and comes to the expansion valve with the pressure of the refrigerant slightly reduced and cooled to a level

lower than the saturation temperature. A small amount of refrigerant, whose pressure and temperature has been reduced through it, enters the vapor, but rather into the evaporator in the liquid phase.

Between points 1 and 2: The fluid entering the evaporator in the vapor-liquid (wet steam) phase draws energy from its environment (soil, water, air, etc.) and enters the vapor phase and leaves the evaporator completely in the vapor phase and goes back to the compressor.

4. Heat pump basic principle

It is a natural phenomenon known by everyone that thermal energy automatically passes from the high temperature medium to the low temperature medium, ie in the direction of decreasing temperature. This phenomenon occurs spontaneously without any machine. In contrast, the opposite of this phenomenon, that is, heat transfer from a low temperature medium to a high temperature medium does not occur spontaneously. This process requires the use of special machines called cooling machines and heat pumps. Heat pumps and cooling machines operate according to the same cycle. However, the intended use is different. Cooling machines are intended to cool a space, while heat pumps aim to heat a space. In the heat pump systems, the medium where the heat energy is taken is called the source and the medium where the heat energy is transferred is called the well. Heat pumps make use of heat sources such as air, soil, sun, water etc. around us. These systems are generally named according to source types or well types. For example, a heat pump using soil as a heat source is called a ground source heat pump. The heat pump system, which takes the heat energy from the air and transfers it to the water, can be called as air-to-water or air-water heat pump. The technical and economic performance of heat pumps is closely related to the quality of the heat source used. Therefore, the type of heat source and heat well to be used in heat pump system selection is very important.

4.1. Air system

Air is the most widely used heat source because it can be found everywhere, is easy to use and economical. The main disadvantage is that it does not have a stable temperature, and especially in continental climates, the air temperature decreases very much during the winter months, even during the day. As the temperature difference between the heat source and the heat well increases in heat pumps, the decrease in outdoor air temperature decreases the capacity and performance of the heat pump as the system performance decreases. Therefore, air source heat pumps are not widely used in continental climates. In addition, air source heat pumps have icing on the evaporator coil at temperatures of 0°C and below. The resulting icing reduces the heat transfer and reduces the performance of the heat pump. To defrost, the heat pump must be defrosted in the opposite direction. As the frequency of defrost increases, the energy consumption will increase and the heat pump performance coefficient will decrease.

4.2. Surface water system

In these systems, sea, lake, pond, etc. are used as heat sources. large water bodies are used. Sea and lake water temperatures vary less than air and soil. The initial investment costs of river and lake water source heat pump systems are lower than ground source heat pumps. However, there may be various restrictions or prohibitions, as their use and evacuation depend on local government regulations. In river and lake water heat pumps, the water depth should not be less than 2 m and the surface area should be at least 80 m^2 per kW of installed heat pump capacity. The major disadvantages of these heat sources are that winter temperatures drop to around 0°C .

4.3. Groundwater systems

Groundwater can be used as a heat source if they are present in sufficient quantity, quality and appropriate depth. The most advantageous aspect of groundwater is that it has a higher and almost constant temperature at 10 m and deeper. In many areas, groundwater has a stable temperature of $4\text{--}10^{\circ}\text{C}$. Temperature of water;

- Depth of extraction,
- Climate

Depends on the geological structure of the region. To benefit from this heat source, open and closed systems are used. In open systems, groundwater is pumped to the heat pump, receiving heat and then returning it to a separate well or surface water. In closed systems, it can be direct expansion type (refrigerant evaporates in underground heat exchanger) or brine cycle type [12,14]. Seasonal temperature change of groundwater is low. Therefore, systems using this heat source are particularly advantageous for terrestrial climates where the air temperature varies greatly between summer and winter. Groundwater temperature in a space is locally equivalent to the average annual air temperature throughout the year. Groundwater temperatures with excessive well depth are higher than the average annual ambient temperature. Main disadvantages of groundwater;[6]

- Availability of water,
- The adequacy of the amount,
- High initial investment cost,
- Problems caused by low quality water.

