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Improving snow melt systems energy performance

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Abstract:

The object of this report is the district heating snowmelt system installed in Notodden, Norway. The heat is generated by 4.7 MW wood chip burner, together with oil and electrical boilers to cover peak loads. The heat is transported to the customers via distribution pipes with hot water.

The aim of this research was to make field observations based on physical modeling. Manual about installations for the field observations is provided in this report. As a task was to observe real-time snowmelt process all data information is provided vise analysis.

Different problem of the heat losses were described in the report. Few way of reducing heat losses and saving operation cost were discussed. It was provided results of real-time experiment with conditions in low surrounding temperature and dried street.

All pictures that were provided in this report were discussed and explained

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Preface

This report is written as a Master's thesis as part of the masters education at Telemark University College.

The following report is based on various data that is the base for analysis and solutions of melting process. The data is gathered from Master's Thesis, which was written in Telemark University College (HiT) in 2012 by Benjamin Lyseng. I would like to thank Benjamin for help that he provided.

The main observations focuses on the early spring months. Information was also received from local newspaper Varden in Notodden and Siemens as a partner of Termocraft AS. I'm thank them for the useful information that I got to write this report. And I would like to thank Termokraft AS who provided a place where to install video cameras and especially Hallgeir Haddeland for his help with installations. I would like to express mine gratitude for Thermokraft AS, who let me make a research about their snowmelt system.

The main task of the project was to make real time observations of the snowmelt system and to find out why system where is a problem of different time response along the street. When I visited Notodden representative from Termocraft AS told that there is a problem part of the street where snow melt much slower compere to the whole system. That was one of the observation objects during my work.

I'm very thankful to my supervisor, Wilhelm Rondeel, who help me a lot with writing this report. He helped me to understand the way to write this report. He guided me through the whole fourth semester of my master program in Norway. He helped me to find useful people from other companies who can help me with providing necessary information. Especially I would like to thank him for helping me even when he did not have ordinary day at school.

Porsgrunn, 27.06.2013

Arthur Prakhovnik

Nomenclature

NOK – Norwegian kroner

Q - total heat losses per operation period, kWh

q - amount of heat delivery, W/m^2

S - total area of the driveway, m^2

t - time difference between dry driveway and system is off, h

Q_g - energy which is need to heat up the ground, kJ

m - mass the is need to heat up, kg

c - heat capacity of the ground, J/kgK

ΔT - temperature difference, K

t_h - time to heat up the ground, h

P – power that is heating the ground, W

1 Introduction

Snowmelt system is a popular way to clean and keep dry streets from the snow and ice in most of the north countries. Such systems are quite efficient and they have low environmental impact.

1.1 What is snowmelt system?

Snowmelt system is a system, which is mainly used to melt snow on the surface. The aim of this system is to avoid of snow creation and remove snow layer during the snowfall to provide safety for costumers. Usually snowmelt system installed during construction period of the district heating system as a part of such system. Quite often, it is possible to see that the snowmelt system is a biggest costumer of district heating system, which is using the biggest part of total district heating power demands. Snowmelt system can be divided on a 2 types: electrical or hydronic. Usually by saying hydronic is mean mixture between water and propilenhlycol. Area of usage snowmelt system is wide. This system installed to remove snow from the driveways, walkways in the city or it can be runway at the airport, everywhere where human safety is a preferably.

1.2 Snowmelt system in Norway

Snow plays an important role in Norwegian society, while removal of the snow plays an important role on its safety. For this reasons snowmelt system is normal fact for Norwegians towns and cities. Most of these systems were installed during construction period of the whole district heating system. As it was saying earlier Snowmelt system divided on a hydronic and electric systems, Norway uses both of these types. Depending on the resources, which can be provided for power generations on different areas, electrical or hydronic system, must be chosen. For example some cities with a huge industrial park use as a main heat resource waste heat from the industry, while other cuties that doesn’t have any industry must to provide heat by buying wood chip burners, oil burners or install electrical systems to provide heat demands.

1.3 Snow melt system in Notodden

Today, snowmelt system is the biggest costumer of Nottoden district heating system. It was built as a part of district heating system to utilize waste heat from industry, mainly company Becromal. As Becromal moved to another city in 2011. It was decided to buy wood chip burner to cover power demands of the system. In addition to burner were installed 2 oil burners and one electrical heater. As snowmelt system is main costumer it covered 12 465 m^2 in 2009. Preferably all main streets in the town. Since snow melt system is main costumer and turning on this system cause appearing of the peak loads. Understand the main snowmelt process and to find ways to optimize system is necessary.

1.4 Literature review

Finding the best strategy for system operation is a biggest challenge for people who are trying to make snowmelt system more economically beneficial. This report is a part of big study work, which is doing by students to optimize snowmelt system in the city Notodden. Based on two works that done in frame of Master's thesis and Group project by student of Telemark University College, it is possible to say that the solution to optimize system exist. Also by overviewing of some researches done in other countries is it possible to build typical model for snowmelt system in Notodden.

1.4.1 Strategies

During previous studies, it was suggested to operate system with one of strategies.

1.4.1.1 Constant heating

With this strategy, system works continuously to keep surface above 0 ^{o}C. In this case, all snow that appears on the surface will melt immediately. As advantage of this strategy is a zero amount of peak loads. However, with continuously working period system has huge energy consumption and heat losses when streets are dry.

1.4.1.2 Dew point

This strategy is similar to constant heating strategy but the difference is that the surface keeping with 1 or 2 degrees difference from air temperature. It still has high-energy consumption, but less than constant heating. Response time is smaller than it is today and no peak loads.

1.4.1.3 On/off with storage

In this strategy were done some research about storage possibility of the ground and turning on a full capacity woodchip burner 5 hours before predicted snowfall. This will give a lover response time, quite low energy consumption and low amount of the peak loads.

1.4.1.4 On/off

This strategy operates nowadays in Notodden. This strategy has a big drawback as a high peak loads.

2 Problem description

Problem description

The snowmelt system in Notodden is a big costumer of whole district heating system. District heating was built to provide heat for cities demand. From the beginning of the operation of all the system, it used inexpensive waste from industry, which was situated on Hydroparken. The main source was waste heat from Becromal AS. When in February 2011 company moved, to cover base demands it was installed a 4,7 MW wood chip burner. After fist operation season it was found that power demand dramatically crowing with operation snowmelt system at the same time with district heating. To cover additional power demand were installed two oil burners and one electricity heater. 1kW of energy produced by wood chip burner is three times cheaper compere to usage of oil or electricity.

Earlier in Telemark University College (HiT), were done several researches on energy and economical optimization of the system. First and basic research was done in frame of Master's Thesis where was shown the main precipices of working process of the system. In addition, it was shown that economical and energy optimizations can improve working regimes and save operations cost. Second work was done in a frame of Group project were was don research of different operations regimes with their economical considerations. Based on this two works it was suggested to make 3 researches in a frame of Master's Thesis. This report focused on physical processes of the snowmelt system in a real time.

The task descriptions, which was given for the Master's Thesis, can be found in Appendix 1. Main aim of the task can be divided on several tasks:

1. To get real-time information about working process of the snowmelt system
2. Install and set up outdoor video observation
3. Analyze data received data from the cameras
4. Make propose to optimize system

3 Notodden snow melt system

3.1 Physical system

The Notodden snowmelt system has heating plant, which generate heat for the system, distribution pipes, to distribute heat to the heat exchangers, heat exchangers, which distribute heat to the pipes under the street.

