Bachelor's thesis

NTNU
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Harnessing Bitcoin ASICs for Home Heating

Turning Household Heating into Income in Trøndelag

Bachelor's thesis in Economics
Supervisor: Sepehr Cyrusian
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Abstract

The purpose of this research is to examine how the electricity bill for households in Trøndelag can be affected by heating using Bitcoin ASICs. The data set contains weekly observations of ASICs earnings, electricity prices, and energy consumption from January 2018 to December 2021. The results show that current households use most of their electricity consumption for space heating. By replacing resistive heating, which is common in panel heaters and underfloor heating, with ASICs, households may end up with a negative electricity bill, i.e. having an income associated with heating their homes.

Sammendrag

Hensikten med studien er å se på hvordan strømregningen til husstanden i Trøndelag kan påvirkes av oppvarming ved bruk av Bitcoin ASICer. Datasettet inneholder ukentlige observasjoner av ASICers inntjening, strømpriser og energiforbruk fra januar 2018 til desember 2021. Resultatene viser at dagens husholdninger bruker mesteparten av sitt strømforbruk på oppvarming av rom. Ved å erstatte motstandsoppvarmingen, som er vanlig i blant annet panelovner og varmekabler, med ASICer, kan husholdningene ende opp med å få en negativ strømregning, altså få betalt for å varme opp husene sine.

List of Abbreviations and Terms

To better understand the concepts and ideas presented in this thesis, it is essential to be familiar with the terminology used in the field of Bitcoin mining. This section provides a list of key terms and abbreviations related to Bitcoin mining, and some other important explanations that will be frequently used throughout this thesis.

Hash	In Bitcoin mining, a hash is the output of a cryptographic function used to secure and validate transactions on the blockchain. ASICs compete to find a hash that meets a certain requirement to create the next block on the Bitcoin blockchain.
ASIC	ASIC, also known as a bitcoin mining machine is an abbreviation for 'Application-Specific Integrated Circuit', a type of specialized hardware designed to rapidly generate hashes. ASICs are much more efficient at mining Bitcoin than general purpose CPUs or GPUs.
Hash rate	Hash rate refers to the computational power used by miners to validate transactions on the Bitcoin blockchain. Hash rate is measured in hashes per second (H/s) and determines a miner's likelihood of successfully creating a block on the blockchain. In Bitcoin mining, a commonly used metric to operate with is terahashes per second (TH/s). This measure is an important metric in assessing the efficiency and profitability of mining operations.
Hash price	Hash price refers to the daily revenue an ASIC earns per unit of computational power, when operating uninterrupted. It represents the amount of NOK earned by the ASIC for each TH/s of computing power it contributes to the network on a daily basis. The hash price is an important metric for miners because it directly affects their profitability. The higher hash price, the higher revenue a miner gets for each unit of computing power contributed to the network.
NOK	Norwegian Krones, currency
SSB	Statistical research at Statistics Norway (Statistisk sentralbyrå) is the national statistics institute of Norway. It conducts research and analysis to produce statistical data and reports on various topics, including the economy, population, and social trends.
NVE	The Norwegian Water Resources and Energy Directorate (Norges vassdrags- og energidirektorat) is a government agency responsible for managing Norway's water resources and energy supply. It oversees the regulation of electricity production, transmission, and distribution, including the licensing and supervision of power plants and grid operators.

Mining difficulty	Mining difficulty is a measure of how hard it is to mine a new block on the Bitcoin blockchain, based on the specific requirements for a valid hash. Roughly in each 10 minutes, a new block is added to the blockchain. As more computing power is added to the Bitcoin network, the harder the competition becomes to unlock the next block. Harder competition increases the likelihood for a new block to be unlocked, and at the same time, the likelihood for one single ASIC to unlock a new block decreases. To ensure a constant rate of block creation, every 10 minutes, the difficulty is each 2016 block automatically adjusted.
Block reward	Block reward refers to the amount of Bitcoin that miners receive as a reward for successfully creating a new block on the Bitcoin blockchain. This reward serves as an incentive for miners to continue contributing their computing power to the network and is also the way in which new Bitcoins are introduced into circulation. Initially, the block reward was 50 bitcoin per block, but it is halved approximately every four years. Current block reward is 6.25 bitcoin per block. To emphasize the extent of the mining process, the miner was paid 6,405 BTC equivalent to 1.92 million NOK in the latest block mined at the time of writing (block number 786357). This amount consists of 6.25 BTC which is the current block reward + 0.155 BTC which were transaction fees from the transactions included in that block.
Bitcoin	Bitcoin with upper case first letter refers to the Bitcoin network, while bitcoin with lower case first letter refers to the coins existing on the blockchain.
Mining pool	A mining pool is a group of miners who combine their computing power to increase their chances of earning rewards. By working together, they can unlock blocks more quickly and share the rewards among themselves based on the amount of work contributed by each miner.
Trøndelag	Trøndelag is a region in the middle of Norway. When writing Trøndelag, I am referring to the electricity region NO3 Midt-Norge. This is appropriate because the electricity prices are equal in the entire region.
Hashrate index	Bitcoin mining analysis company. I got access to their API and could download hash price data.
kWh	A measure of power consumption. 1000 watts for one hour.
BTC	bitcoin, currency.
Bitcoin cycle	Bitcoin cycles refer to the recurring patterns of booms and busts in the price of Bitcoin. The cycles are driven by a combination of factors, including block reward halving, investor sentiment, market speculation, media coverage, and technological advancements.
CAPEX	Capital expenditure, investment cost, acquisition cost.

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1 Introduction

Bitcoin mining machines, also known as ASICs, are designed to rapidly generate hashes to unlock the next block on the Bitcoin blockchain. These machines are dedicated solely to this task and consume a significant amount of energy, causing them to generate a lot of heat. An interesting idea that has been proposed is to repurpose Bitcoin ASICs as direct-acting heaters to heat Norwegian homes. Given that resistive heating and hash boards in Bitcoin ASICs both operate with a 1:1 energy-to-heat generation ratio, they could theoretically be used to replace existing electric appliances and potentially reduce the heating bill for Norwegian households. This study aims to investigate the potential economic impact of replacing the current heating system in an average household in Trøndelag, Norway, with Bitcoin ASICs. Figure 1 and Figure 2 illustrate a high-level overview of how the systems operate.

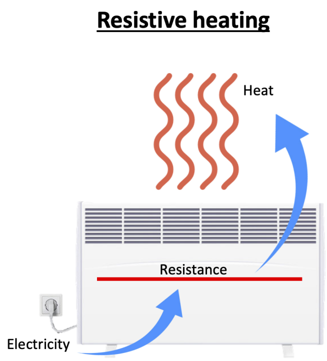

Figure 1: Illustration of resistive heating.

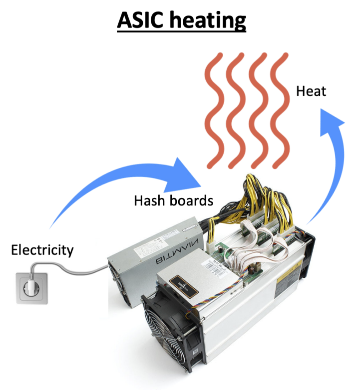

Figure 2: Illustration of ASIC heating.

The study is based on weekly observations of ASICs earnings, electricity prices, and energy consumption from January 2018 to December 2021. This specific period is chosen because it defines what is called a Bitcoin cycle. Every four years, the reward miners receive for contributing computing power to the network is halved, and the value of Bitcoin has historically fluctuated in line with these halving events. By studying a four-year period, we will therefore capture both the highs and lows in the price of bitcoin and the profitability of mining machines, making it a representative sample and allowing us to draw the most realistic conclusion possible.

As Bitcoin is still in its early stages, research and theses on the topic are limited. It is important to understand the phenomenon of Bitcoin to facilitate informed discussions on different future scenarios. Thus, this study aims to contribute to the field by examining the research question, "Can Bitcoin ASICs impact households' heating bills in Trøndelag".

To address this question, this thesis will be divided into the following sections: Section 2 will provide a review of existing literature and theory on Bitcoin and Bitcoin mining, providing a solid foundation for the study. Section 3 will describe the data collection process and methodology used in this study, ensuring the research is conducted with rigor and accuracy. Section 4 will present the findings of the study and any additional insights gained. This section will use statistical analyses and visualizations to support the findings. Section 5 contains a discussion on the implications of the study's results, highlighting the significance of the findings and their potential impact on the field of home heating. Lastly, the references used in this thesis are provided, ensuring the study's sources are transparent and easily accessible.

2 Literature review

2.1 Theoretical background

2.1.1 Bitcoin

The Bitcoin network was invented by the pseudonym Satoshi Nakamoto in 2008. In the wake of the great financial crisis, containing the bailout of banks, Satoshi wanted to create a digital peer-to-peer system that was fully decentralized and could not be controlled by any authority. A system that was not credit based and could not be manipulated at the expense of the people.

When a private person, or a group wants to invent a new money, it will have no value in the beginning. If the distribution of the new money is unfair, the likelihood of people adopting it will be significantly diminished. To solve this basic problem, Satoshi invented a genius idea. In order to receive some money in the digital world, you must show that you have invested resources in the real world. If you invest your time, pay the cost for mining equipment, and pay the cost of electricity consumption in order to create a new block, then you will receive money in the digital world. This concept is called proof-of-work, and it ensures that all the bitcoins in existence are 'deserved', and hence fairly distributed.