4.4. Connections used in heat pump calculations

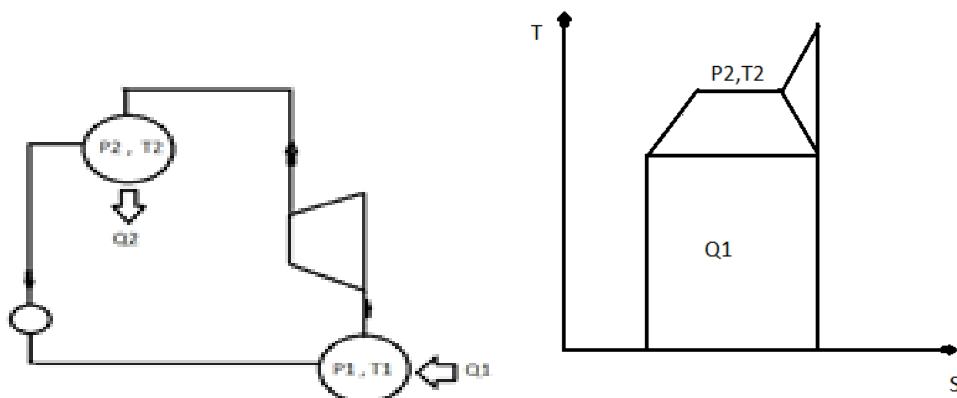


Figure 5. Heat Pump Cycle diagram.

In this closed cycle, heat Q_1 is sensed from a low potential energy source and thermally equivalent mechanical energy, defined as the AL field, is consumed. The heat Q_2 , defined as $Q_2 = Q_1 + AL$, is returned with a higher temperature. This means that in each case, in the heat pump, the amount of heat returned is higher than the thermal equivalent of the mechanical energy consumed.

Thermal efficiency coefficient of heat pump;

$$\eta_{HP} = \frac{Q_2}{AL} > 1,$$

The ratio between the useful heat output Q_2 heat and the AL thermal equivalent of the mechanical energy consumed is called the COP1 performance coefficient.

$$COP_1 = \frac{Q_2}{AL} > 1,$$

Heat is given isothermally at temperature T_1 and isothermally drawn at temperature T_2 . Compression

and expansion are carried out in constant entropy and the work is delivered from the external motor. Using the definition of entropy and thermodynamic laws, we can say that the coefficient of performance (COP1) for the Carnot cycle is:

$$COP_1 = \frac{T_1}{(T_2 - T_1)} + 1 = \frac{T_2}{(T_2 - T_1)},$$

The heat pumps produced in the world are no better than the characteristics of the Carnot cycle and all practical cycles try to approach the characteristic as close as possible.

A heating operation with a lower temperature, as can be achieved in a tubular floor system, will increase efficiency compared to a system with a higher temperature, such as a heating panel system. The opposite of a cooling process - a lower cold temperature will improve efficiency.

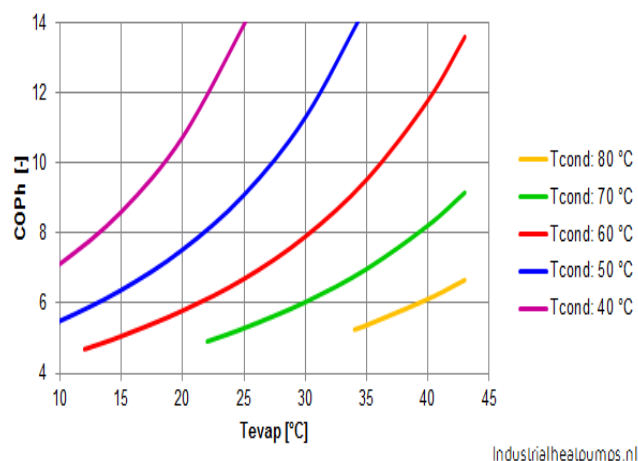


Figure 5.:Heat Pump Cycle diagram.

