The Role of Electric Snowmobiles and Rooftop Energy Production in the Arctic: The Case of Longyearbyen

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***Abstract*—The research presented here has been conducted in the Smart Charge project. It has addressed the use of renewables, e-mobility and battery charging in the Arctic as part of an effort to solicit fossil-fuelled alternatives. Of particular interest has been to determine what impact and support electric snowmobiles can provide together with local, renewable energy production. The relevance of vehicle-to-grid/building (V2G/B) solutions have been investigated in the project too. The idea has been to use electric snowmobiles for load shaving during extensive periods of the year. The research has looked at cost aspects, value stacking, climate impact as well as aggregated effects of controlled fleet management of idle snowmobiles. A case study undertaken at Longyearbyen at Svalbard, Norway has provided the most important empirical basis for the research presented. The research concludes that electric snowmobiles can have a positive effect on the local energy system and despite limited range can be quite attractive for the individual to operate if energy for charging is based on local driving solar power.**

***Index Terms*—Arctic, e-mobility, forecast, LSTM, smart energy.**

I. Introduction

Communities in the Arctic are scattered and subjected to harsh climate conditions. Very low temperatures, strong winds and tough snow and ice conditions dominate several months of the year. Infrastructure is often poor and vulnerable to shifting weather conditions. Several communities find themselves with no connection to a regular power system and therefore need to rely on local generation of heat and electricity based on fossil fuels. Drivable roads and navigable seaways are often accessible only during parts of the year. In the less populated areas transportation is often dependent on terrain vehicles and snow mobiles rather than regular cars. Up to now diesel and gasoline have been the only fuel options. Multiple studies and government initiatives have addressed the needs for a transition to non-fossil alternatives for heating, lights and mobility alike [1], [2]. A strong impetus exists for making a transition to new energy and transportation solutions which must be more climate friendly and robust, less costly and can help these communities to maintain a standard of living that is comparable to regular city life. One, obvious direction is electrification based on renewable energy sources by means of local generators. Due to the latitude the summer period lasts only for a short period, typically through the months of June. July and August. However, already in March or April the same communities may experience 24-hour daylight. This provides a potential for Photovoltaic (PV) generation in addition to wind-based production during the darker winter periods. In recent years electric terrain vehicles and snow mobiles have been introduced in the market both in North America and in Europe. Although not a common site, the operation of electric snowmobiles can be witnessed both at Svalbard and the northern parts of Norway, Sweden and Finland. With this background the Smart Charge project was initiated.

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II. Problem Description

The basic ambition has been to investigate how a transition from a fossil fueled regime to a renewable could be enabled. Like in many other parts of the world local rooftop production and e-mobility have gone mainstream as part of the growing « green shift ». Since Arctic communities are dependent on a reliable energy supply and dependable transportation to survive, perhaps more than other communities in the world, it is relevant to ask whether electrification based on local, renewable supply can be the full or a significant part of the answer.

The development of electric snowmobiles has been the focus of research for more than a decade [3], [4] and recently electric snowmobile models have entered the market [5], [6]. The research reported here has looked into the potential effects of this type of electric mobility and how this can provide the necessary support for Arctic communities. Associated with this are concerns related to extensive battery charging and what impact it can have on the local energy system. Several initiatives to replace or to reduce reliability on petroleum and coal in the Arctic have been documented in other research [7]-[12]. The typical focus has been to create some kind of cogeneration between diesel based generators and solar power in small and more extensive microgrids. In the research presented here the possibilities for a symbiosis between transportation and a local energy system with renewable sources have been investigated. In association with this it has been relevant to ask how electric vehicles can serve as an asset, not only as a load, to the local energy system in the Arctic. Two-way flow of electric energy promises a reciprocal relationship between the local energy system and vehicles. Capacity issues will always be an issue in smaller energy systems. As a result power management is an important requirement. This implies leveling out peak loads. How can electric snowmobiles offer the necessary energy flexibility? And more specifically, how can snowmobiles as mobile batteries be mobilized to yield economic and emission benefits? The investigations conducted have provided insight that answer these questions

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in part or in full.