3.1.1 Distributions

Notodden is a city of 9200 inhabitants in eastern Telemark, located where the Tinne River empties into the lake of Heddalsvannet. It has roots as a typical industrial town grown from the pump and paper industry and hydropower (Notodden commune, 2011). The main source, heat central, situated at the industrial park Hydroparken, which is located at the mouth of the river.

The current distributions system consist of 5373 m long pipes and heat exchangers all over the city. Total volume of the water that is pumping inside the piping system is approximately 212 m^3. The current distribution system depicted in Figure 3.1 includes only the main distribution pipes and does not include service pipes to the consumer substations (Lyseng, 2012).

Figure 3-1 Notodden district heating system distribution piping (Google Earth, 2012). Yellow – DN80, Orange – DN100, Green /Black – DN125, Blue – DN150, Red – DN200

3.1.2 Snowmelt system in Notodden

Snowmelt system provides heat for melting snow in different parts of the city Notodden. It can be seen on the main streets of the city, bus terminal or artificial turf football field, to make turf softer during winter days. Other parts heated to clean from the snow and dry out all the water from the ground to provide safety for inhabitants. Research done by Canadian student in 2012 showed that on the days when snowmelt system was ON, snow-days, total power demand of the district heating system dramatically grew. Turning on snowmelt system cause peak loads appearance, which can be covered by expensive in operation ail burner or electricity heater. Difference in word days of the district heating system can be seen from the Figure 3-2 where, blue dots are dry days without snow fall and snowmelt system is OFF, while red dots are snow-days with turned ON snowmelt system.

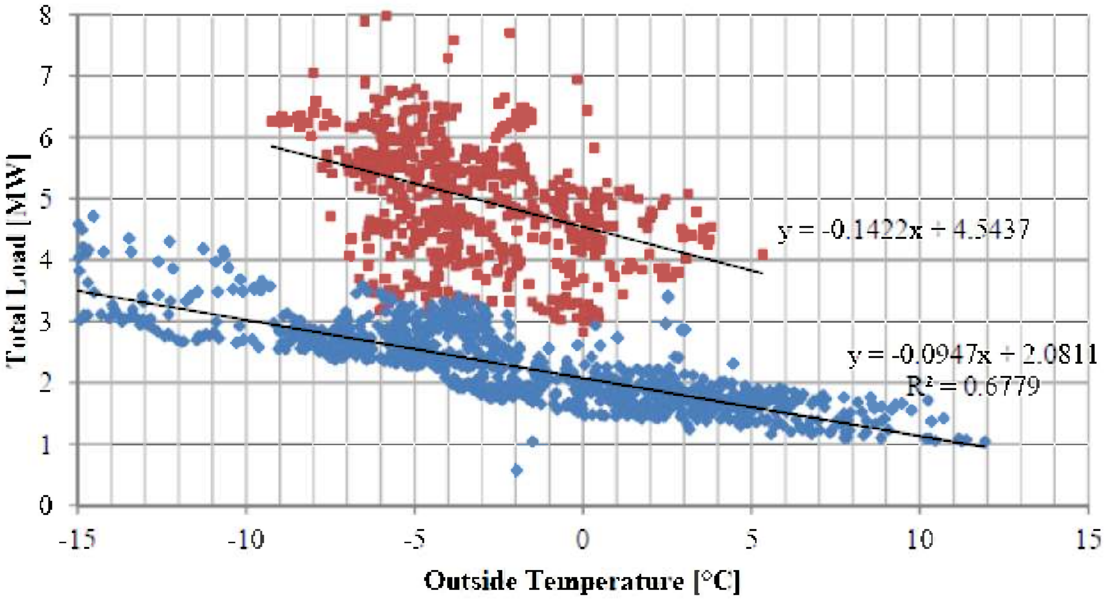

Figure 3-1 Load versus temperature winter of 11-12(Lyseng, 2012)

3.1.3 Heat central

The heat central consists of several energy generators such as 4.7 MW wood chip burner, two 2 MW oil burner and 1.2 MW electricity boiler. All this sources has different work place in the system. Wood chip burner hat to cover basic loads, while oil burner and electricity boiler cover peak loads caused by snowmelt system. Total capacity of heat central is 9.9 MW. Also is was installed 90 m^3 buffer storage tank , which provides around 5 MW of energy in case of falling temperature at the contained water down to 50 °C.

As a part of snowmelt system to provide better heat distribution for melting snow there are several small heat stations around the city. Heat stations has heat exchangers to suck heat from the main circuit of the system and give it to secondary circuit. Heat stations consist of heat exchanger, pump and pipes system with vessels. Pipes system is splitted after pump to provide heat on a pavement and street apart and connected again before heat exchanger.

More detailed scheme provided in Figure 3-3.

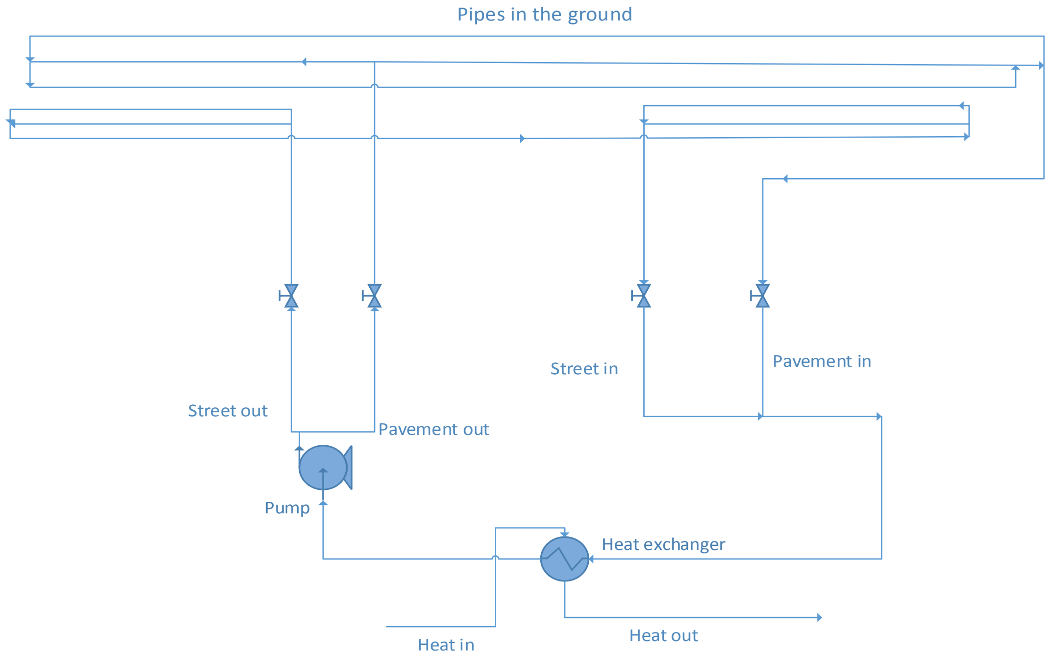

Figure 3-3 Scheme of the heat central for the snowmelt system

3.1.4 Base loads VS Peak loads

The snow melting system is the largest customer of district heating and proper management of the system will reduce heat loss, as well as to reduce the consumption of expensive resources. Nowadays, the district heating system with the street heating system operates in a mode on / off. During the dry days when no precipitation system is able to cover all demands of the city at the expense of the woodchip burner, but the appearance of precipitation is included street heating system, which is shocking to the system and for rapid reaction, district heating system requires additional energy. This extra energy and is covered by expensive oil and electricity. The snow melting system is automatically activated when sensors sense the appearance of moisture on the surface at temperatures below 0°C. Figure 3-2 shows the distribution of load at different days depending on the temperature in turning on and off street heating system. As can be seen from the chart made by a student from Canada, some of the days, when the street heating system is on, consumption increases to 2.5 times. Since the power is 4.7MW for base load, it will not be enough to cover 6MW or sometimes even 8MW. Choosing correct solutions for working regime of the system can reduce peak loads, or at least reduce their impact on the overall operation regime of the system.

