**The Ecological and Social Impacts of Ineffective Heating**

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**Summary**

The way in which we heat our buildings and homes has significant negative impacts on sustainable development goals, both national and international, as heat accounts for nearly half of all energy consumption, and about 40% of energy-related carbon dioxide emissions. Additionally, energy waste when it comes to heating has steadily increased its price, making it less of an option for those in the lower end of society, in some places where heating may be a necessity rather than a luxury. These issues directly clash with several of the United Nations Sustainable Development Goals.

A proposed digitalization solution is using IOT. Namely, this solution involves using sensors, thermometers, microcontrollers, and machine learning to build a smart heating system that will not only be able to minimize energy waste in heating, but will also provide valuable data on how heating is used in modern society and its shortcomings. This will be a welcome solution as it will drive down heating prices and encourage a more sustainable use of heating.

**Introduction**

Heating systems have been an integral part of human society, as well as a necessity, especially in colder regions such as Sweden. However, the way in which we heat our homes, offices, and buildings in general has had significant negative impacts on the environment and contributed to climate change. One of the leading issues regarding heating is the sheer amount of wasted energy that comes with poorly designed and managed heating systems.

The International Energy Agency has estimated that around half of all energy demand for buildings in 2021 was used for space and water heating (Goodson 1). Not only does this constitute an enormous amount of energy waste, but also directly leads to 2450 megatons of CO2 emissions. The agency speaks about how fossil fuels still (written in 2021) correspond to over 60% of the heating energy demand, showing how ineffective and unrenewable heating practices are in our modern day world.

Considering sustainability issues other than just the environmental consequences of heating, higher energy waste directly leads to higher energy costs. While this consequence impacts businesses and building owners, a lesser talked about impact is how poor communities deal with these issues, especially in locations where heating is a necessity and not just a luxury.

In this report, we will focus on the issue of energy waste caused by unsustainable heating practices. Specifically, we will examine what solutions digitalization can provide that will allow us to minimize energy waste in the heat sector. By addressing this issue, we can significantly reduce the carbon footprint of buildings and specifically focus on the United Nations Sustainable Development goals three and six, from a social justice perspective, and goals seven, eleven, and thirteen, from a climate justice perspective.

**Aim**

The overall aim of this report is to explore the possibilities of digitalization in reducing energy waste associated with poor and modern heating practices. Specifically, I aim to identify the benefits of using digital technologies such as sensors and thermostats, coupled with energy management systems, in order to optimize heating performance, ensuring minimal energy usage when directly compared to amount of heating done in a building.

This report will not only have to assess the main shortcomings and causes of energy waste when relating to heating, but also the negatives involved with the proposed digitalization solution to this problem. I will measure the environmental and social consequences that implementing heating sensors and digitally managing the heating system may have. These consequences may be in the form of more energy usage by the sensors, system failures, and many other ways. Regardless, these are potential consequences that may not be ignored, and for which we must weigh the costs and benefits.

Overall, the report should give a reasonable set of guidelines on the main causes of unsustainable heating, as well as how building owners and planners may address these issues to not only help them save costs, but also waste less energy and emit less carbon emissions.

**Sustainability Challenge**

Despite being such a crucial aspect of our lives, the way in which we heat our buildings and homes has had and continues to have significant negative impacts on sustainable development goals, both national and international. The United Kingdom’s Department for Energy Security and Net Zero has estimated that globally, heat accounts for nearly half of all energy consumption, and about 40% of energy-related emissions (Sahni 18). Considering that fact, as well as the graph shown at lecture three of the course that details how much carbon dioxide is in our atmosphere compared to throughout earth’s history, it’s clear why this 40% is so significant.

Chart, histogram

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Figure 1: Atmospheric CO2 concentration from the Vostok ice core record. Taken from lecture 3.

The releases of these greenhouse gases into the atmosphere has resulted in a steady increase in global temperatures, which is partly (and largely) responsible for the claim that combined land and ocean temperature has increased at an average of 0.08 degrees Celsius per decade since 1880 (NOAA 3). That means about 1.12 degrees Celsius in total, and projected to get worse. Keeping in mind the UNSD (United Nations Sustainable Development) goals mentioned in lecture eight, goal number thirteen details climate action, which heating is, as shown, directly contrasting with. Considering the idea of a doughnut economy proposed by Kate Raworth, heating has affected and contributed to humanity’s “overshooting” on several of the planetary boundary categories, such as land-system change, stratospheric ozone depletion, climate change, and biosphere integrity. While none of these categories are yet on the “red” high risk zone, they are largely on the “yellow” uncertainty zone and, with exception to the ozone depletion, have been steadily rising.