The efficiency of the heat pump, COPh, depends on several factors. In particular, the temperature difference between the waste heat source and the potential user is an important factor. The temperature difference between the condensation and the evaporation temperature basically determines the efficiency: the smaller the difference, the higher the COPh. These values are based on figures obtained

from a Grasso 65HP compressor containing refrigerant Ammonia. The figure shows an increase in COPh with increasing evaporation temperature. Moreover, the condensation temperature shows a decrease in decreasing COPh. In general, COPh decreases with an aware increase in temperature between condensation and evaporation.

5. Use of heat pump in Europe

The heat pump market is currently recovering after 4 years of stagnation. The main factors affecting the market dynamics (energy price ratio, construction sector development, policy support) showed positive development:

The price relationship of the different energy sources and technologies (together with the investment cost of the respective heating system) determines the heating cost per kWh of thermal energy (€ / kWh_{th}) and allows a direct comparison of the operating cost.

European building and construction markets are developing heterogeneously across Europe, greatly influencing the installation of heating systems in new and renovated buildings. Although heat pumps have a large share in new buildings, the renovation sector lags behind both construction activities (the renovation rate is below 2%) and the use of heat pump technology.

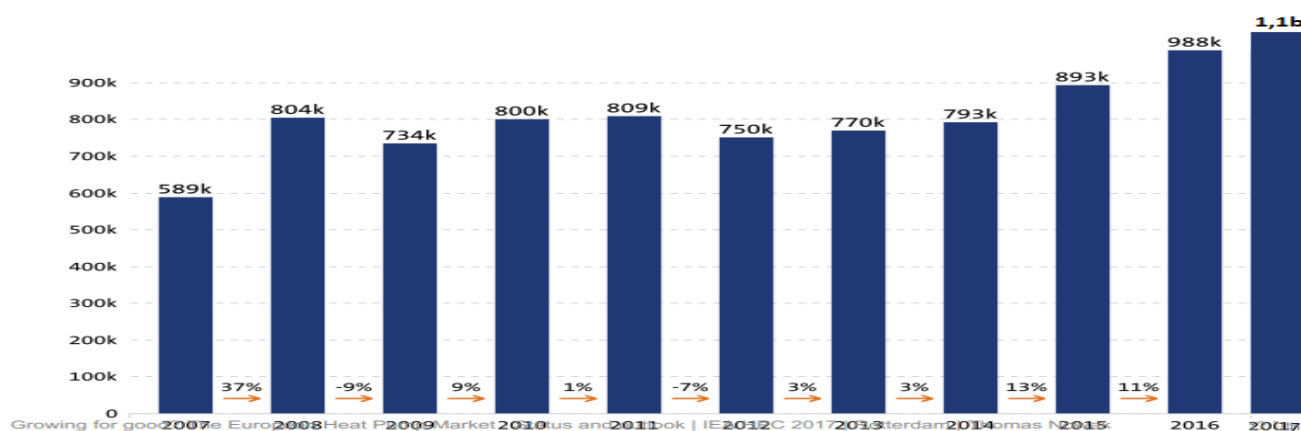
The last four years of low renovation have benefited from heat pump technology. The industry has developed new, more powerful and more compact solutions to suit market requirements. As a result, projects that were used three years ago with a fossil fuel solution will probably find suitable heat pump

solutions today.

A policy framework should focus on heating and cooling as the cornerstone of every energy strategy. It should include institutional and (even more important) financial support programs at European and national level, both for buildings and products - as well as for renewable energy sources.

Policy measures should be supported by increased security of supply, increases in energy costs and associated risks. [7]

Environmental impact of non-renewable resources, All energy-related policy measures, whether directly or indirectly and once fully implemented, should support market development.