To understand how Bitcoin works, it might be helpful to think of it as an open spreadsheet. The spreadsheet keeps track of which addresses have which coins. Every time a new block is generated, a number of transactions are settled, and the spreadsheet is updated with the new balances. The Bitcoin blockchain's target is to create a new block of transactions every 10 minutes [1]. The machines used to create new blocks are called mining machines or ASICs. ASICs are computers designed to do one thing, guess the right hash. A hash is a fixed-length string of characters that is generated by a mathematical function called a hash function. The machine who finds a valid hash can include a number of transactions into a block, broadcast the new block to the blockchain, and collect its reward. There is an extremely small chance that a specific ASIC will be able to find a valid hash and get paid. This means that people form groups that mine together in something called pools. When someone in the pool finds a valid hash, they share the payout proportionally among themselves based on the share of computing power each contributes.

This is a very high-level way to explain Bitcoin. The system is incredibly complex, and it takes a long time to understand all the processes. The most important thing to know in order to understand this study is that ASICs around the world get paid in the form of bitcoin by using energy to settle transactions and secure the Bitcoin network. A typical Bitcoin ASIC looks like shown in Figure 3.

Figure 3: Antminer S9.

2.1.2 Heat management

The first law of thermodynamics states that energy cannot be created or destroyed. This means that the energy that is fed into a Bitcoin ASIC cannot disappear. Instead, the energy is converted into heat. A bitcoin ASIC therefore has what we call direct-acting electricity, meaning that it has a 1:1 ratio between power consumption and heat generation, similar to panel heaters or underfloor heating. However, there are different ways to use ASICs to heat a house depending on where and how the mining machines are placed, and whether they are cooled with air-cooling fans or water-cooling pipes.

Three ways to place ASICs:

1. One way ASICs can be placed is by placing them around the house with fans that cool the machines down and heat up the house, similar to panel heaters. Shown in Figure 4.

2. Another way is by placing the ASICs in a technical room, cooling them with fans, and transporting the heat in a ductwork system around the house. Shown in Figure 5.

3. A third way ASICs can be placed is by using water cooling. Water flows in pipes through the machine, gets heated up, and is then sent through a piping system around the house's floors. Shown in Figure 6.

Figure 4: ASIC in livingroom.

Figure 5: ASIC in technical room with heat transportation through ductwork.

Figure 6: ASIC in technical room with waterborne heat transportation.

Different ASIC heating solutions have their advantages and disadvantages. Placing air-cooled ASICs in the living room will convert all the energy into heat in the living room, but noise levels may be a significant issue. If the household places their ASICs in a technical room, on the other hand, the house will be silent. However, the second law of thermodynamics states that heat always spontaneously transfers from a place of higher temperature to a place of lower temperature, which means that heating and heat transportation in pipes, such as air or water, can result in heat transfer to undesired locations, and thus to heat loss.

This study will focus on households' earnings by replacing resistive heating with ASIC heating, which means that heat loss due to heat transportation, smart placement of ASICs, advantages and disadvantages of different systems will not be included in any calculations. However, some practical advantages and disadvantages are discovered in the discussion section.

3 Methodology

The methodology section of this study provides an overview of the research design, data collection process, and data analysis technique employed to investigate how the heating bills for households in Trøndelag can be affected by ASIC heating.

3.1 Research design

By adopting a quantitative research design and utilizing time series analysis techniques, this study aims to gain a comprehensive understanding of the relationship between heating methods and heating bills. By analyzing a comprehensive data set comprising weekly observations of ASICs earnings, electricity prices, and energy consumption spanning from January 2018 to December 2021, this approach enables the examination of patterns and trends within the different heating systems over time. The findings will contribute to a better understanding of the potential impact of ASIC heating on households' heating bills, providing valuable insights for households considering the adoption of this heating method.

3.2 Data Selection

Researching online, reading relevant articles, and utilizing data gathered from individuals in the Bitcoin mining industry are all important elements of the attempt to obtain a solid foundation to address the research question. To obtain ASIC statistics, it has been necessary to receive knowledge transfer and reports from individuals who engage in mining and ASIC heating on a daily basis. Other data, such as market prices, electricity consumption, and electricity prices, are important to study carefully to obtain the most realistic result possible. The references used in this section are listed in the Bibliography section and referred to with square brackets.

This study is based on two categories of data, electricity, and bitcoin mining. The electricity data contains a calculation on the average Norwegian households' electricity consumption monthly from January 2018 to December 2021, and electricity prices for NO3 (Midt-Norge), the middle part of Norway, for the same period. The Bitcoin mining data contains ASICs capital expenditure, computing power, energy consumption as well as monthly revenue from January 2018 to December 2021. An overview of the data collection is presented in Table 7.

3.2.1 Data on Electricity

To examine how Bitcoin ASICs can affect households' heating bills, it is important to collect data on the households' electricity consumption, how the electricity consumption is distributed throughout the year, and what price the households are paying for the electricity.

Numbers from SSB show that the total electricity consumption in Norwegian households ranged between 38,2 and 39,8 TWh yearly from 2018 to 2021 [2]. The total number of Norwegian households ranged in the same period from 2.409.257 to 2.512.317 [3]. The average electricity consumption for a Norwegian household is hence total electricity consumption divided by total households and is represented in Table 1.

Table 1: Average Norwegian household's electricity consumption.

Year	Total electricity consumption (TWh)	Number of households	Average electricity consumption per household (kWh)
2018	38,5	2409257	15980
2019	38,3	2493242	15702
2020	38,2	2475168	15433
2021	39,8	2512317	15842

Determining the accurate distribution of electricity consumption among various household appliances throughout the year presents a considerable challenge. A report published by NVE in 2012 [4] provides insights into several studies conducted on the allocation of electricity within Norwegian and Nordic households. The report concludes that about two thirds of the total electricity consumption in the average Norwegian household are used in space heating, 12% is used for water heating, and 22% is used for electricity specific use, such as washing machines, lightning, television, and white goods. Statistics from NVE [5] released in 2019, show that 67% of a typical Norwegian household electricity consumption is used for space heating, 13% for water heating, and 20% for electricity specific use. Also heat pumps have become more common in the last decade, and a report from NVE [6] states that 27% of Norwegian households use a heat pump to heat their home. Heat pumps are more electricity efficient than direct acting heating [7], which means that the households with heat pump installed will use less electricity on space heating than homes without heat pumps will do. This research will look at how heating bills for households only using resistive heating will be affected by ASIC heating.

Based on the reports from NVE and the assumption that the average Norwegian household does not use heat pump, this study will assume that the electricity distribution in the households of Trøndelag equals the Norwegian average households distribution, and hence the share of space heating consumption to be 67%, the share of water heating consumption to be 13%, and the share of specific electricity consumption to be 20% of the total electricity consumption consumed in the average Norwegian household. The estimated average consumption of the different categories is represented in Table 2.

Table 2: Electricity distribution in the average Norwegian household.

Year	Total electricity consumption (TWh)	Number of households	Average electricity consumption per household (kWh)	Electricity used in space heating (67%)	Electricity used in water heating (13%)	Specific electricity use (20%)
2018	38,5	2409257	15980	10707	2077	3196
2019	38,3	2493242	15702	10520	2041	3140
2020	38,2	2475168	15433	10340	2006	3087
2021	39,8	2512317	15842	10614	2059	3168

After determining the annual electricity consumption for space heating in an average household, the subsequent task involves estimating the monthly consumption. Since there are significant temperature differences between summer and winter in Trøndelag, it would be impractical to distribute the electricity consumption equally over the year. Therefore, data is obtained from NVE which depicts the change in monthly electricity consumption from 2020 to 2021 in Trøndelag [8]. Data from these two years would provide us with a somehow reliable representation of the distribution of electricity consumption throughout the year. Table 3 contains two parts, divided by a thicker vertical line. The left part shows the proportion distribution of the yearly electricity consumption for households in Trøndelag, based on statistics from 2020 and 2021. Each month's consumption share is calculated by averaging the corresponding month's share in the years 2020 and 2021. For January, $5.06/52.65 = 0.096106$, which means 9.6106% of the yearly consumption is estimated to be used in January. The right hand side of the table multiplies the yearly consumption stated in Table 2 by the monthly proportion in the given month, and shows an estimate of the household's electricity consumption every month from 2018 to 2021.

Table 3: Distribution of annual electricity consumption and household's monthly consumption.

Yearly electricity consumption distribution in households in Trøndelag (TWh)					Monthly electricity consumption Trøndelag (kWh)			
Month	2020	2021	2020+2021	Proportion distribution of yearly consumption	2018	2019	2020	2021
January	2,48	2,58	5,06	0,096106	1536	1509	1483	1523
February	2,38	2,38	4,76	0,090408	1445	1420	1395	1432
March	2,46	2,5	4,96	0,094207	1505	1479	1454	1492
April	2,19	2,25	4,44	0,084330	1348	1324	1301	1336
May	2,08	2,11	4,19	0,079582	1272	1250	1228	1261
June	1,79	1,88	3,67	0,069706	1114	1094	1076	1104
July	1,78	1,89	3,67	0,069706	1114	1094	1076	1104
August	1,76	1,94	3,70	0,070275	1123	1103	1085	1113
September	1,91	2	3,91	0,074264	1187	1166	1146	1176
October	2,19	2,25	4,44	0,084330	1348	1324	1301	1336
November	2,33	2,39	4,72	0,089649	1433	1408	1384	1420
December	2,55	2,58	5,13	0,097436	1557	1530	1504	1544
Total	25,9	26,75	52,65	1,00	15980	15702	15433	15842

After estimating the monthly electricity consumption for the household in Trøndelag, the subsequent procedure for estimating monthly heating consumption entails multiplying the electricity consumption by 0.67, as previously determined to represent the proportion of electricity allocated to space heating within the household. Given the reasonable assumption that electricity consumption for hot water and various electrical appliances, including TV, lighting, and refrigerator, remains somehow constant throughout the year, it can be deduced that such consumption is evenly distributed over the course of the year. By subtracting the electricity consumption for hot water and electrical appliances from the household's monthly electricity consumption, we are left with a suitable estimate on how much electricity the average household in Trøndelag uses for space heating each month.