3.1.5 Gatevarme

Street heating system is a biggest costumer and for better understanding of the snow melting process, it is given Figure 3-4 where shown snow distribution on the pavement during melting process. As part of the upgrading of Storgata, the city's main street, heating pipes were installed under the road and sidewalk. From 2001-2003 the heated area was 3390 m^2, then from 2004-2008 the area was 9530 m^2, and from 2009 the area was further increased to 12

465 m^2. A cross-section of the road of the road construction can be seen in Figure 3-5 (Lyseng, 2012).

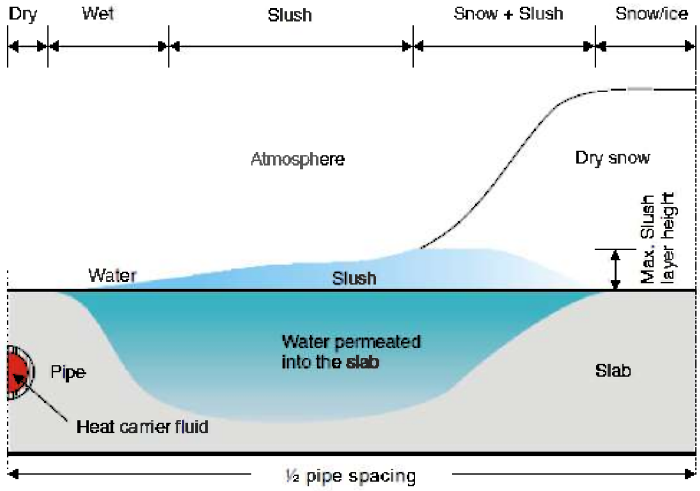

Figure 3-4 Variation of surface condition on a heated pavement slab during the snow melting process (Liu, 2007)

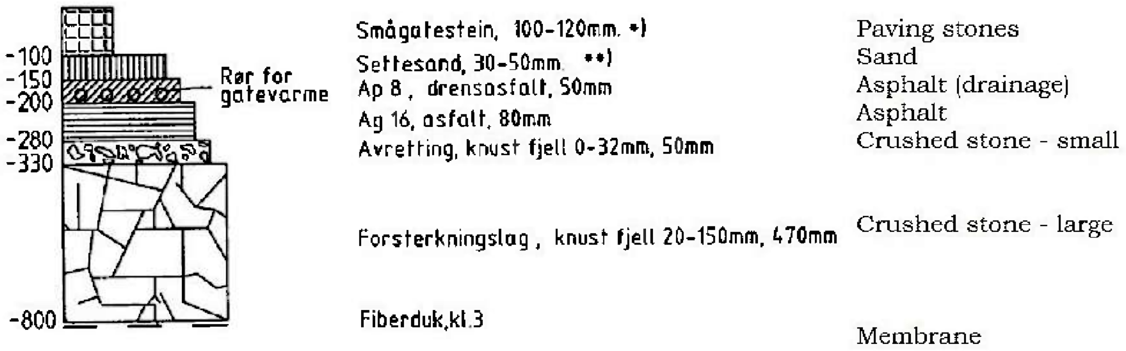

Figure 3-5 Cross-section of the roadway with "gatevarme" system (Lyseng, 2012)

4 Equipment and Software

The following chapter is written to provide help and can be considered as a manual for installation and setting up program software to observe outdoor systems working processes.

4.1 Choosing observation place

As the main aim of the work was to make outside observations, first step was to define the best place to observe working process of the system. According to conditions that is should be observe street and pavement as well it was chosen main street of the town, Storgata. After one visit during snowfall, it was found that system has a problem part beside Main Street. This problem part has much lower respond time compere to others part of the system. To find out reasons for this it was suggested to install two cameras on both directions. First one will be focused on the street and pavement while second will be observe problem part at the same period. Based on this conditions best place to install cameras was office with a balcony on which it was installed. Chosen place showed on a Figure 4-1.

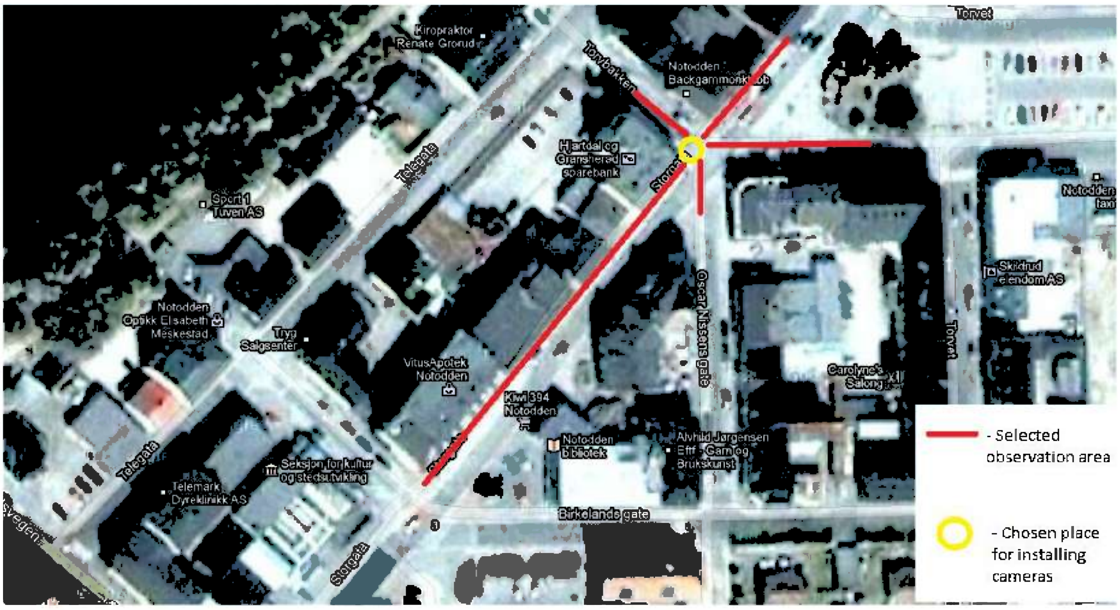

Figure 4-1 Place were cameras were installed for observations.

