KOJA JE NAMENA VELIKIH INDUSTRIJSKIH TOPLOTNIH PUMPI?

WHY LARGE INDUSTRIAL HEAT PUMPS AND WHERE ARE THEY USED?

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'Heat pump' has become a buzzword within the refrigeration and air conditioning industry, and the technology behind is also discussed when the subject is decarbonisation. However, many think of heat pumps as part of domestic air conditioning systems, which can cool in the summer and heat in the winter, so where does a heat pump fit into large industrial systems, and is it a good idea? In industrial applications, which can exploit both the cold and the warm side of a heat pump, the business case can be very attractive because the savings that can be obtained during the service life may add up to a lot of money.

Many cities struggle with air pollution and, on a global scale, it is estimated by WHO, FAO and others that between 8 and 10 million people die prematurely every year due to air pollution. By stopping the use of fossil fuels including gas, oil and coal - but also biomass etc. - the cities can reduce pollution. By using heat pumps in industrial processes, the number of boilers can be reduced by about 5 million in the EU alone, which also means elimination of fossil fuels.

1 Introduction

The Sars-Cov-2 or the Covid-19 pandemic has coincided with events causing bush fires, floodings and losses of lives caused by other natural disasters. The IPCC report [1] released in August 2021 made it very clear that the changes in the climate are caused by human activities. The EU has decided to reduce CO_2 emissions by 55% by 2030, which is a challenge to all parts of society. The International Energy Agency (IEA) has estimated that in order to achieve this goal, at least 30% of the reductions should be related to cuts in emissions and another 30% should be related to increasing efficiency in the energy use. The link between these two values indicates that if we cannot increase the efficiency, the cut in use of CO_2-emitting energy production has to be increased and vice versa.

The European Environment Agency (EEA) estimates that in 2018, approximately 379,000 premature deaths were attributable to particulate matter in the 27 EU member states and the United Kingdom (see figure 1). The number of premature deaths, especially in China, has more than halved since 1990 [2]. This indicates that it is possible to decrease the pollution even while the economy grows just you focus on the problem. To this can be added that reports have shown that air pollution can be a vehicle for the spread of virus such as the Covid-19 virus [3]. The more pollution, the more virus in the air, and more pollution also affects the lung health and thus possible loss of life. Air pollution also affects the mental health of the population living in it [4]. Another report [5] says: "In July 2018, the BBC reported the tragic case of Ella Kissi-Debrah, a nine-year-old girl living close to the South Circular Road in London, who was admitted to hospital 27 times over a 3-year period before suffering a fatal asthma attack in February 2013. In December 2020, she became the first person in the UK to officially have air pollution listed as a cause of death in a coroner's report." In a review paper [5] it states: "Air pollution has already been listed among the factors associated with higher viral transmission and COVID-19 severity. This could be due to the proven role of atmospheric particulate matter in creating an environment where the virus survival is facilitated for hours, causing it to spread via airflows over large distances. Additionally, air pollutants such as nitrogen dioxide and carbon dioxide can contribute to the development of a serious inflammatory response that mainly

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concerns the respiratory system, which represents a possible reason for the higher severity of COVID-19 observed in highly polluted regions in China and Northern Italy". This leads to a possible connection between COVID-19, urbanisation, pollution and mental health [6]. Ventilation and filtration are therefore essential to ensure better indoor air quality, less illness and better mental health. Buildings also emit a lot of warm and humid air and, at the same time, heat is needed for space heating and production of hot tap water. In spaces such as data centres, the heat emitted from the computers can be enough to heat part of a city or a village of a decent size.

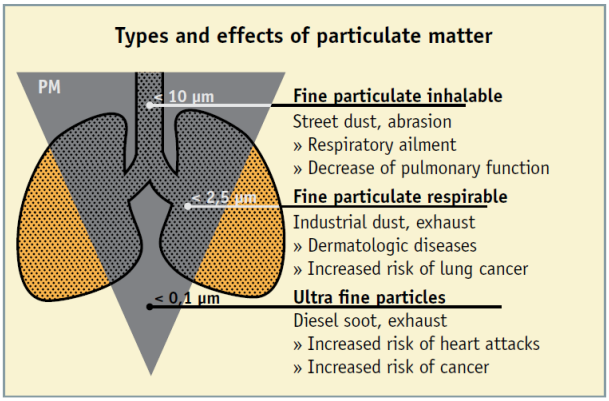

Figure 1 Size of particulate matter (PM). Domestic wood burning stoves are one of the sinners in this context. In some areas, the domestic units produce more than half of the soot in the air.