III. Method of Approach

A. Smart Charge in Finland and Norway

The research which has been undertaken have been based on on-site metering and empirical analyses supported by simulations to determine the scalability of the findings. Data has been gathered from different locations in the Arctic, including Longyearbyen at Svalbard in Norway and the Rovaniemi region in Finland. Emphasis has been placed on the former for the work presented here. Data scientific methods to analyse extensive sets of time series to determine seasonality and to be able to predict extraordinary peak loads has also been applied. This was meant to facilitate load control and energy management at different levels. The basic method used here was the LSTM method [13]. The details around this part of the research is available in a separate publication [13]. The site studied at Svalbard encompasses local production facilities with rooftop photovoltaic panels (PV). This system is connected to the central legacy energy system in Longyearbyen, which is based on coal. In addition, this site also operates a suite of electric snowmobiles that are charged on location. The full set of facilities have provided an important case study with on-site measurements for a period of twelve months. Despite the impact on activities due to Covid-19 pandemic the data collected have provided reasonable substance to draw some conclusions.

B. The case of Longyearbyen

Longyearbyen is located at Svalbard 1260 km north of the mainland of Norway. Key data for this small Arctic town can be seen in Table I. Longyearbyen has less than 2200 permanent residents. During a normal year, the influx of non-permanent visitors can be as high as 30.000. Svalbard has a long history and has historically prospered on hunting, whaling, and trapping. In the past century coal mining has been a significant source of wealth for the local community and the mining companies that have operated there. But since the last decade coal mining has been politically discouraged. Svalbard and people in Longyearbyen are looking elsewhere to secure a living. Tourism is emerging as a significant alternative. Arctic safaris have become popular. The most common means of transportation for safaris and for daily transport are snowmobiles. There are more than 2000 snowmobiles registered at Svalbard. A few can be found in small settlements in other places at Svalbard, but the bulk of them are located in Longyearbyen. From May to October most of them are left idle until the first snowfall in the autumn allows their use once more (see Fig. 1).

TABLE I: Key Data for Longyearbyen at Svalbard

Geographical data		**Energy related data**	
Location	78°13'23"	**Energy supply concept**	Coal fueled + diesel fueled reserves
Population	2144	**Power plant peak capacity**	28MW (16MW thermal & 7,5 (11) MW electric)
Number of residential units and other buildings	App.1500	**Genset capacities**	App. 8,5MW electric
Average temperature Nov-Mar	-13,5 C	**Total capacity**	16MW
Average temperature Apr- Oct	-0,6	**Annual CO2 emissions**	450.000 tons
Days of 24-hour daylight	125	**Annual SO2 emission**	1.250 tons
Days of 24-hour darkness	79		

Fig. 1. Snowmobiles are parked idle in Longyearbyen during the summer period.

Mining activities and administrative needs have demanded a minimum of roads to support local transportation (less than 45 km). But almost all transportation is still gasoline or diesel based. One argument for resisting a transition to electric mobility, in contrast to the developments on the Norwegian mainland is that the local energy supply is still dependent on coal and diesel. There are limited climate gains if electric vehicles charge with energy generated by fossil fuel. The main energy supply supports both the local district heating system and the local supply of electricity. It can be considered a microgrid with a theoretical peak capacity of 11MW. But due to operational and technical limits the actual ceiling is as low as 7,5MW. The coal fueled plant is supported by reserve/peak load power in the form of diesel gensets providing up to 8,5MW.

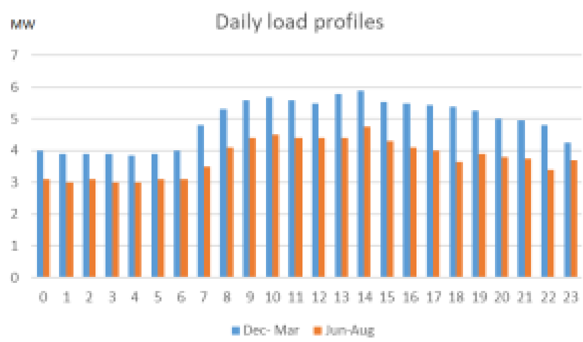

Fig. 2. The graph above shows average hourly loads per day in the local distribution grid winter (blue bars) and summer (orange bars). Y-axis is in MW. (Source: Longyearbyen Lokalstyre).