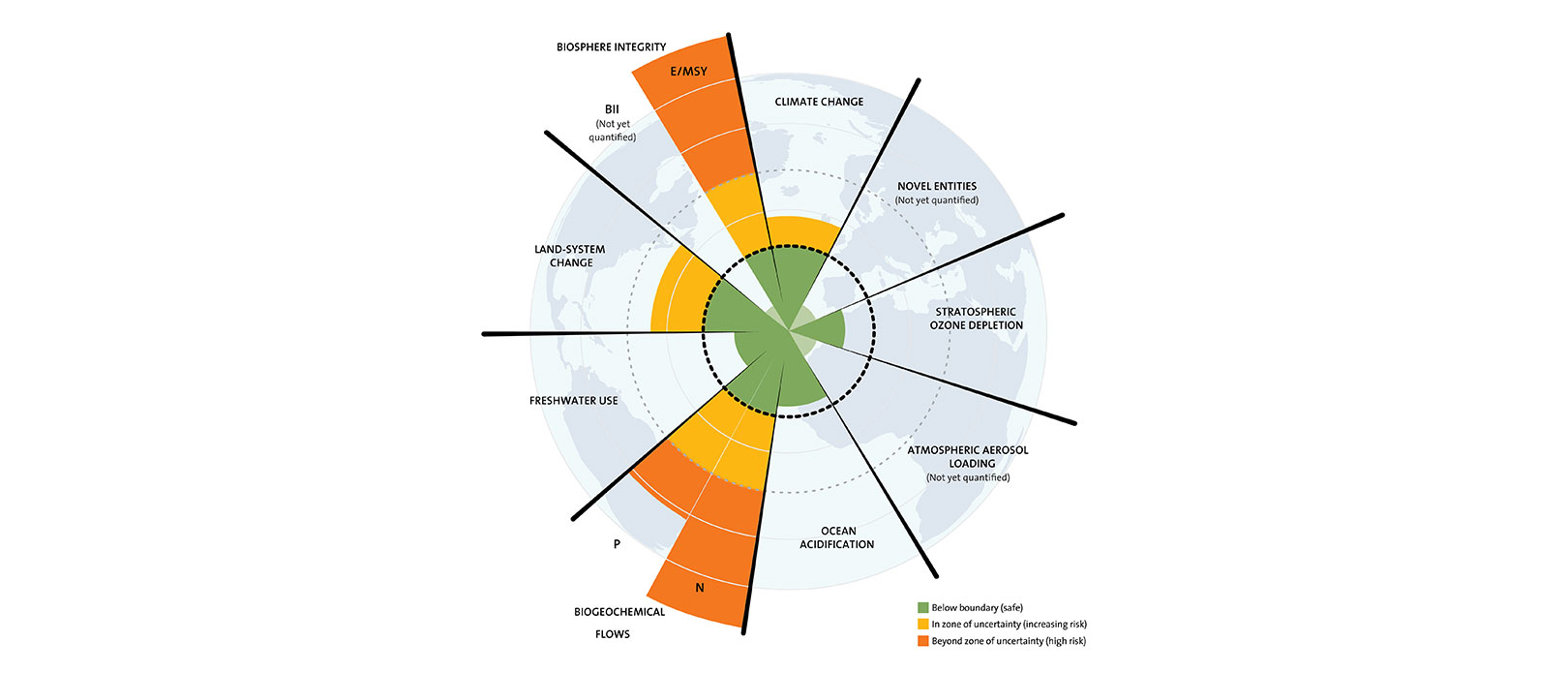


Figure 2: The nine planetary boundaries

A lot of the issues caused by heating directly correlate to a misuse of it. By and large, when society is building itself, it doesn’t consider how their buildings and spaces will accommodate heating as a first priority. Despite efforts to do so in recent history, the way buildings trap heat and allocate heating is in several ways ineffective (Shandilya). This leads to a direct huge amount of energy waste regarding heating, in direct contrast with the UNSD goal number eleven (sustainable cities and communities). The government of Sweden has recognized this issue, and vowed to lead “society's transition to a sustainable energy system” funding national research on renewable energy technologies, smart grids, vehicles, and more (3).

This energy waste of course is one large reason why the aforementioned problems are so prevalent, but a lesser talked about issue is the social impact this has. When people pay for heating, they’re essentially paying for energy usage. Higher energy usage directly correlated with higher heating prices, and that’s exactly what happens in society. While of course this has an effect on building owners and landlords, the most affected group are those in the lower end of society who can no longer afford heating. Heating is a necessity, especially in colder countries such as Sweden, and especially if you don’t have a permanent shelter. Because of this, high heating prices directly affect a decently sized chunk of the population that must then resort to other means, which directly clashes with the UN’s sustainable development goal seven (affordable and clean energy), ten (reduced inequalities).

