FUELLING EVs WITH RENEWABLE ELECTRIC ENERGY

A Visual Analysis of BC's Renewable Energy Generation in Relation to Projected Electric Vehicle Charging

Prepared for TIPSlab

August 8, 2016

TABLE OF CONTENTS

ABSTRACT

Renewable energy used for EV charging presents both the opportunity of harnessing energy from sustainable sources and the challenge of managing their varying levels of output. While unmediated charging demand profiles show that high charging demand peaks on a daily basis, energy from natural resources instead follows seasonal patterns of highs and lows. This situation calls for two strategies: the use of digital interfaces to match daily charging activity with available energy and the management of renewable sources to minimize seasonal fluctuations. Upon analysis of the various renewable sources and their energy profiles, run-of-river hydro and wind energy can be seen to have opposite seasonal trends. To maximize the potential of this correlation, more investigation is needed to compare the wind profiles of different regions. Wind energy generated in many regions at once may minimize the day-to-day variability of this source and increase power output so that it reaches levels comparable to run-of-river hydro power, thus mitigating seasonal fluctuations and increasing the capacity of sustainable energy sources to meet EV charging demands throughout the year.

INTRODUCTION

This study aims to develop and refine the analysis of EV charging demands and the potential for their alignment with renewable energy generation in BC, which was initiated in the TIPSlab report entitled “A Visual Analysis of British Columbia’s Energy Generation Profiles in Regard to Projected Electric Vehicle Fleets”[1] (also referred to as the “previous TIPSlab Energy Report”).

In this study, data obtained from BC Hydro for BC’s IPP renewable energy generation is analyzed in relation to projected EV use for various fleet sizes to estimate to what extent those demands can be met by the province’s current renewable energy sources. To do so, the study first examines the projected unincentivized charging demands for B.C.’s current EV fleet in relation to actual charging data for EV fleets in other North American cities with and without time-of-use rates. The study next analyzes the trends and power generation profiles of renewable IPPs in B.C. by energy type and region. Finally, the study extrapolates how greater investment in specific types of renewable energy sources could assist in adjusting the seasonal availability of renewable energy to better match PEV charging demands.

All of the energy generation data visualized in this report refers to energy generated or managed by BC Hydro and therefore excludes private and competing grids. The timeframe of the actual generation and charging data is the calendar year of 2013, while any projected data referenced corresponds to the future timeframe indicated.

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1. “A Visual Analysis of British Columbia’s Energy Generation Profiles in Regard to Projected Electric Vehicle Fleets.” TIPSlab. November 2014.

GLOSSARY

B.C. — Acronym for the Canadian province of “British Columbia”.

BC Hydro — Refers to “BC Hydro and Power Authority”, the main electrical utility in the province of British Columbia.

Dispatchable — Dispatchable energy sources are referred to here as sources of electricity that can be dispatched at the request of power grid operators. Dispatchable generating plants can be turned on or off, or adjust their power output on demand, such as fossil-fuel power stations or hydroelectric dams.

Non-Dispatchable — Non-dispatchable energy sources are referred to here as sources of electricity that can neither be dispatched in order to preserve potential energy, nor adjust their power output on demand. Non-dispatchable energy sources have a fluctuating nature, like wind power and solar power.

EV — Acronym for “Electric Vehicle”. In this report EV refers exclusively to Electric Vehicles that can obtain electricity from the power grid, i.e. are plugged-in for charge.

IPP — Acronym for “Independent Power Producer”. IPPs are electricity producers that are not public utilities; they own facilities to generate electric power for sale to utilities and end users. In 2002, the BC government stipulated that IPPs “will develop new electricity generation, with BC Hydro restricted to improvements at existing plants”* .

Storage Hydro — Storage hydro facilities employ large reservoirs to store water for perennial and large scale electricity production. The potential energy in the water volume can be considered stored power, which is drawn down as needed.

Non-storage Hydro — Non-storage hydro has no capacity to retain water, and therefore no capacity to store power. Non-storage hydro is also referred to as run-of-river hydro. This mode of electricity generation is produces a variable output, as it depends on the natural river flow, but has a very low carbon footprint.

TOU Incentive — TOU is a acronym for “Time Of Use”. It refers to electricity pricing that varies depending on the time of day when electricity is drawn from the grid. Utilities make use of TOU pricing to encourage the use of electricity at certain times of the day and to discourage the use of electricity at others.

I. ANALYSIS OF EV CHARGING BEHAVIOUR

PROJECTED NON-INCENTIVIZED EV CHARGING IN B.C.

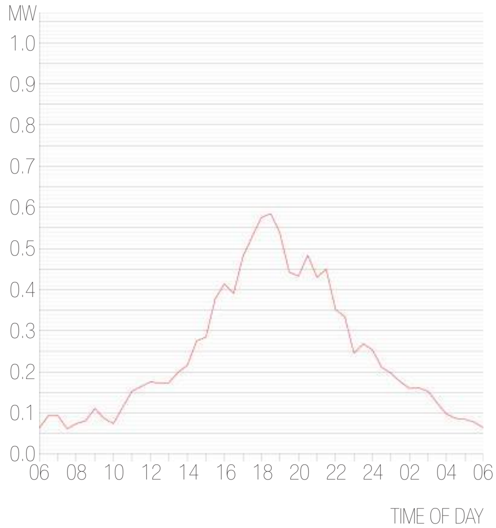

Figure 1.1
Projected Energy Demand - Axsen et al.
B.C. EV fleet

As in the previous TIPSlab Energy Report, projected charging data were sourced from John Axsen *et al*'s study "The Canadian Plug-in Electric Vehicle Survey (CPEVS 2013): Anticipating Purchase, Use, and Grid Interactions in British Columbia"[2] to estimate the energy consumption of EV users in B.C., both at the present time and as the EV fleet grows in the future. This recent study surveyed respondents from B.C. in the "early mainstream" market segment for the passenger vehicle sector.[3]

The CPEVS 2013 used 202 driving diaries from the survey responses to extrapolate EV charging patterns and energy demands over a 24-hour period for a hypothetical EV user in B.C. under current conditions in 2013. These are shown in Figure E-9 in Axsen's report, wherein the "user informed" profile represents a scenario most closely resembling the conditions of driving an EV in this province in 2013. This scenario estimates the energy demands of EV charging throughout the day if the B.C. survey respondents are driving their choice of an electric or rechargeable hybrid vehicle according to their reported driving routines, with their present access to charging infrastructure.[4]

Since Axsen's Figure E-9 shows the projected charging profile of one 'average' EV in B.C., these values were multiplied by the number of vehicles in British Columbia's 2013 passenger vehicle fleet to estimate current fleet loads. The estimation of British Columbia's 2013 EV fleet size—at approximately 1000 vehicles—was sourced from Matthew Klippenstein of GreenCarReports.[5] This number represents approximately 0.037% B.C.'s 2013 passenger vehicle fleet, which was 2,738,785.[6] The implications of EVs' increasing in number to a larger proportion of B.C.'s fleet will be discussed in Part III of this report.

This profile, pro-rated to the size of the 2013 B.C. vehicle fleet, is shown in Figure 1.1 and represents unincentivized charging behaviour by EV users in B.C. It can be used as a basis for comparison with the EV fleet charging profiles of selected North American cities, particularly those that do not have TOU incentivization programs.

It should also be noted that since this profile represents EV charging patterns over the course of an average day, it does not take into account any seasonal variations. This consideration will also be addressed in the following section.

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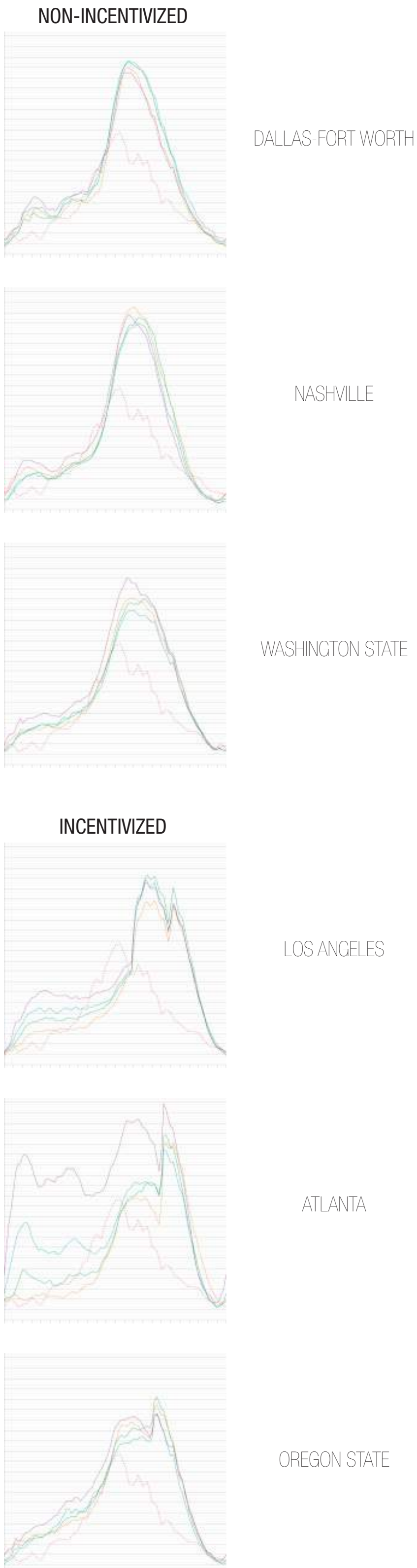
2. Axsen, John, Harry Joe Bailey, and George Kamiya. "The Canadian Plug-in Electric Vehicle Survey (CPEVS 2013): Anticipating Purchase, Use, and Grid Interactions in British Columbia." Energy and Materials Research Group - Simon Fraser University, 2013, Figure 18, p. x.
3. *Ibid.*, pp. ii-iii
4. *Ibid*., p. x.
5. Klippenstein, Matthew. "British Columbia Hits 1,000 EV's (and Gov't Drops Support)." Eclectic Lips. March 1, 2014. Accessed September 11, 2014.
6. "Motor Vehicle Registrations, by Province and Territory (Saskatchewan, Alberta, British Columbia)." Statistics Canada. June 13, 2014. Accessed October 8, 2014. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/trade14c-eng.htm (from the category "Vehicles weighing less than 4 500 kilograms").