Table 4 is based on the right hand part of Table 3, and shows the estimated electricity consumption distribution in the household each month from 2018 to 2021. The estimated consumption for space heating is marked with boldface. The bottom row in Table 3 and Table 4 represent the total sum of the consumption estimates, and equals the data presented in Table 2.

Concerned that this might be confusing, I will use January 2018 as an example. Data shows that the average electricity consumption per Norwegian household in 2018 was 15,980 kWh. Of this, 13% (2,077 kWh) went to water heating, while 20% (3,196 kWh) was used in specific electrical appliances. Knowing that households of Trøndelag in January used 9.61% of the annual electricity consumption, it means that households in January 2018 used 15,980 kWh * 0.0961 = 1,536 kWh. Of this consumption, 173 kWh was for water heating(2,077 kWh divided by 12 months), and 266 kWh was for specific electrical use (3,196 kWh divided by 12 months). We are then left with 1,536 kWh - 173 kWh - 266 kWh = 1,096 kWh, which is the estimate for the average household's electricity consumption for heating in January 2018.

Table 4: Estimated electricity consumption distribution in the household each month. Based on estimates from Table 3.

	2018			2019			2020			2021		
Month	Water heating	Specific el. use	Space heating	Water heating	Specific el. use	Space heating	Water heating	Specific el. use	Space heating	Water heating	Specific el. use	Space heating
January	173	266	**1096**	170	262	**1077**	167	257	**1059**	172	264	**1087**
February	173	266	**1005**	170	262	**988**	167	257	**971**	172	264	**997**
March	173	266	**1066**	170	262	**1047**	167	257	**1030**	172	264	**1057**
April	173	266	**908**	170	262	**892**	167	257	**877**	172	264	**900**
May	173	266	**832**	170	262	**818**	167	257	**804**	172	264	**825**
June	173	266	**674**	170	262	**663**	167	257	**651**	172	264	**669**
July	173	266	**674**	170	262	**663**	167	257	**651**	172	264	**669**
August	173	266	**684**	170	262	**672**	167	257	**660**	172	264	**678**
September	173	266	**747**	170	262	**734**	167	257	**722**	172	264	**741**
October	173	266	**908**	170	262	**892**	167	257	**877**	172	264	**900**
November	173	266	**993**	170	262	**976**	167	257	**959**	172	264	**985**
December	173	266	**1118**	170	262	**1098**	167	257	**1079**	172	264	**1108**
Total	2077	3196	10707	2041	3140	10520	2006	3087	10340	2059	3168	10614

With an estimate of the monthly heating consumption from 2018 to 2021 for the average household in Trøndelag, we can find the price households have paid for their space heating during the same period. These prices are downloaded from the website of the Norwegian electricity company Elkompis [9]. By multiplying the monthly heating consumption by the monthly electricity price, we can estimate the monthly heating bill for the average household in Trøndelag. The results are presented in the "Heating bill with current resistive system (NOK)" in Table 8.

3.2.2 Data on Bitcoin Mining

In order to determine the impact of ASICs on households' heating bills, it is crucial to calculate the revenue generated by these devices. As there are many types of ASIC machines with varying profitability and power consumption, it is useful to obtain data on how much income each type generates per kWh consumed.

'Hashrate index' provides data on ASIC earnings, which they refer to as 'hash price'. Hash price measures how much a mining machine earns per day for every unit of TH/s capacity it has. For example, if we consider an ASIC with a 13.5 TH/s capacity and a hash price of 2 NOK, the earnings for this ASIC would be 13.5 * 2 = 27 NOK for that day. The observations of the hash price were made every Monday from January 1st, 2018, to December 27th, 2021. The average hash price each month over these four years is calculated by including the observation in the corresponding month. That is, the observation made on Monday, April 30th, 2018, is included in the average for April 2018, even though the last six days of that week took place in May. The hash price data from Hashrate Index's API [10] is provided in USD. The numbers are converted to NOK using a historical currency converter [11].

All Bitcoin mining machines that contribute to the Bitcoin network by creating new blocks and securing the network, will receive payment in the form of bitcoin. When this study measures earnings in NOK, it is assumed that the conversion from bitcoin to NOK occurs smoothly and without any fees. Such a conversion would always entail a small cost, varying in size depending on where and when one chooses to convert, but for simplicity in this study, we assume that the conversion takes place instantaneously and without any cost. Possible impacts of that assumption is discussed in Section 5. The average monthly hash price can be found in Table 5, together with the average exchange rate, and the corresponding NOK value.

Table 5: Monthly average hash price.

	Hash price (USD)	Avg. Ex.rate per month	Hash price (NOK)
January 2018	1,8019	7,9239	14,2779
February 2018	0,8625	7,8286	6,7520
March 2018	0,6568	7,7698	5,1030
April 2018	0,5587	7,8401	4,3800
May 2018	0,4976	8,0921	4,0267
June 2018	0,3458	8,1202	2,8082
July 2018	0,3364	8,1308	2,7351
August 2018	0,2621	8,3358	2,1850
September 2018	0,2373	8,2650	1,9610
October 2018	0,2231	8,2504	1,8409
November 2018	0,1911	8,4702	1,6190
December 2018	0,1718	8,6341	1,4837
January 2019	0,1582	8,5578	1,3534
February 2019	0,1568	8,5803	1,3450
March 2019	0,1634	8,6025	1,4053
April 2019	0,2141	8,5669	1,8341
May 2019	0,3056	8,7339	2,6694
June 2019	0,3356	8,6335	2,8972
July 2019	0,3167	8,6059	2,7252
August 2019	0,2657	8,9571	2,3801
September 2019	0,1991	9,0160	1,7955
October 2019	0,1639	9,1439	1,4983
November 2019	0,1623	9,1440	1,4842
December 2019	0,1413	9,0298	1,2758
January 2020	0,1495	8,9283	1,3346
February 2020	0,1583	9,2821	1,4698
March 2020	0,1142	10,2407	1,1700
April 2020	0,1254	10,4248	1,3073
May 2020	0,1045	10,1069	1,0561

June 2020	0,0829	9,5446	0,7909
July 2020	0,0805	9,3175	0,7503
August 2020	0,0947	8,9615	0,8487
September 2020	0,0784	9,1326	0,7156
October 2020	0,0889	9,2870	0,8254
November 2020	0,1356	9,1023	1,2342
December 2020	0,1729	8,7092	1,5062
January 2021	0,2429	8,5186	2,0692
February 2021	0,3129	8,5074	2,6620
March 2021	0,3514	8,5278	2,9967
April 2021	0,3631	8,4036	3,0511
May 2021	0,2722	8,3058	2,2613
June 2021	0,2388	8,4237	2,0112
July 2021	0,3164	8,7633	2,7731
August 2021	0,3720	8,8562	3,2945
September 2021	0,3126	8,6616	2,7079
October 2021	0,3763	8,4735	3,1884
November 2021	0,3433	8,7426	3,0010
December 2021	0,2595	8,9780	2,3298

This study will examine two different ASICs and assess how they would affect the households' heating bills during the period from January 2018 to December 2021 compared to the current existing resistive heating system. The assessment will consider the machines' investment cost, power consumption, and revenue. The machines examined are in this thesis called Antminer S9 max capacity and Antminer S9 reduced capacity. The observant one would have noticed that this is the same machine. That's correct, but since this machine has a high noise level when running at max capacity, this research includes how the same machine would perform if it were run at a slightly lower intensity. The machine would then consume less electricity, perform fewer calculations (lower TH/s), and thus have slightly lower daily revenue. However, it will have a significantly reduced noise level. Although this study will not assess the noise level of these machines, it could be of great help for future studies if it calculates power consumption and revenue for the Antminer S9 at a reduced level as well. Crypto Cloaks measured the noise level of a standard S9 on max capacity to be 83 db [12]. In comparison the S9 run on reduced capacity had a noise level of 60 db. However, if the machine fans were replaced by more silent fans, the noise level could be reduced to 51 db. In the rest of this thesis, the names of the ASIC systems are abbreviated for simplicity. The Antminer S9 operating at max capacity will be referred to as "S9 max", while the Antminer S9 operating at reduced capacity will be referred to as "S9 reduced".

To obtain statistics from various ASICs, I got in touch with Crypto Cloaks. They conduct research on ASICs for heating and have conducted several studies on the Antminer S9 max and S9 reduced. Their results indicate that an Antminer S9 max pulls 1300W and has a hash rate of 13.68 TH/s [12]. In comparison, an Antminer S9 reduced pulls 600W and has a hash rate of 7.634 TH/s. It's worth mentioning that such machines can vary in power consumption and hash rate, so nothing is entirely constant.

The Antminer S9 is a unit that was introduced to the market in 2016. The pricing of such ASICs is often tied to the profitability of operating them, hence the price varies greatly from month to month. As it may take some time to transport and set up such an ASIC heating system, the market price in November 2017 is considered for the machines. By buying the machines on November 5th, 2017, the user would get them delivered in the producers "December batch", and be ready to operate from January 1st, 2018. To find that price, the producer Bitmain's home pages from November 5th, 2017 were browsed, using 'wayback machine', a website allowing users to go back in time, and see how different websites looked in the past [13]. The price of an S9 was $1415 in November 2017. In order to use these machines as silent as possible, it is necessary to replace their original fans [14]. The price of the needed fans in November 2017 (549 NOK) [15] [16] is added to the capital expenditure of the S9 reduced (not needed for S9 max, while they are considered in a technical room where noise is not an issue). The capex for the different machines are converted to NOK by using an online historical currency converter [11].