Wood and wood pellets are perceived as being natural and innocent. However, it is estimated that small-scale domestic combustion has been responsible for more than 45% of the total PM 2.5 emissions in Europe [7]. The same document shows that a little more than half of the soot produced (Figure 1) comes from domestic wood burning stoves. Microparticles were the issue in the "Diesel-gate" scandal in 2015, and this can apply to domestic combustion systems as well. If the energy is wind or solar power, the heat pump will have no emission of particles. WHO estimates that while 4.2 million premature deaths are contributable to polluted ambient air, 3.8 million deaths are caused by polluted air in private homes [8]. WHO data show that nine out of ten people breathe in air that exceeds the WHO guideline limits.

The situation is clear to some of the major business leaders around the world, and they now start to take action before the politicians force them to do so. One of the world's largest container lines, Maersk [9], is ordering new ships designed for green methanol. The push to accelerate the development is a response to the company's big customers, who are asking for sustainable and green transport solutions. Not only the motor fuel must be green, but the refrigerants used on board the ships have to be natural too.

Initiatives with Green Public Procurement (GPP) are seen on EU as well as state levels. This is to create a critical mass and bring down the price, which in turn will encourage the private sectors to follow the trend. The use of electric cars in public service is also a way to create a critical mass allowing installation of a network of charging stations in the major cities. This also takes out particulate matters and soot, which is the first step to avoid emissions and pollution from transport. All these steps are part of a broader picture and follow the lines in the IEA Roadmap [10]**Error! Bookmark not defined.**. Many governments have declared targets for emission reductions, but even with these pledges, the world will not achieve net zero emission by 2050. The politicians have to unite and show will and power at the COP26 summit, from 31 October to 12 November 2021, in order to make it happen.

Heat pumps in marine and industrial applications are often an investment with a Return-On-Investment (ROI) of less than two years, if applied and used in applications where both the cold and warm side can be used. Depending on the price of electricity, the ROI can also be relatively short, even if you use the ambient air as heat source and the required temperature level is not too high. In many industrial applications, the standard temperature today is about 180°C @8.2 bar, which is quite demanding, especially if the ambient air is the only heat source. It is therefore very important to incorporate the heat pump into the production cycle and recover surplus heat as the heat source to keep up the evaporation temperature on the "cold" side of the application. When natural refrigerants

are chosen by industrial clients, the trend is the same as in the shipping industry: customers do not want to invest in a technology that is already or may be deemed negative in the near future, which is the case for some of the available working fluids.

2 Heat pumps in industrial applications and large commercial buildings

Until recently, many building owners were not aware that the current boiler technology will not be an option in the future. They would still consider this as an alternative to heat pumps. However, the signal from many legislators and local authorities are becoming so loud and clear that it no longer makes sense to use the old technology as a reference when discussing heat pumps. As boilers are no longer an alternative, they should not be considered. With an open mind and the will to exploit the options, heat pumps have many benefits to offer. Better indoor climate and better economy are two of the key benefits that are revealed when diving into calculations and comparisons. This is an eye-opener to many.

Aquatic centres are very popular in most parts of the world, and they all have one thing in common – large-capacity ventilation systems to handle parameters such as temperature, humidity, chlorine concentration etc. The centres operate at different temperatures depending on their use, see table 1, but all have the relative humidity as a common nominator. The following is important:

- Water and air quality are of paramount importance in a modern aquatic centre
- Part of the requirements can become more efficient by using heat pumps
- Water bleed-off and consumption is high and has a high heat value
- Bleed-off depends on a number of factors and of the use
- Exhaust air has a high heat value, subject to heat recovery
- Air humidity is important, both to the building and to the occupants.

Table 1 Temperature and humidity in aquatic centres for different uses

Type of pool	Air Temperature, °C	Water Temperature, °C	Relative Humidity, %
Recreational	24 to 29	24 to 29	50 to 60
Therapeutic	27 to 29	29 to 35	50 to 60
Competition	26 to 29	24 to 28	50 to 60
Diving	27 to 29	27 to 32	50 to 60
Elderly swimmers	29 to 32	29 to 32	50 to 60
Hotel	28 to 29	28 to 30	50 to 60
Whirlpool/spa	27 to 29	36 to 40	50 to 60

To meet the requirements, the basic loads are based on:

- Dehumidification and heating ~50%
- Pool heating ~25%
- Sanitary hot water ~25%
- Sanitary hot water 60°C (bacteria kill) – use a separate dedicated heat pump
- Pool heating load can be taken from desuperheaters on the heat pumps
- Dehumidification main load – heat recovery from exhaust air
- Air change standard is 4.