Thumnbnails from Figure 1.2:
Reported Quarterly Energy Demand - EV Project
For every 1000 vehicles of EV fleets of selected incentivized and non-incentivized cities and states.

INCENTIVIZED AND NON-INCENTIVIZED EV CHARGING PROFILES FROM SELECTED NORTH AMERICAN JURISDICTIONS

In order to better understand EV user charging habits in both TOU incentivized and non-incentivized jurisdictions, B.C.'s projected EV charging profile from the CPEVS 2013 was compared with reported charging data collected by the Idaho National Laboratory (INL) as part of The EV Project: Plug-in Electric Vehicle Charging Infrastructure Demonstration. Specifically, charging data for selected states and cities was sourced from the EV Project Quarterly Reports for 2013,[7] which allowed for comparisons of both daily EV charging patterns and any seasonal changes in these patterns.

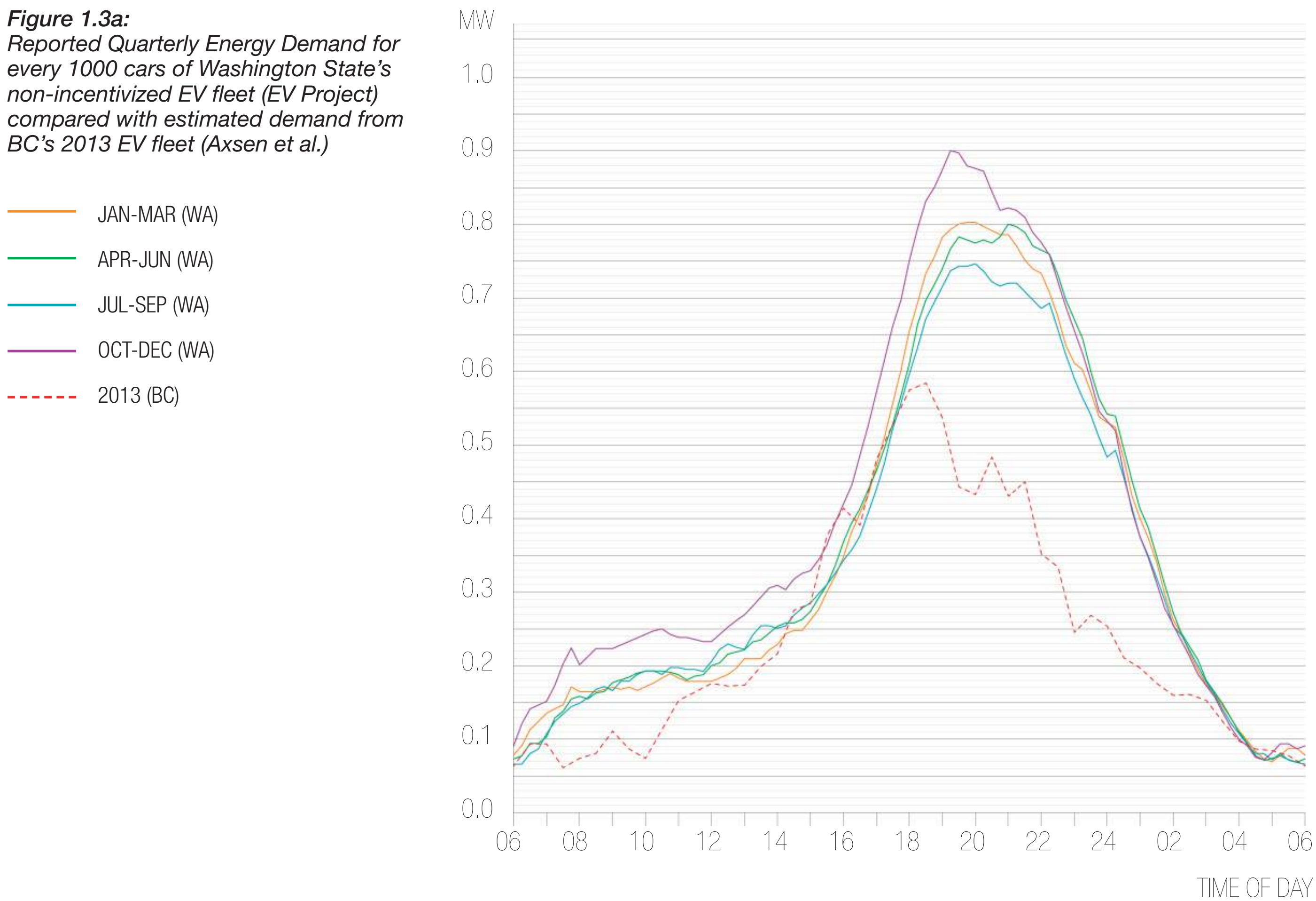
The INL-managed EV Project was selected as a reference for its holistic focus on the development of an EV charging network to determine where future charging stations should be installed, in part by considering EV drivers' preferences for using charging infrastructure at home, at work or in public locations.[8] The study therefore tracked charging habits, both by recording the charging events initiated by the users of individual EVs enrolled in the project and those that took place at the residential and public charging stations installed for the project.[9] The fact that the charging of a relatively consistent group of EVs was monitored throughout the 2013 year of the study[10] suggests that this data provides a reliable estimate of the charging habits of the drivers of a vehicle fleet in a given area, and can be compared to the estimated charging habits of the drivers of B.C.'s EV fleet produced in the Axsen survey.

For the purposes of this analysis, the following areas participating in the EV Project were considered: Washington State; Nashville, TN; and Dallas-Fort Worth, TX, for those without TOU rates; and Oregon State; Los Angeles, CA; and Atlanta, GA, for those with TOU rates. One jurisdiction for non-incentivized charging and one for TOU incentivized charging were then selected for comparison with B.C.'s charging profile.

7. "EV Project Electric Vehicle Charging Infrastructure Summary Report." Quarters 1, 2, 3, 4 of 2013 (2013). Idaho National Laboratory. Accessed February 29, 2016. https://avt.inl.gov/project-type/quarterly-and-annual-reports-and-maps.
8. Francfort, Jim, et al. "Plug-in Electric Vehicle and Infrastructure Analysis." Idaho National Laboratory. Prepared for the U.S. Department of Energy. September 2015, p. 9-3. Accessed April 26, 2015. https://avt.inl.gov/sites/default/files/pdf/arra/ARRAPEVnInfrastructureFinalReportLqltySept2015.pdf
9. *Ibid*., p. 9-3.
10. *Ibid*., Fig. 9-12, p. 9-9.

NON-INCENTIVIZED CHARGING PROFILES

Figure 1.3a:
Reported Quarterly Energy Demand for every 1000 cars of Washington State's non-incentivized EV fleet (EV Project) compared with estimated demand from BC's 2013 EV fleet (Axsen et al.)



EV charging data from the INL's EV Project for jurisdictions without TOU incentivization[11] was examined as a source of actual data for comparison with the hypothetical charging profile produced by the Axsen survey for B.C.'s EV fleet.

The focus of this comparison was to ascertain whether any seasonal changes in EV charging emerge in practice that could not be captured in the Axsen survey. The comparison area was selected on the basis of fleet size, data reliability (based on the number of project vehicles), and driving distance.