It may be worth mentioning that this task refers to the Antminer S9 in two different ways: S9-machine and S9-system. The S9-machine, which is the Antminer S9 ASIC running at max or reduced capacity, is a single unit. When referring to the S9-system (either S9 max-system or S9 reduced-system), it pertains to the total acquisition cost and operational outcome for the whole system, which is the number of S9-machines required to generate a sufficient amount of heat for the household. This study relies on the ASIC values presented in Table 6.

Table 6: ASIC values considered in this study.

	Antminer S9-machine (max capacity)	Antminer S9-machine (reduced capacity)
Capital Expenditure (NOK)	11572	12101
Watts	1300	600
TH/s	13.68	7.634
Decibel	83	51

Table 7: Data collection overview.

Data	Category	Description	Reference
Electricity consumption	Electricity	Total el. consumption Norwegian households	[2]
Number of Households	Electricity	Total households Norway	[3]
Households' consumption breakdown	Electricity	Breakdown of household electricity consumption into three categories: water, specific use, and heating	[4] ,[5]
Consumption distribution	Electricity	Distribution of household electricity consumption over the year	[6],[8]
Electricity price	Electricity	Historical electricity for the NO3-region (Midt-Norge)	[9]
Hash price	Mining	Miners revenue	[10]
Concurrency converter	Mining	Historical currency converter	[11]
ASIC stats	Mining	Statistics on ASICs, CAPEX, Watt and TH/s	[12],[13],[15],[16], [17]

4 Results

After estimating the average electricity consumption and electricity bill for households in Trøndelag, as well as finding and converting data on ASICs' income and consumption, this information can now be combined.

This section will first carefully review the comprehensive table composed of all the key data described in Section 3. Then, it will delve into the specifics and examine the key results, before presenting the profitability of the three different heating systems on a monthly basis. Finally an analysis of the systems' acquisition costs in relation to their earnings will be presented, in order to determine when the different projects would break even.

4.1 Result Overview

Table 8: Final table summarizing results part 1.

	Month	Monthly days	Hash price, daily revenue per 1 TH/s (NOK)	Avg. household heating consumption (kWh)	Avg.Electricity price in NO3 per KWh (NOK)	Heating bill with current resistive system (NOK)
2018	January 2018	31	14,278	1096	0,3897	427
	February 2018	28	6,752	1005	0,4754	478
	March 2018	31	5,103	1066	0,538	573
	April 2018	30	4,380	908	0,4712	428
	May 2018	31	4,027	832	0,4065	338
	June 2018	30	2,808	674	0,5357	361
	July 2018	31	2,735	674	0,6202	418
	August 2018	31	2,185	684	0,618	422
	Septembe 2018	30	1,961	747	0,5877	439
	October 2018	31	1,841	908	0,5088	462
	November 2018	30	1,619	993	0,5697	566
	December 2018	31	1,484	1118	0,627	701
2019	January 2019	31	1,353	1077	0,6412	691
	February 2019	28	1,345	988	0,5517	545
	March 2019	31	1,405	1047	0,4997	523
	April 2019	30	1,834	892	0,497	443
	May 2019	31	2,669	818	0,4726	386
	June 2019	30	2,897	663	0,3166	210
	July 2019	31	2,725	663	0,4157	275
	August 2019	31	2,380	672	0,4562	306
	September 2019	30	1,795	734	0,4138	304
	October 2019	31	1,498	892	0,4625	413
	November 2019	30	1,484	976	0,5222	510
	December 2019	31	1,276	1098	0,4469	491
2020	January 2020	31	1,335	1059	0,2912	308
	February 2020	29	1,470	971	0,1743	169
	March 2020	31	1,170	1030	0,1253	129
	April 2020	30	1,307	877	0,066	58
	May 2020	31	1,056	804	0,12	96
	June 2020	30	0,791	651	0,0422	27
	July 2020	31	0,750	651	0,034	22
	August 2020	31	0,849	660	0,0849	56
	September 2020	30	0,716	722	0,1338	97
	October 2020	31	0,825	877	0,1636	143
	November 2020	30	1,234	959	0,0624	60
	December 2020	31	1,506	1079	0,1888	204
2021	January 2021	31	2,069	1087	0,5686	618
	February 2021	28	2,662	997	0,551	549
	March 2021	31	2,997	1057	0,3175	336
	April 2021	30	3,051	900	0,347	312
	May 2021	31	2,261	825	0,461	380
	June 2021	30	2,011	669	0,446	298
	July 2021	31	2,773	669	0,5926	396
	August 2021	31	3,294	678	0,7447	505
	September 2021	30	2,708	741	0,6739	499
	October 2021	31	3,188	900	0,3123	281
	November 2021	30	3,001	985	0,5215	513
	December 2021	31	2,330	1108	0,7596	842

Table 9: Final table summarizing results part 2.

ASIC type	Antminer S9 - max capacity					Antminer S9 - reduced capacity				
Capital Expenditure (NOK)	11572					12101				
Effect (W)	1300					600				
TH/s	13,68					7,634				
Noise (db)	83					51				
kWh/day	31,2					14,4				
	ASIC stats			Electricity bill reduction		ASIC stats			Electricity bill reduction	
Month	Revenue per kWh consumed (NOK)	kWh consumed (100% runtime)	Number of ASICs needed for given consumption	Revenue from ASICs (NOK)	Heating bill with ASIC heating (NOK)	Revenue per kWh consumed (NOK)	kWh consumed (100% runtime)	Number of ASICs needed for given consumption	Revenue from ASICs (NOK)	Heating bill with ASIC heating (NOK)
January 2018	6,260	967	1,1	6863	-6436	7,569	446	2,5	8298	-7871
February 2018	2,960	874	1,2	2976	-2498	3,579	403	2,5	3598	-3120
March 2018	2,237	967	1,1	2385	-1812	2,705	446	2,4	2884	-2310
April 2018	1,920	936	1,0	1744	-1316	2,322	432	2,1	2109	-1681
May 2018	1,766	967	0,9	1469	-1131	2,135	446	1,9	1777	-1438
June 2018	1,231	936	0,7	830	-469	1,489	432	1,6	1004	-643
July 2018	1,199	967	0,7	809	-391	1,450	446	1,5	978	-560
August 2018	0,958	967	0,7	655	-232	1,158	446	1,5	792	-369
Septembe 2018	0,860	936	0,8	643	-203	1,040	432	1,7	777	-338
October 2018	0,807	967	0,9	733	-271	0,976	446	2,0	886	-424
November 2018	0,710	936	1,1	705	-139	0,858	432	2,3	852	-287
December 2018	0,651	967	1,2	727	-26	0,787	446	2,5	879	-178
January 2019	0,593	967	1,1	639	51	0,718	446	2,4	773	-82
February 2019	0,590	874	1,1	583	-38	0,713	403	2,4	704	-159
March 2019	0,616	967	1,1	645	-122	0,745	446	2,3	780	-257
April 2019	0,804	936	1,0	718	-274	0,972	432	2,1	868	-424
May 2019	1,170	967	0,8	957	-571	1,415	446	1,8	1157	-771
June 2019	1,270	936	0,7	842	-632	1,536	432	1,5	1018	-808
July 2019	1,195	967	0,7	792	-516	1,445	446	1,5	957	-682
August 2019	1,044	967	0,7	701	-395	1,262	446	1,5	847	-541
September 2019	0,787	936	0,8	578	-274	0,952	432	1,7	699	-395
November 2019	0,651	936	1,0	635	-125	0,787	432	2,3	768	-258
December 2019	0,559	967	1,1	614	-124	0,676	446	2,5	743	-252
January 2020	0,585	967	1,1	620	-311	0,708	446	2,4	749	-441
February 2020	0,644	905	1,1	626	-456	0,779	418	2,3	757	-587
March 2020	0,513	967	1,1	528	-399	0,620	446	2,3	639	-510
April 2020	0,573	936	0,9	503	-445	0,693	432	2,0	608	-550
May 2020	0,463	967	0,8	372	-276	0,560	446	1,8	450	-354
June 2020	0,347	936	0,7	226	-198	0,419	432	1,5	273	-246
July 2020	0,329	967	0,7	214	-192	0,398	446	1,5	259	-237
August 2020	0,372	967	0,7	246	-190	0,450	446	1,5	297	-241
September 2020	0,314	936	0,8	226	-130	0,379	432	1,7	274	-177
October 2020	0,362	967	0,9	317	-174	0,438	446	2,0	384	-240
November 2020	0,541	936	1,0	519	-459	0,654	432	2,2	628	-568
December 2020	0,660	967	1,1	713	-509	0,798	446	2,4	862	-658
January 2021	0,907	967	1,1	986	-368	1,097	446	2,4	1192	-574
February 2021	1,167	874	1,1	1163	-614	1,411	403	2,5	1406	-857
March 2021	1,314	967	1,1	1389	-1053	1,589	446	2,4	1679	-1343
April 2021	1,338	936	1,0	1204	-892	1,617	432	2,1	1456	-1144
May 2021	0,991	967	0,9	818	-438	1,199	446	1,8	989	-609
June 2021	0,882	936	0,7	590	-291	1,066	432	1,5	713	-415
July 2021	1,216	967	0,7	813	-417	1,470	446	1,5	983	-587
August 2021	1,444	967	0,7	979	-474	1,747	446	1,5	1184	-679
September 2021	1,187	936	0,8	880	-380	1,436	432	1,7	1064	-564
October 2021	1,398	967	0,9	1259	-977	1,690	446	2,0	1522	-1241
November 2021	1,316	936	1,1	1296	-782	1,591	432	2,3	1566	-1053
December 2021	1,022	967	1,1	1132	-290	1,235	446	2,5	1368	-527

The final table summarizing the results of the three different heating systems is divided into two parts for ease of presentation and understanding. The first part (Table 8) contains data related to resistive heating. The second part (Table 9) contains data related to heating using the S9 max- and S9 reduced-systems.