4.2 Varden

Earlier before this balcony was used by local newspaper Varden to install their own camera. This camera taking snapshot and sending it to the newspapers web site every 10 minutes from five different positions. That it means that there is 50 minutes between snapshots at the same position. Camera sending pictures directly to web page and re-recording old pictures, so there is no saved information from any of the snowfall during last winter that can be used for further research. Also after agreement with Varden and setting their camera for sending information on the school server, it was found some problems with connections. All pictures were sent with bugs. This is was another reason for installation our own cameras.

4.3 Cameras

A major step in this project was the selection of the right equipment. To select the right product was applied a few conditions:

1. Access to the Internet. For direct transmission of data to the server and the remote control.

2. Night mode of the camera. Since the essence of the project is the ongoing monitoring, camera should be able to take clear pictures at nighttime.

3. Ability to work with precipitation and cold temperature. The camera should be installed outside, that means that low temperatures, as well as precipitation in the form of rain and snow would expose it.

Given these conditions was selected camera Wanscam for outdoor applications with operating temperatures from -10 to +50, and the possibility of direct access to the Internet via cable or Wi-Fi. More detail properties about the camera can be read in Appendix 2.

4.4 Installation

For safety a stability, it was build a wooden box on which cameras were screwed. All communications such as internet cable and electricity were placed under the cover in the box. This provided protections for all connections when snow started to melt. Internet cable were connected to the router, which is belong to local newspaper. All connections were insulated to protect from the ingress of water. Result of the installation can be seen in Figure 4-2.

Figure 4-2 Installed cameras on the balcony and focused on two major directions

4.5 Server settings

For storing information, it was sent request to the schools IT-center to create space on a school server for saving incoming data from the installed cameras. After few days, it was opened access to the ftp server with the following settings:

1. Ftp-username -- u113876 (optional)
2. Ftp- password -- jhsdkjhs (optional)
3. Name of the Ftp server -- ftp.hit.no

For easy access, IT-center provides program Winscp376. Screen shot of the program provided in the Figure 4-3.

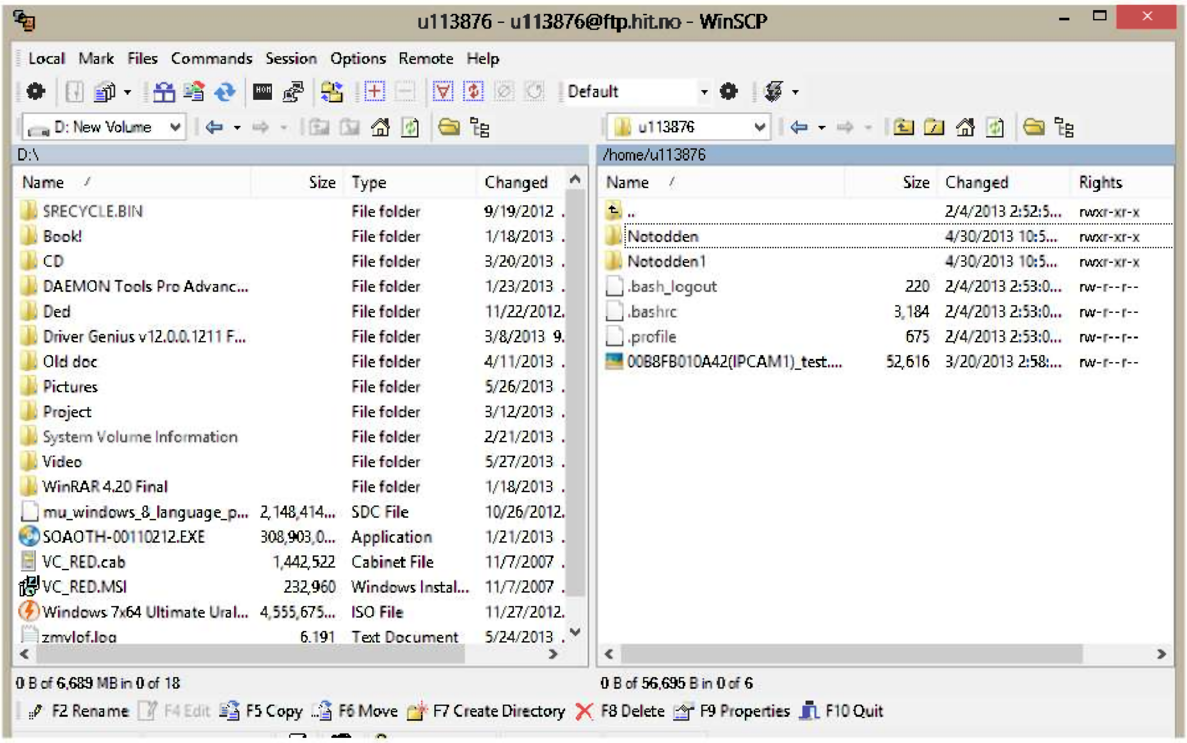

Figure 4-3 Winscp376 were provided for easy access to the server

Left part of the program shows all the files and folder on the computer while right part shows files on the ftp-server. As it seen from the figure 3.2 there is two folders on the server. Firs folder with name "Notodden" storing all snapshots from the first camera. Folder "Notodden1" was created for snapshots from the second cameras.

On the Figure 4-4 can be seen how snapshots organized in the folder.