According to participant responses in the Axsen survey for B.C., the average driving distance per day was 54 km, excluding zero-trip days.[12]

In part since the Axsen survey considered data from respondents in B.C., not only Vancouver, Washington State was selected as a comparable jurisdiction. Washington

11. The presence or absence of TOU rates for a given project participant area was determined by consulting the following report: Anair, Don and Amine Mahmassani. "State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings across the United States." Union of Concerned Scientists. June 2012, pp. 21-22. Accessed March 14, 2016. http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_vehicles/electric-car-global-warming-emissions-report.pdf

12. Axsen, John, et al. CPEVS 2013, p. 32.

State has a relatively large fleet size, with 7,896 plug-in EVs registered by the end of 2013.[13] In the Axsen survey, 261 of the 538 respondents were located in the Metro Vancouver area.[14] Similarly, King County, the metropolitan area surrounding Seattle, accounts for over half of the EV registrations in Washington.[15] The Puget Sound region also shares a moderate climate with Vancouver, which is considered “ideal” for driving all-electric vehicles.[16]

Data for Washington State was compiled from an average of 875 EV Project vehicles participating in 2013.[17] In comparison to the Axsen survey, the daily average driving distance of EV Project participants in Washington state is greater, at 67.5 km.[18]

The EV Project graphs for “Charging Demand: Range of Aggregate Electricity Demand versus Time of Day” were consulted for all four quarters of 2013.[19] In Figure 1.3a, the non-incentivized charging profile for Washington State was pro-rated to the 1,000 cars in B.C.’s fleet for comparison purposes. The dashed red line represents B.C.’s profile according to the Axsen survey’s Figure E-9.[20]

As Figure 1.3a shows, there is some seasonal variation in the charging profiles in this state, particularly at peak times: from July to September, the energy demand of 1000 cars in this EV fleet peaks at 300 kW lower than it does from October to December. The peak time for charging also appears to be at around 8 p.m. rather than the 6 p.m. time estimated for B.C. The greater amount of energy consumed by each car could be attributable, at least in part, to the differences in driving distance, which is on average 25% greater according to the data for Washington. However, on the whole, this region’s charging profile is quite similar to the B.C. profile, except that the INL participants in Washington appear to charge more in the morning than their B.C. survey respondent counterparts.

Overall, this comparison shows the estimated profile from Axsen’s survey to be quite similar to actual charging profiles, but highlights that charging habits can vary slightly by season. The particular reasons for these variations are difficult to determine, and so these particular seasonal patterns may not necessarily transfer to a B.C. context.

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13. “Washington State Electric Vehicle Action Plan 2015-2020.” Washington State Department of Transportation. February 2015, pp. 9–10. Accessed April 22, 2016. http://www.wsdot.wa.gov/NR/rdonlyres/28559EF4-CD9D-4CFA-9886-105A30FD58C4/0/WAEVActionPlan2014.pdf
14. Axsen, John, et al. CPEVS 2013, “Figure 7: Geographical representation of the BC survey sample by postal code”, p. 32.
15. “Washington State Electric Vehicle Action Plan 2015-2020”, p. 9.
16. *Ibid*. p. 10.
17. “EV Project Electric Vehicle Charging Infrastructure Summary Report.” January 2013-December 2013. Washington State, p. 99.
18. Francfort, Jim, et al. “Plug-in Electric Vehicle and Infrastructure Analysis.” Figure 9-44. INL, 2015, p. 9-32.
19. “EV Project Electric Vehicle Charging Infrastructure Summary Report.” Quarters 1, 2, 3, 4 of 2013 (2013). Idaho National Laboratory. Accessed February 29, 2016. https://avt.inl.gov/project-type/quarterly-and-annual-reports-and-maps.
20. Axsen, John, Harry Joe Bailey, and George Kamiya. “The Canadian Plug-in Electric Vehicle Survey (CPEVS 2013): Anticipating Purchase, Use, and Grid Interactions in British Columbia.” Energy and Materials Research Group - Simon Fraser University, 2013, Figure 18, p. x.

Figure 1.3b:
Reported Quarterly Energy Demand for every 1000 cars of Los Angeles Metropolitan Area, CA's incentivized EV fleet (EV Project) compared with estimated demand from BC's 2013 EV fleet (Axsen et al.*)*

INCENTIVIZED CHARGING PROFILES

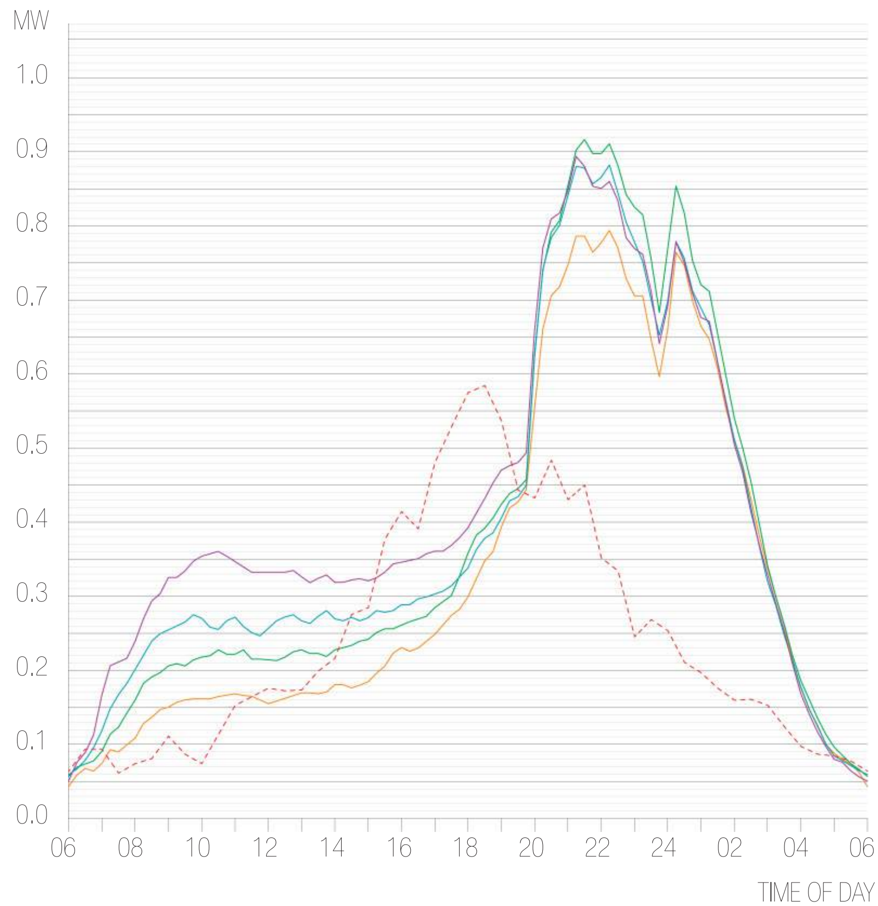

***Figure 1.3a** (reproduced for comparison): Reported Quarterly Energy Demand for every 1000 cars of Washington State's non-incentivized EV fleet (EV Project) compared with estimated demand from BC's 2013 EV fleet (Axsen* et al.*)*

EV charging data from the INL's EV Project for jurisdictions with TOU incentivization[21] was examined as a source of actual data for comparison with the hypothetical charging profile produced by the Axsen survey for B.C.'s EV fleet.

The focus of this comparison was to determine to what extent TOU rates affect the times of day at which EV users choose to charge their cars, thereby potentially modifying the charging profile. The comparison jurisdiction was selected on the basis of fleet size, data reliability (number of project vehicles), and driving distance.

According to participant responses in the Axsen survey for B.C., the average driving distance per day was 54 km, excluding zero-trip days.[22]

As in the previous TIPSlab Energy Report, Los Angeles was selected as a comparable jurisdiction. Los Angeles was chosen in part because it has the largest

21. The presence or absence of TOU rates for a given project participant area was determined by consulting the following report: Anair, Don and Amine Mahmassani. "State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings across the United States." Union of Concerned Scientists. June 2012, pp. 21-22. Accessed March 14, 2016. http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_vehicles/electric-car-global-warming-emissions-report.pdf

22. Axsen, John, et al. CPEVS 2013, p. 32.

EV fleet in North America, with 27,411 EVs on the road as of February 2014.[23] It also has a large sample size in the EV Project, with an average of 624 participating project vehicles throughout 2013.[24]

Moreover, Los Angeles was chosen because of its EV TOU Meter Service and EV Discount program that is offered through the Los Angeles Department of Water & Power.[25] If EV users install a separate TOU meter dedicated to their EV charging, the following incentives apply: "This option qualifies for a rebate up to $750. Residential customers will also receive a $250 LADWP credit if a separate TOU meter panel is installed. This option also qualifies for 2.5 cents per kWh discount off the base period."[26]

In Los Angeles' climate, TOU rates are designed to discourage energy use throughout the year during peak hours from 1 to 5 p.m., and more generally from 10 a.m. to 8 p.m.[27] Rates become steeper during these times in the high season from June to September.

The EV Project graphs for "Charging Demand: Range of Aggregate Electricity Demand versus Time of Day" were consulted for all four quarters of 2013.[28] In Figure 1.3b, the non-incentivized charging profile for Los Angeles was pro-rated to the 1,000 cars in B.C.'s fleet for comparison purposes. The dashed red line represents B.C.'s profile according to the Axsen survey's Figure E-9.