Roughly speaking, it can be said that the two tables contain the average household's electricity consumption related to heating, their electricity bill associated with the heating, and how the heating bill would look like by replacing the current heating system with two different ASIC systems. The results show that households would generally end up with a negative electricity bill, e.g. in most months from 2018 to 2021, households would generate income by heating their homes with S9s. To clarify the electricity costs, the columns in Table 8 and Table 9 that describe the heating bill in the three different heating systems are formatted to be red if the electricity bill is positive (deficit), and green if the electricity bill is negative (profit). A quick glance at the tables shows that the current resistive heating system gives red fields, i.e. a cost associated with heating, every month. The S9 max-system would, except for one month, have given a negative electricity bill, while the S9 reduced-system would continuously generate income for the household. The following paragraphs will go through the tables column by column, from left to right, and explain the different numbers and relationships.

The tables are divided into various sections. On the left-hand side of the tables, the 48 months from January 2018 to December 2021 is listed, along with the number of days in each month. All other numbers in the table are observations and calculations for each of the respective months.

In Table 8, the four rightmost columns contain data from the data collection, as well as one calculation:

1. The first column,"Hash price, daily revenue per 1 TH/s (NOK)", represents the income generated by ASICs daily per TH/s computing power in the given month. This data was described in Section 3 in Table 5 and will henceforth be referred to as hash price.
2. The next column, "Avg. household heating consumption (kWh)", describes the estimate of electricity usage for households' of Trøndelag's space heating during the given month.
3. Column three, "Avg. Electricity price in NO3 per kWh (NOK)", represents the electricity price for the given period in Trøndelag.
4. Finally, the column "Heating bill with current resistive heating system (NOK)", represents the calculation of the electricity cost for the average household associated with space heating. For January 2018, the estimated electricity consumption for heating was 1096 kWh, the electricity price was 0.3897 NOK, resulting in an electricity cost of 1096 * 0.3897 = 427 NOK.

Table 9 contains sections on the two different ASIC systems considered in this study. The systems are colored pink and yellow to make it easier to distinguish between them. At the top of each section, we find the capital expenditure associated with the purchase of one ASIC, how many watts it pulls, its computing power, noise level, and an estimate of how many kWh it consumes everyday if it is left running uninterrupted. An ASIC with a power consumption of 1300W will consume 1.3 kWh in one hour, and multiplied by 24 hours, the machine will consume 31.2 kWh per day. The two sections with different ASIC systems are divided into five columns:

1. The first column, "Revenue per kWh consumed (NOK)", defines how much the given ASIC will generate in revenue for each 1 kWh of electricity consumed. It is given

by the hash price multiplied by the machine's computing power (TH/s) and divided by the number of kWh the machine consumes per day. In January 2018, the hash price was 14,278 NOK. An ASIC with a computing power of 13.68 THs and 1300W effect, would generate an average revenue of 14,278 * 13,68 / 31,2 = 6.26 NOK for each kWh consumed in January 2018.

2. The column "kWh consumed (100% runtime)" tells us how many kWh the ASIC will consume in the current month if it operates continuously. This figure is the daily consumption multiplied by the number of days in the given month.

3. "Number of ASICs needed for given consumption" refers to how many ASICs of the given type that are needed to meet the monthly heating needs. In January 2018, households' heating needs were 1096 kWh. Since an ASIC with a power consumption of 1300W can only consume 967 kWh in the same month, the household would need 1.1 machines, which means they would need two.

4. "Revenue from ASICs (NOK)" refers to the given ASICs' earnings by consuming the household's monthly heating needs. In January 2018, households needed 1096 kWh for heating, and an ASIC of the type S9 max would earn 6.26 NOK per kWh consumed. Therefore, the households heating system would generate revenue of 1096 * 6.26 = 6863 NOK in the given month (decimals not specified), if replaced with S9 max.

5. Finally, we have the column "Heating bill with ASIC heating (NOK)". This column describes what the household's heating bill would look like if they replaced their heating system with the given ASIC system. In January 2018, the cost of electricity for heating was 427 NOK, while an ASIC system (have in mind the difference between an ASIC machine and an ASIC system, as described in the last paragraph of Section 3) of the type S9 max would generate 6863 NOK in revenue. Therefore, the heating bill for that month would be 427 - 6863 = -6436 NOK, a negative heating bill. The household would receive 6436 NOK for heating their home with the given system that month.

4.2 Monthly Heating Net Result

In Figure 10, the heating bills from the three different heating systems described in Table 8 and Table 9 are compiled. To make the table easier to understand, the numbers are multiplied by -1, and thus describes the heating systems' earnings rather than costs each month from January 2018 to December 2021. This means that resistive heating in January 2018 generated an income of -427 NOK, rather than a cost of 427 NOK as is presented in Table 8. For simplicity, the fields in Figure 10 with negative income (deficit) are colored red, while the fields with positive income (profit) are colored green.

The results from Figure 10 are presented in Figure 7. The graph clearly shows that the monthly cost associated with heating is much higher when using resistive heating compared to ASIC heating. The red line represents the monthly net income of households using resistive heating. It is naturally negative, which means that the household has a cost associated with heating. The red line is mostly stable around the average of -367 NOK monthly, and we can see the outline of four recurring periods where the heating bill is lower in the summer months.

The orange and green lines represent the S9 system at max and reduced capacity, respectively. The lines follow each other quite closely, but we can see that the green line, S9 reduced, is slightly above the orange line, and therefore will have slightly higher earnings each month than S9 max.

Table 10: Monthly heating net revenue.

HEATING NET REVENUE				
Year	Month	Resistive heating	Antminer S9 max capacity	Antminer S9 reduced capacity
2018	January 2018	-427	6436	7871
	February 2018	-478	2498	3120
	March 2018	-573	1812	2310
	April 2018	-428	1316	1681
	May 2018	-338	1131	1438
	June 2018	-361	469	643
	July 2018	-418	391	560
	August 2018	-422	232	369
	Septembe 2018	-439	203	338
	October 2018	-462	271	424
	November 2018	-566	139	287
	December 2018	-701	26	178
2019	January 2019	-691	-51	82
	February 2019	-545	38	159
	March 2019	-523	122	257
	April 2019	-443	274	424
	May 2019	-386	571	771
	June 2019	-210	632	808
	July 2019	-275	516	682
	August 2019	-306	395	541
	September 2019	-304	274	395
	October 2019	-413	174	296
	November 2019	-510	125	258
	December 2019	-491	124	252
2020	January 2020	-308	311	441
	February 2020	-169	456	587
	March 2020	-129	399	510
	April 2020	-58	445	550
	May 2020	-96	276	354
	June 2020	-27	198	246
	July 2020	-22	192	237
	August 2020	-56	190	241
	September 2020	-97	130	177
	October 2020	-143	174	240
	November 2020	-60	459	568
	December 2020	-204	509	658
2021	January 2021	-618	368	574
	February 2021	-549	614	857
	March 2021	-336	1053	1343
	April 2021	-312	892	1144
	May 2021	-380	438	609
	June 2021	-298	291	415
	July 2021	-396	417	587
	August 2021	-505	474	679
	September 2021	-499	380	564
	October 2021	-281	977	1241
	November 2021	-513	782	1053
	December 2021	-842	290	527

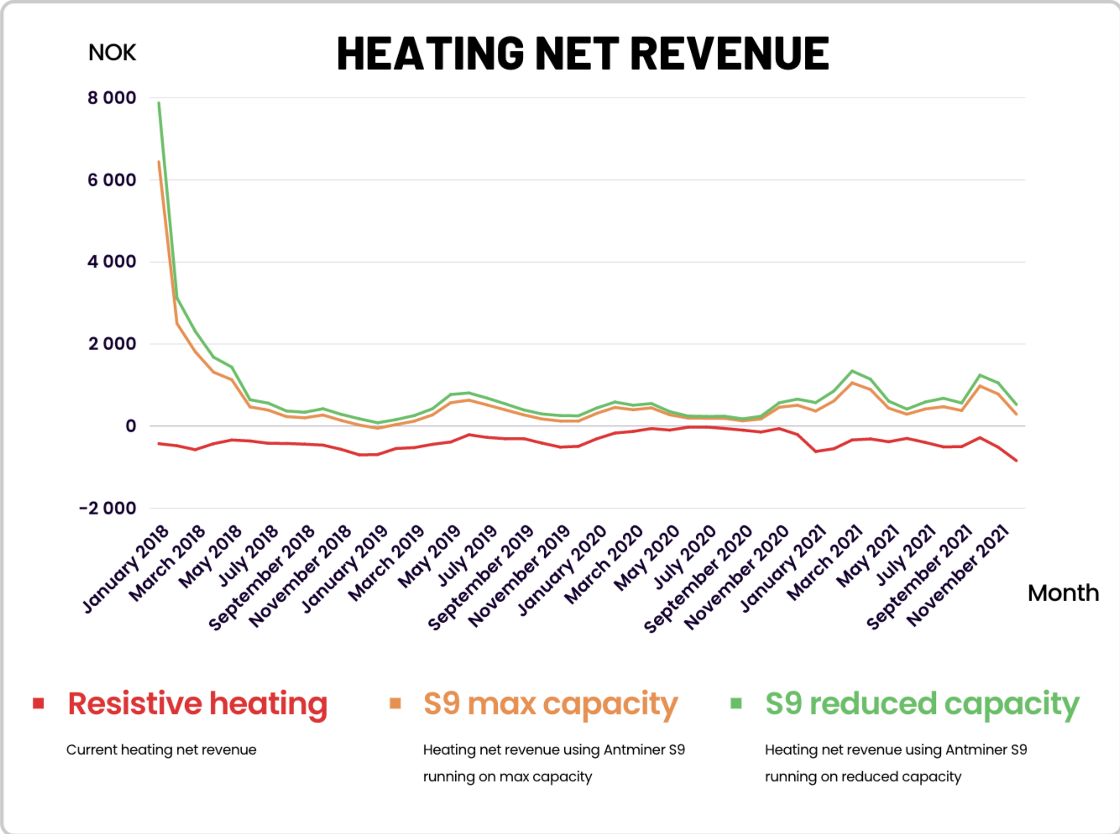

Figure 7: Monthly heating net revenue (from Figure 10)