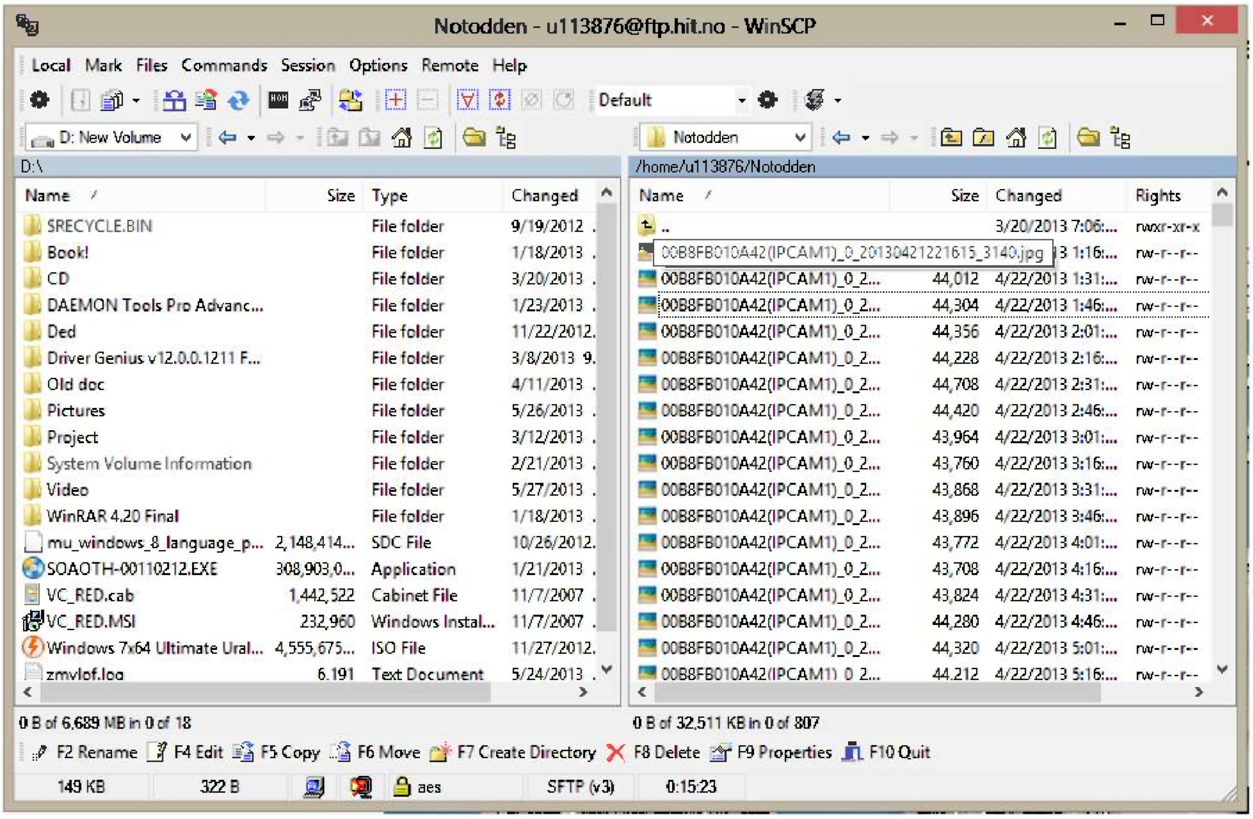

Figure 4-4 Folder organization in the program Winsscp376

Each file has time and date when it was created, which can be read from the name. Detailed information about files name shown in the Figure 4-5.

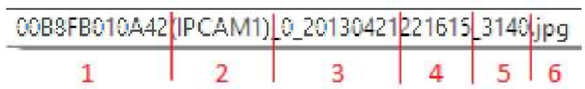

Figure 4-5 File name, which is created by camera

Where:

1- General name for all pictures
2- Name of the camera which took it
3- Date in a format yyyy/mm/dd
4- Time in a format hh/mm/ss
5- Number of snapshot
6- File format

Cameras were set up to make a shot every 15 minutes. According to limited space on server every 3 days all picture were moved from the server to the hard drive.

4.6 Settings

All the products of the Wanscam Company are provided with a Driver CD. On this Compact disc, company gives all necessary programs for stable work of the cameras.

After installations of cameras it was done setup of the software for controlling and programing cameras. This software gives full access directly to the camera and easy to program it. Chosen cameras working as IP cameras, all the setting done in browser.

To get access to the camera IP address has to be written on the browser input line. Be for this connection via cable with camera should be checked. In the given situation connection were done through the router. After correct connection and writing IP address 191.168.1.99 which is given, following Figure can be seen:

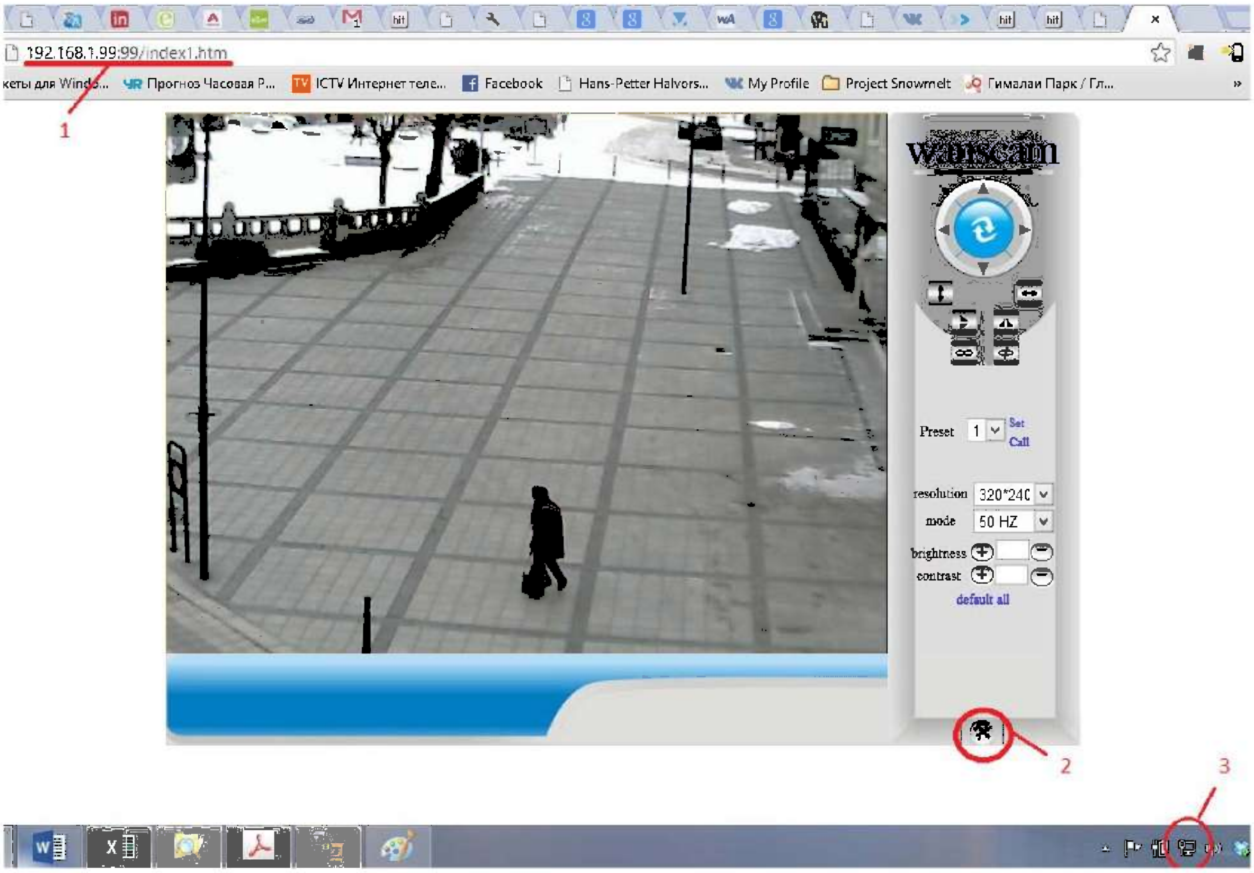

Figure 4-5 Screenshot of the pictures from the cameras that show proper connection

Where:

1- IP address of the camera
2- Setting button
3- Indicator which show correct connection

For further settings should be pressed Settings button. In appeared window it was written all information about school sever, where all pictures were sent. As it seen from the Figure 4-6 chosen time interval was 900 seconds which is approximately 15 minutes. Ftp Upload folder were chosen different for each cameras for better analyzing.

