ERG/201004

Integrating wind generated electricity with space heating and storage batteries

Anirudh Muralidhar and Larry Hughes
Energy Research Group
Electrical and Computer Engineering, Dalhousie University
Halifax, Nova Scotia, Canada
larry.hughes@dal.ca

8 May 2010

To be presented at International Green Energy Conference, Waterloo, Ontario, June 2010.

Integrating wind generated electricity with space heating and storage batteries

Anirudh Muralidhar and Larry Hughes
Energy Research Group
Electrical and Computer Engineering, Dalhousie University
Halifax, Nova Scotia, Canada.

Abstract

Renewable energy sources, such as wind, solar, and wave, are often seen as possible replacements for fossil fuels; however, electricity generated from these sources is intermittent, meaning that electricity providers cannot use them as dispatchable sources of electricity. This shortcoming can be overcome by matching intermittent supplies of electricity with energy services that do not require a continuous, uninterrupted supply of electricity.

It has been shown that wind-generated electricity, an intermittent source, can meet most of the space heating requirements of a typical household by storing electricity from the wind in electric-thermal storage (ETS) units. Despite this, the intermittent nature of wind still means that there are periods during which there can be either insufficient wind to meet demand or a surplus of wind that cannot be used. Many proponents of wind-generated electricity call for the export of excess electricity, especially to U.S. markets where a premium is placed on renewable electricity. In a time of volatile energy markets, typified by problems in accessibility and affordability, the best energy security policy is to utilize domestic energy to its fullest before considering exports.

This paper examines how wind-generated electricity can be applied to two fundamental energy services: space heating (for electric-thermal storage) and transportation (for plug-in electric vehicles, or PEVs, such as the Tesla Roadster). The paper presents two charging algorithms, ETS-first and PEV-first, and discusses their advantages and limitations of each.

Keywords: Electric thermal storage (ETS), Plug-in electric vehicles (PEVs), electricity

1 Introduction

Concerns over climate change and volatile energy markets are forcing some politicians and policymakers to reconsider the use of energy in their jurisdictions. In addition to reducing demand through conservation and energy efficiency measures, there can also be actions that are intended to replace existing energy sources that are insecure or environmentally damaging, or both, or restrict new demand to energy sources that are secure, environmentally benign, and preferably sustainable (Hughes, 2009b). One energy source that has caught the attention of both the public and politicians is wind-generated electricity as it is seen as a clean, environmentally sustainable energy source (Maritime Electric, 2009).

However, wind, like other renewable energy sources used for electrical generation produces electricity intermittently, making it difficult to dispatch and integrate into a traditional energy network (E.ON, 2005). If wind is to make a significant contribution to meet the world's rising demand for electricity (EIA, 2008), it will be necessary to change the way it is consumed. Ideally, the electricity supplier has sufficient rapid-response electricity that can be brought on-stream at short notice to handle those instances when it is necessary to "top-up" unexpected shortfalls in planned electricity supply or to find a consumer that will purchase the "spill" when there is more electricity being produced than expected. When shortfalls occur, it is necessary to have backup energy sources, such as hydroelectricity or gas-fired turbines to produce electricity rapidly (Luickx, Delarue, & D'haeseleer, 2008). Alternatively, connecting to a large grid can offer backup when there is insufficient wind, potentially allow sales of excess electricity, or simply be so large that any fluctuations in wind output are lost; for example, see statistics for Nordel (ENTSOE, n.d.).

In jurisdictions with limited access to backup or a significant grid structure to handle the intermittency of wind-generated electricity there are limited options, typically either lose the excess or limit the amount of wind that can be on the grid. However, this need not be the case, if one considers the different energy services available to most modern jurisdictions, notably transportation, heating and cooling, and a continuous supply of electricity (Lund & Mathiesen, 2009).

Although wind is problematic when it comes to offering a continuous supply of electricity, it can be used in transportation and for heating and cooling if storage is available. Hughes (2009a; 2010), describes how wind-generated electricity can be used for space heating when combined with electric-thermal storage (ETS) systems. This work shows that despite the availability of thermal storage, intermittency means that there is still a need for backup electricity and there is still excess electricity.

Since space heating is not required throughout the year and there is excess wind-generated electricity when using thermal storage, the excess can be used as a source of electricity for electric vehicles if they can be charged intermittently. By using the electricity for transportation, some or all of the energy needs of another important service can be met, potentially reducing greenhouse gas emissions and improving energy security.

This paper examines the potential of employing wind-generated electricity for both space heating (using ETS units) and transportation (using plug-in electric vehicles or PEVs). Two charging algorithms are considered, ETS-first, in which the wind-electricity is made available to ETS units first and any surplus to PEVs, and PEV-first, in which the wind-electricity is made available to the PEVs first and any surplus to the ETS units. The overall objective is to find ways of maximizing the use of wind-electricity for heating and transportation.

2 Background

2.1 Wind Resource

Due to its geographic location, parts of Atlantic Canada have excellent wind potential (Power Advisory LLC, 2009). The wind data was obtained from a wind farm located on Prince Edward Island (PEI). The data used in this paper is for 1 July until June 30 of 2005-06, as this allows the entire heating season (September to May) to be considered. The total annual output from the wind farm for 2006 was 32.31 GWh. The monthly output of the wind farm is shown is Figure 1.