4.3 Cumulative Monthly Heating Net Result

To assess the profitability of the different heating systems, it is necessary to consider their investment cost in relation to their income. By doing so, we can determine when the investments may be recovered and obtain a result on which of the three systems would have been the most profitable over the four-year period. To present this in the best understandable way, it is created a cumulative table (Figure 11) containing capital expenditure and income for the different heating systems. Since resistive heating is already installed, and hence does not require any investment cost for households, this system has no capital expenditure, and therefore starts at 0 NOK. ASICs, on the other hand, have an acquisition cost, and will therefore start with a negative income, equivalent to the acquisition cost. Figure 11 contains three different colors. In addition to the red and green colors used in Figure 10, a lighter shade of pink has been added, to represent the months in which ASIC systems have a cumulative negative value(deficit), but are still more profitable than the existing resistive heating system.

As shown in Table 9, the household will need two Antminer S9s at max capacity to be able to continuously generate the heat needed from 2018 to 2021. The capital expenditure for this system is therefore 2*11572 = 23144 NOK. With January 2018's net income of

6436 NOK, the table will show a cumulative income of -16708 NOK for that month.

Figure 11 is visualized in Figure 8. Here, we can see that the red line, representing resistive heating, starts at 0 and has a negative slope. This shows that the cumulative income from resistive heating over time becomes lower. In other words, the cumulative cost of resistive heating becomes larger. The orange and green lines, representing the two different ASIC systems, start with a large investment cost, so when the machines are activated on January 1st, 2018, the projects are already in the red. In contrast to resistive heating, the ASIC systems have a positive slope in the cumulative graph, meaning that the projects become more profitable with each passing month. Over time, we see that both ASIC systems approach a crossover point with the red line. At the crossover point, the systems are equally profitable, and after the crossover point, ASIC systems become more profitable than the resistive system. The S9 max and S9 reduced crossed the red line in May 2019 and February 2020, respectively. The overall income of the three different heating systems after a four-year period is presented in the bottom row of Figure 11. The cumulative income of the resistive heating after December 2021 is -17612 NOK. The corresponding number for the S9 max-system is 5691 NOK, and for the last system, S9 reduced, the cumulative income is 2243.

In other words, the current resistive heating system will have a negative net income over the four years, and the ASIC systems on the other hand will end in a net income, and thus profit. The S9 max-system proves to be the most economically profitable option for heating. The ASIC S9 reduced-system will be the second-best option, while the current resistive system is the least profitable option for heating the average household in Trøndelag from 2018 to 2021.

The resistive heating lets the household continue space heating without further costs, but the electricity bill continues every year. The ASICs on the other hand require a capital expenditure, but once they are running, they will use the same amount of electricity, generate the same amount of heat, and at the same time let the household earn money while heating their home. The results show that ASIC systems have a lower monthly heating cost, and considering the investment cost, it's only a matter of time before they become more profitable than the existing resistive heating. Further analysis, discussion, and conclusion will be presented in Section 5.

Table 11: Cumulative monthly heating net revenue, capital expenditure considered.

CUMULATIVE HEATING NET REVENUE				
Year	Month	Resistive heating	Antminer S9 max capacity	Antminer S9 reduced capacity
	CAPEX (November 2017)	0	-23144	-36303
2018	January 2018	-427	-16708	-28432
	February 2018	-905	-14210	-25311
	March 2018	-1479	-12398	-23001
	April 2018	-1907	-11082	-21320
	May 2018	-2245	-9951	-19882
	June 2018	-2606	-9482	-19239
	July 2018	-3024	-9091	-18679
	August 2018	-3447	-8859	-18310
	Septembe 2018	-3886	-8655	-17972
	October 2018	-4348	-8384	-17548
	November 2018	-4914	-8245	-17261
	December 2018	-5615	-8219	-17083
2019	January 2019	-6305	-8270	-17001
	February 2019	-6850	-8233	-16842
	March 2019	-7374	-8111	-16585
	April 2019	-7817	-7837	-16161
	May 2019	-8204	-7266	-15390
	June 2019	-8414	-6634	-14582
	July 2019	-8689	-6118	-13900
	August 2019	-8995	-5723	-13359
	September 2019	-9299	-5449	-12964
	October 2019	-9712	-5275	-12668
	November 2019	-10222	-5150	-12409
	December 2019	-10712	-5026	-12157
2020	January 2020	-11021	-4715	-11716
	February 2020	-11190	-4259	-11129
	March 2020	-11319	-3859	-10620
	April 2020	-11377	-3415	-10070
	May 2020	-11473	-3139	-9716
	June 2020	-11501	-2940	-9470
	July 2020	-11523	-2748	-9233
	August 2020	-11579	-2559	-8993
	September 2020	-11675	-2429	-8815
	October 2020	-11819	-2255	-8575
	November 2020	-11879	-1796	-8007
	December 2020	-12083	-1287	-7349
2021	January 2021	-12701	-919	-6775
	February 2021	-13250	-305	-5918
	March 2021	-13585	749	-4574
	April 2021	-13898	1641	-3431
	May 2021	-14278	2078	-2822
	June 2021	-14576	2370	-2407
	July 2021	-14972	2786	-1820
	August 2021	-15477	3261	-1141
	September 2021	-15976	3641	-577
	October 2021	-16257	4618	663
	November 2021	-16771	5400	1716
	December 2021	-17612	5691	2243

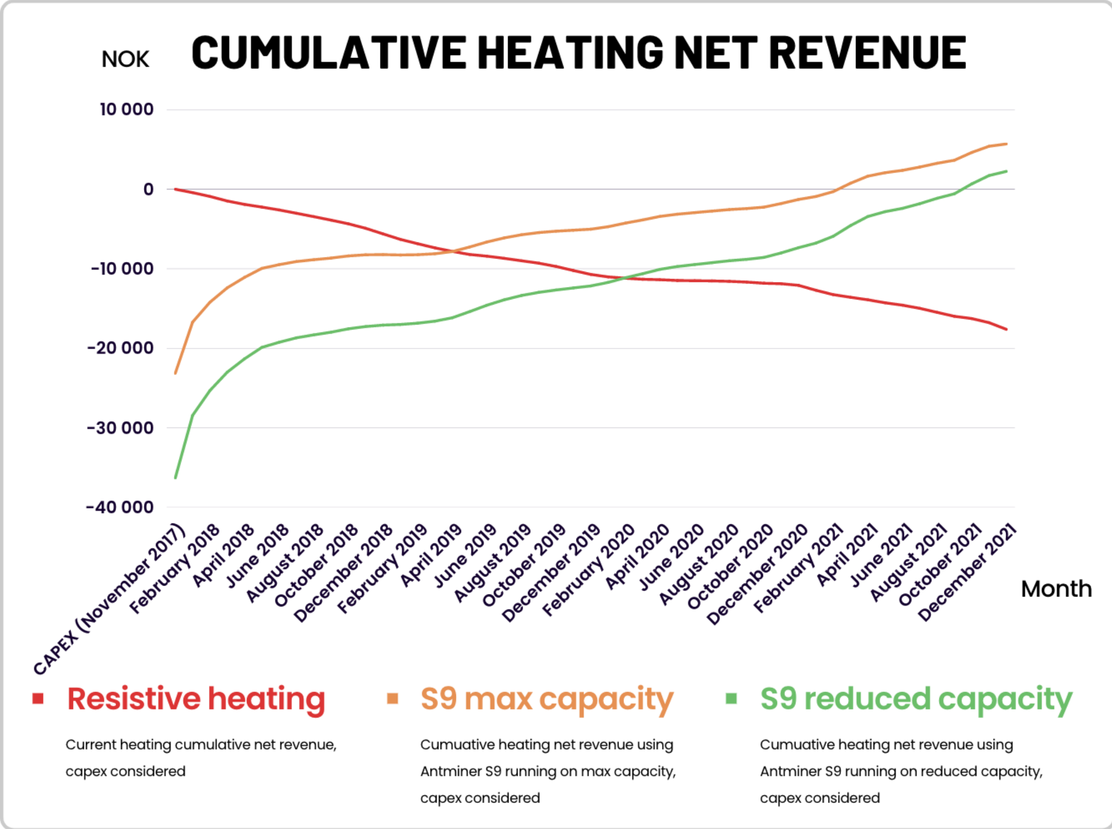

Figure 8: Cumulative monthly heating net revenue (from Figure 11)

5 Discussion and Conclusion

This section presents an interpretation of the results from section 4 and a discussion on their implications for the average household in Trøndelag. The section begins with a summary of the study's assumptions, followed by an extensive discussion. The limitations of the study will be pointed out, discussed and there will be suggested possible directions for future research. Finally, the section concludes by summarizing the study's key findings in a conclusion.