As Figure 1.3b shows, the TOU incentives have succeeded in altering times of energy consumption from EV charging, moving the peak charging period to 10 p.m. Some morning charging also occurs before the peak rates begin at 1 p.m. Seasonally, the trends are more difficult to quantify, as overall charging in the third quarter, from July to September, when TOU incentives are at their height, is less than from October to December, but greater than from January to March. Therefore, Los Angeles' TOU rates appear to effectively shift charging habits out of the daily peak period but have little impact seasonally. This analysis suggests that significant seasonal adjustments in EV charging profiles may not be achievable by opt-in TOU incentivization programs such as the one implemented by L.A.

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23. Romero, Dennis. "L.A. Is America's Electric Car Capital." LA Weekly. February 25, 2014. Accessed September 18, 2014. http://www.laweekly.com/informer/2014/02/25/la-is-americas-electric-car-capital. Cited from the previous TIPSlab Energy Report (2014).
24. "EV Project Electric Vehicle Charging Infrastructure Summary Report." January 2013-December 2013. Los Angeles, p. 24.
25. "Electric Vehicle Incentives." Los Angeles Department of Water and Power. 2013. Accessed April 19, 2016. https://www.ladwp.com/ladwp/faces/ladwp/residential/r-gogreen/r-gg-driveelectric/r-gg-de-evncentives?_adf.ctrl-state=nry9em8pl_4&_afrLoop=689742328483805
26. "Electric Vehicle Level 2 (240 volt) Charging and Meter Options." Los Angeles Department of Water and Power. Revised August 1, 2013. Accessed April 19, 2016. https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=LADWP004810&RevisionSelectionMethod=LatestReleased
27. "Your Electric Rates." Los Angeles Department of Water and Power. 2015. Accessed April 19, 2016. http://www.myladwp.com/understanding_your_electric_rates
28. "EV Project Electric Vehicle Charging Infrastructure Summary Report." Quarters 1, 2, 3, 4 of 2013 (2013). Idaho National Laboratory. Accessed February 29, 2016. https://avt.inl.gov/project-type/quarterly-and-annual-reports-and-maps.

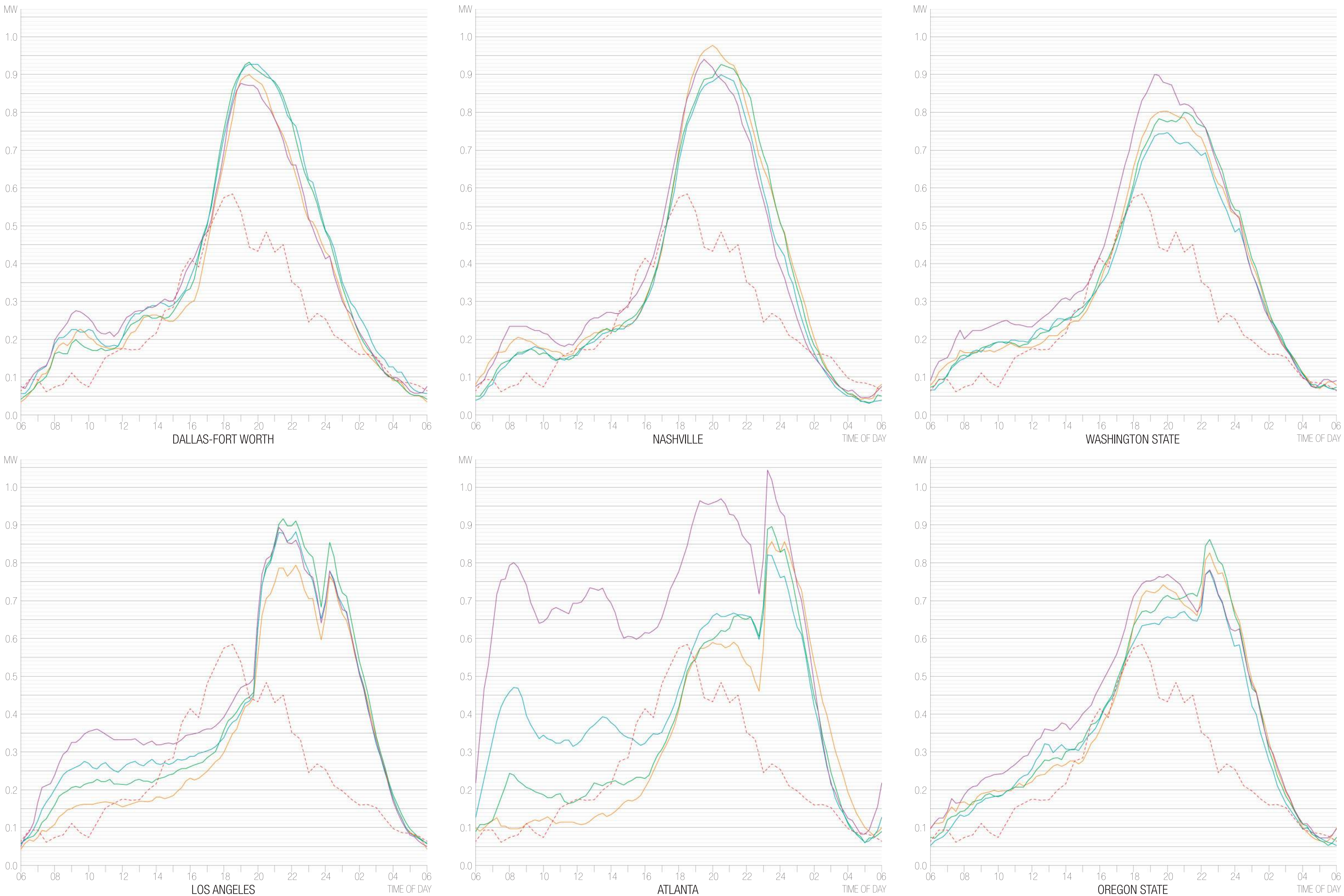


Figure 1.2:
Reported Energy Demand by Jurisdiction - EV Project

Non-incentivized:

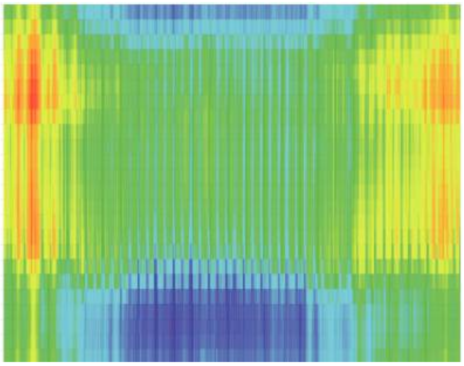
Dallas/Fort Worth
Nashville
Washington State

Incentivized:

Los Angeles
Atlanta
Oregon State

The figure shows that despite variations in daily charging patterns and times of peak load depending on the presence or absence of incentivization programs, peak load per 1000 EVs remains near the same value in each jurisdiction.

BC
JAN - MAR
APR - JUN
JUL - SEP
OCT - DEC



Thumbnail of Figure 1.4: *B.C.'s Annual Grid Load (see next page)*

COINCIDENCE OF PEAK B.C. GRID LOAD AND PEAK CHARGING TIMES

Domination of daily over seasonal trends

Both the Axsen survey and the INL data discussed above show that peak non-incentivized charging times occur around 6 p.m., which is also the point of time in the day when there is the greatest load on B.C.'s power grid. The peak load times can be seen in Figure 1.4, which plots the hourly energy demand on BC Hydro's grid, in MWh, over the course of the year, as reported by the utility's Balancing Authority.§ The coloured segments form a data topography showing the grid load during each hour of the day throughout the year.

This figure illustrates that BC Hydro's grid load follows both seasonal and daily patterns. The seasonal trends show that electricity demand is at its lowest during the spring and summer months, from late March to mid-August, and higher during the rest of the year, particularly from late December to early February. The daily patterns demonstrate greater electricity use through all seasons during the daytime hours, with a peak around 6 p.m. particularly evident in the winter months.

The trends illustrated in Figure 1.4 highlight considerations that support the development of renewable energy as a source for EV charging. As discussed in the previous TIPSlab Energy Report, electric vehicles can store energy drawn from the grid during non-peak hours, helping distribute the demand on BC Hydro's electrical grid. From the perspective of daily charging patterns, TOU incentivization may be an effective method of reshaping the EV charging demand.

Figure 1.4 illustrates that BC Hydro's grid load follows both seasonal and daily patterns. The seasonal trends show that electricity demand is at its lowest during the spring and summer months, from late March to mid-August, and higher during the rest of the year, particularly from late December to early February. The daily patterns demonstrate greater electricity use through all seasons during the daytime hours, with a peak around 6 p.m. evident in the winter months.

§. "Balancing Authority Load Data." BC Hydro. January 1, 2014. Accessed February 12, 2016. http://transmission.bchydro.com/transmission_system/balancing_authority_load_data/.

