In Praise of Heat Pumps. Can technology resolve the climate impasse?

WORKING PAPER - MARCH 2023

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RECOMMENDED CITATION
PIERRE CHARBONNIER, LÉO CAMILLI, IN PRAISE OF HEAT PUMPS.CAN TECHNOLOGY RESOLVE THE CLIMATE IMPASSE?, WORKING PAPER, MARCH 2023.

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1.

The winter of 2022 marks a key moment in the shift in both energy and climate policy. Since the invasion of Ukraine, Europe has voluntarily subjected itself to the pressure of energy markets by limiting its imports of Russian fuels, and in return enduring Russian-orchestrated supply cuts. At the same time, the idea that energy security could be put in jeopardy in order to engage in a geopolitical rivalry with Vladimir Putin's regime was able to gain ground by invoking the pre-existing need to decarbonize member countries' energy mix. The ecological transition and European security therefore go hand in hand, and the loss of Russian supplies should spur increased climate efforts. But with winter coming, and with it the risk of grid interruptions (especially in France, where many nuclear power plants are offline), heating cuts, and/or spiraling prices, the question of Europe's techno-political strategy becomes much more pressing, and much more noticeable. This is especially true for the millions of households that are already experiencing energy insecurity, and who may feel that they are being sacrificed at the altar of some distant strategic imperative. Is the energy trap set by the Russian regime for Europe closing? Is it limited to the winter of 2022-2023, or will it last longer? Should we delay the transition and simply look for other gas and oil suppliers in order to avoid a string of hard winters? Or, on the contrary, should we take advantage of the historic opportunity before us to reflect deeply on our use of energy and its very political aspect?

Social studies on energy tend to present these challenges as a trilemma. At its three points we find (1) supply security, meaning the ability to maintain a sufficient level of domestic production or imports to cover needs and ensure industry, and therefore the economic model more generally; (2) the response to climate objectives, or the ability to ensure energy needs through decarbonized means within the framework of the Paris Agreement; and (3) the social distribution of energy costs and the risks stemming from its use, meaning how technological choices and the organization of energy markets impact socio-economic hierarchies, particularly in times of crisis and/or transition. It is a trilemma because the answer to each of these constraints is not automatically aligned with the others: for example, we can imagine that the response to the climate challenge comes at the expense of supply security or social justice, but it must be agreed that, for the moment, it is the security imperative that acts as a conditioning and limiting factor with respect to the other two.

There are currently two major responses to this trilemma, two primary ways of considering the alignment of these three constraints. The first one, which was endorsed by President Macron in his energy policy speech at Belfort in February 2022, consists of relying on technological innovation to reduce the tension between production needs and the response to the climate constraint. Just as in the post-war years, technology is presented as an inexhaustible intellectual resource that can replace environmental limits and pave the way for a mode of production that is always geared towards growth without creating unsustainable environmental and social externalities. For techno-optimists, the atom, particularly in France, is the cornerstone of this modernizing socio-technological mechanism; even though nuclear energy is no longer a new technology, it retains its cultural associations related to scientific progress and appears, especially in France, as a major symbol of the avant-garde. In response to this argument, which, as we recalled, has its roots in post-war governance and was reinforced by the oil crises of the 1970s, came a critique of «techno-solutionism», driven primarily by environmentalist organizations. The argument is that the transition can only be achieved through energy sobriety, as technical innovation only creates new risks and imposes unnecessary costs. The moderation of needs, it is argued, allows the energy needs of society to be reduced without undermining justice and equality, because it is aligned with health criteria (less pollution and stress) and social norms (post-material values) which are regarded as ensuring the common good, while at the same time stimulating a reflection on the value of work and the time we give it. This approach has long given central importance to the critique of technology as a tool for the depoliticization of society, and as a capitulation to industrial interests and to an ideology of instrumental science.