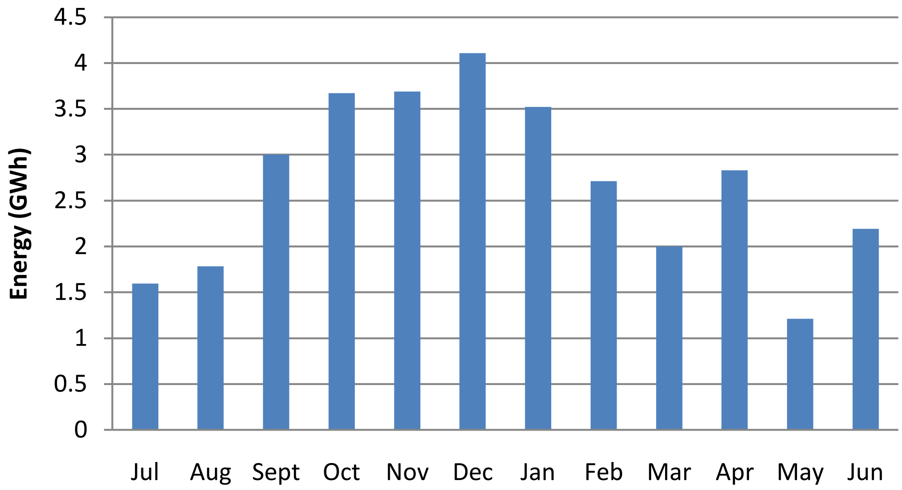

Figure 1. Monthly wind output for 2005-2006

2.2 Residential space heating

In the Canadian residential sector, energy is used for a variety of activities, space heating, water heating, appliances, lighting, and space cooling. Space and water heating are essential in Atlantic Canada due to a long heating season and accounts for most of the residential end energy use as shown in Table 1. Since about two-thirds of households in Nova Scotia are single-detached (Statistics Canada, 2007), this work focuses on satisfying the space heating demand of a single-detached household in Halifax.

Table 1: Single Detached Secondary Energy Use by service for Halifax (NRCan, 2009)

Service	kWh	Percentage
Space Heating	16,289	58.7%
Water Heating	4,371	15.7%
Appliances	5,106	18.4%
Lighting	1,915	6.9%
Space Cooling	56	0.2%
Total	27,736	100%

Heating Degree Hours (HDH) is similar to Heating Degree Days and is done hourly rather than daily. Hourly demand is the demand for space heating that is to be satisfied for that hour for a particular household. The hourly analysis was carried out since hourly wind and Halifax temperature data (Environment Canada, 2009) was available. Since hourly demand is not readily available, it was calculated using the following steps:

1. Calculating the Heating Degree Hours (HDH) from Eq. (1) using the hourly temperature data of Halifax, where BT_H is the base temperature and OT_H is the outside temperature:

$$\mathrm{HDH} = \sum_{h=1}^{h=8760} BT_H - OT_H \tag{1}$$

2. Calculating the percentage of each hour's HDH by dividing the hour's HDH by the sum of all HDH.
3. Using the space heating value from Table 1 (16,289 kWh) and the percentage of each hour's HDH to find the hourly demand.

Figure 2 shows the monthly space heating demand for a single-detached household in Halifax in 2005-06.

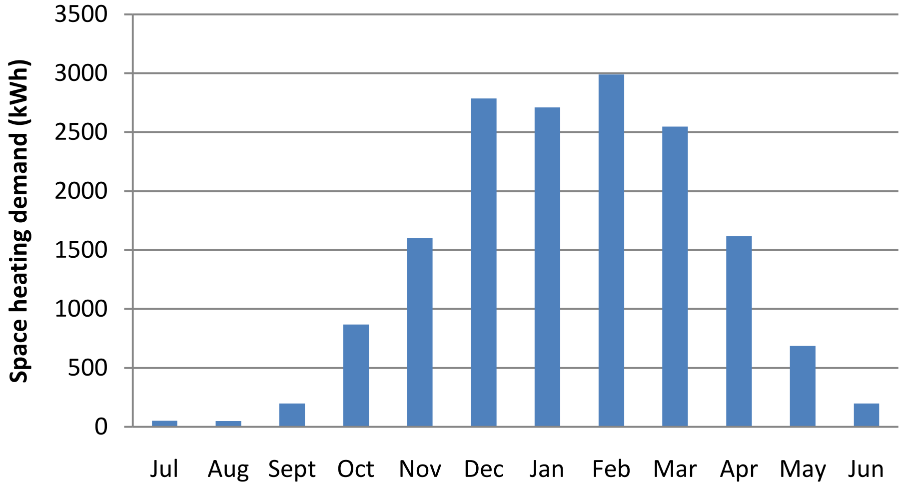

Figure 2: Monthly space heating demand for Halifax

2.3 Electric thermal storage (ETS)

ETS units charge from the electricity grid during off peak hours which are periods when the electricity provider sells electricity at cheaper rates. The ETS is an alternative to resistance or baseboard heating and is gaining popularity in North America; for example, one such manufacturer, Steffes, has sold over 100,000 units (Steffes, 2008). Although they are normally charged during the eight hours period from 23h to 7h in Nova Scotia, some other areas a load control switch is installed at the site and is connected to one or more heaters. If the load control switch is addressable, it can switch heaters on or off from a central utility connection (Dan Gaffney, personal communication, February 19, 2010). This feature can be used to integrate the ETS whenever wind generated electricity is available (Hughes, 2009a).

2.4 Electric vehicles

Plug-in Electric Vehicles (PEVs) are an alternative to gasoline-powered vehicles and many are designed to be charged through a wall socket. The PEV chosen for analysis is the Tesla Roadster, consisting of a 375 volt AC induction air-cooled electric motor with variable frequency drive with a top speed of about 200 km/hr (125 miles/hr) and can travel about 390 km (244 miles) on a full recharge (Tesla Motors, 2010). The battery capacity is 52 kWh (myteslaroadster, n.d).

The Table 2 shows the mode of transportation for the city of Halifax; almost 76% of the people who commute to work either drive or travel as passengers in car, trucks, or vans.

Table 2: Mode of Transportation in Halifax (Statistics Canada, 2010)

Mode of transportation	Total
Car, truck, van as driver	121,400
Car, truck, van as passenger	19,830
Public transit	22,115
Walked	18,845
Bicycle	1,825
Motorcycle	240
Taxicab	520
Other method	1,640
Total - Mode of transportation	186,420

The commuting distance to work is shown in Table 3; for this analysis it is assumed that car owners drive about 40 km every day.

Table 3: Commuting distance to work in Halifax (Statistics Canada, 2010)

Commuting distance (km)	Total
Less than 5 km	68,085
5 to 9.9 km	42,855
10 to 14.9 km	20,710
15 to 19.9 km	15,710
20 to 24.9 km	7,930
25 to 29.9 km	3,725
30 km or more	7,970
Median commuting distance	6.5
Total - All commuters	166,980

The relationship between battery capacity and distance travelled is linear; for a driving distance of 40 km/day would mean that the battery needs to be charged to about 5.3 kW every day; giving an annual battery demand of 1935.5 kWh. The PEVs used in this analysis are charged using the home connector which has a charging rate of 16.8 kW (Tesla Motors, 2010) and since the manufacturer says “the vast majority of our customers charge their cars at night in their garages” (Tesla Motors, 2010), the charging period is during the off peak hours between 23h and 7h.