5.1 Assumptions

The following paragraph provides a summary and discussion of the assumptions made in this study, including whether these assumptions are justified and reliable, and how they may affect the results.

5.1.1 Foreign exchange fee

The hash price data used as a basis for ASIC profitability calculation is given in USD and is converted to NOK. ASICs are paid for their work in the form of bitcoin, so if a miner wants to convert their earnings to NOK, they need to transfer the bitcoins to an exchange, sell them for NOK, and then transfer the currency to their desired bank account. This process will first require a small fee to use the Bitcoin blockchain. Then a small fee to the exchange that converts the bitcoins, and finally possibly a small fee associated with sending NOK from the exchange to the desired bank account. The first two steps of this process take minutes, but since the process also depends on the traditional banking system in the last step, it may take several business days before the transaction is finally settled. The total fee associated with this process varies from exchange to exchange and from time to time. It will also be affected by how often miners want to convert their earnings. If they convert every day, they must expect a higher percentage cost than, for example, if they collect and convert once a month. Some miners may want to keep their earnings in bitcoin, and will hence not pay any fees. Since fees associated with converting bitcoin to NOK will vary by timing and strategy, this study has chosen to focus only on the NOK value of earnings, and a small fee must therefore be taken into account when reading the results.

5.1.2 Mining pools

It is assumed that households' ASICs mine in pools to receive somehow stable rewards for their energy consumption. This assumption must be done because there is an extremely small chance that a specific ASIC will be able to find a valid hash and get paid.

5.1.3 Electricity consumption

In this study, the average electricity consumption and electricity distribution of households on a national level are found. Then, statistics from the average household in Trøndelag determine the distribution of electricity consumption during different months of the year. Here, it is made an assumption that the average household in Trøndelag consumes the same amount of electricity as the average household in Norway, and that the distribution of electricity consumption around the house is the same nationally and regionally in Trøndelag. It is difficult to determine whether this assumption is sound or not, but it is crucial in order to estimate households' consumption. Temperature and weather conditions affect the heating needs of households, and it sounds reasonable that the southern regions of the country have lower heating needs than those further north. If the assumption turns out to be inaccurate, the profitability of ASICs will be affected, such that the more electricity is used for heating, the more profitable ASICs will be compared to resistive heating. Underestimating households' consumption would mean that ASICs will be even more profitable than the results indicate, and vice versa.

5.1.4 Heat pump not installed

It is assumed that the energy consumption of the average household represents a household that only uses direct-acting electricity and not a heat pump. Furthermore, it is assumed that all other heating in the household that does not use electricity, such as wood-burning or oil heating, remains constant, or in other words, continues in the same way after resistive heating is replaced with ASICs.

5.1.5 Functional existing resistive heating system

The paper assumes that households have a resistive system and therefore do not have any capital expenditure on this system. New buildings that consider the type of heating system or existing houses that experience a defective resistive system, however, must consider the acquisition cost of a new resistive heating system.

5.1.6 Electrical appliances stable consumption

The study assumes that electrical appliances such as TV, lighting, and refrigerators remain somehow constand throughout the year.

5.2 Discussion

The purpose of the study is to examine how Bitcoin ASICs can affect households' heating bills in Trøndelag. The study focuses on how ASICs, with their energy consumption, heat generation, and revenue generation, can replace the existing resistive heating system of the average household in Trøndelag, and whether such a replacement affects the household's heating costs. In Section 4, the study demonstrates that the monthly operating costs of ASICs are considerably lower compared to resistive heating. This finding is expected since both the ASIC system and the resistive system consume the same amount of electricity; however, the ASIC system additionally generates income. With a few exceptions, ASICs will generate income for the household every month. To assess the profitability of the various systems, the second half of Section 4 compares the profitability of the different heating systems over a four-year period, considering the acquisition cost and the cumulative net income of the different systems. It turns out that even with a high acquisition cost, ASIC systems would end up with a net income, compared to resistive heating which started without capital expenditure, but in contrast had steadily increasing overall cost. In other words, economically speaking, households will benefit from ASIC systems over time, and the more electricity used for heating, the more profitable it is to operate ASICs compared to resistive heating.

The results show that the acquisition costs of ASICs vary enormously from month to month. Looking at Hashrate Index's historical Antminer S9 prices [17], the price fell by over 90% from January 2018 to January 2019. It is impossible to predict how the prices of such machines will develop as prices depend on many different factors such as bitcoin price and mining difficulty. However, even though the investment timing may affect the profitability of the projects, the trend is clear. The machines will generally have net income from heating, and over time it is very likely that the investment cost will be recouped, and the systems will operate with a surplus.

The study compares two different ASIC solutions as heating systems. Which ASIC system households should use depends on the house's initial state regarding existing installations. The relatively quiet ASIC system, which runs at reduced capacity, will give the household higher investment costs but, in return, will have higher operating income compared to the ASIC system running at max capacity.

As soon as the quiet system is connected, it can be placed around the house where the household wants the heating unit. It has no fixed installation like the ASIC system running at max capacity. This S9 max-system has a very high noise level and will realistically need to be placed in a technical room and from there distribute the heat around the house. The advantage of this system is that it requires fewer machines, and therefore the investment cost will be lower. However, if the household does not have installed a system that can transport the heat from the technical room, the investment cost will be much higher with this S9 max-system. There are many advantages and disadvantages associated with the three different heating systems. In the following paragraphs, we will discuss some of the most important advantages and disadvantages of the different systems.

This study aims to investigate whether households can benefit economically from investing in an ASIC heating system compared to the existing resistive heating system. Since the electricity cost is the same for both ASIC- and resistive heating, the income generated by the ASICs can be considered as pure profit. Although the difference between ASIC- and resistive heating in terms of heat generation is only whether the electricity flows through a resistor or a hash board, there are still multiple factors that need to be taken into consideration when deciding whether to opt for an ASIC based heating system or not.

It is possible that future heating appliances, such as panel heaters, underfloor heating, and hot water tanks, will contain hash boards rather than resistors. However, as this technology is relatively new and the market is not yet flooded with various hash board solutions or service and support personnel, households must carefully consider the advantages and disadvantages of implementing the different systems. The following are the most important factors that households should consider:

1. Profitability:
   The household must first consider the profitability of the ASIC system they prefer. From an economic standpoint, we know that ASIC heating will pay off over time. Nevertheless, there is some risk that the ASICs may become defective at some point. The Antminer S9 was introduced in 2016, and many of the machines are still working excellently seven years later. Others experience slightly shorter lifetimes, but the basis for predicting the durability of different ASICs is thin compared to, for example, panel heaters. As we saw in Section 4, S9 reduced will have higher earnings per unit of energy used than S9 max. This is probably due to the fact that S9 max operates at its limit and is more likely to overheat than S9 reduced, making the ASIC less efficient. As S9 max is run harder than S9 reduced, it is therefore likely that S9 max may have a slightly shorter lifespan than S9 reduced, although it is difficult to say anything for certain. There is therefore a risk associated with the investment that the ASICs may become defective before they have had a chance to pay off the acquisition cost. However, there is a high chance that households will benefit financially from the ASIC system, given the associated risk.

   In the assessment of the profitability of replacing current resistive heating systems with ASICs, it is essential to take into account the alternative cost associated with investing in these machines. The capital tied up in ASICs represents an opportunity cost, as it could have been directed towards other potentially lucrative investments, such as the stock market or real estate ventures. By considering the risk-return tradeoff and liquidity implications of alternative investment options, the household can make a more comprehensive evaluation regarding the overall profitability and desirability of investing in an ASIC heating system.

2. Purchase:
   When a household decides to acquire an ASIC heating system, they must determine which type suits them best. If they already have a technical control room with associated heat transportation into the house through a ductwork system, it may be suitable to acquire an S9 max-system. If the household considers this option, they must also prepare for some of the heat generated by the ASICs to heat unwanted areas during transportation. Therefore, it will be necessary for the household to generate more heat than they need, so that when some of the heat disappears during transportation, the correct amount of heat will come out into the house. With the S9 max-system, the household saves money on acquisition costs, while the machine's location in the technical room makes the noise level irrelevant. For most households, it may be easiest to go with an S9 reduced-system. This system requires a higher investment cost but, in turn, produces significantly less noise. Crypto Cloacks has researched the noise level of the Antminer S9 [12]. The study shows that the S9 max has a noise level of 83 dB with factory settings. The S9 reduced, in comparison, was measured at 60 dB with factory settings and as low as 51 dB if the fans were replaced with some more quiet ones (as we have included in the CAPEX for the S9 reduced).

3. Setup and maintenance:
   When the household has decided on the type of ASIC heating system they want and purchased the machines, they must set up the system. This process involves setting up the machines, connecting them to the network, and a mining pool so that they can generate income, and finally placing the system correctly, whether it is around the house or in a technical room. These processes can be demanding for people, so it is important for the household to assess whether they have sufficient technical expertise to do this themselves. Alternatively, they must get help from acquaintances or consider the possibility of hiring professionals to set up and maintain the system.