However, the confrontation between these two ideologies, these two conflicting relations regarding technological innovation, does not necessarily reflect the real options available to us to serenely make it through the winters that await us, and to achieve the «just transition» recently defined by the IPCC report. It is possible to show that techno-solutionism, just like the mechanical opposition it provokes, fails to address the social relationship with machines that will have to be established in order to accomplish the just transition. On the one hand, there is always the risk of giving in to the illusion of an infinite techno-scientific frontier by investing in «disruptive» technologies such as green airplanes, certain geoengineering technologies, or the generalized use of artificial intelligence,[1] which respond less to real needs and ecological imperatives than to the expectations of private investors. On the other hand, there is a risk of turning a deaf ear to the expectations of development, security, and employment that drive society, including when it seeks to avoid the climate shock.

In order to overcome the energy trilemma without turning to crude and ineffective solutions, there are real socio-technological opportunities that, until now, have not received the attention they deserve. This is the case of the heat pump, a modest little machine whose basic principles have long been known, and which will play an essential role in the energy transition process, all while serving as a model, a test case, for thinking about this transition. Indeed, the

1 — Regarding the energy cost of AI, see https://arxiv.org/abs/1906.02243 and https://spectrum.ieee.org/deep-learning-computational-cost.

heat pump teaches us to link security, transition, and social justice by reducing the friction between these three imperatives as much as possible.

We are therefore going to give ourselves a «little lesson in the sociology of science» on this particular object, in the manner and spirit of Bruno Latour.

2.

Europe's great dependence on energy forms that are at once emitters of greenhouse gasses and held by a geopolitical rival has been widely commented on since the war in Ukraine began, as this event revealed a new ecological and political order. In 2019, oil and natural gas made up 58.5% of the gross energy available in the European Union, and these two fuels were imported from Russia at the rate of 29% and 40% respectively.[2]

This crisis is accompanied by an accelerated activation of the theme of sobriety within public debate: decreasing consumption, increasing the share of renewable energies in the energy mix, and developing energy-efficient technologies. The consumerist models that feed the current energy order are being directly discussed as the main levers that will allow both the ecological and geopolitical situation to be turned around at the same time. These consumption patterns are nevertheless deeply dependent on technological and social infrastructures, which are linked to urban development and major energy choices, limiting individual discipline room for maneuver and giving the problem of sobriety an especially political dimension. In Europe, around half of annual energy demand comes from heating and cooling demands (mainly from residential heating and industrial process heating). The residential heating sector accounts for 45% of gas consumption and 13% of oil consumption.[3] Therefore, changing this sector through new practices and tools is an essential part of the energy transition that must take place: besides transportation and agriculture, this is one of the areas with the greatest potential savings in greenhouse gas emissions, which is why the potential of a tool such as the heat pump is attracting increased interest.

Heat pumps work through a refrigeration cycle – in other words, a type of thermodynamic cycle that allows the transfer of heat from a cold source to a hot source, in contrast to the natural process. This transfer is possible by a mechanical energy input (compression), generally through an electrical source. And so, a refrigeration cycle draws energy from the cold source and diffuses it to the hot source and it can therefore be used to cool the cold source in the case of air conditioning as well as to heat the hot source in the case of heating. Refrigerators work on the same cycle: it cools its contents and releases the heat it draws to the exterior through the radiator located on its rear surface. Heat pumps work in the opposite way: they capture thermal energy from outside (in air, water, or the ground), and release it into the building to be heated.

The distinctive feature of a refrigeration cycle is that the heat supplied to the

2 — Toute l'Europe. (2021, 14 April). La dépendance énergétique dans l'Union européenne.

3 — IEA (2022), Heating, IEA, Paris https://www.iea.org/reports/heating, License: CC BY 4.0.

hot source (the «heating») is equal to the sum of the heat drawn from the cold source (the «cooling») and the mechanical energy supplied by the compression.

$C_{heating} = C_{cooling} + E_{energy}$ therefore $C_{heating} > E_{energy}$

And so, in the case of heat pumps, the usable energy (heating energy) is always greater than the electrical energy that the system receives because some of the heating is supplied by the thermal energy already present in the outside air, water, or soil. For one unit of electric energy supplied, an average of 3 to 5 units of heating are received (this number, called the coefficient of performance, obviously will vary according to the heat pump and temperature). It should be noted that since the heat energy present in the cold source is renewable, heat pumps are sometimes classified as a renewable energy source. This is where the technological ingenuity and social interest of the heat pump lies: instead of only performing an energy conversion, as in the case of the electric radiator or the hot water system, it uses electricity as a means of heat transfer that can exploit calories present in the environment and previously inaccessible or overlooked. This is why heat pumps are both a converter and a «source» of energy: they provide us with much-needed and readily available calories without any technological breakthrough. They help us move from being energy «producers» to being hunter-gatherers, so to speak, on the lookout for the smallest unit of heat present in the environment.