3 Wind integration

Wind data for 2005-2006 is used to satisfy both space heating and charging PEV batteries. By doing so this provides an alternate to shift to different energy source like wind from conventional heating oil for space heating and coal for electricity and also help reduce consumption of or replace fuels that are insecure or carbon intensive, or both.

The total number of single-detached households that can be theoretically heated with the wind is shown in Eq. (2) (Hughes, 2009a).

$$\sum_{h=1}^{h=8760} \frac{hourly\ wind\ supply}{hourly\ space\ heating\ demand} \tag{2}$$

For 2005-06, the hourly wind supply was 32.3 GWh, while the total hourly space heating demand for a single-detached house in Halifax was 16.3 MWh, meaning that 1983 single-detached households could be heated regardless of the wind production being coincident with demand.

The total number of PEV batteries that can be theoretically charged with the wind between 23h and 7h is shown is Eq. (3).

$$\sum_{Day=1}^{Day=365} \frac{\sum_{h=23}^{h=7} Wind\ supply_{Day,hour}}{Battery\ demand_{Day}} \tag{3}$$

Where the total, annual wind supply between 23h and 7h was 11.5 GWh and since 5.3 kW is to be charged every day the annual battery demand for a single PEV is 1.94 MWh/PEV. From Eq. (3) the number of PEVs that can be charged for 2005-06, regardless of the wind production being coincident with demand, is 5921.

4 The charging algorithms

The charging of the ETS and PEVs are based on different charging algorithms, ETS-first and PEVs-first. The algorithms are discussed in detail below. For these simulations, transmission, distribution, and heat loss from the ETS units in the off state and discharge from the PEVs batteries are not considered. During the analysis if at any hour either the ETS units or PEVs goes to zero, it remains in that state until it is recharged by the wind generated electricity. Even though some form of backup electricity is necessary to bridge the gap when wind is unavailable and the ETS units and PEVs have exhausted their energy, this algorithm does not take backup electricity from the grid or any other source into account but mentions the amount required. The ETS and PEV units are considered to be fully charged at the beginning (first hour) of the analysis.

4.1 ETS-first

In this charging algorithm the objective is to use the available wind to charge the ETS, if any surplus wind is available, charge the PEVs between 23h and 7h; any excess wind is available for export or other uses. The ETS-first algorithm is as follows (note that for simulation purposes, the PEV is discharged at 23h):

1. *For each Day of the year*
2. *For each Hour in the day*
3. *Calculate the available wind for the hour (Available); if Available is equal to zero, skip to step 7.*
4. *Calculate the required energy for ETS units for the hour (ETS energy), up to the maximum rate of hourly recharge.*
5. *If Available < ETS*
    a) *Distribute Available equally amongst the ETS units (limited to full capacity)*
    b) *Skip to step 7*
    Else
    a) *Distribute ETS energy amongst the ETS units (limited to full capacity)*
    b) *Surplus = Available – ETS energy*
6. *If Hour between 23h and 7h*
    a) *If Hour is 23h*
        - *Decrease PEV energy by the daily driving requirements of each PEV*

   b) *Calculate the required energy for all PEVs for the hour*
   c) *If Surplus < PEV*
      - *Distribute Surplus equally amongst the PEV units (limited to full capacity)*
      - *Skip to step 7*

      Else
      - *Distribute required PEV energy amongst the PEV units (limited to full capacity)*
      - *Excess = Surplus – PEV energy*

   Else

   a) *Excess = Surplus*
7. *Each hour, decrease ETS by the required energy to meet Hour's heating demand*
8. *Next Hour*
9. *Next Day*

4.2 PEVs-first

In this charging algorithm, PEVs are charges first. The objective of this algorithm is to use the available wind to charge the PEVs between 23h and 7h; if any surplus wind is available, ETS units are charged. Any excess wind is available for other uses or export. The PEVs-first algorithm is as follows:

1. *For each Day of the Year*
2. *For each Hour in the Day*
3. *Calculate the available wind for the hour (Available); if Available is equal to zero, skip to step 7.*
4. *If Hour between 23h and 7h*
   a) *If Hour is 23h*
      - *Decrease PEV by the daily driving requirements of the PEVs.*

   b) *Calculate the required energy for PEVs for the hour (PEV energy)*
   c) *If Available < PEV energy*
      - *Distribute Available equally amongst the PEV units (limited to full capacity)*
      - *Skip to step 7*

      Else
      - *Distribute Available amongst the PEV units (limited to full capacity)*
      - *Surplus = Available – PEV energy*

   Else

   d) *Surplus = Available*
5. *Calculate the required energy for all ETS for the hour (ETS energy).*
6. *If Surplus < ETS energy*
   a) *Distribute Surplus equally amongst the ETS units*
   b) *Skip to step 7*

   Else

   c) *Distribute required ETS energy amongst the ETS units*
   d) *Excess = Surplus – ETS energy*
7. *Each hour, decrease ETS by the required energy to meet hour's heating demand*
8. *Next Hour*
9. *Next Day*

5 Simulations and results

The simulations were carried out using the two charging algorithms. The number of ETS units tested ranged from 1 to 2000, while the number of PEVs ranged from 1 to 6000. The results are discussed in detail below for the respective algorithms.

5.1 ETS-first results

Figure 3 shows the results of running the ETS systems alone. The surplus wind is the amount of wind energy available after heating has been met, while the backup energy is the electricity required from other sources to bridge the gap when wind is unavailable and the ETS units are fully-discharged. The space heating met is the percentage of space heating load that is satisfied by wind generated electricity.