4. Practical challenges:
   After considering the acquisition, setup, and maintenance of ASICs, households must address the practical challenges of the heating system. Today's resistive heating is often installed with thermostats that ensure even and stable heat at the desired level. There is no technical impediment to developing an equivalent for ASICs, but since ASICs as a heating device are a relatively new idea, households may initially have to manually regulate the temperature by turning the machines on and off. It should also be considered whether heat generated from ASICs affects the experience of temperature. It is possible that the room temperature may be ideal, but the floor feels cold. In such a case, it may be worth questioning whether ASICs are a valid replacement. However, ASICs placed throughout the house would be comparable to panel heaters. Thus, this issue would also arise with resistive heating. To achieve

ASIC underfloor heating, households would need to install liquid-circulating heating in the floor and use ASICs to heat up the liquid in a technical room.

Hot and cold days occur alternately, and households should consider how many machines they need in order to generate sufficient heat on the coldest days. As shown in Table 9, during the four years of ASIC heating, the months with the highest heating demand (February and December 2018) required 1.2 S9 max-machines and 2.5 S9 reduced-machines. Since the number of machines must be purchased as an integer, this means that S9 max and S9 reduced needed 2 and 3 machines, respectively, to meet heating needs. In other words, the heating systems considered for the average household have some margin in heating capacity, which could mean they may handle cold days. However, if the ASIC system is not able to generate sufficient heat some days, the case will be comparable to the resistive heating system, where the households may need to supplement with other alternatives in addition to their existing system. The household can consider purchasing more ASICs, but these will be required so infrequently that the capital expenditure will be extremely slow paid off, and the household should consider another option for these cold days instead.

5.3 Limitations

This study provides an estimate of the average heating cost for households in Trøndelag if they were to replace their existing resistive heating system with ASIC based systems. It may be easy to determine the most cost-effective option in hindsight, but since section 5.1 partly discusses the considerations households must make when deciding to invest in an ASIC-based heating system, it is important to note significant limitations.

5.3.1 Future profitability

While this study indicates that, over the four-year observation period, it would have been more cost-effective to heat using ASICs, and that the systems would have recouped their investment costs within 17 to 26 months, there is no guarantee that this will continue to be the case. Historically, with an ever-increasing total hash rate on the Bitcoin network, the ASICs' share of the total hash rate falls. Higher network hash rate will weaken the income generated by households' ASICs. With a stable bitcoin price, the income generated by households' ASICs will decrease accordingly. The profitability of ASICs depends on the bitcoin price, the ASICs' share of the total hash rate on the Bitcoin network, as well as Bitcoin's block reward and transaction fees. Therefore, it is entirely or partially impossible to predict future profitability, meaning that this study can only provide an idea of what future profitability may look like, without being definitive.

5.3.2 Capital expenditure

Today, one can obtain Antminer S9 machines for a very low cost. These machines will make up a significantly lower share of the total hash rate in 2023 than they did in 2018 and will therefore consume more power to generate the same amount of bitcoin. However, with such low capital expenditure for these machines in 2023, the investment case will look very different, even though the machines' decreasing competitiveness will result in lower income.

5.3.3 Number of ASICs

The profitability of ASICs will depend on the household's heating needs. A household that requires 1.9 machines to meet its heating needs will have slightly lower earnings compared to a household that requires 2.1 machines. On the other hand, the household's capital expenditure (capex) will be significantly higher if they require 2.1 machines, as this means they need to purchase three machines, instead of two in the other scenario. Heating needs and the number of ASICs required are factors that will impact the duration of the payback period for the machines and, therefore, must be considered by households.

5.3.4 Internet connection

The S9 reduced-system is assumed to be placed throughout the household where it is most convenient. However, it is worth noting that all machines need to be connected to the internet. The simplest way to achieve this is by using a network cable, but it is also possible to plug in a Wi-Fi receiver into the machines, enabling wireless mining. This means that the household either needs to have internet outlets where the machines are located or invest in additional equipment to allow for placement anywhere in the household.

5.3.5 Heat loss

This study examines the income generated by ASICs when consuming an equivalent amount of power to the existing resistive heating system. The heat generated by the ASIC S9 max-system is assumed to be transported around the house from a technical room. Heat loss will vary from household to household and from transport system to transport system. This study does not account for such heat loss in its calculations.

5.3.6 Electricity distribution

The study only considers the total amount of power consumed by ASICs. The study says nothing about when this consumption occurs, such as whether it occurs during the day or night, or whether it is turned on or off. This means that some households may use an extremely large amount of power at certain times, such as on a very cold day, and may not have enough ASICs to consume the needed amount of power.

5.3.7 Tax and tax deduction

Finally, it is worth noting that when a household heats its home with ASICs, the machine's income is taxable. Without knowing too much about the subject, Norway allows a tax deduction for income-generating expenses (Norwegian: utgift til inntekts ervervelse). Therefore, it is possible that in Norway, one is entitled to a tax deduction for the capital expenditure and energy bill associated with ASICs. It may sound strange, but according to some Norwegian home miners, that is the case. This study finds that, economically speaking, households will benefit from ASIC systems over time. However, if tax deductions are available, this would further enhance the cost-effectiveness of ASIC heating, and make them even more profitable.

5.4 Future Research

The findings of this study are interesting, and the thesis, with its topic and angle, could be helpful for future studies. In this section, I will provide some suggestions for possible future research directions.

1. This study examines the profitability of ASIC projects when their earnings are immediately converted into NOK. If one believes that the price of bitcoin will increase significantly in the long term and is not required to convert the ASICs' income immediately to cover operating costs, the investment scenario could be compelling. The higher the price goes, the more promising the investment will appear in the future, and conversely, if the price were to decrease.

2. It would be interesting to study how ASICs can impact other electrical devices and industries. The profitability by replacing resistive heating with ASICs in different electrical appliances, such as hot water cylinders, pools, or hot tubes, would be interesting to study as well as how ASICs can affect the heating bill for hotels, business buildings etc. It would make sense to think that larger buildings can benefit more from ASIC heating, as they typically have technical rooms with heat transfer systems installed to a greater extent.

3. A potential future study that could be interesting, is a comparison of different heating systems associated with ASICs. How will the heat be perceived when ASICs are placed around the house versus when they are located in technical rooms? How does the heat transported through ductwork systems compare to heat transported through heating liquid pipes?

4. An interesting topic that builds on this study is how Bitcoin's security can be affected by households' ASIC heating. Bitcoin's security lies in the total hash rate on the Bitcoin network. To attack Bitcoin, you must control more than half of the hash rate on the network, which is an incredibly expensive process. Unlike professional miners, households using ASICs for heating can operate at a loss. This is because households' ASIC systems, even with negative monthly earnings, can be more profitable than resistive heating. So, in situations where professional miners would turn off their rigs, households are more likely to keep their machines running. In a world where households use ASIC heating, it will be even more expensive to carry out attacks on the Bitcoin blockchain. The security implications associated are an interesting research topic.

5. For most households, the economic result combined with comfort will be the main factor in considering ASIC use. However, something that not many people will think about, or perhaps bother to care about, is how such ASIC heating can affect Bitcoin or the environment. It is expected that the mining industry acts rationally, which means that the miners who operate at a profit will continue to operate, while miners who experience losses will cut back on operations. The implications of that are when a new ASIC is connected to the network, it will take a share of the profit, and thereby force another machine on the network over the limit to operate at a loss. The new ASIC will thus, with its participation, force the least profitable machine on the network to turn off. Often, it is the machines with the most expensive electricity that are least profitable, and it is often the case that the most expensive electricity is fossil fuel-based or in areas with high demand. Therefore, it is not unlikely that the household's new ASIC heater will force the least profitable miner off the power grid in areas with high alternative uses, and perhaps even force it to find cheaper electricity, thereby incentivizing the search for renewable or stranded energy. In short, it is not inconceivable that an ASIC heater can contribute to lower energy costs where demand is high and can also help ASICs operating on fossil fuels to find more sustainable operations. That would be an interesting topic for future research.

5.5 Conclusion

After a thorough examination of the advantages and disadvantages associated with replacing resistive heating with ASIC heating, it can be concluded that such a transition would yield significant economic benefits. ASIC machines operate at significantly lower monthly expenses compared to resistive heating, and the investment cost associated with the machines will eventually be paid off by the earnings from ASICs. However, households must consider the risk that ASICs, like any other electrical appliance, may become defective and thus cause acquisition costs that are not paid off. The investment cost must also be evaluated in relation to the opportunity cost of allocating the funds elsewhere.

Furthermore, households must carefully consider whether their technical prerequisites are good enough to set up and operate an ASIC system, or alternatively look into the options for getting service personnel to help with the setup and operation. The household's initial infrastructure is an important factor to consider when choosing a suitable ASIC system. If the household does not already have a technical room with heat transportation around the building, an additional investment cost will be necessary to install this.

When it comes to comfort associated with heating, it is important for the household to consider temperature adjustments, as the ASIC system does not have the same automatic temperature adjustment that often comes with resistive heating. The household must either set up the ASIC system with equivalent automatic temperature adjustment or turn it on and off manually when they want heat.

Despite these practical and technical aspects, it is likely that households will benefit from switching to ASIC heating. If ASIC heating continues to be profitable in the future, it is possible that development will move towards integrated and user-friendly solutions, including maintenance and service agreements from sellers of ASIC systems, similar to today's heat pumps.

In the short term, resistive heating may be tempting due to its simplicity and low start-up and installation costs. However, by sticking with resistive heating, households may be missing out on the potential for substantial financial gain in the long run. On the other hand, ASIC heating has a higher start-up cost but will eventually save households' money, given that the electrical appliances remain functional. In conclusion, this study suggests that Bitcoin ASIC heating have the potential to significantly impact the average households' heating bills in Trøndelag, but as of today, households must carefully evaluate whether the technical and practical aspects associated with it justify the potential profitability.

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