In this sense, heat pumps are bound to disappoint innovation enthusiasts because they are already a mature technology and are only waiting for installation infrastructure to become widespread. Techno-critics will also be disappointed because heat pumps also allow pre-existing demand to be sustained without questioning it, all while appearing in certain respects as a purely technological solution to a social problem. But this is exactly where its advantage lies: heat pumps have no need for the sterile competition between techno-utopians and techno-critics.

Drawing most of its energy from a renewable source, and the rest from an electrical supply (and therefore compatible with renewable sources), heat pumps have the potential to significantly reduce the heating sector's energy demand and carbon bill. A large-scale rollout of heat pumps in Europe and the world therefore seems to be a significant lever for the energy transition and relieving current geopolitical pressures as well as for household bills. But effectively converting the technological potential of heat pumps into a reduction in emissions that benefits everyone requires a two-part reflection on the political means of a mass rollout of heat pumps: redefining the role of the State in large-scale policy on one hand, and creating a political and cultural imperative for sustainability on the other.

3.

A number of energy management agencies – such as ADEME[4] in France and AIE[5] internationally – are currently promoting heat pumps as transition technology. The reason for this is that their rollout could hardly be completely left to market forces and the spontaneous development of demand: these machines only become interesting from a technological-political point of view if they are integrated into organized energy distribution networks. The usefulness of a heat pump increases when it is integrated into optimization and recovery systems, such as local heating networks, heat storage systems, industrial heat recovery systems, etc. In the heating sector, energy savings are all the more important if the transition is thought out in a global manner: from supplying energy to heaters, to the urban network, including the insulation of buildings – which presumes voluntary coordination of action with the support and mediation of the State. In fact, there are different types of heat pumps,[6] some more efficient than others, and their installation requires expertise and customer support. Simply replacing a gas or oil heater does not provide significant climate and energy benefits; it is only when combined with building insulation that its ability to resolve the energy trilemma becomes apparent. Furthermore, the capture of calories from the ground by geothermal heat pumps is generally, depending on geographical conditions, the most economical option, although it is the one that requires the largest array of incentives, subsidies, and support.[7]

Integrating heat pumps into these infrastructures raises the question of streamlining the management of heating in technologically advanced societies. Indeed, among the reasons for the historic success of fossil energies and their immense power in our socio-political environment, we must mention the fact that they favor highly individual forms of consumption (individual vehicle and heating systems), that they take the form of an easily identifiable and exchangeable commodity, and that they create a profound division between those who reap the economic benefits of their being brought to market and the social groups that bear the burden of their externalities. Fossil resources are fundamentally rare, finite, and exhaustible, but their relative abundance was organized to satisfy socio-economic criteria that we can summarize by saying that ease of access and use was favored over energy efficiency and ecological sustainability.

If we make a quick socio-technological comparison between the fossil fuel system and what heat pumps allow, we come up with a set of quite distinct contrasts: heat pumps rely on voluntary coordination of heat use, and are therefore less individualized; they partially disrupt the logic of enclosure in the energy market by providing access to calories available in the external

4 — ADEME, Agence de la transition écologique. Les pompes à chaleur – Ademe. (s. d.). (2022).

5 — International Energy Agency. The Future of Heat Pumps, World Energy Outlook Special Report. IEA: 2022.

6 — https://www.energy.gov/energysaver/heat-pump-systems.

7 — Regarding the link between transition technologies and this legal environment, see https://www.sciencedirect.com/science/article/pii/S2542435120304402.

environment, unconstrained by access limitations; and above all, they only make sense from the perspective of preventing waste and optimizing the technological and behavioral use of calories. The heat pump is a machine whose central characteristic is to stimulate energy efficiency and sobriety "by design", and to interrupt the opposite incentive of unbridled overexploitation previously caused by fossil fuels.