These gensets are often used, because of operational issues with the central plant. Coal and diesel combined make the Longyearbyen citizen one of the worst polluters in the world. The average demand per hour on an average day is shown in Fig. 2. The winter demand per hour is approximately 2-2,5 MW higher than the summer demand. During summer a ridge between hour 7 and hour 17 can be noted. During winter, a similar ridge extends further into later hours. Electric energy is charged per kilowatt hours (kWh). The general tariff is NOK 2 per kWh (app. €0,2) for all consumption below 10.000 kWh per year. For consumption above 10.000 kWh the price is NOK 2,2. Annual consumption above 50.000 kWh has a unit cost of NOK 2,40. On a general scale these prices are more than twice as high as those for the rest of Norway.

TABLE II: THE PV CONFIGURATION AT HS

PV panel section	Surface	Tilt	Azimuth
1	Horizontal	20	221
2	Horizontal	20	201
3	Horizontal	90	200
4	Horizontal	45	242
5	Horizontal	20	110

C. Point of Study

Although data was gathered from different sites the primary point of study was the headquartes of Hurtigruten Svalbard (HS) situated at the waterfront of Longyearbyen. The facilities at HS encompass a solar panel consisting of five separate sections (Table II) covering 106 m2 of roof top area. HS has also bought a fleet of eight electric snowmobiles typically referred to as eSleds. These snowmobiles were put into operation late 2019 and are meant to be used for tourist safaris. HS is aiming to take a lead on sustainable tourism and is pioneering both local production and e-mobility in the Arctic. As a part of their sustainability ambition HS wants to use snowmobiles as instruments for energy flexibility and local reserve power too. In that context Smart Charge addressed the application of two-way flow of energy both when parked at the depot and when out on safaris, when located at camps and small lodgings. Since electric snow-mobiles, like all others, will be parked and left idle for multiple months when the snow is gone in spring they could be considered regular batteries connected to the local grid or the HS buildings. This opens for dual purpose operations that can increase the capitalization factor on investment in snowmobiles and make a positive impact on the operation of the local grid. Key data for HS is shown in Table III. An initial idea was to define a control mechanism to optimize operations at HS and include the snowmobiles as an active set of energy buffers to accumulate surplus local production and use this later. It became evident early that this would be irrelevant. From Table IV it can be seen that imports dominate and would do so even with exceedingly bigger production capacity. Without time-of-use (ToU) pricing or capacity tariffs, shifting consumption within the context of HS, yield no rewards. However, for the purpose of reduced climate emissions it should make sense. The eSleds, were equipped with telemetric devices that allowed the capture of different types of data both when driving and when at rest. This allowed analysis of the state-of-charge (SOC), the state of the charger, battery temperature and degree of heating to keep the battery warm. Due to the novelty of the snowmobiles some metering problems were experienced. This caused some issues and data washing was required. Assuming that the results from HS would scale up to community level an analysis of the aggregated impact was also conducted.

TABLE III: KEY DATA FOR ESLEDS AND HURTIGRUTEN SVALBARD HEADQUARTES

HS prosumption		Snowmobiles (eSleds)	
PV panel capacity (kWp)	19,2	**Model**	Aurora eSled-A03
Wind generator		**Range (km)**	<= 35
Yearly electric energy consumption	179.000	**Peak power (kW)**	80
Yearly production - PV (kWh)	9.100	**Battery type**	Li-Ion
Net production capacity kWh/year/kWp	470	**Battery capacity (kW)**	9,3
Imports September-March	App. 99%	**Charging Power (kW)**	6,6
Imports April-August	App. 90%	**Vehicle plug**	Type 2
		Charging time up to 95%	1,5 hrs

IV. FINDINGS AND ANALYTIC RESULTS

A. PV Generation

The monthly yield is shown in Table IV. Aggregated, the performance of the panel reached 470 kWp/year for 2020. As expected, the production during the period between November to February was very little or nil (see Fig. 3). The best PV production period was in the month of May.

The 19,2kW panel was in no way capable of covering the local consumption. Imports were always very high. Only less than 1.5% export of the local production was ever fed into the local distribution system. Even during the prime summer months less than 10% surplus was exported. Therefore, the local production reduces the base load only. The modest yield, however, generated 18.000 NOKs in cost savings for 2020. This pay-off is comparable to that of regions in the southern part of Norway. The CO2 savings are significant as the local production defer imports from the gensets, and the coal fueled plant. Another observation that can be made from Fig. 3 is that the PV alone can hardly support the charging of more than one eSled at full power (6,6kW).