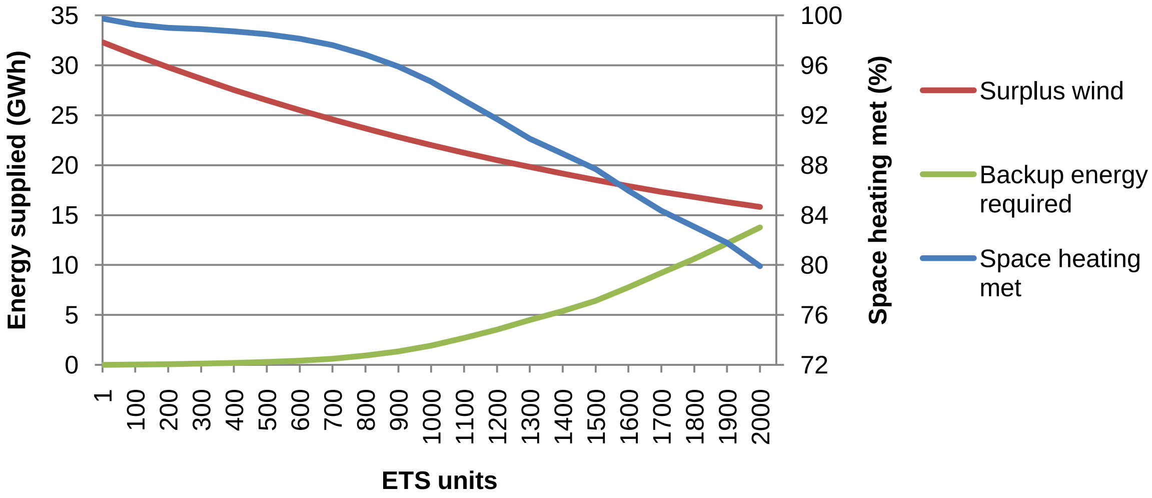

Figure 3. Surplus wind backup energy required and space heating met for ETS

The percentage of grid backup required increases gradually to about 10% with 1300 ETS units connected. By 2000 units, wind was able to satisfy almost 80% of the space heating demands. As the number of units increases, the need for backup from the grid also increases. Since wind might be available at times when space heating is not required or excess after space heating needs are satisfied there is surplus wind energy available, at 2000 units the surplus wind available was about 16 GWh.

Figure 4 shows the battery demand met for the PEVs with the surplus wind available after satisfying the needs of the ETS units. If a single ETS unit was integrated with 6000 PEVs, 80% of the PEVs battery demand was met and if 2000 ETS were integrated with 600 PEVs, about 90% of the battery demand was met. For 2000 ETS and 6000 PEVs about 25% of the battery demand would be met.

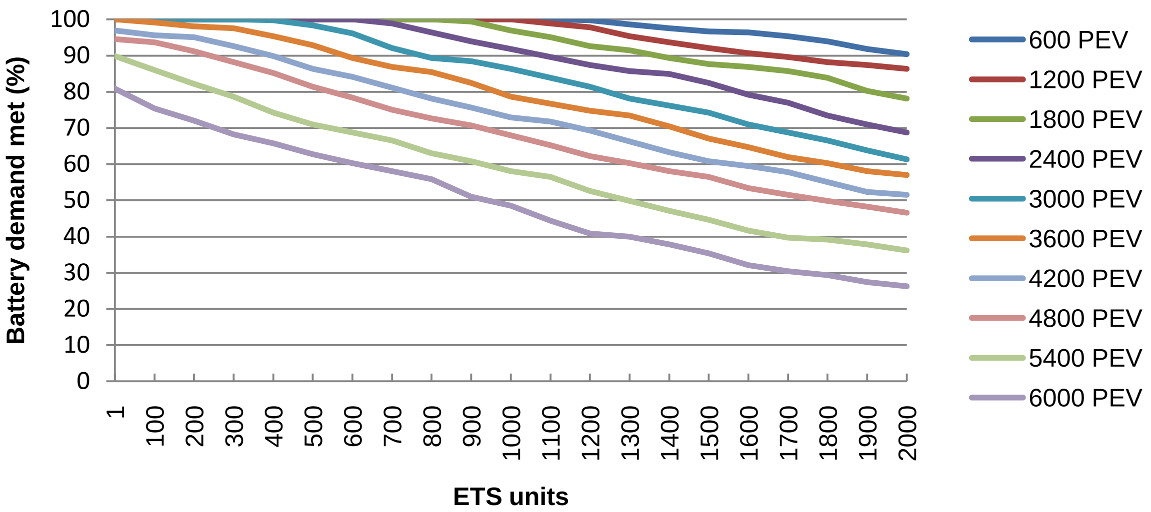

Figure 4. Battery demand met for PEVs when integrated with ETS

The amount of backup energy required for PEVs when integrated with ETS units is presented in Figure 5. A single ETS unit integrated with 6000 PEVs requires a backup of about 1.5 GWh and if 2000 ETS units were integrated with 600 PEVs a backup of only 0.1 GWh would be required.