These questions had been raised at the beginning of the 20th century by economist and sociologist, Thorstein Veblen, in a series of texts concerning the «technocratic»[8] trend at the time. Veblen's observation is as follows. In advanced market and capitalist societies, the need for technological streamlining is secondary to the need for accounting streamlining. What matters to the owner and the investor is not using human and natural forces economically and efficiently, but deriving maximum profit from minimum effort, which can lead, for example, to arranging the artificial scarcity of a good in order to increase its price, or to creating demand for goods whose social value is questionable (typically goods that give rise to health and environmental risks, the cost of which is not paid by industry). Therefore, for Veblen, it is not true to say that the pathologies of modernity are linked to the destructive reign of science and technology. For him, on the contrary, these pathologies are related to the subordination of material constraints, in particular those related to the thrifty and sustainable use of essential goods, through the constraints of optimizing the yield of capital. From this point of view, we can say that the era of fossil fuels, which was not inevitable, and which coexisted with other energy options,[9] enshrines geopolitical, military, and commercial imperatives as a priority over the streamlining of collective life.

Today, the ecological and climate imperative echoes Veblen's concern. As soon as heating usage must be made subject to strict principles of streamlining and economy – for reasons that are at once social, environmental, and sovereign – the challenge is to not only denounce the market's social injustice, but also, at the same time, its ecological inefficiency. The consideration of the long term, of future generations, of the social cost of environmental risks, is a powerful incentive to switch from a sub-optimal fossil system to an optimized electrified system, of which heat pumps are emblematic, but this switch requires a new art of governing. The large-scale deployment of heat pumps therefore requires production management methods that are at least partly independent of market rules and closer to a form of technological intelligence dirigisme as imagined by Veblen, where the central political criterion is the search for an optimum social outcome: fair distribution, minimization of resource wastage, and sustainable organization.

4.

The public debate over what concrete direction to take in order to decarbonize

8 — See in particular "The vested interests and the common man", and "The engineers and the price system",both reprinted in The collected works of Thorstein Veblen, Routledge, 1994, vol. 7.

9 — See for example François Jarrige and Alexis Vrignon, Face à la puissance. Une histoire des énergies alternatives à l'âge industriel, La Découverte, 2020.

the economy often comes back to the question of what role technological innovation must play in the transition. To state the problem formally, we can say that the more we move towards a transition through technological substitution, the lower the political cost of the transition and, conversely, the more we define the transition as a behavioral and social effort, the higher the political cost due to the unpopularity of these decisions. This dilemma explains the high political investment in a model of transition through substitution as this appears to promise a path forward where everyone wins: new profit opportunities appear for investors, social habits are preserved, and the classic discourse of modernization can be recycled. The electrification of the automobile fleet is a good example of this *path dependency* of the transition and its appropriation by the mechanisms of public opinion. While a systematic overhaul of travel patterns, investment in public transport, the reorganization of cities, and even a shift to a four-day work week appear to be politically costly, the idea of substituting the combustion engine with the electric motor involves less effort and fewer electoral risks in a context in which motorists are an interest group likely to extort anti-environmental compromises from the government. The preference for technical substitution over social reorganization can be explained by the ecological problem's deep, democratic roots.

But this transition trajectory raises a major problem, which is regularly pointed out by specialists in the extractive and polluting sectors.[10] Indeed, transitioning from thermal to electric without significantly reducing demand or traffic still leads to substantial environmental externalities, particularly urban congestion and noise, pollution related to road and tire wear, road accidents, continued urban sprawl and, of course, the extreme pollution related to the extraction of the metals needed for the production of batteries, not to mention the more fundamental uncertainty about the accessibility of the necessary resources. In other words, transition by substitution leads to what economists call a rebound effect, or the Jevons effect: the "green" car can create a new desire for unhindered, individual mobility, now reclassified as an environmental act, no longer a problem, and therefore encouraged. In the name of climate preservation, the extractive burden and the nature of these externalities will be shifted to other regions, other populations, and the benefits of the transition may be swallowed up in this rebound effect.