By cooling the exhaust air, the heating and cooling needed for dehumidification, pool heating and space heating can all be produced. Depending on the sanitary hot water needed and bacteria kill requirements (55°C to 65°C) in the country in question, either a dedicated heat pump or a desuper-heater on the main heat pump can be used to boost the hot water.

Figure 2 shows how the energy flows may be, but other solutions are possible too. The essential part is to use both the “cold” and the “warm” side of the heat pump in the flows. Traditionally, a boiler did all the heating, and the chiller/refrigeration system did the dehumidification and cooling (the condenser released the heat to the atmosphere). This is the main difference – the condenser heat will now be used actively on site instead of being released into free air.

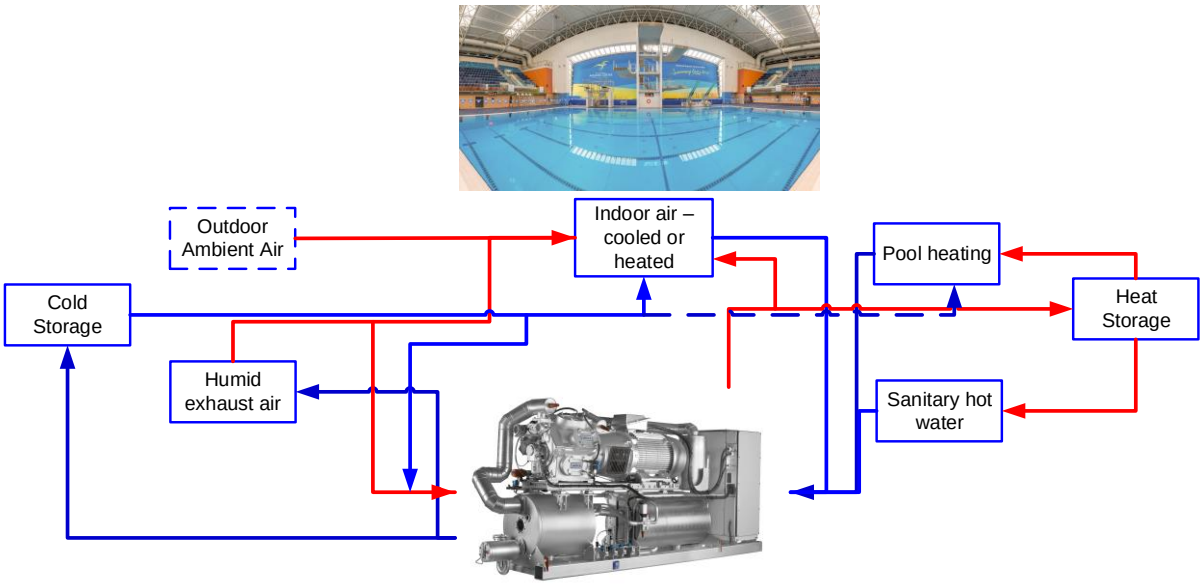

Figure 2 Illustration of heat flows in an aquatic centre and how a heat pump can be used.

A heat pump solution was calculated for the aquatic centre in Sydney, Table 2, and the values for summer and winter conditions were considered. The indoor pool area is a pool in international measures for competition purposes (previously used for Olympic competition).

Table 2 Loads for a centre in winter and summer conditions. Climate zone: Sydney, Australia

Indirect solution	Capacity (kW)	COP	cold side in	cold side out	warm side in	warm side out	Motor (kW)	Model	Evap	cond
Summer conditions	1849,6	10,50	25	20	25	30	176,2	112L	15,6	35,1
Winter conditions	1168,8	6,70	0	.5	25	30	174,4	112L	2,2	32,9

The load in the aquatic centre was calculated to about 1 MW in the winter time and 1.8 MW in the summer. For the chiller/heat pump, the load on the motor was approximately the same all year, even though the temperatures change with the season. Compared to cold climates, the temperatures are not that extreme in Australia. The capacity in the exhaust air was sufficient to produce the heating needed in the building itself.