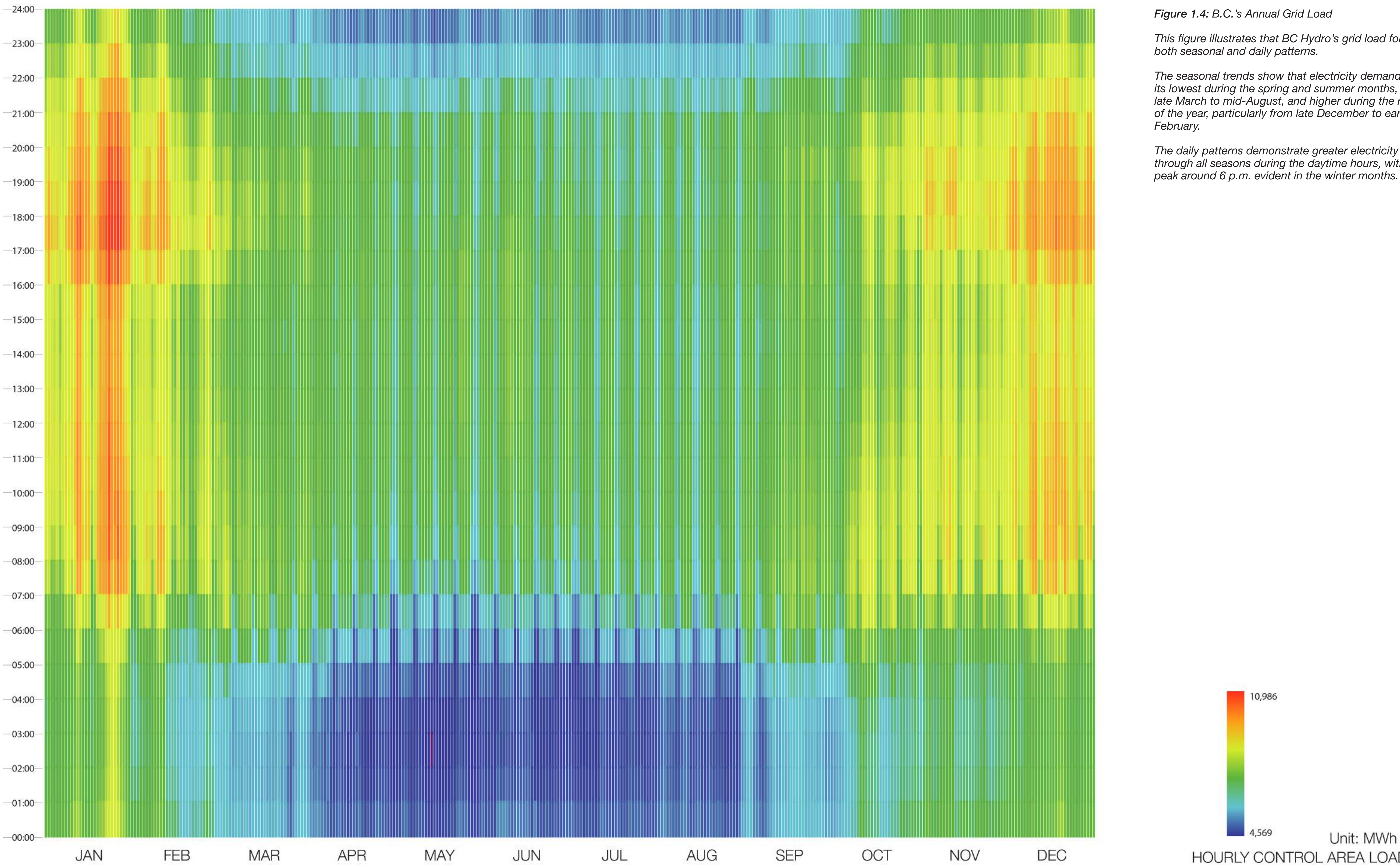
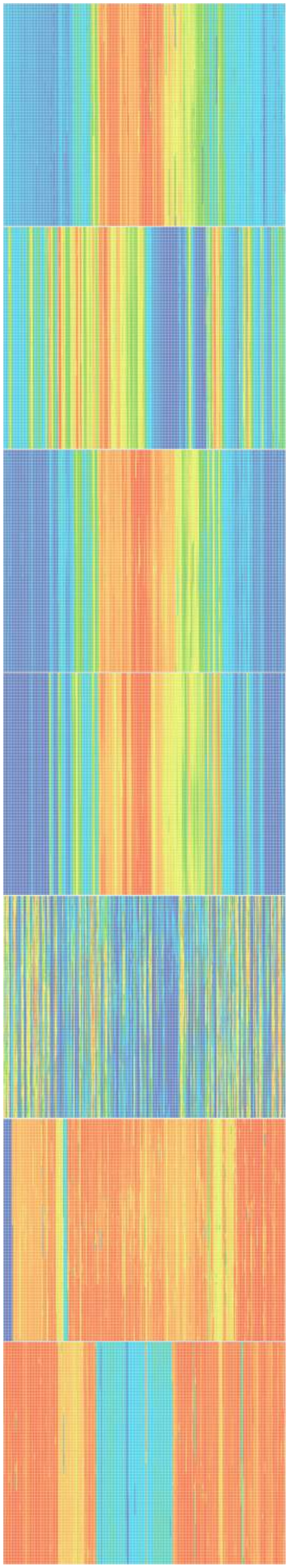


Figure 1.4: *B.C.'s Annual Grid Load*

This figure illustrates that BC Hydro's grid load follows both seasonal and daily patterns.

The seasonal trends show that electricity demand is at its lowest during the spring and summer months, from late March to mid-August, and higher during the rest of the year, particularly from late December to early February.

The daily patterns demonstrate greater electricity use through all seasons during the daytime hours, with a peak around 6 p.m. evident in the winter months.



II. ANALYSIS OF RENEWABLE ENERGY GENERATION IN B.C.

METHODOLOGY

Data for renewable energy generation by B.C.'s IPPs in 2013 was obtained from BC Hydro in partnership with the Institute for Integrated Energy Systems at the University of Victoria. The data was available in a number of groups, mainly according to IPP type and geographical area, which facilitated an analysis based on renewable energy category and region. For the purposes of this report, the following analysis categories for renewable sources were used: run-of-river hydro, wind, and thermal energy.

The data was available in 5-minute intervals for each group. The ability to track changes over short time intervals has highlighted considerations of generation patterns and reliability, as will be addressed below. As can be seen in the following analysis, the vast majority of the renewable energy generated by B.C.'s IPPs shows clear seasonal trends typical to each energy category.

For non-dispatchable hydro, the geographical regions identified for the purposes of this analysis are the Sunshine Coast and Fraser Valley, Southern B.C., Vancouver Island, and the Peace Region. These regions emerged from the relative geographic proximity of the IPPs in this category, to the extent permitted by the groups in which the data for these IPPs was made available by BC Hydro.

As only one data set for wind energy could be obtained, the wind category is represented by one region only—the Peace Region. For purposes of comparison, hypothetical data (for 2024) projected by BC Hydro was obtained for the IPPs currently in operation in the Vancouver Island region. This projected data for the Vancouver Island IPPs has not been incorporated into the total energy generated; it is used for purposes of comparison with actual wind data for the Peace Region only.

For the thermal energy category, the analysis focuses on two regions, according to the groupings of IPP data available: Metro Vancouver and the Southern Interior.

PREDOMINANT TRENDS IN B.C.'S RENEWABLE ENERGY SOURCES

To determine the predominant trends of the energy profiles for each renewable energy category, the 5-minute energy generation data for non-dispatchable hydro, wind and thermal IPPs was analyzed using an innovative visualization method.

This method created "data topographies", in which dots of colour are used to map the energy generated in each time interval throughout each day over the course of the year. The graphs were instrumental to identifying whether the energy generation data followed daily or seasonal trends. As the colour dots on each "topography" correspond to the quantity of energy generated in each 5-minute interval for that IPP category and region, the predominant trends for each data set were revealed according to the axis along which patterns in these colours are aligned, while the strength of the trends was shown by the consistency of colour distribution.

[Left: Thumbnails of Figures 2.1a to 2.3b (see following pages)]

YEAR-LONG TREND ANALYSIS BY REGION

As shown in the data topography graphs on the pages that follow, the trends that emerge for all energy types--non-storage hydro, wind and thermal--are seasonal. This is made clear by the lines and bars of consistent colour that often run across all hours of the day for either several days, weeks or months of time.

The patterns that emerge for run-of-river hydro energy are seasonal highs in the summer months and lows in the winter months, with variations more prevalent in the spring and fall. Wind energy overall follows the opposite trend, but with much more variability. Thermal energy output is relatively constant over the course of the year.

Hydro

Hydro energy generated by IPPs in the Peace Region has consistent low periods over many months in the winter and a relatively stable high period from May to July, with noticeable week-to-week variation only occurring for a month in the spring and a couple of months in the fall. There are no repeating daily trends.

Hydro energy generated by IPPs in the Vancouver Island region shows similar seasonal trends, except that the summer output is shifted forward from mid-March to mid-June. However, periods of consistency are rare; at most times of the year stable output lasts for days to a week. No significant daily patterns are in evidence.

Hydro energy generated by IPPs in the Southern B.C. region is seasonally distinct and similar to the Peace Region, with reliably little output from December to February and month-long periods of consistent high output from May to July. In between, fluctuations occur from week-to-week or, particularly in late April and late September, over several days. There some minor daily variations but is no discernable daily trend.