A simple illustration of this phenomenon is the first large study carried out by Stanley Jevons in England in the second half of the 19th century: despite the phenomenal improvements in the efficiency of English factories thanks to the widespread use of the steam engine, we see a great increase in the amount of coal consumed by industry. The idea can be explained very simply in macroeconomic terms: an increase in usable energy obtained from the same quantity of coal consumed leads to a decrease in production costs. So at the same time that supply can increase and prices fall, demand increases in turn, thereby increasing coal consumption. In the same way, the spectacular improvement of the thermal engine's energy efficiency in the automobile sector has not led

10 — See for example this report https://www.climateandcommunity.org/more-mobility-less-mining and in general the work of Thea Riofrancos. For a more accessible overview, refer to this podcast episode https://podcasts.apple.com/us/podcast/volts/id1548554104?i=1000598693126.

to energy savings, but to the development of heavier models, at the expense of energy efficiency.

An energy transition is always accompanied by the specter of a rebound which at first glance would undermine any possibility of reining in consumption through innovation because the development of more efficient machines is generally followed by even costlier consumption patterns. But this mechanism is by no means natural, primarily because certain technologies and certain technological environments do not present a major risk of a rebound effect. This is at least partially the case with heat pumps, in contrast to electric vehicles. If their deployment is complemented, as it ought to be, by a campaign to insulate buildings and recover heat "waste", the gains in technological efficiency are not, in principle, followed by an increase in gross consumption – at least not as much as in the automotive sector, for example. However, some recent studies have shown that the switch to heat pumps could lead to a rebound effect because the incentive to save energy decreases; on average, energy consumption related to heating decreases much less than what the heat pump could produce,[11] or even increases in some cases, depending on the comfort desires of households.[12] In order to avoid this rebound effect, deploying infrastructure that complements the heat pump's efficiency is therefore not enough; it is necessary to anticipate the change in residential usage that it may cause. For this purpose, a brief review of past energy transitions reveals the social dimension of increased heating demand, and therefore the need to align collective practices with the imperative of sobriety.

5.

Starting in the 19th century, domestic comfort became a standard of progress to be made universal in western societies.[13] This encompassed several aspects of social changes stemming from modernity: the birth of the middle class, consumerism, hygiene considerations, technological progress through fossil fuels, etc. Beginning with this period through today, domestic demand for energy has only increased. This "rebound" can only be understood by examining the evolution of three inseparable factors: standards of comfort, the organization (social and spatial) of domestic spaces, and the technological tools used.

England during the 19th century was entirely dependent on coal, the use of which shaped domestic spaces, notably through the open-hearth fireplace, which largely dominated usage until the end of that century. The dominance of the open fireplace was not for lack of an alternative (such as wood burners or even gas stoves, which are much more energy efficient and have existed since the beginning of the 19th century) but rather because of its social embeddedness: the attachment to fire, the unsuitability of homes for other forms

11 — Christensen, T., Gram-Hanssen, K., Petersen, P. E., Larsen, T. F., Gudbjerg, E., Rasmussen, L. S., & Munter, P. (2011). "Air-to-air heat pumps: a wolf in sheep's clothing?" ECEEE Summer Study. Stockholm: European Council for an Energy Efficient Economy.

12 — Winther, T., Wilhite, H. "An analysis of the household energy rebound effect from a practice perspective : spatial and temporal dimensions". Energy Efficiency, (2015) 8:595-607.

13 — Crowley, J. E. The Invention of Comfort: Sensibilities and Design in Early Modern Britain and Early America. Baltimore : Johns Hopkins University Press, 2001. 384 pp.

of heating, the cost of transition, and the specific uses and skills associated with coal (the constraints of which are primarily borne by women). These are all elements that make a "coal civilization", whose inertia is explained by its cultural character.[14] The energy transition from coal to gas for domestic use therefore came largely after the appearance of gas heating technologies in the second half of the twentieth century. And this energy transition once again depended on the convergence of technological possibilities and social changes: in Western societies, the post-war period has been characterized by a more sedentary lifestyle linked to the emergence of consumer society, a spatialization of household tasks thanks to electrical appliances, and women's work, all of which are domestic changes that gas heating has made possible.[15] Indeed, gas heating made it possible to heat the entire home for less money, thereby expanding the possibilities of sedentary living. This was paired with public utilities assuming responsibility for the distribution of gas, thereby minimizing the efforts and actions associated with the management of heating in the home, which until this point had been largely carried out by women. Even though gas stoves and heaters are much more efficient than open hearth fireplaces, the transition from coal to gas was marked by a great increase in the demand for heat in homes in the second half of the 20th century, precisely because of this reorganization of the domestic space that it allowed. Once again, we can see that the demand for heating is a social fact, and that in addition to the technological and infrastructural parameters, we must include the «domestic culture» that co-constructs the energy transition.