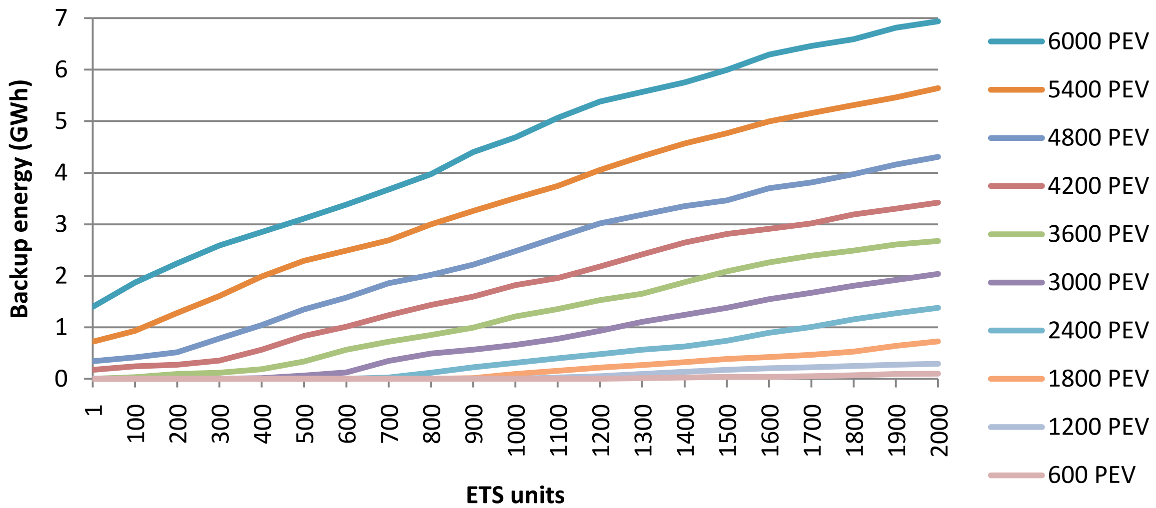

Figure 5. Backup energy required for PEVs when integrated with ETS

Figure 6 shows the excess wind available after charging the PEVs' batteries with surplus wind from the ETS units. A single ETS unit when integrated with 600 PEVs has excess wind close to 32 GWh and when integrated with 6000 PEVs has excess wind of about 24 GWh; this dropped to less than 12 GWh for 2000 ETS and 6000 PEVs.

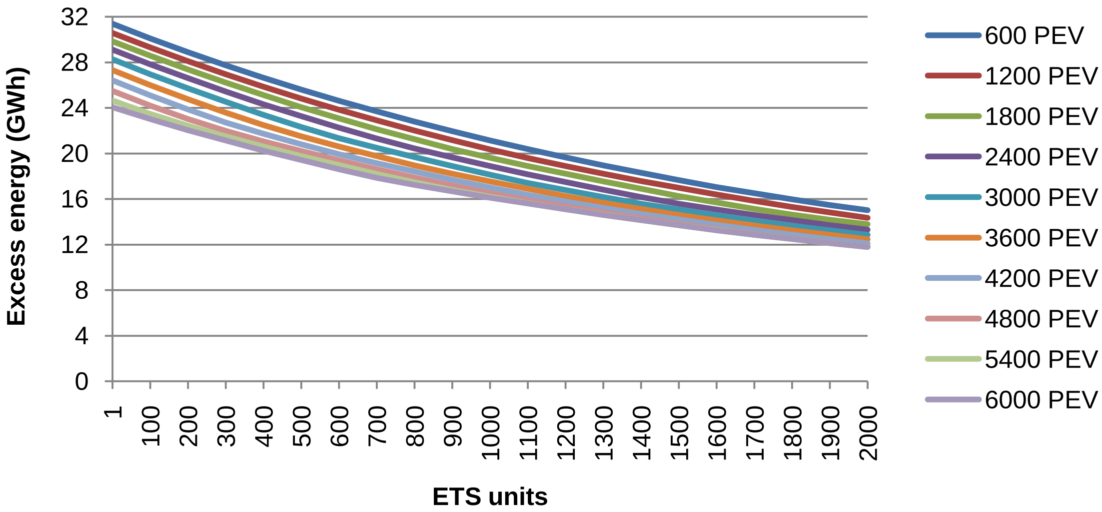

Figure 6. Excess wind available for PEVs when integrated with ETS

5.2 PEVs-first results

The PEV-first results are shown in Figure 7 without supplying the surplus to the ETS units. Backup energy refers to the energy required to bridge the gap when wind is unavailable and the PEV battery needs to be charged, surplus wind is the wind energy available after meeting the battery demand, and battery demand met is the demand for the PEV batteries that is satisfied by wind generated electricity.

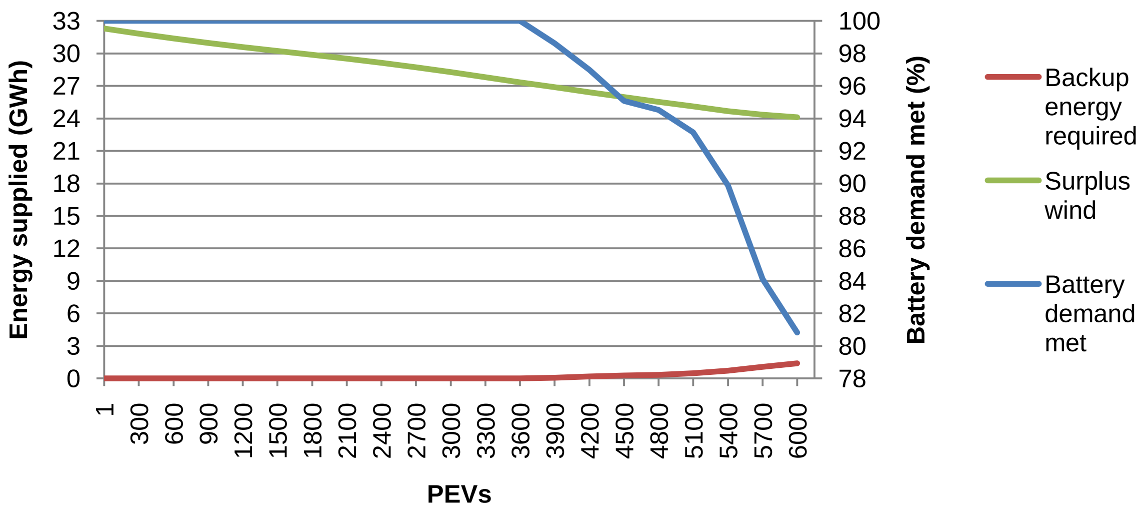

Figure 7. Backup, surplus wind, battery demand met for PEVs

Grid backup was not required and 100% of battery demand was met for up to 3600 PEVs. When supplying wind for 6000 PEVs, about 81% of the charging was met by the wind and the remainder came from backup electricity sources. At 6000 PEVs, about 1.5 GWh were supplied by backup and about 24 GWh was surplus.

Figure 8 shows the percentage of space heating met for ETS when integrated with PEVs. If one PEV is integrated with 2000 ETS units then about 80% of the space heating demand is met. For 6000 PEVs and 2000 ETS the percentage of space heating met is about 71%.