The same concept can be applied in a dairy system. In the past, all heating was produced by a boiler, which was fired by different types of fuels, and lately very often using natural gas, which is also a CO_2 emitting fuel. Figure 3 shows how milk in a dairy is cooled, heated for pasteurisation and then cooled again. By applying a heat pump, the heat can be produced by the heat pump, which uses the warm milk as heat source on the cold side providing the heating for the pasteurisation. In the future, heat pumps will even be able to produce heat for UTH milk, which is heated to 110°C. Heat from the refrigeration system is also a great capacity that can be used as a heat source for the heat pump system.

If an industrial site cannot use the heat itself, the heat may be sold to the grid or neighbouring industrial sites.

In a paper [10] discussing low-temperature cooling systems, it is shown how even a relatively small heat pump with a cooling capacity of 300 kW can save the user money and result in a ROI of less than two years, see table 3, without considering the savings on the boiler.

Besides electricity, other parameters contribute to the economy of a heat pump (table 3). Many refrigeration plants use a cooling tower for the condensing side. It is relatively easy to plug in a heat pump in the water loop, use the heat from the condenser and boost it to 70°C or higher. It is worth noting that the cleaning water should not be too hot as some types of meat and fish will stick to steel surfaces if the water is too warm. In the actual application, the water production was 68°C for the cleaning process equipment for fish products.

Table 3 Using the heat from a cooling system, which is much larger than the heat pump, so it is not bringing down the condensing pressure, the savings include the following [9]: ***Error! Bookmark not defined.***

Water	6,716.16	€/year
Chemicals	1,210.40	€/year
inspection	0.00	€/year
Saving on tower	**7,926.56**	**€/year**
Net Energy savings	33,115.28	€/year
Total savings	**41,041.84**	**€/year**
Aprox price	80,000	€
ROI	1.95	**Year**

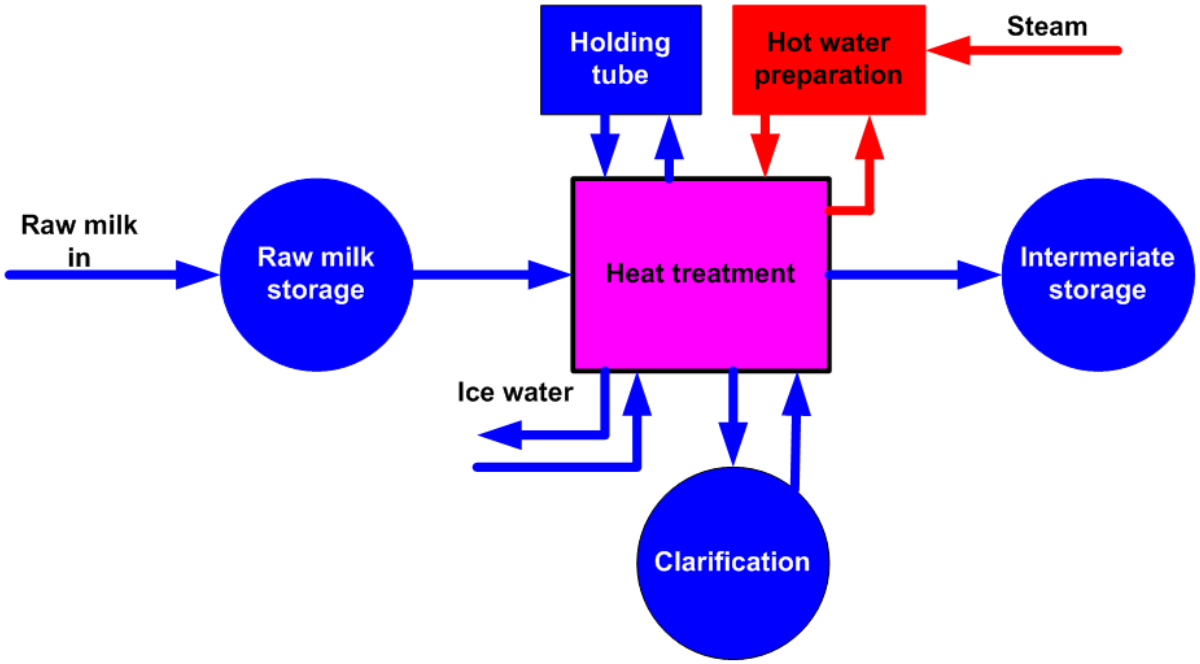

Figure 3 One of the processes in a dairy is pasteurisation of milk. This requires a quick heating of the milk to 82°C and then a quick cooling back to about 5°C. Traditionally, the heating was provided as steam at 180°C/8.2 bar and cooling by chillers and air.