TABLE IV: PROSUMPTION AT HS

Month	Temperature	Production (MWh)	Consumption (MWh)	Potential CO2 savings (kg)
January	-14,6	0	16,2	0
February	-15,2	0,00177	14,9	1,68
March	-14,5	0,05532	11,24	52,55
April	-11	1,07	12,27	1016,50
May	-3,1	2,18	11,8	2071,00
June	2,9	1,93	12,8	1833,50
July	6,5	1,8	13,3	1710,00
August	5,2	1,51	14,8	1434,5
September	0,5	0,41462	15,72	393,89
October	-5,5	0,04692	17,18	44,57
November	-10,2	0	17,4	0
December	-12,9	0	21,6	0
For all 2020		9,00863	179,21	8558,2

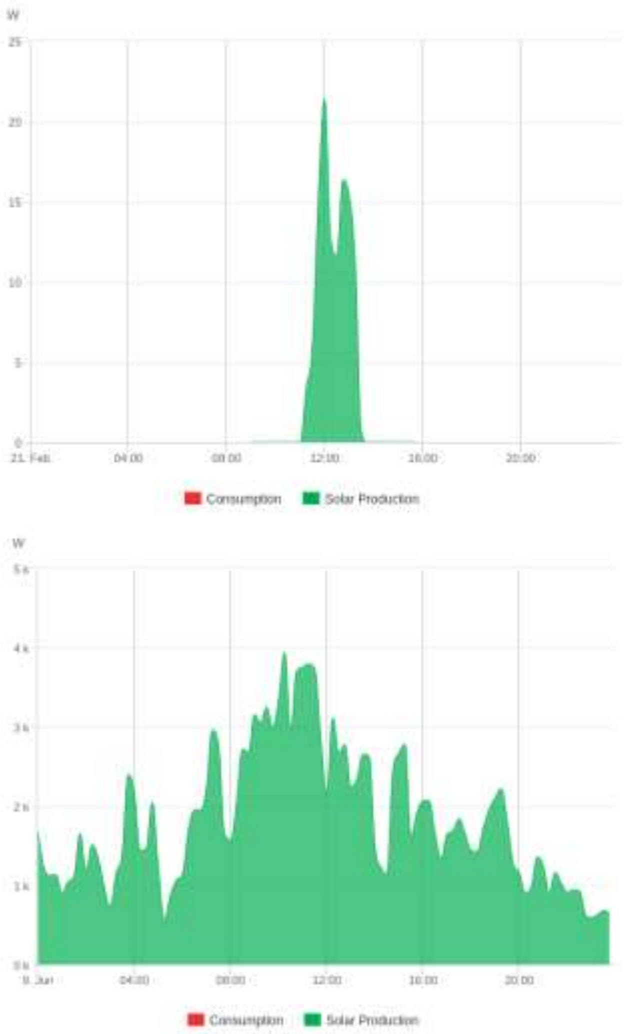

Fig. 3. Production profiles for February 21(upper) and June 9, 2020 (lower). Note the yield at midnight on June 9.

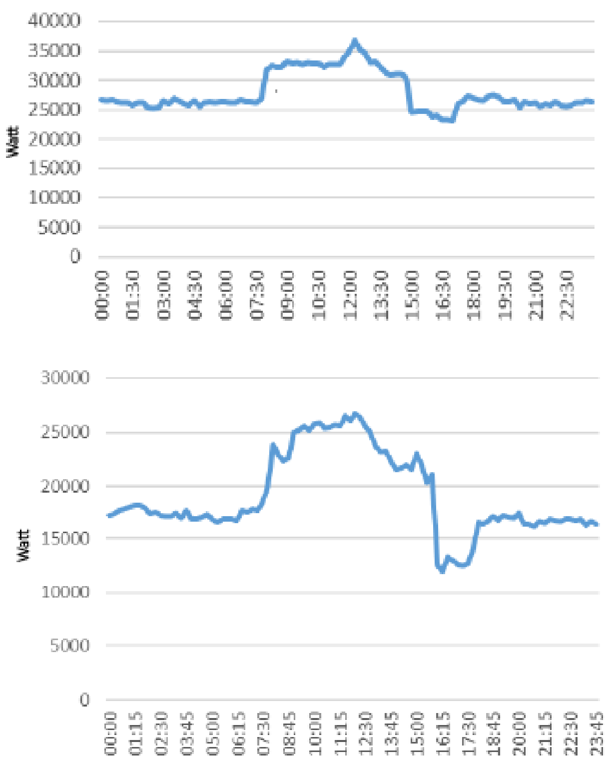

Fig. 4. Average consumption profiles per day for the HS complex. Winter (upper). Summer (lower). The y-axis represents Watts.