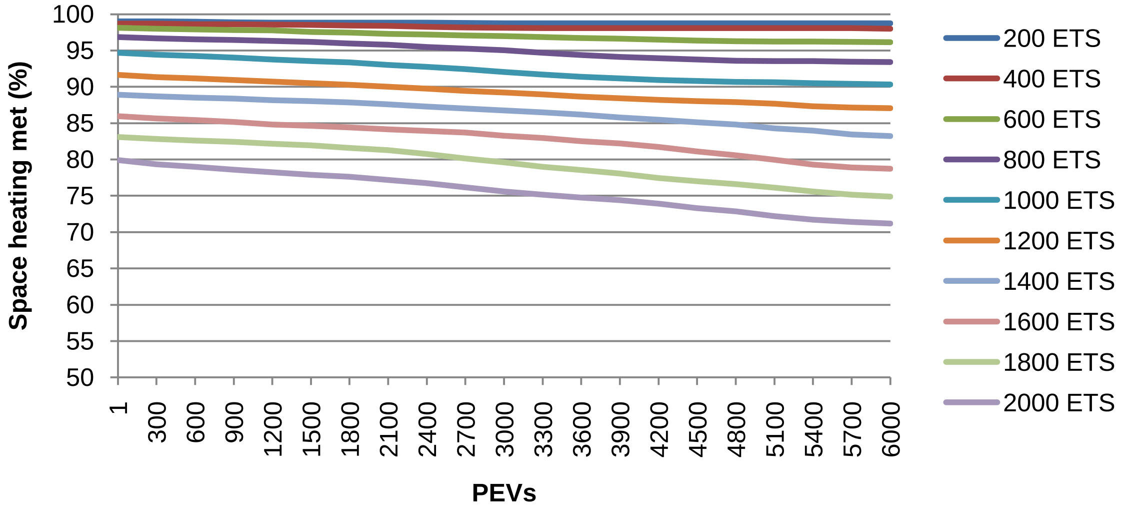

Figure 8. Space heating met for ETS units when integrated with PEVs

Figure 9 shows backup energy required from the grid when including ETS units. For a single PEV and 2000 ETS units, the amount of backup required is about 14 GWh. If all 6000 PEVs and 2000 ETS units are connected, backup of just over 18 GWh is required.

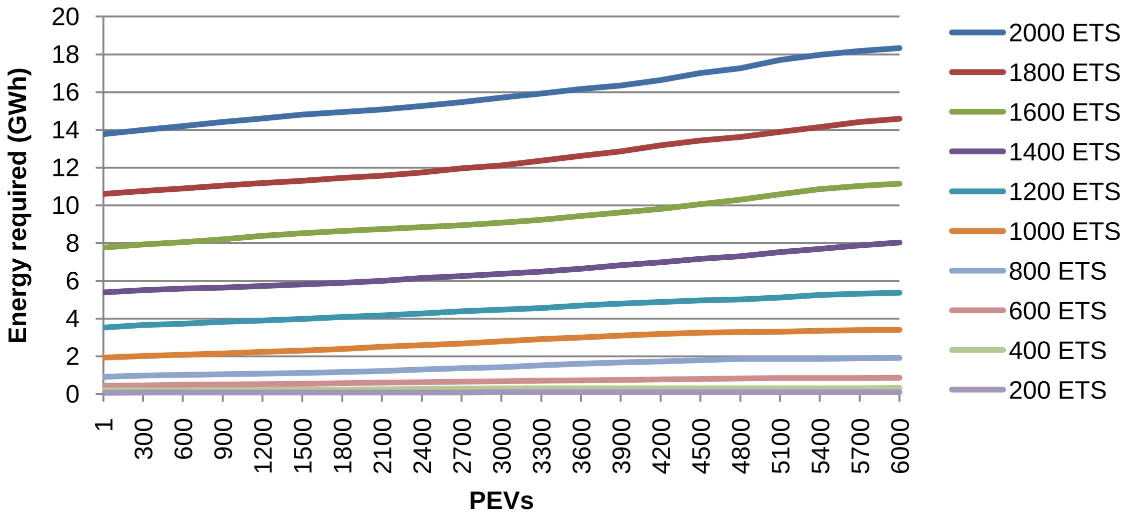

Figure 9. Backup energy required for ETS when integrated with PEVs

Figure 10 shows the amount of excess wind when the ETS units are charged with electricity surplus to the PEVs. For a single PEV and 200 ETS units the excess wind available is about 30 GWh and drops to about 16 GWh when integrated with 2000 ETS units; this drops to less than 12 GWh for 6000 PEVs and 2000 ETS units.

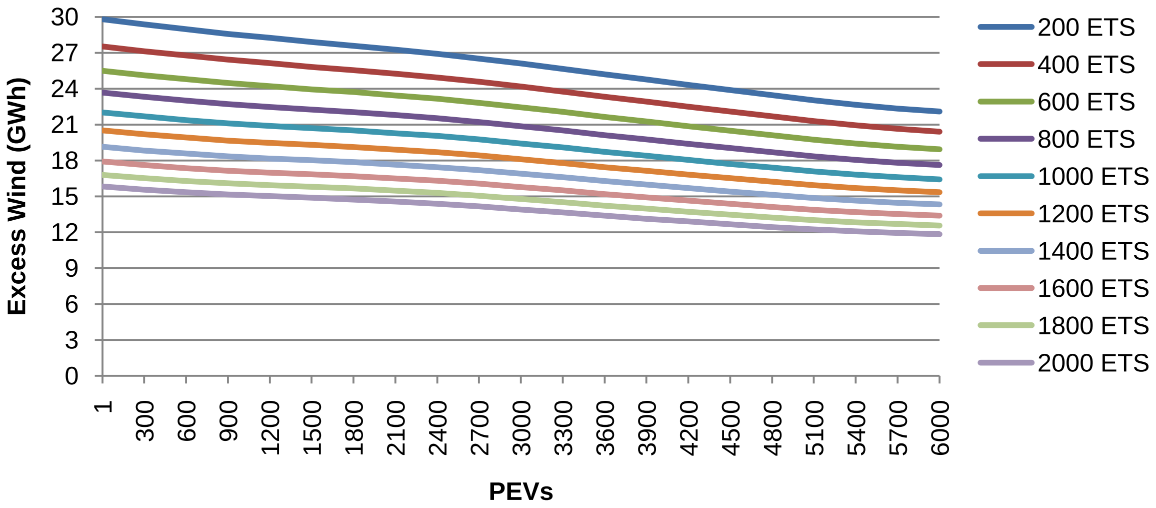

Figure 10. Excess wind available for ETS when integrated with PEVs

6 Discussion

The previous section showed how the two charging algorithms, ETS-first and PEV-first, could be used to meet space heating demand and electric vehicle energy needs. As the names suggest, when wind is available, it is first used to meet ETS (or PEV) demand and then, if there is a surplus, to meet PEV (or ETS) demand. Any excess is then available for use in other services or export.