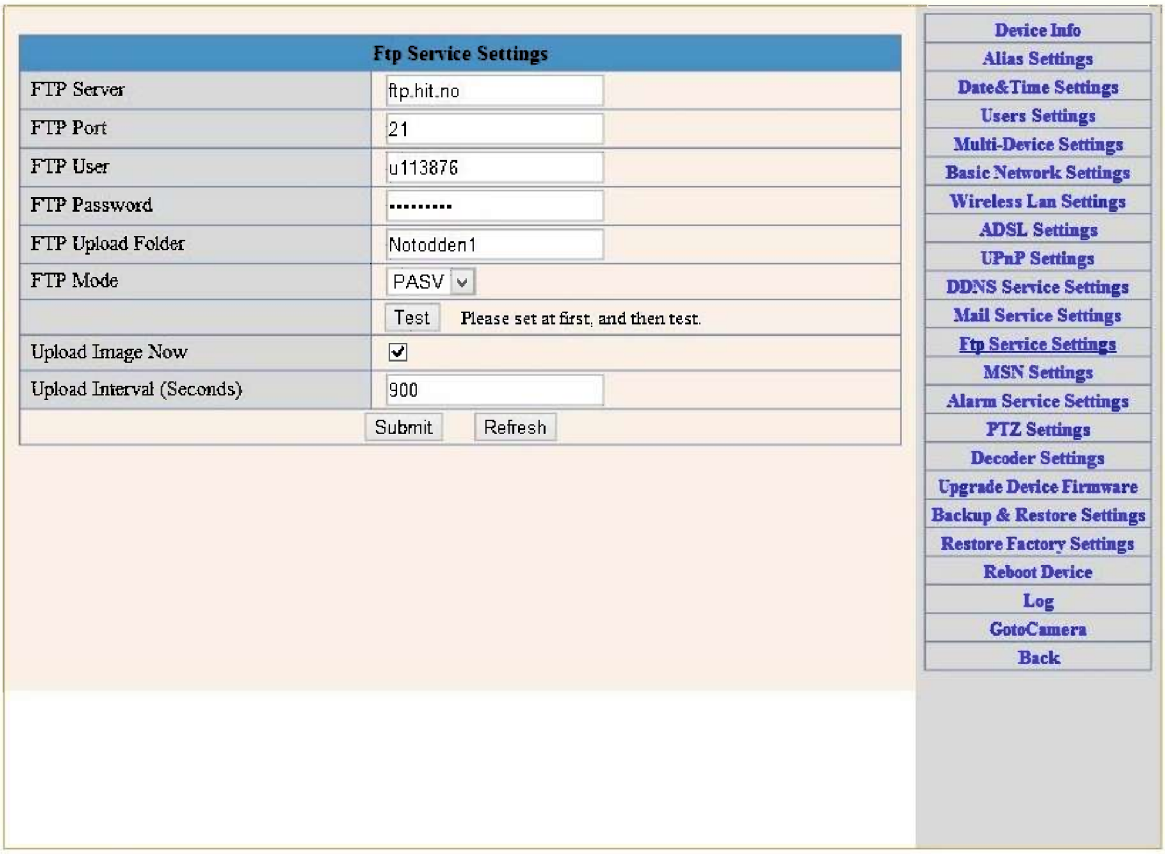

Figure 4-6 Cameras setting menu with all relevant settings

5 Observations

For this project, observations were done from the end of February until mid of April. The major task before observations was to choose equipment and its installation. In a period of choosing cameras was a possibility to get snapshots from the camera, which was installed by local newspaper. After sending them information about server, it was given access to the snapshots from the camera, but for some reasons after small sending period camera started to send pictures with bugs. These bugs were as just a half of the pictures and with the time of last good picture. When cameras were bought, installation was done to show two directions. First was on the problem part of the street where respond time is the biggest and second was installed to make observations of the street and pavement. Snow melting process provided in the Figures below. These snapshots helps for better understanding of drawbacks of the system. For first few Figures, which were taken from Varden weather conditions were 5mm of snow and -5 ^{o}C of air temperature. For Figures, which did installed cameras weather conditions were -4 ^{o}C and around 3mm of snow precipitation.

Figure 5-1 Snow precipitation on 15th of March. Problem part of the street. Vardens camera

Figure 5-2 Vardens camera. When snowfall is over

Figure 5-3 Vardens camera. Start point of snow melting

Figure 5-4 Vardens camera. After 8 hours of snow melting

Figure 5-5 Vardens camera. Snow melting process after 30 hours of melting

Figure 5-6 Camera on the problem part. Snowfall on 20th of March. Precipitation period at 20:05

Figure 5-7 Camera on the problem part. Maximum level of the snow at 21:50

Figure 5-8 Camera on the problem part. Start of melting period at 00:20

Figure 5-9 Camera on the problem part. Melting process at 02:35

Figure 5-10 *Camera on the problem part. Melting process at 05:50*

Figure 5-11 Camera on the problem part. Melting process at 10:35

Figure 5-12 Camera on the street. Precipitation period at 20:05

Figure 5-13 Camera on the street. Maximum level of the snow on the ground at 21:50

Figure 5-14 Camera on the street. Start of melting period at 00:20

Figure 5-15 Camera on the street. Melting period at 02:35

Figure 5-16 Camera on the street. Melting period at 05:50

Figure 5-17 Camera on the street. Melting period at 10:35

6 Results

During observation period, it was found that system has drawbacks and heat losses through the street surface. As it is seen in Figures 6-1 and 6-2, snow on the driveway disappearing much faster compare to pavement and problem part of the street.

Figure 6-1 Driveway is clear from the snow while the is still on the pavement

Figure 6-2 System is off and street is almost clean

6.1 Losses

This can be explained by splitted systems of the pipes and less heating area of the driveway is compare to pavement. According to Figures 6-1 and 6-2 and doing time analyze, the difference in time between clean driveway and when system is off is around 8 hours. Take it to account this street has around 8 hours of losses. Earlier before it was done research by Nosk Energi where the found that average amount of heat delivery per m^2 in Norwegians snowmelt systems is 250 W/m^2. Assuming that the driveway area is approximately 680 m^2 we can calculate average amount of losses when driveway is dry. Calculations where done by following formula:

$$Q = q \cdot S \cdot t \qquad (6.1)$$

Where,

Q - total heat losses per operation period, kWh

q - amount of heat delivery, W/m^2

S - total area of the driveway, m^2

t - time difference between dry driveway and system is off, h

Economic calculations were done by following formula:

$$Cost = Energy[kWh] * Price[\frac{NOK}{kWh}] \qquad (6.2)$$

Making simple calculations, we are getting 1.36 MWh loses during taken snowfall. According to that price of energy are 0.65 NOK/kWh for oil and electricity or 0.23 NOK/kWh for woodchip. Calculation of cost of losses will give us 313 NOK for base loads and 884 NOK for observed part of the street. One of the way to reduce losses is to closing vessel which controlling flow to the driveway. Reducing amount of the flow to the driveway mill smooth difference in melting time between different parts of the streets. As all vessels manipulated manually, it should be done real time experiment with different conditions of the vessels. In addition, to reduce amount of heat losses one of the suggestions will be to turn system off 3 hours earlier that will give a possibility to save approximately 1.35 MWh just for observed part of the system. Cost of losses for total part of the street with pavement will be 877 NOK for peak loads and 310 NOK for base loads. Research done by Canadian student shows that street has possibility to store energy and drying long time of operation system has losses. With turning off system 3 hours, earlier snow will melt with the energy, which was accumulated in the ground.

6.2 Snow cover of the surface

Along snow precipitations, snow cover all surface slightly during short time period. Figure 6-3 shows how much area in percentage covered by snow during operation period from 15th till 16th of March. To build this graph as a start point was taken time before snowfall when surface is clear of snow. As it seen from the graph snowfall was during 4 hours and all this time it covered surface up to 95% other 5% were clear because of morning time human activity. From the beginning of the snowfall system started to heat up ground and temperature reached 0 ºC on the surface at 5hour of operation period. From this moment system started to melt snow on the surface. Overall operations period was more than 40 hours. After 40 hours of operation street was clear and dried.