B. Consumption Patterns

The average consumption profile per day for the months of January, February, November and December 2020 is shown in the upper part of Fig. 4. The base load is high throughout the day with a ridge stretching from 7:30 in the morning to 15:00 in the afternoon. A similar profile for the summer months shows a much lower base load, but with a distinct peak during the same hours, a peak which is about 75% of the winter maximum. This consumption pattern aligns well with the overall pattern for the whole of Longyearbyen as shown in Fig. 1. Hence, it supports the assumption that the daily consumption profile at HS represents the mainstream consumption pattern for the community. By extrapolating on this experience, the aggregated effect of PV installations for the broader community can better be inferred.

C. The eSleds and Their Use

The eight *eSleds* were procured to support sustainable tourism in the Arctic. Despite some initial technical issues in the beginning of our investigation sufficient data was collected to determine the distribution of loads across the day and their daily and seasonal use. As with traditional snowmobiles these eSleds were also parked idle after the snow was gone. The behavioral patterns observed were likely influenced to some degree by the pandemic during the period of observation due to lower activites than usual. However, records were collected that still suggested patterns of interest. The rate of discharging during use and when parked was established. Charging and charging time could also be ascertained. The patterns of use per eSled varied considerably.

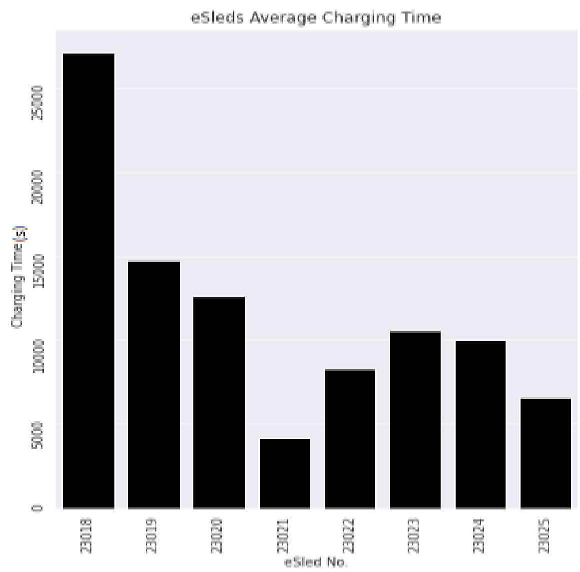

Fig. 5. Charging times per eSled

The average drive was less than an hour. The maximum use recorded was approximately 1,5 hour and the minimum around half an hour. The latter suggests that some of the eSleds were parked at the depot for a substantial period of time. The consumption rate for the average eSled was 0,26 kWh per kilometer. This suggest that a 1,5 hour drive at around 50 km per hour would deplete the battery. Consequently this means that the practical use of the eSleds were limited to short range service trips and short distance excursion at Svalbard. The eSleds require frequent recharging of the batteries if used much. Fig. 5 shows the average charging times per eSled. The uneven distribution of use that this reveals supports the notion that eSleds may be fully charged and be stationary for longer periods of time. Though, a normal year the tourist season is likely to demand more frequent services by each eSled. However, the uneven use and lessons from urban e-mobility at large indicate that electric snowmobiles may be parked fully charged for major periods of the day even during the winter. It should also be noted that a fully depleted battery reached 100% SOC (staste of charge) in approximately one and a half hour of charging. Hence, disregarding battery degradation multiple charge/discharge cycles per day is possible. This is relevant in the context of V2G/B.

D. Economic Assessments

In addition to the limited range the capital investment in snowmobiles and their operating costs need to be taken into account. An obvious benchmark is the procurement and operational cost of gasoline driven snowmobiles. Due to limited and early editions of the snowmobiles studied only operational costs made sense to emphasize. The purchase cost for the eight eSleds for HS was high, but the manufacturer anticipated that the cost would reach parity with regular snowmobiles as production is ramped up. But that provided no firm reference. Comparison of fuel costs per kilometer for a gasoline driven vehicle versus cost of charging was more meaningful. The result is shown Table V.