Note that if a heat pump on the cooling side has a COP of 3, the COP on the warm side will be around 4; but if they can both be used, the overall COP will be 7. An electrical heater has a COP of 1, a boiler a COP below 1 – closer to 0.85, or even less, depending on how it is calculated.

3 Why heat pumps?

Traditionally, heating has been supplied by burning some kind of fuel, be it coal, oil, gas, wood, biogas or other sources. In the landmark IEA Net Zero by 2050 report [11], one of the milestones within the building sector is to provide 50% of the building heating in 2045 by using heat pumps, which means that about 500 MW of heat pump capacity must be installed every month from now until 2050. This is a challenge, and the longer we wait, the bigger the challenge becomes. At the same time, 50% of the building mass must be retrofitted to meet new energy performance requirements in order to reduce the heat/cooling loads.

There are many milestones on the way to global net zero emissions by 2050. If any of the sectors fall behind, it may be impossible to make up for by other sectors. It is therefore important that all parts of the industry - but also communities, societies, countries and regions – all pull in the same direction. Otherwise, the risk of not reaching the goal will be vast. It is a big challenge, bigger than most people realise today. Although there are many heat pumps in operation today, many more must be applied within the building sector. The industry sector too has the potential to apply many more heat pumps. See Figure 5 to get an impression of the challenge.

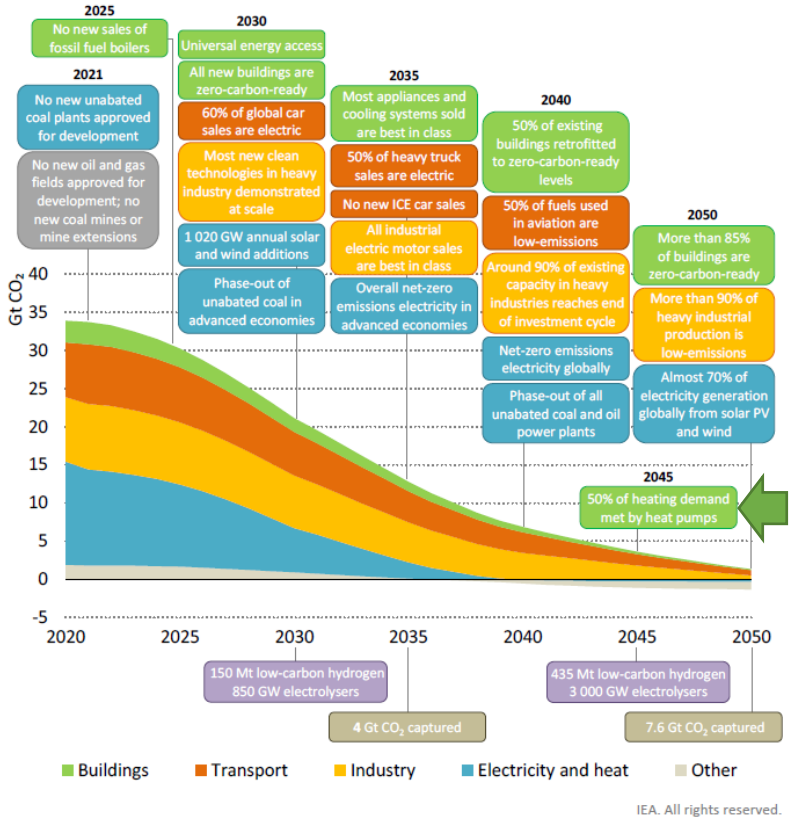

Figure 4 Selected global milestones for policies, infrastructure and technology deployment in the net zero emission future. Note that in 2045, at least 50% (see pointer) of heating demand must be met by heat pumps.

"Electricity accounts for about 40% of the heat demand by 2030 and about 65% by 2050. For low- (<100°C) and some medium- (100-400°C) temperature heat, electrification includes an important role for heat pumps (accounting for about 30% of total heat demand in 2050). To achieve the net zero emission goal, around 500 MW of heat pumps need to be installed every month over the next 30 years. Along with electrification, there are smaller roles for hydrogen and bioenergy for high-temperature heat (>400 °C), accounting for around 20 and 15% respectively of the total energy demand in 2050" (Figure 5), says the Net Zero by 2050 report [10]**Error! Bookmark not defined.**.