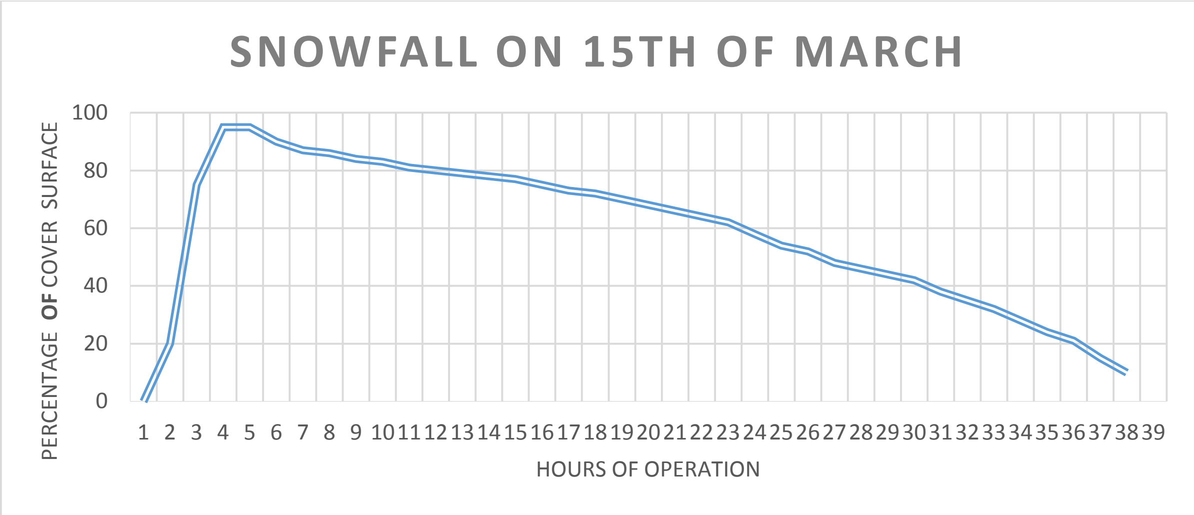

Figure 6-3 Graph of snow coverage on the surface on 15th of March

During observation period were two snowfalls. Results of the snow coverage from the second snowfall demonstrated in Figure 6-4. As it seen from the graph, which is more detailed because of time step in 15 minutes, that snowfall continue even after system started to melt snow on the surface. This can be seen on a graph between points 10 and 18 where we have a small drop in surface coverage. After 19 step snowfall stopped and system started to melt snow on the surface. Overall operation period took 16 hours. 3 hours was taken to heat up surface and to start melting snow. Lover response time and operation period can be explained by higher surrounding temperature and less precipitation compare to previous snowfall.

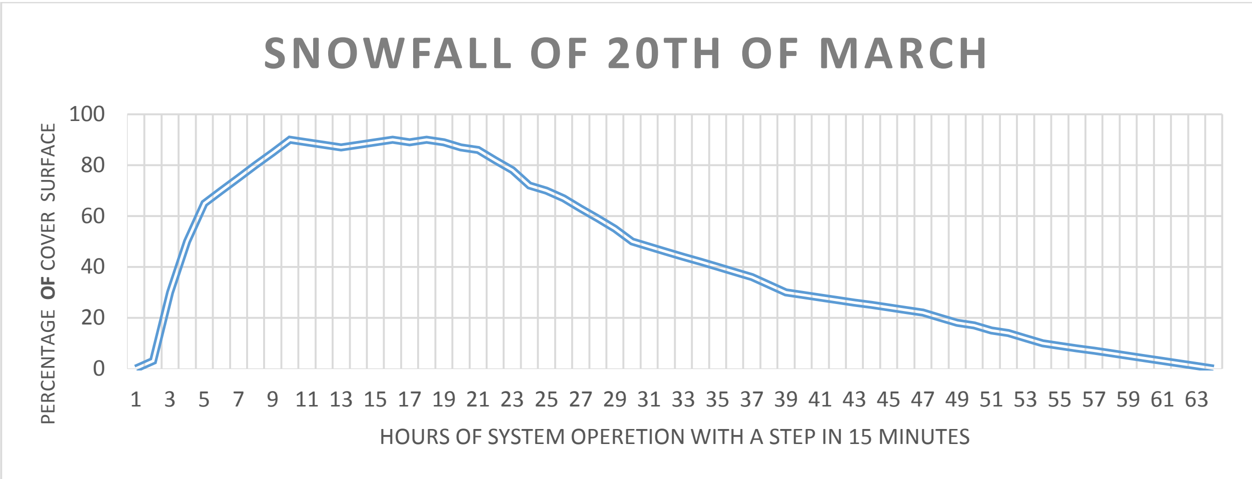

Figure 6-4 Graph of snow coverage on the surface on 20th of March

6.3 Heating ground

To understand the difference in respond time it better to make calculation of how much energy is needed to heat up the ground:

$$Q_g = c \cdot m \cdot \Delta T \qquad (6.3)$$

Where,

Q_g - energy which is need to heat up the ground, kJ

m - mass the is need to heat up, kg

c - heat capacity of the ground, J/kgK

ΔT - temperature difference, K

Assuming that we have area in 1 m^2 and taking to account that ground consist of three different layers is it possible to make calculations for amount of energy which is needed to heat up the ground by using properties of the ground from Master thesis of previous year (Lyseng, 2012). All result of calculations demonstrated in the table 6-1. Street properties are demonstrated in Appendix 3.

	Thinkness , mm	Density, kg/m3	Specific heat, J/kgK	Volum, m3	mass, kg	Q, kJ
Paving stone	100	2500	1000	0.1	250	1250
Sand	50	1500	1200	0.05	75	450
Asphalt with pipes	50	1500	920	0.05	75	345

Table 6-1 Energy consumption calculations for the ground

By summering energy consumptions for different layers total energy consumption for the 1 m^2 of the ground will be 2045 kJ to heat up the ground from -4 °C to +1 °C. According to this it is possible to calculate how much time it will take to heat up the ground if heating energy is 250 W/m^2 or 250 W for given situation with 1 m^2. To calculate the time it use following formula:

$$t_h = \frac{Q_g}{P} \cdot 1000/3600 \qquad (6.4)$$

Where,

t_h - time to heat up the ground, h

P – power that is heating the ground, W

After doing simple calculations result for the time will be 2.2 hours to heat up 1 m^2 of the ground. Which seems reasonable according to real time graphs.