Hydro energy generated by IPPs in the Sunshine Coast and Fraser Valley region is very similar to the Southern B.C. region, but with the periods of week-to-week variation extending from late February into early May and from late August to early September. Except for a period from mid-August to mid-September when power generation tends to dip slightly during the daytime, no clear daily patterns emerge.

Wind

Wind energy generated in the Peace Region follows some seasonal patterns, being on average lower in late spring and midsummer and peaking sporadically throughout the rest of the year. Output usually remains within a narrower range for several days to a week at a time, and then changes. Although overall seasonal trends exist, with the longest steady period being a low lasting from about mid-July to mid-August, the data is strongly characterized by significant, frequent fluctuations.

There is also some variation in energy generation at different times of day, such that sometimes a high or low will occur at a certain time of day over several consecutive days and perhaps for as long as a week. However, these trends are short-lived and prone to change. Therefore, no daily pattern in any season can be reliably determined.

Thermal

Thermal energy generated in the Metro Vancouver region is relatively stable throughout the year, with only a few lower periods lasting for a week or two. There also appears to be some variability on individual days, with relative lows sometimes occurring during the day, but these patterns only appear from time to time. (N.B.: The period of apparent zero output in early January is should be ignored, as it is caused by an absence of data for this period.)

Thermal energy generated in the Southern Interior region exhibits periodic changes that are quite abrupt. The overall high output dips slightly from early March to mid-April, and later enters a low from late April to early August. There are otherwise a couple of low periods lasting for several days in the fall. No meaningful daily patterns appear to exist.

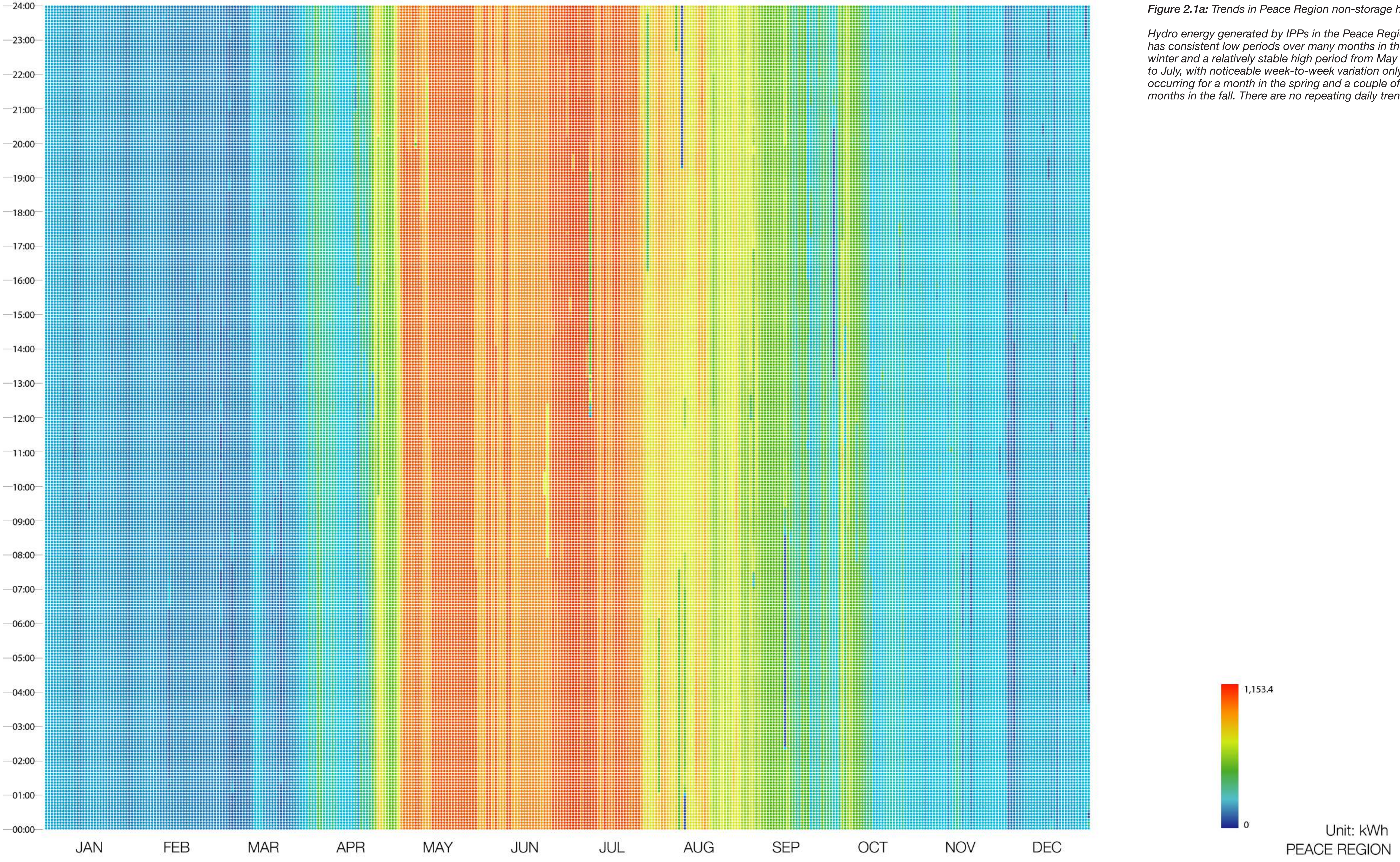


Figure 2.1a: *Trends in Peace Region non-storage hydro*

Hydro energy generated by IPPs in the Peace Region has consistent low periods over many months in the winter and a relatively stable high period from May to July, with noticeable week-to-week variation only occurring for a month in the spring and a couple of months in the fall. There are no repeating daily trends.

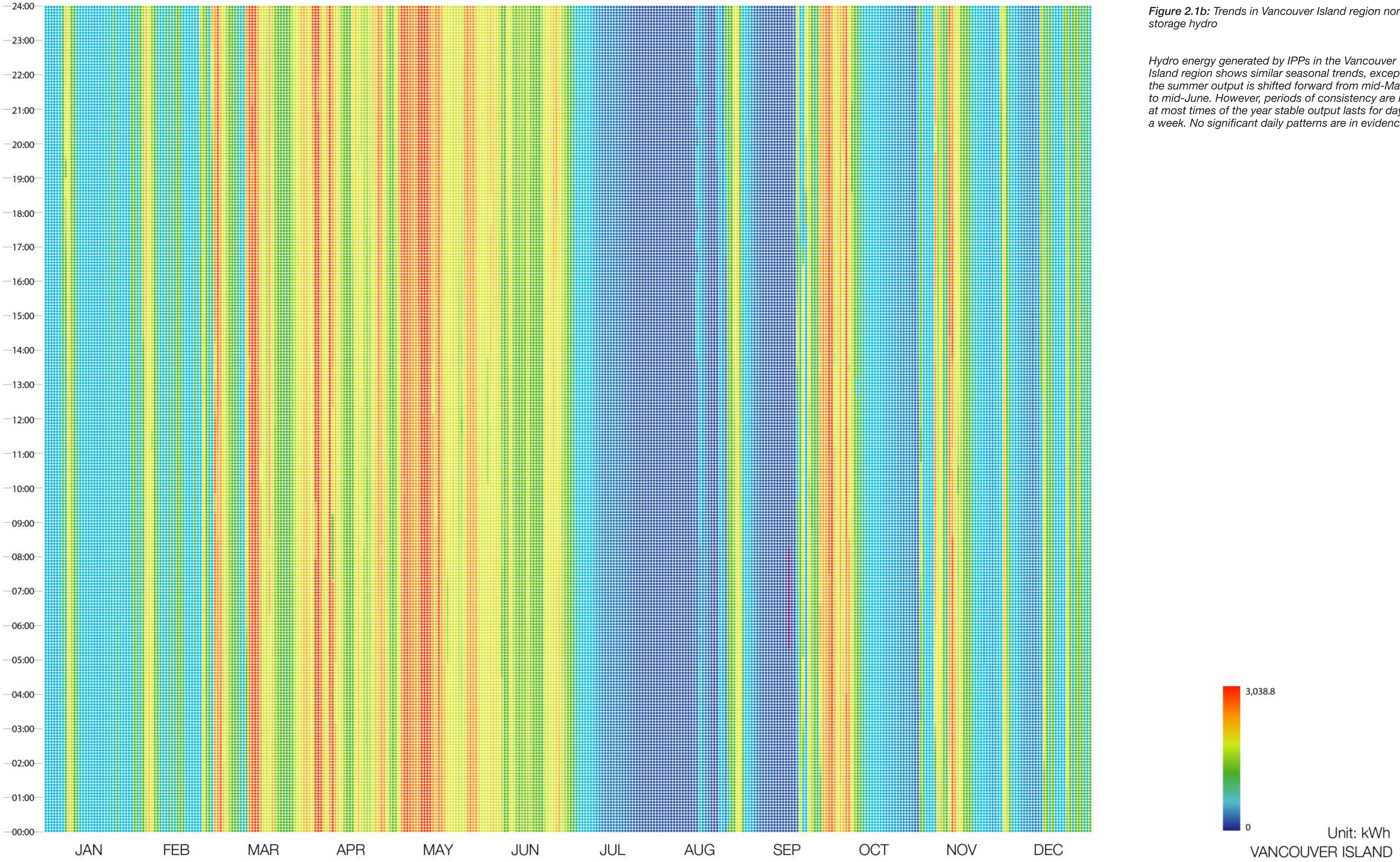


Figure 2.1b: *Trends in Vancouver Island region non-storage hydro*

Hydro energy generated by IPPs in the Vancouver Island region shows similar seasonal trends, except that the summer output is shifted forward from mid-March to mid-June. However, periods of consistency are rare; at most times of the year stable output lasts for days to a week. No significant daily patterns are in evidence.