Both the ETS and PEV store electricity; in the case of ETS, up to 180 kWh as heat in ceramic bricks, and in the PEV, up to 52 kWh as electricity in batteries. Although an ETS unit stores more energy than a PEV, its daily demand for heat is such that in the most extreme conditions, the ETS could be called upon to supply 10 kWh every hour, whereas the PEV uses about 5.3 kWh per day. The difference in storage capacity and daily demand are such that the PEV is able to withstand lengthy periods without being recharged; the same cannot be said for the ETS, which is normally recharged every 24 hours or less (typically between 23h and 7h) during the heating season.

In addition to the above, an ETS unit can be charged at anytime throughout the day when there is electricity available from the wind, whereas a PEV can only be charged between 23h and 7h (as recommended by the manufacturer). These differences are highlighted in the following figures, which show the effect of lengthy periods of limited wind between 13 February 2006 and 28 February 2006.

The effect on the state of ETS units during periods of cold temperatures and a decrease in wind supply is shown in Figure11. In this example, temperatures averaged -15.6°C between hours 149 and 160 and -11.8°C between hours 289 and 361. The limited wind brought the state of charge of a single ETS to zero between hours 252 and 274, at which point a small amount of wind allowed the ETS to recover. However, when 2000 ETS units are considered, the cold and lack of wind meant that whatever wind was available, it went straight to heating and not to recharging the units. The results are for ETS-first; during this time, the PEVs were not recharged.

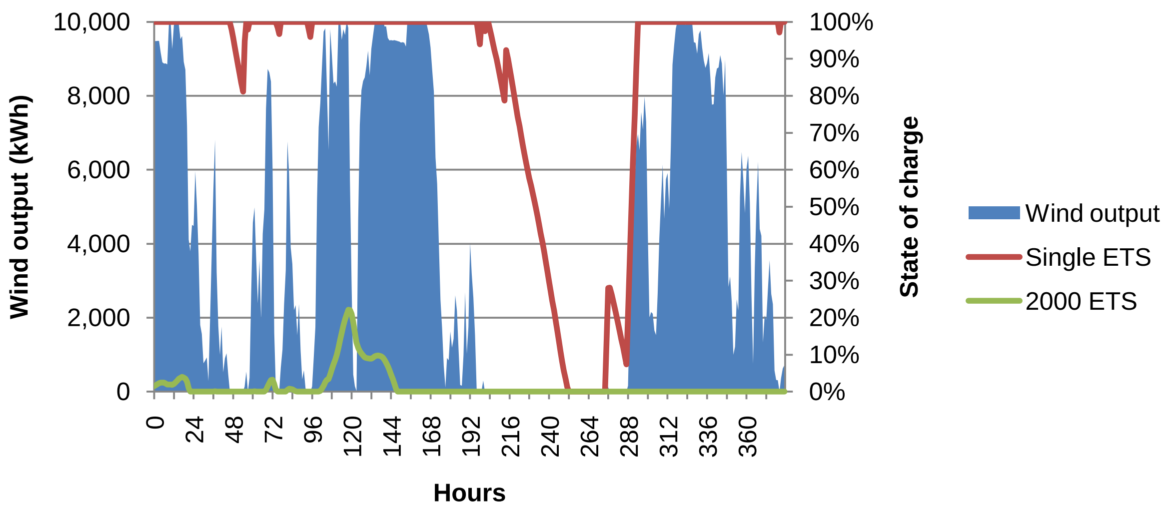

Figure11. Effect of limited wind availability on ETS units

The total distance traveled each day and the size of the batteries mean that PEVs can go for extended periods without recharging; this is illustrated in Figure 12, which shows the state of charge of a single PEV and 6000 PEVs. Unlike the ETS units, the batteries allow the PEVs to bridge the periods of no wind easily. Similarly, the size of the batteries and the recharging rate allows all the batteries to benefit from the available wind.

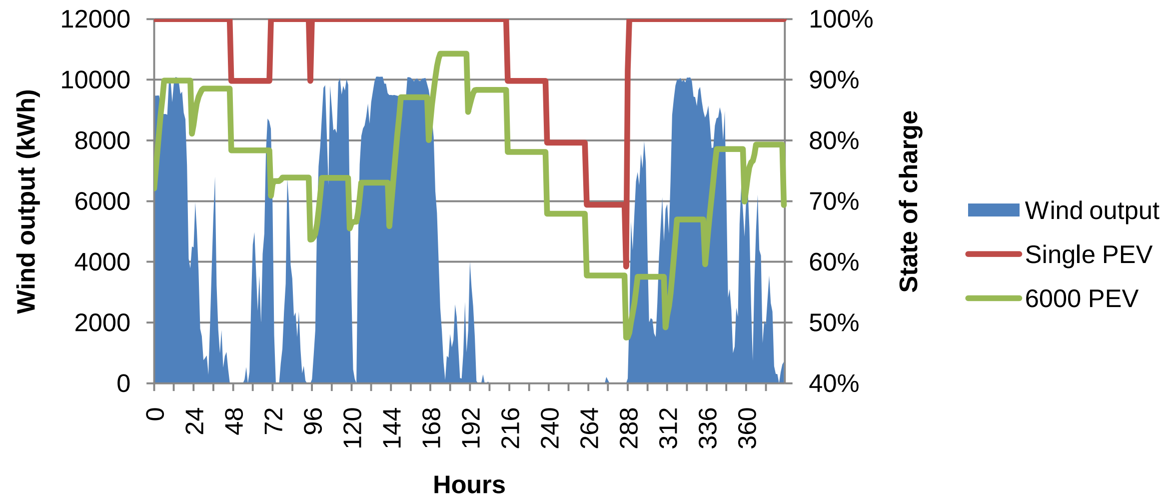

Figure 12. Effect of limited wind availability on PEVs

The benefits associated with operating ETS-first or PEV-first vary, as these observations attest:

- In ETS-first, 1000 ETS units and 3000 PEVs could be integrated to meet about 95% of space heating and 85% of the battery demand, with 2000 ETS units the percentage of battery demand met reduces to about 25%.
- In PEV-first, 3000 PEVs and 1200 ETS units could be integrated to meet about 100% of battery demand and 90% of the space heating load; with 6000 PEVs the percentage of space heating met reduces to about 71%.