TABLE V: COMPARISON: SNOWMOBILE ECONOMY

Type of snow mobile	**Size and charging type**	**Cost/ km (NOK)**
Petroleum driven	Small	1,1-1,2
	Medium	1,5-1,6
	Big	2,1-2,3
Electric	Small - charged by main supply	0,6 – 0,7
	Small - charged by local supply. Capital costs for PV included	3-5
	Small - charged by local supply Capital costs for PV not included	0

The cost for the PV panel was depreciated over 15 years with a 2% interest rate. Even with an extended payback time the operational cost using the local supply becomes high when converting the investment to cost per kilometer. But to be noted too, the cost savings for 2020 observed equals the fuel cost for gasoline powered snowmobiles that accumulated to 15000 km driving per year. Electric snowmobiles with the same milage and charged with solar power would essentially operate for free. When excluding the capital costs of the PV investments the operation of the eSleds and similar vehicles become very attractive. Even when « alternative cost » (prioritizing charging against other types of consumption) is taken into account the operating cost of snowmobiles can be estimated to 0,54 NOK per km, which is still attractive. In addition the emission reduction in terms of CO2 and SOX will be signficiant. The transition to e-mobility without local, renewable production obviously makes no or only marginal climate gains.

E. The Energy Flexibility Potential

The different findings described above were synthesized to determine the potential use of the eSleds as instruments of energy flexibility. To escape a possible extra load on the local system, which would result in added imports from the central plant the electric snowmobiles should avoid charging during the periods 08 :00 to 15 :00 hours during the wintertime and between 08 :00 and 16:30 during summer (see also Fig. 6). Charging in the period between hours 7 and 17 should be avoided.

To determine the required capacity to handle peak shavings two things should be taken into account. One is the power reduction in kW. The other is the duration of that specific reduction. The area encapsulated by the duration and the difference between the current peak or ridge and the ceiling set determines the minimum energy requirement i.e. for a battery. This can be found numerically with the following equation:

$$Capacity \geq \sum_{t=1}^{T} P_t - Ceiling \quad (1)$$

Here T is the required duration, typically measured from 10 minutes up to one hour intervals, depending on the time resolution. Ceiling is the target maximum power limit that should be maintained during T. P_t is the measured load without the curtailment. To take out the average ridge, shown in orange in Fig. 6, 11.6 kWh of energy and approximately 3kW of power is needed. To increase the gain and eliminate the average hump approximately 45kWh are needed. That shaves off 8kW. Assuming that 60% of the battery capacity can be exploited, the eight snowmobiles together can achieve that reduction. That means reducing the load on the local system during midday and maintaining a stable load level of approximately 20kW. Applied without local production load shifting, not peak reduction, would provide the only gain.

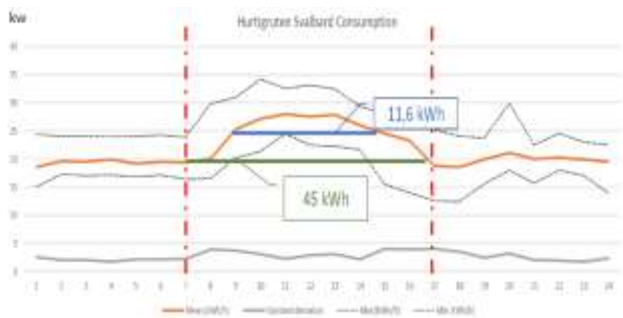

Fig. 6. Average energy use per hour for a whole year including variations (max/min). The lower grey line represents the standard deviation. Y-axis represents kW.

F. Load Prediction

The LSTM method (see Fig. 7) proved to be quite reliable for load predictions with an hourly forecast horizon and would therefore be relevant for a real-time control regimes to manage peaks [13]. Multi-step predictions (up to 30 hours) for longer look-aheads proved to be sufficiently reliable to support the mobilization of V2G/B resources. This provides support for timely operation of a V2G/B regime where use of snowmobiles to some degree can be adjusted to the forecasts produced. The long-term predictions can be used to prepare a critical mass of eSleds or other types of snowmobiles in due time. The short term predictions would enable mobilization and connection of the necessary units for initial curtailment of a peak or a ridge.