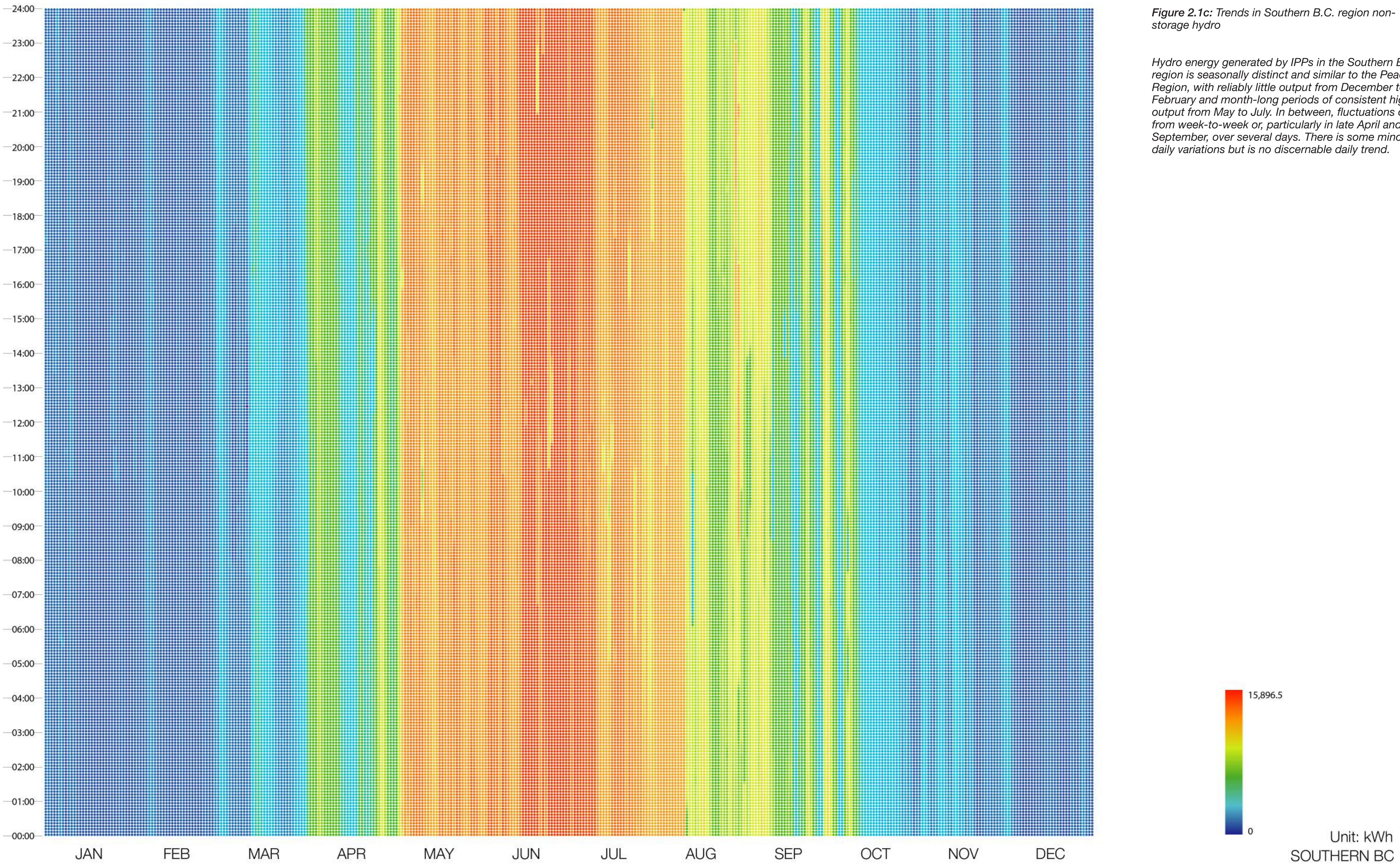


Figure 2.1c: *Trends in Southern B.C. region non-storage hydro*

Hydro energy generated by IPPs in the Southern B.C. region is seasonally distinct and similar to the Peace Region, with reliably little output from December to February and month-long periods of consistent high output from May to July. In between, fluctuations occur from week-to-week or, particularly in late April and late September, over several days. There is some minor daily variations but is no discernable daily trend.

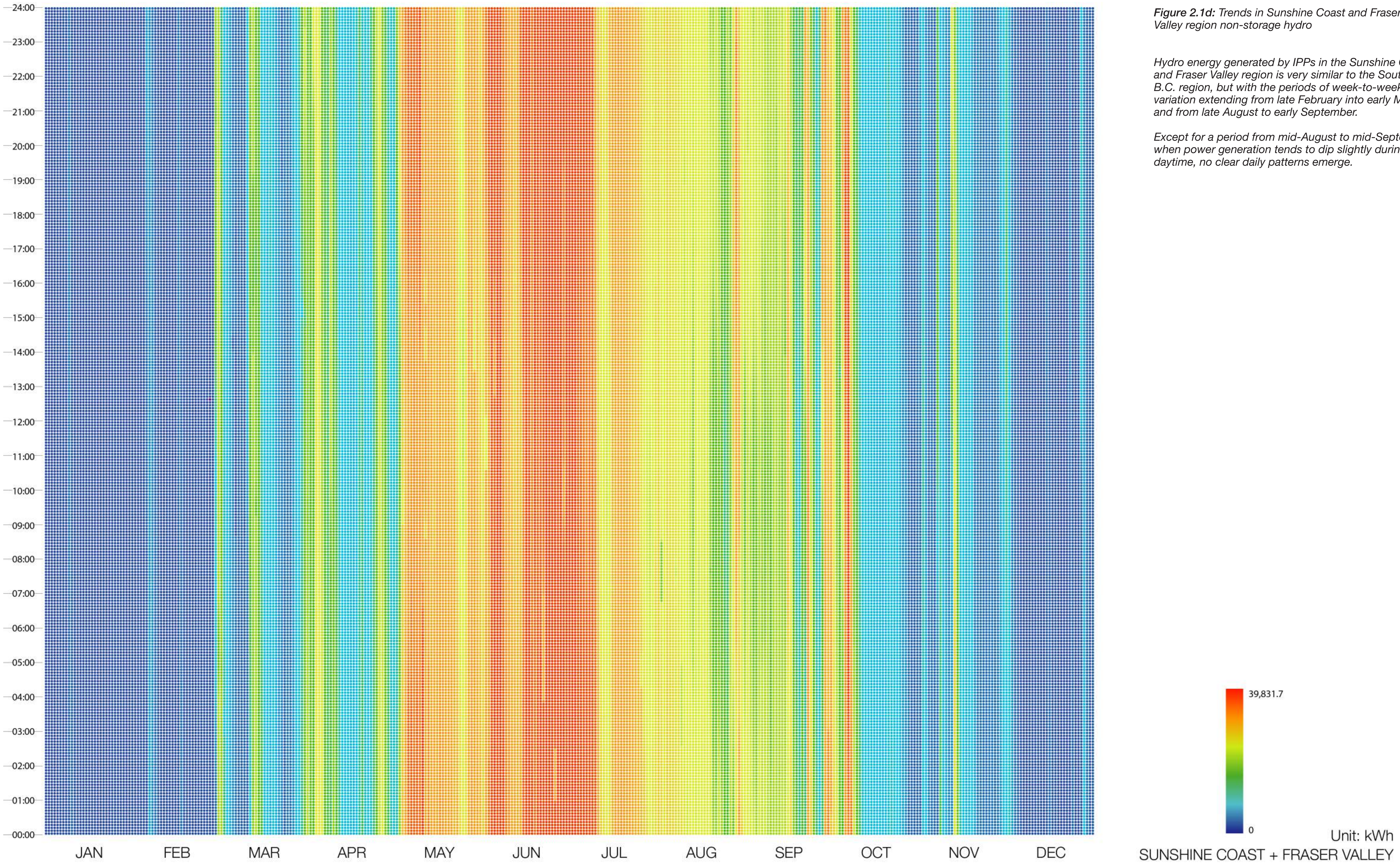


Figure 2.1d: *Trends in Sunshine Coast and Fraser Valley region non-storage hydro*

Hydro energy generated by IPPs in the Sunshine Coast and Fraser Valley region is very similar to the Southern B.C. region, but with the periods of week-to-week variation extending from late February into early May and from late August to early September.