In other words, in addition to the heat pump's tendency towards efficiency by design, there must be socio-economic incentives developed to control demand and promote a «19°C culture» (information campaigns, renovation subsidies, training technicians to pass on good practices in terms of sobriety), to the detriment, of course, of energy suppliers. This is the delicate balance between efficiency and sobriety: the former is achieved by improving the quality of the machinery used, the latter by reshaping collective practices, social standards, and habits.

The fight against the rebound effect therefore has inseparably technological and sociological dimensions: it is impossible to take a binary position on the primacy of the technological factor (as the proponents of techno-solutionism would like) or of the social factor (as the proponents of a happy sobriety would like) in the reorganization of needs and material infrastructure. If, in the past, the major technological and energy choices, and in particular the spectacular development of fossil infrastructures, have favored inefficiency and the explosion of environmental externalities, today we have the means to renegotiate our relationship to energy by relying on a new generation of machines, of which the heat pump is a very interesting example.

14 — Mathis, C-F. La civilisation du charbon en Angleterre, du règne de Victoria à la Seconde Guerre mondiale Paris, Vendémiaire, 2021, 560 pp.

15 — Kuijer, L. Watson, M. "'That's when we started using the living room': Lessons from a local history of domestic heating in the United Kingdom", Energy Research & Social Science, Vol. 28, 2017, pp. 77-85. See also the works of Renan Viguié, for example https://www.cairn.info/revue-flux-2020-3-page-102.

6.

Reflecting on heat pumps, the technological transition networks, and the Jevons effect also allows us to put forward a hypothesis on the persistent political failure of environmentalism. This has indeed been constructed as a critique of technological modernism in a context where, it is true, most of the innovations proposed to unburden the future, to emancipate society from want and insecurity, have ended up producing unforeseen risks and threats. Out of this observation, ecologists have drawn the conclusion that technology will never be able to save us, and they have therefore fostered an opposition to modernizing liberalism that is not based on the defense of work, but on the objective of emancipating ourselves from machines.
The main limitation of this approach is, of course, that it is inconsistent with ongoing demands for economic justice from the working classes, while also failing to mobilize a critical mass of proponents for a new kind of society. This impasse, which is both ideological and electoral, can be overcome if defenders of the environment and of justice accept that certain technologies, or rather certain techno-political infrastructures, have the power to promote the development of sobriety, and to set up a path towards transition through social reorganization rather than through simple technological substitution. The technological anomie that characterized the 20th century was not inevitable – there is nothing natural in the succession of political and geopolitical crises and rebound effects that we have always responded to by increasing our energy intensity and becoming less risk averse. Nor is there anything inevitable about relegating the ecological imperative to third place behind the distribution imperative and the imperative of securing supply (and therefore growth). What we must conclude is that we must abandon techno-critical ideology, which is only the negative copy of techno-solutionist ideology, in order to take political advantage of these few technologies that allow us to envision a soft landing.

In other words, there is no need to choose between love of technology and sustainability because there are machines that exist that can put us on the path to sobriety without having to break with the modern ideals of development, equality, and of distancing ourselves from the ecological limits of free action. We do not necessarily have to choose between responding to demands for comfort, well-being and security, and ecological imperatives. Provided that innovation is reintegrated into a systemic reflection on technological choices and their political dimension, provided that we accept the idea that today ecology is a question of industrial policy, and provided that we clearly define what is at stake in the creation of a State that will organize the deployment of machines against the private interests that benefit from technological anomie, the impasse can be broken. The heat pump is only one catalyst of this relationship between technology and energy which must override one or the other modern utopias (technophile or technophobe), but it points to a path to be taken.