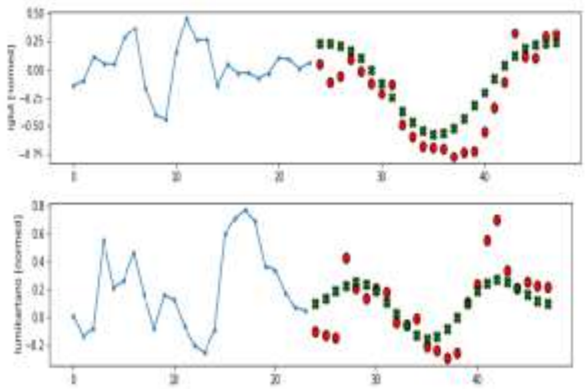

Fig. 7. Load predictions (normalized) with the LSTM method. Single-step, one hour prediction (upper). Multi-step prediction (lower). The blue, continuous line represents actual values and basis for training. Red dots represent actualvalues. for training. Green dots represent predictions.

V. Aggregating the Results

Based on the assumption that HS is a forerunner for similar intiatives in the future an effort to aggregate the results from the HS site was made. As was observed, the PV panel installed at HS covered only a fraction of the electric energy demand, even during the summer. To cater for concurrent charging of the eight eSleds the PV panel should have been nine times bigger. The required roof top area needed for this would not be achievable for HS. On a community level it is also doubtful whether it would be feasible to reach the demand shown in Table I with rooftop PV panels only. But then assuming that the HS concept would scale up for 400 residential rooftops and public buildings in Longyearbyen the climate gas emissions would be reduced by approximately 6-8%.

It is essential that future electrification of the snowmobile fleet in Longyearbyen is managed well during the winter period. If 10% of the present fleet is replaced by electric equivalents similar to the eSleds an additional load of 1,3MW can be expected. This means that concurrent charging during the period 07:00 to 17:00 hours should be suspended to keep below the existing peak load for the Longyearbyen energy supply (see Fig. 1). During day time « smart charging » would be needed. This means that only a fraction of the electric snowmobile fleet in Longyearbyen would be charged at full power at the same time. Based on the use and charging pattern of the eSleds at HS this may be feasible.

As in the case of HS the use of snowmobiles may vary considerabl, which does provide an opportunity for non-concurrent charging during the winter. During the summer time the charging of snowmobiles is a non-issue since they are not going to be driven. But their idleness would potentially provide a support for the Longyearbyen electricity system as energy buffers and peak load reduction mechanisms. Table VI shows examples of curtailment to maintain a certain power ceiling for the entire energy system in Longyearbyen. Using equation 1, cases with different power ceilings were analysed. Results for ceilings of 3MW, 3,5MW and 4MW for the whole energy system during operation in the summer are shown in Table VI. For the winter months results for ceilings of 4MW, 4,5MW and 5MW are shown. Based on this, estimates for required power (MW) and energy (MWh) to reduce the load on the power plant were calculated. Reference values behind Fig. 1 were used. The required number of snowmobiles estimated to be engaged in a vehicle-to-grid regime needed are shown in the same table. To level out up to 1 MW during an average summer 1254 units of the eSled type would have to be engaged. This would imply a rolling engagement with 200 snowmobiles of the eSled type activated concurrently to provide the necessary peak reduction. However, the energy capacity for these 200 would be insufficient. Their batteries would be depleted before the end of the required peak shaving period. 1254 units would be needed to sustain the curtailment for the whole period with 200 working in shifts. With 2000 snowmobiles being idle during the summer season this concept is theoretically feasible. During winter a reduction of 0,9MW would require approximately 1470 eSleds activated in batches of more than 180. That is less likely since snowmobiles are not so stationary during the winter months. However, using the experience from HS and the park and charging patterns observed there this option should not be discarded entirely. But to mobilize 20% of the snowmobile fleet during wintertime and to make a flexibility gain of 400kW represents a far more demanding future scenario. However, as shown for the HS case, even quite irregular peak loads can be predicted quite some time ahead. This does support the possibility of rallying a high number of snowmobiles organized under a V2G/B regime in time.