Regardless of whether ETS-first or PEV-first is adopted, the amount of excess electricity during the 2005-06 simulation for the maximum number of ETS units and PEVs was about 12

GWh, meaning that about 20 GWh of energy previously required for space heating and transportation was displaced. However, this is somewhat misleading as it masks the amount of electricity required for backup. When using ETS-first, the maximum backup required was 20.7 GWh, while with PEV-first charging, the maximum backup required was 19.7 GWh.

7 Conclusions

Concerns over greenhouse gas emissions and energy security mean that non-traditional energy sources will be needed to meet the energy needs of basic energy services such as transportation and heating and cooling. This paper has shown that wind-generated electricity can be used to meet both residential space heating with ETS units and PEVs being used in a typical Canadian city with 40 km commuting distances. The results show that of the two algorithms discussed, if PEVs are charged first, there is less need for backup electricity. Furthermore, this reduces the amount of energy that needs to be imported into the jurisdiction.

In order to increase the utilization of wind still further and reduce the need for energy imports and exports, we are developing algorithms to allow PEVs to charge throughout the day while acting as electric backup for discharging ETS units.

Acknowledgements

The authors would like to thank Environment Canada for the wind data and the members of Energy Research Group (ERG) for their comments and suggestions.

References

E.ON. (2005). *Wind Report 2005.* Bayreuth, Germany: E.ON Netz GmbH.

EIA. (2008, June). *International energy data and analysis*. Retrieved January 25, 2010, from Energy Information Administration: http://www.eia.doe.gov/iea/elec.html

ENTSOE. (n.d.). *Nordel Annual Report 2008*. Retrieved March 22, 2010, from European Network of Transmission System Operators for Electricity: http://www.entsoe.eu/index.php?id=66

Environment Canada. (2009). *National Climate Data and Information Archive*. Retrieved 09 15, 2009, from Environment Canada: http://climate.weatheroffice.gc.ca/climateData/canada_e.html

Hughes, L. (2009a, November). Meeting residential space heating demand with wind-generated electricity. *Renewable Energy* , doi:10.1016/j.renene.2009.11.014.

Hughes, L. (2009b, June). The four 'R's of energy security. *Energy Policy , 37* (6), pp. 2459-2461.

Hughes, L. (2010). The technical potential for off-peak electricity to servce as backup in wind-electric thermal storage systems. *International Journal of Green Energy* .

Luickx, P. J., Delarue, E. D., & D'haeseleer, W. D. (2008, September). Considerations on the backup of wind power: Operational backup. *Applied Energy , 85* (9), pp. 787-799.

Lund, H., & Mathiesen, B. (2009). Energy system analysis of 100% renewable energy systems—The case of Denmark in years 2030 and 2050. *Energy , 34* (DOI: 10.1016/j.energy.2008.04.003).

Maritime Electric. (2009). *Renewable Energy*. Retrieved 01 15, 2010, from Maritime Electric: http://www.maritimeelectric.com/environment/env_energy.asp myteslaroadster. (n.d). *Incentives*. Retrieved 01 25, 2010, from The Tesla Roadster Buyers Guide : http://www.myteslaroadster.com/incentives.html

NRCan. (2009, April 20). *Residential Sector Nova Scotia Table 35: Single Detached Secondary Energy Use and GHG Emissions by End-Use*. Retrieved June 26, 2009, from Natural Resources Canada: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/tablestrends2/res_ns_35_e_3.cfm?attr=0

Power Advisory LLC. (2009). *Study finds significant opportunity for Atlantic Canada wind exports to U.S.* . Retrieved 01 15, 2010, from CANWEA: http://www.canwea.ca/media/release/release_e.php?newsId=60

Statistics Canada. (2010, January 6). *2006 Census of Canada: Topic based tabulations*. Retrieved January 25, 2010, from Statistics Canada: http://www12.statcan.ca/census-recensement/2006/dp-pd/tbt/Rp-eng.cfm?TABID=1&LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GK=0&GRP=1&PID=90657&PRID=0&PTYPE=88971,97154&S=0&SHOWALL=0&SUB=763&Temporal=2006&THEME=76&VID=0&VNAMEE=&VNAMEF=

Statistics Canada. (2010, January 6). *2006 Census of Canada: Topic-based tabulations*. Retrieved January 25, 2010, from Statistics Canada: http://www12.statcan.ca/census-recensement/2006/dp-pd/tbt/Rp-eng.cfm?TABID=1&LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GK=0&GRP=1&PID=90655&PRID=0&PTYPE=88971,97154&S=0&SHOWALL=0&SUB=762&Temporal=2006&THEME=76&VID=0&VNAMEE=&VNAMEF=

Statistics Canada. (2007, 10 12). *Private households by structural type of dwelling, by province and territory (2006 Census)* . Retrieved June 25, 2009, from Statistics Canada: http://www40.statcan.ca/l01/cst01/famil55a-eng.htm

Steffes, P. (2008). *Wind Assisted Heating.* North Dakota: steffes corporation.

Tesla Motors. (2010). *Charging demo & FAQ*. Retrieved 01 25, 2010, from Tesla Motors: http://www.teslamotors.com/electric/charging_demo.php?displayall=1

Tesla Motors. (2010). *Charging solutions*. Retrieved 01 25, 2010, from Tesla Motors: http://www.teslamotors.com/electric/charging.php

Tesla Motors. (2010). *Performance Specs*. Retrieved 01 15, 2010, from Tesla Motors: http://www.teslamotors.com/performance/perf_specs.php