7 Discussion

This work was part of a project to optimize the district heating system. One of the tasks of the work was to synchronize the data from heat central and video observation. Due to the fact that part of the sensors has been installed for the first time, after installation there were only two snow, so correctly and accurately synchronize the system was not possible. It was also revealed that the company Siemens, which is engaged in the installation and configuration of software for Termokraft AS treated only some information about the system. While in the online mode, the control system can receive detailed information. All the basic data is temperature data from different parts of the street. After identifying a lack of data and a request to obtain data on the flow rate and the amount of heat transferred, the company began to store the data on the server, but unfortunately due to the end of the snow season it was not snowfall. Because of this reasons It was suggested to conduct an experiment and turn the system at sub-zero temperatures. Temperature data is summarized in Table 7-1. The data show that at low temperatures, as well as clean snow from the streets, the system needs a half hour to heat the surface of the street above 0 ^{o}C. The experiment was filmed temperature readings s several different points of the street, such as roadway, sidewalk and problematic part of the street. These temperature differences and different rates of heat transfer from the pipe to the surface. One embodiment of this effect may be the difference of coating materials and their thickness. Some temperature are grooving not slightly, which can be explained by taking measurements from different points. Some places had influence of the sun that heated just a surface of the ground. Given assumption requires a more detailed and laboratory research.

Time	Pavement	Driveway	Problem part
9:00	-0.6	0.4	-2
9:30	-0.5	0.4	-1.7
10:00	-0.4	0.5	-1.5
10:30	-0.8	0.8	-0.9
11:00	2.6	3.4	1.0

Table 7-1 Temperature data from the experiment

During the observation expected a slight difference between the time the snow melts on the affected areas and the main part of the street. As shown in the figures, the main difference is the melting of the snow between the sidewalk and the roadway. As this site was chosen because of its specificity and a long process of snow melting studies have shown that the difference lies in the difference between the heated areas of the territory supplied by the same thermal load. To solve this problem, we propose to tighten the valves readings when the system will run smoothly, thus reducing heat loss through a dry roadway.

Another solution to reduce heat losses can be turning off system 3 hours earlier, if there is no predicted snowfall. This solution will reduce heat losses and utilization time of the system. Heat that is accumulated and stored in the ground will be used to melt rest of the snow on the surface. These proposals require experimental verification.

8 Conclusion

Snowmelt system in Notoden is the biggest costumer for district heating system. Optimization of snowmelt system will reduce total energy consumption of all district heating system.

The report was done to show real time process of melting snow in order to use system in on/off regime. Observations showed that system has a huge drawback in heat losses through the street surface. There is a huge difference in time between the point when driveway is dry and system is turned off. Difference in heated area for pipes system can be as explanation for time difference. Heat central has splitted pipes system after pump. A smaller area of the driveway get the same amount of heat as bigger pavement area. To reduce heat losses and to make smoother melting period, vessel on the driveways should be partly closed. This manipulation will give less heat flow to the driveway pipes system and make melting on the street surface slighter. With reducing heat losses through the driveways it is possible to save up to 884 NOK for peak loads or 313 NOK for base loads on the observed part of the system.

Different strategies, which were suggested in the previous project, can be observed by using same equipment and installation parameters as it used in this project. Manual how to setup cameras was provided for easier and fast installation. Observations of different strategies will help better understand which regime is more efficient.

References

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Appendices

Appendix 1: Project task description

Appendix 2: Cameras properties

Appendix 3: Material properties of street construction

Appendix 1: Project task description

Telemark University College
Faculty of Technology

FMH606 Master's Thesis

__Title__: **"Improving snow melt systems energy performance"**

__TUC supervisor__: Prof. Wilhelm Rondeel, TUC

__External partners__: Andreas Faye, Thermokraft AS

__Task description__:

Snow melt systems represent a relatively large consumer of energy in a number of district heat operations in Norway.
One such operation is located at Notodden, operated by Thermokraft AS.

Based on physical modelling and new (to be installed, as part of the project) field observation, an operational procedure for optimum economic operation of a street/pavement snow melt system shall be developed.
Statistical weather data and earlier operational experience, together with new field observations in the winter months January – February – March 2013, is expected to be the most important input parameters in the study.
The field observations will have to be based on new sensors to be installed (partly temporarily) in the system. The selection and installation of these may be an important part of the task.
One of the possible options is to utilise optical observations by Web – cameras, together with direct monitoring of supplied energy to the observed area.

A literature survey might provide useful data and knowledge.

__Task background__:

Experience from installed snow melt systems has shown that as little as 5 to 10 % of the heat input is actually necessary to melt the falling snow. In addition total heat consumption of the street heating seems to be better correlated with outside temperature than amount of snow registered during the same period. These observations may indicate that it may be possible to

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cut energy consumption substantially when a better understanding of how the system functions has been obtained.
Thermokraft AS is a district heating system supplying a number of larger customers in central parts of the town Notodden with heat. The annual heat delivery is about 15 GWh, expected to grow towards 20 GWh within some years.
Installed base load capacity, a wood chip burner, is about 4.7 MW.
Energy supply to the snow melt systems amount to about 3 GWh annually, and the installed capacity for the snow melt is about 3.5 MW.
The snow melt installation is expected to increase by 50 % in the near future.

Student category:

PT and EET students

Practical arrangements:

Access to the Thermokraft installations at Notodden will be secured, as well as provision of data from the operation.
The installation of new sensors or cameras in the snow melt area will have to be made in cooperation with Thermokraft personnel.
All data concerning the installation, the pipeline distribution system, customer based heat centrals (with heat exchangers) will be available.

Signatures:

Student (date and signature): 31/1-13

Supervisor (date and signature): 31/1-13

Appendix 2: Cameras properties

Specification

System Security:	Supports there-level account, password, user authority management
DDNS:	Free DDNS bounded i.e., http://demo.88safe.com
Cell Phone View:	Support Iphone,Windows Mobile,Symbian,Android cell phone view.
Signal System:	CMOS 300,000 pixel
Frame Rate:	25fps
Resolution:	VGA(640*480), QVGA(320*240)
Video Adjustment:	Brightness and contrast adjustable, Auto White Balance, Auto Backlight Compensation
Lens Standard:	6 mm
Nightvision:	36Φ5 LED IR distance: 20m
Network Interface:	RJ-45 10/100Mb self-adaptable Ethernet slot
Wireless:	WIFI,802.11 b/g
Protocol:	Support TCP/IP,HTTP,ICMP,DHCP,FTP,SMTP,PPPoE etc.
Online Visitor:	Support 4 visitors at the same time
IP Mode:	Dynamic IP address, Static IP address, PPPOE
Shape:	Use Environment Gun type : Waterproof outdoor use
Power:	DC12V 1A
Working Temperature:	-10~50 °C
Working Humidity:	95% RH
Item size:	175mm x 74mm x 84mm (LxWxH)
Packaging size:	200mm x 120mm x 179mm(LxWxH)
Weight N.W.:	650g G.W.: 980g(Note:Actual Weight Final)
Accessories Adaptor:	CD(including manual), Bracket, Screw
Alarm Detection:	Motion detection ,Motion Detect Sensibility can be adjusted
Alarm Action:	Support Email photo, FTp photo etc.
System Requirement:	Microsoft Win98 SE/ME/2000/XP,Vista,Win 7,
Browser:	IE6.0, IE7.0, IE8.0, FireFox,Google Browser or other standard browser

Appendix 3: Material properties of street construction

	Thickness [mm]	*Density [kg/m^3]*	*Specific heat [J/kg·K]*	*Thermal Conductivity [W/m·K]*
Paving stones	100	2500	1000	1.4
Sand	50	1500	1200	1
Asphalt - with pipes	50	1100	920	0.75
Asphalt - lower	80	1100	920	0.75
Crushed stone - small	50	1500	800	0.2
Crushed stone - large	470	2000	1000	0.2