TABLE VI: V2G/B Impact

Curtailment requirements	**Summer**		
Power ceiling (MW)	3	3,5	4
Max curtailment (MW)	1,5	1	0,5
Required energy capacity (MWh)	14,6	7	1,9
Minimum fleet to manage power demand	300	200	100
Minimum fleet to manage the energy requirement	2616	1254	341
	Winter		
Power ceiling (MW)	4	4,5	5
Max curtailment (MW)	1,4	0,9	0,4
Required energy capacity (MWh)	15,8	8,2	2,1
Minimum fleet to manage power demand	280	180	80
Minimum fleet to manage the energy requirement	2832	1470	376

VI. Discussion

Under the circumstances described the project has generated insight that can also be found elsewhere [7], [10]. Nevertheless, some additional lessons can be learned from the efforts documented here. The ratio between local production and consumption at HS shows that rooftop solar panels would require an extensive area to cover the required energy demand alone. Even during the summer, the consumption at HS outperforms the local production by magnitudes. Itcan be ascertained that roof top PV panels alone cannot replace fully what coal and diesel fueled generation cover today, not even during the summer time. The roof area is too limited. Some kind of cogeneration is required to enable sufficient energy supply.

The power needed for simultaneous charging of eSleds would also require a bigger PV panel at HS or some kind of cogeneration. PV panels, as the only support for eSled charging at camps and remote sites were tourists would go is unlikely. To make charging efficient and practical, sufficient power is needed, which in turn demands a very large PV system or other types of generators as described by others [1-2, 7]. For the tourist industry PV panels combined with small generators based on biodiesel could possibly support charging and other convenience systems at such outposts. The logistics involved would be marginal and not impose very high costs as such visits will only take place during spring with both snow and sufficient daylight.

In spite of the limitations of the solar alternative its contribution to emission cuts are signficant. As long as the pollution part is still considered an externalty and not priced in, the economic impact of PV panels and e-mobility will not harvest its full economic potential. Despite this, the results show that a symbiotic relationship between local production based on solar power and electric vehicles like the eSleds can be attractive.

If the HS case is extrapolated for the whole of Longyearbyen with 2000 snowmobiles going electric rooftop solutions alone are unlikely to support charging of these. A solar park to take the bulk of the demand would be needed. There exists open acreage in the vicinity of Longyearbyen that could be used for this purpose. Non-fossil, cogenerating facilities represent an additional option that is currently being evaluated [1]. To limit the size of the PV panel « smart charging » should be employed to avoid concurrent loads.

If the snowmobiles are employed for V2G/B services the results show that they offer a potential that cannot be ignored. This opens for value stacking for individual owners as well as for the larger community. There is a battery degradation issue involved that the project will continue to address. However, the potential gains for community and individuals alike would possibly outweigh that. The forecast concept established promises better state driven control and management of a V2G/B enabled fleet and avoid time driven management that may invoke battery engagements that yield little or no gain.

In the summer snowmobiles may be used as a reserve power asset. The coal fired power plant operates two turbines. However, according to [1] and [8] the use of both during the summer is a question of necessary reserves only. Two operating turbines are not needed to cover regular services. Mobilizing 1200+ snowmobiles with similar capacities like the eSleds would help to liberate one turbine from service and cut emissions accordinlgly. This would provide relief for the plant and make maintenance simpler and less expensive. If there is at least one deep charging/disharging cycle per day for half a year that amounts to more than 6000 km driven during the winter and an estimated lifeloss per year of approximately 2,5%. Compensation for V2G based flexibility would have to match this. The Smart Charge project will investigate this further to balance the battery lifeloss and loss of inconvencience for an eSled owner with an economic compensation that matches the relief of the central plant. Moreover, the project is looking into battery swapping for electric snowmobiles that better can combine regular services and V2G/B as explained above.

VII. Conclusion

The research reported here has investigated the role of solar power to support energy provisions in the Arctic. The work presented is based on a case study from Longyearbyen at Svalbard in Norway It has also investigated the impact of electric snowmobiles on an energy system accommodated in a microgrid with a fossil fueled power plant as the main generating unit – all to support a transition to a more sustainable future. The research shows that extensive renewable resources are needed to cover the entire energy demand. However, establishing a symbiotic relationship between local, renewable production, charging and V2G/B the combination could become favorable both economically and in terms of emission reductions. By refraining from concurrent charging during peak hours and by means of « smart charging » peak load accumulations can be avoided. The use of electric snowmobiles in a V2G/B regime for energy flexibility could provide a signficiant and positive impact on the local energy system. This proved to be the case for Longyearbyen.

Conflict of Interest

The authors declare no conflict of interest.

Author Contribution

Concept/method by Bernt A. Bremdal, Shayan Dadman; Bernt A. Bremdal, Shayan Dadman wrote paper; Data management by Shayan Dadman, Kristoffer Tangrand; Analysis by Shayan Dadman, Bernt A. Bremdal, Kristoffer Tangrand.

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