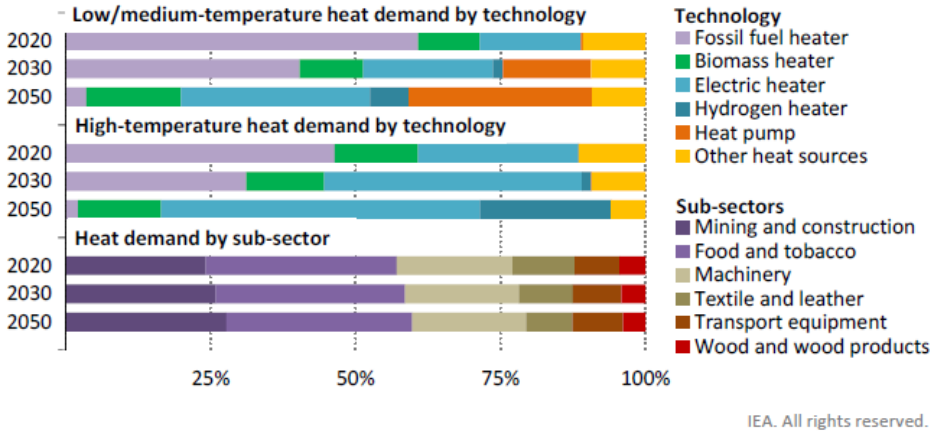

*Figure 5 The IEA Net Zero by 2050 report [10]**Error! Bookmark not defined.** shows the number of heat pumps in use in 2020 and how this number must grow in the coming years. At the same time, the efficiency of the current systems must be increased. Notice the drop in fossil fuels.*

Notes to Figure 5: Light industries exclude non-specified industrial energy consumption. Low/medium-temperature heat corresponds to 0-400 °C and high-temperature heat to >400 °C. Other heat sources include solar thermal and geothermal heaters as well as imported heat from the power and fuel transformation sector.

For industrial applications, the networks are significantly smaller, but not less important. As described in the introduction, it is necessary to look at the whole production picture in order to utilise the cold and the warm side in an optimal way. As industries vary from one site to another, it is necessary to analyse the sites individually to get the best picture and obtain the best result. Another challenge in the industrial environment is that nothing is static. Production layout changes and products change over time, which require flexibility to be incorporated into the design/layout.

Many major companies no longer discuss the future use of fossil fuels, nor do they consider them as alternatives to future solutions. It used to be that discussions often revolved around the comparison of heat pump efficiency to boiler efficiency, but these discussions are coming to an end. It has been proven many times that heat pumps are an excellent alternative, so now the focus is on optimising their use in the current production lines. Boiler technology belongs in the past and is on its way out.

Space heating in buildings is a sector, which is changing quickly. Many communities still have district heating systems using 120°C, but the trend in new systems is moving towards lower temperatures. In many countries, the temperature of the district heating system is 70°C in order to guarantee the most remote customers at least 60°C. In the future, with 5th generation district heating systems, the supply temperature can come as low as 40°C with local heating of tap water to 60°C. The lower district heating results in lower distribution losses throughout the year.

4 Conclusions

Humanity is to blame for the global warming, says the IPCC report from July 2021. To create a roadmap, the IEA has produced a report that shows a way to reduce the emissions and create a more sustainable way forward. Now, it is up to the politicians at the COP26 summit to show that they too have these ambitions. Certain major companies have already taken the first steps to green their own part of the production, but much more must be done. Many activities are happening, but as the IEA states, things are not happening quickly enough to avoid the 1.5°C temperature rise over preindustrial age.

During the Covid-19 pandemic, there was a drop in the energy consumption in 2020, which in itself was encouraging, but similar drops are needed every year from now until 2050 in order to reach the goal of net zero emissions. Sadly, the energy consumption in 2021 is back to the same level as before the pandemic.

The big question is whether the world has actually understood the urgency of reaching the net zero emissions. For instance, traveling on holiday by airplanes emitting large amounts of CO_2 is not sustainable, but will people give up traveling until an alternative fuel is found? The road transport sector must also contribute to the greening process, but is this going to happen – and will it happen fast enough to have an impact?

Reaching net zero emissions by 2050 is such a great challenge that we will all need to make personal sacrifice if we are to achieve this goal. This involves all parts of society, including politicians, governments and countries – every one of us.

Heat pump technology is one of the key factors that can help humanity survive by reducing pollution from boilers and heating systems that rely on fossil fuels by electrification of the heating systems. The electric grid will need to be reinforced to support the growing use of heat pumps in many places where steam and heating systems used to be based on coal, oil or gas.

Heat pumps can be used in industrial and domestic applications from 30°C up to about 400°C at which point other fuels and methods will take over.

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