Graph 2 - European heat pump market data (source: European heat pump association).

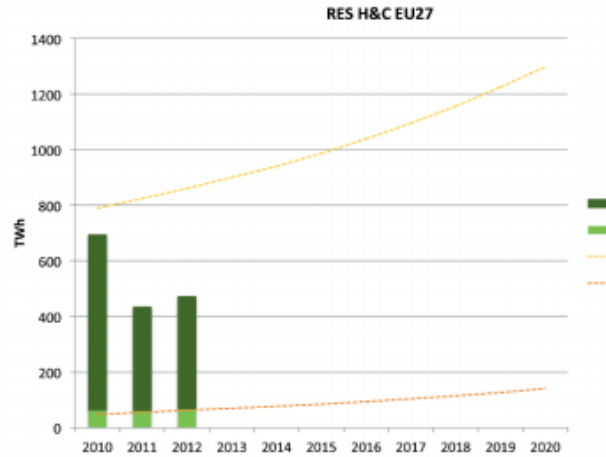
Graph 2 shows the heat pump market data for the last 11 years in Europe. As seen here, sales of 589 thousand units in 2007 increased by 37 percent as 804 thousand units in a year. This ratio increases with the demand for renewable energy. Although there have been decreases from time to time in the European markets due to the crisis etc., the sales

reached 1.1 million units in 2017. The 1.10 million heat pumps sold in 2017 produce 16.7 TWh of useful heat from a 10.5 TWh renewable source. The newly installed heat pumps provide Mt CO₂ emissions and a final energy saving of 13.5 TWh. They also provide a storage capacity of 37.2 GW.

6. Results

For the transformation of existing buildings with heating installations, high-temperature heat pumps (if the installation flow temperature is 75 °C) and active cooling heat pumps come to the fore. High-temperature heat pumps are required, especially in new or system-converted homes that are heated by radiators. Soil or water source heat pumps can use natural cooling by circulating cool primary circuit water in floors with floor heating systems, but this is not possible when using an air source heat pump. Already the outside air is hot and requires active

cooling. Active cooling is offered in cases where natural cooling is not sufficient and air source heat pumps. In addition, depending on the purpose of use, only heaters for pool heating or hot water preparation are available. Today, heat is produced from fossil fuels, which are mostly gas. Efforts to change the status quo are insufficient and there are renewable alternatives such as biomass (87.9%), geothermal energy (10.7%), heat pump technology (5.5%) and solar energy (2.4%). [8]



Graph 3 - The future of ISI PUMP in the world (source: IEA)

The reduction of CO₂ emissions achieved by the assumed application of heat pumps is very important. Considering the direct CO₂ emissions in the sector, business as usual 20 from 2025 to 2050 bir decreased by 78%. If allowance for increased CO₂ emissions in electricity supply is allowed, the gain in 2025 is likely to be cut off. The carbon content of electricity increased to 25% if it decreased to 20% of its current value by 2050 and if it decreased to 20% of its electricity consumption. This option clearly provides significant long-term benefits, but is best supported after 2015, when the carbon density of electricity has dropped rapidly. The increase in electricity demand caused by the widespread adoption of heat pumps in this sector is important to represent a 20% increase in 2025 and an 18% increase in 2050. However, the benefits of significant emission reductions can make this a generally attractive option.

These technologies should be supported in order to avoid the potential of the sector to reach the 2020 targets. According to ECOFYS (2013), achieving targets for the construction sector would not be possible without any heat pump technology, but if sufficiently supported, heat pumps could save 47% of total CO₂ emissions by 2030. With the expected growth, it forces the sector's value chain to prepare for more units each year, from design through production to installation. In this context, the reduction of fluorinated gases is a major challenge, triggering the development of low and now GDP alternatives. Based on the examples of development I have seen, we believe that the industry can solve both growth and component problems by offering better, more efficient and more cost-effective heat pump systems ready to make heating and cooling ready by 2050.

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