The wider system impacts of this sustainability challenge are far and wide. As was mentioned already, many of the poorer ends of society suffer largely from not having access to heating. Lecture eleven provides us with a perfect graphical representation of how energy deprived some societies, specifically the poorer people in those societies, are.

Map

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Figure 3: Global map of energy poverty from 2018.

While this map doesn’t directly mention anything about heating, it gives a general overview of how the energy demand is not being met in several parts of the world, a large part of which constitutes of heating. Because of this, in countries and regions where heating is more of a necessity than a luxury, society has to adapt. This leads to examples of “makeshift” heating. Burning tires, plastic, fossil fuels, and other objects in order to stay warm during a cold winter (Sokołowski 19). The direct consequence of this is an ineffective method of heating and more greenhouse gases released onto the atmosphere. Furthermore, the inhalation of these toxic materials by the people who have to rely on this type of heating causes a myriad of health problems for them. The US department of health’s Environmental Health Perspectives division estimates that “exposure to household air pollution (HAP) from inefficient biomass and coal stoves kills nearly 4 million people every year worldwide” (Rogalsky 7). Not to mention that burning all these objects may be expensive, and therefore at times not even an option, or when it becomes an option may otherwise economically hinder people who are already greatly affected by poverty.

A smaller, but existent, positive system impact that comes with all of this is an incentive to tear down old buildings. Since old buildings were built without heating in mind, it becomes more expensive for building owners to maintain them. This causes an incentive for refurbishing or rebuilding them, which coupled with modern building practices leads to more sustainable buildings, in line with UNSD goal number eleven (sustainable cities and communities). This may pave way for greener communities all around, and may leak over to areas other than just heating and energy.**Digitalization as a Solution**

As has been explored above, one of the biggest issues with modern heating practices is how energy wasteful they are. Ranging from trapping heat poorly, to unnecessary or wrong amounts of heating, a large part of these problems stems directly from a broken system surrounding the heating. There is a lot that data analysis and digitalization can do to help with this, and namely a smart central heating system would minimize several of these shortcomings.

Smart heating systems typically consist of sensors coupled with machine learning algorithms. These are two separate tenets that require separate implementation, and don’t necessarily rely on one another. The first part is implementing sensors to obtain data about occupancy, temperature, weather conditions, and energy consumption patterns. The data collected by these sensors essentially provides a small overview of the energy consumption of a household or building. Then, with this data, a machine learning model can be used to analyze it and optimize heating schedules and temperatures. Alone, and if implemented properly, this solution would be able to optimize the heating output of a heater to ensure that a room, house, or building is only heated as much as it should. It would also be able to directly acknowledge whether it is being more effective than if it weren’t implemented, and therefore give extremely valuable data to its implementors on how its parameters and inputs should be tweaked to make it even more effective.

In terms of ICT system impacts, this digitalization solution has positives and negatives. In terms of direct effects, the production use and disposal of the sensors, thermostats, and other devices used to measure metrics in these buildings aren’t negligible. As mentioned in lecture four, there is a life cycle to every ICT product, and these products are no different. They will all release emissions throughout production, use, and disposal. Each building would require sensors for every room, as well as on average a couple of microcontrollers depending on the size of the building. Thankfully, microcontrollers use relatively low energy (Levy 5) and have a relatively long lifespan, reducing the amount of production and disposal cycles we would have, and also implying that extra energy consumption would likely be negligible compared to the amount of energy waste it would mitigate in terms of heating. This brings us to the second section, which is the enabling effects of this solution. A life cycle assessment, as mentioned in lecture nine, is required to properly assess the negative effects of sensors, microcontrollers, and other components required to make the system work. In terms of the production phase. Similar studies have been made for waste management, and one from the RISE institute in Sweden specifically mentions how these kinds of sensors can be granulated and recycled, and furthermore shows that IOT devices similar to the ones in this proposed solution are generally low-energy (Chiew 23).

As mentioned, the actual effects of the sensors and system running would be quite negligible compared to how much the system itself would help mitigate heating energy waste. The final level in Hilty and Aebischer’s model is what systemic effects the solution would have. One example of these effects that has already been mentioned is an incentive to move away from old buildings. No matter how smart a smart system may be, ineffective heat trapping will not be solved by it. Only refurbishing or rebuilding old buildings to make for better insulation will actually help with it. This means that a recognition of its necessity may be brought about once building owners realize that implementing more sensors isn’t a solution to their poorly insulated structures. Additionally, bringing down energy usage in buildings that *do* have good insulation will eventually mean a reduced price for heating, which in turn will make it more accessible for all parts of society, reducing the social inequality aspect of it.

Some unintended social consequences that are also worth considering from this solution are the affordability of it. While, given that the solution functions, building owners may profit from the amount of energy mitigated compared to the cost of implementing the system, it’s not immediately obvious how impactful this relation would actually be. It’s possible that in lower income areas building owners may not implement this, especially if their tenants are the ones paying for the electricity bills. This would pose a couple of structural obstacles (as mentioned in lecture ten) to the tenants’ health, competence, and one could argue both influence and impartiality as lower conditions may inadvertently lead to lower means and energy for obtaining or maintaining a job, and generally taking care of themselves. This could be solved by the tenants themselves implementing a smart heating system of their own, but this of course has the direct negatives that they would have to put up the money themselves, which may not be an option, as well as that they must get the building owner or landlord’s approval, which may also not be an option.

In terms of other benefits this solution may have that don’t directly correlate with sustainability, lower prices for those paying the energy prices has been mentioned and expanded upon. Additionally, not relying on manual heating settings may also increase general comfort for those who vacate buildings or spend time in them. By detecting what are the ideal heating settings under certain conditions, the smart heating system can predict what temperatures will be ideal for those in them, while also always having the option for the users to manually set the heat themselves.

**Reflection**

In my own role as an engineer and as an individual, it’s very obvious to me how heating may work in countries that are equipped to it versus countries that aren’t. I come from Portugal, where it never truly gets cold enough for heat to be a necessity as much as if we compare it to a country like Sweden. Despite that, I’ve noticed that I feel far colder at home in Portugal than I do here in Sweden, despite having similar heating systems. To me, it has greatly highlighted the exact difference that having a well insulated building that is made for the cold (such as my apartment in Sweden) is from a building that was not built with trapping heat in mind (such as my apartment in Portugal). Other than personal discomforts, this dichotomy makes it immediately obvious to me how much less heat I’m wasting in Sweden, and it also gets reflected on my electricity bill. While a smart sensor would not have fixed this problem for me in a direct sense, it could have given me a good, objective, understanding of how much heat my house truly wastes in Portugal, as had I not come to live here I could have never otherwise truly “felt” the difference.

I also believe it is my duty to, given that my apartment’s heating system is manual, ensure that I am only using heaters when necessary. This report has opened my eyes on just how many carbon emissions heating actually puts out to the environment, which is something I was largely oblivious about beforehand. My heating system is something I never have given much thought to, and this report gave me a foundation for starting to think of it in a more objective and matter-of-factly way.

**References**

“Affordable and Clean Energy.” Swedish Energy Agency, 13 Jan. 2015, https://www.energimyndigheten.se/en/.

Asim, Nilofar, et al. “Sustainability of Heating, Ventilation and Air-Conditioning (HVAC) Systems in Buildings-an Overview.” International Journal of Environmental Research and Public Health, U.S. National Library of Medicine, 17 Jan. 2022, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8776175/.

Chiew, Yoon Lin, and Birgit Brunklaus. “Life Cycle Assessment of Internet of Things.” RISE, 2021, https://www.ri.se/sites/default/files/2021-10/S\_IoT\_LCA%20report%2020211005\_final\_0.pdf.

“The Global Goals and the 2030 Agenda for Sustainable Development.” Regeringskansliet, https://www.government.se/government-policy/the-global-goals-and-the-2030-Agenda-for-sustainable-development/.

Goodson, Timothy, et al. “Heating – Analysis.” IEA, Sept. 2022, https://www.iea.org/reports/heating.

Levy, Markus. “Understanding the Real Energy Consumption of Embedded Microcontrollers.” Digi, Convergence Promotions LLC, 13 June 2012, https://www.digikey.se/en/articles/understanding-the-real-energy-consumption-of-embedded-microcontrollers.

Rogalsky, Derek K, et al. “Estimating the Number of Low-Income Americans Exposed to Household Air ...” US Department of Energy Environmental Health Perspectives, 1 Aug. 2014, https://ehp.niehs.nih.gov/doi/10.1289/ehp.1306709.

Sahni, Aditi, et al. “International Comparisons of Heating, Cooling and Heat Decarbonisation Policies.” GOV.UK, GOV.UK, Nov. 2017, https://www.gov.uk/government/publications/international-comparisons-of-heating-cooling-and-heat-decarbonisation-policies.

Shandilya, Apeksha, et al. “Optimization of Thermal Behavior and Energy Efficiency of a Residential ...” ResearchGate, June 2020, https://www.researchgate.net/publication/342551422\_Optimization\_of\_Thermal\_Behavior\_and\_Energy\_Efficiency\_of\_a\_Residential\_House\_Using\_Energy\_Retrofitting\_in\_Different\_Climates