Except for a period from mid-August to mid-September when power generation tends to dip slightly during the daytime, no clear daily patterns emerge.

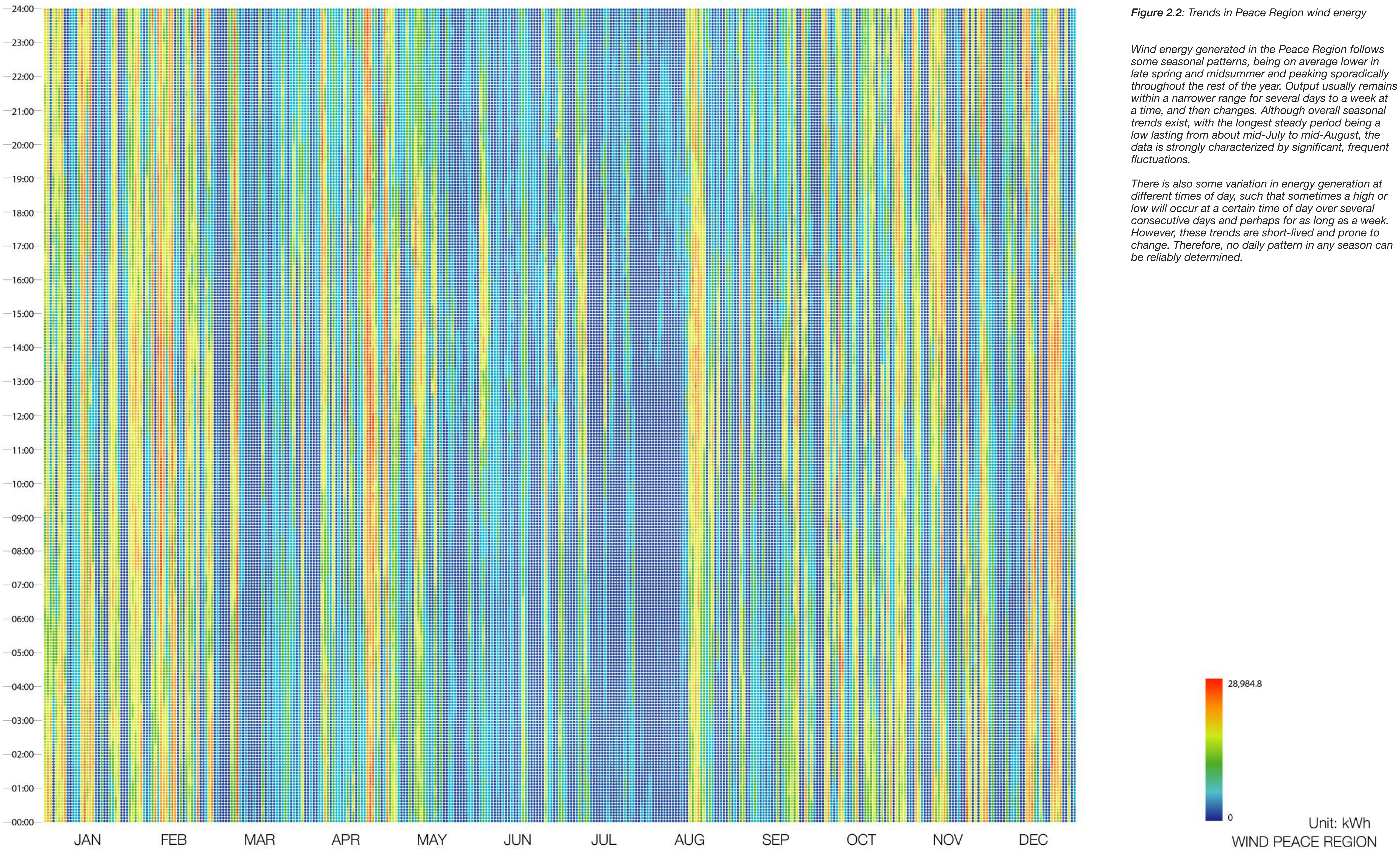


Figure 2.2: *Trends in Peace Region wind energy*

Wind energy generated in the Peace Region follows some seasonal patterns, being on average lower in late spring and midsummer and peaking sporadically throughout the rest of the year. Output usually remains within a narrower range for several days to a week at a time, and then changes. Although overall seasonal trends exist, with the longest steady period being a low lasting from about mid-July to mid-August, the data is strongly characterized by significant, frequent fluctuations.

There is also some variation in energy generation at different times of day, such that sometimes a high or low will occur at a certain time of day over several consecutive days and perhaps for as long as a week. However, these trends are short-lived and prone to change. Therefore, no daily pattern in any season can be reliably determined.

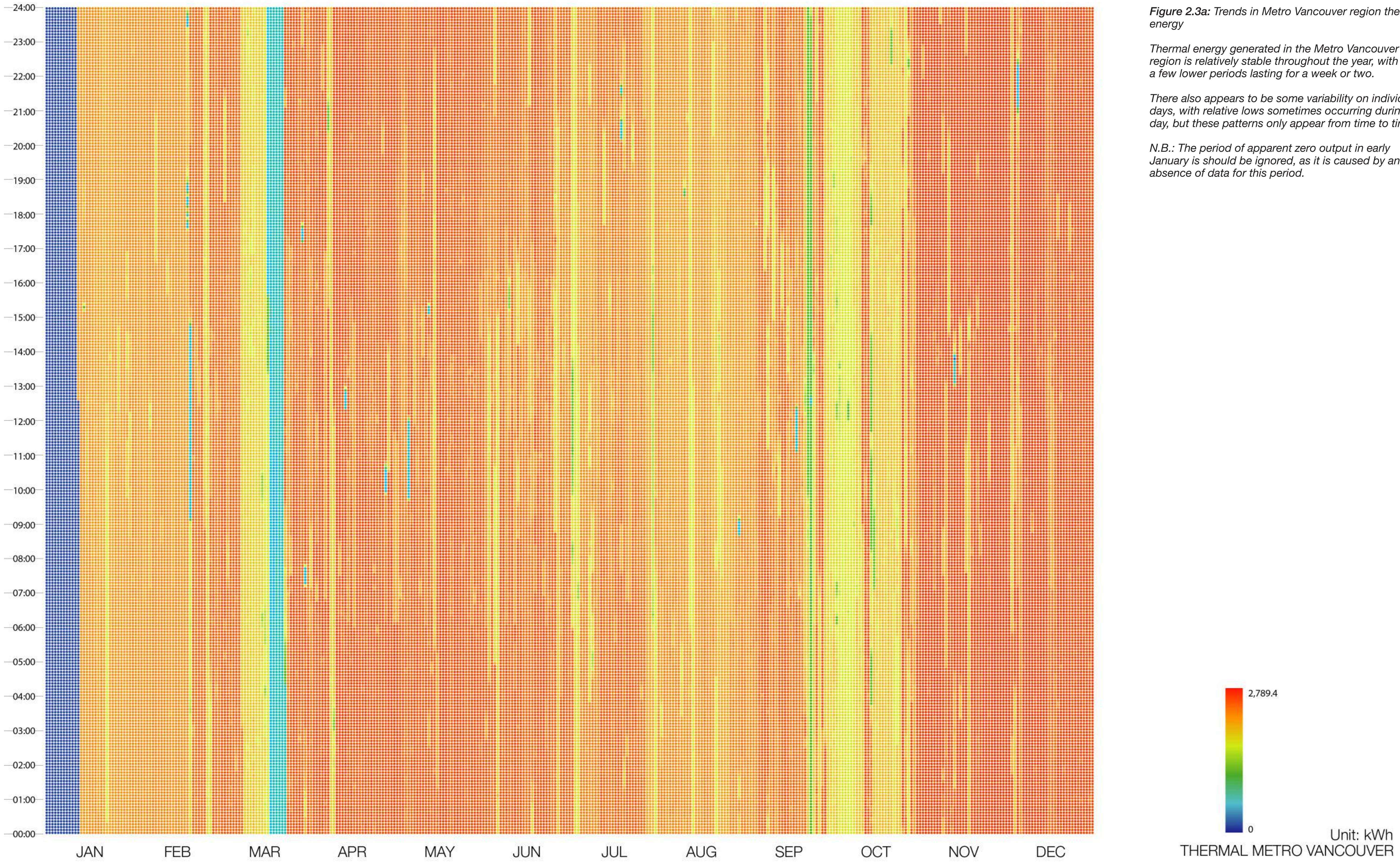


Figure 2.3a: *Trends in Metro Vancouver region thermal energy*

Thermal energy generated in the Metro Vancouver region is relatively stable throughout the year, with only a few lower periods lasting for a week or two.

There also appears to be some variability on individual days, with relative lows sometimes occurring during the day, but these patterns only appear from time to time.

N.B.: The period of apparent zero output in early January is should be ignored, as it is caused by an absence of data for this period.

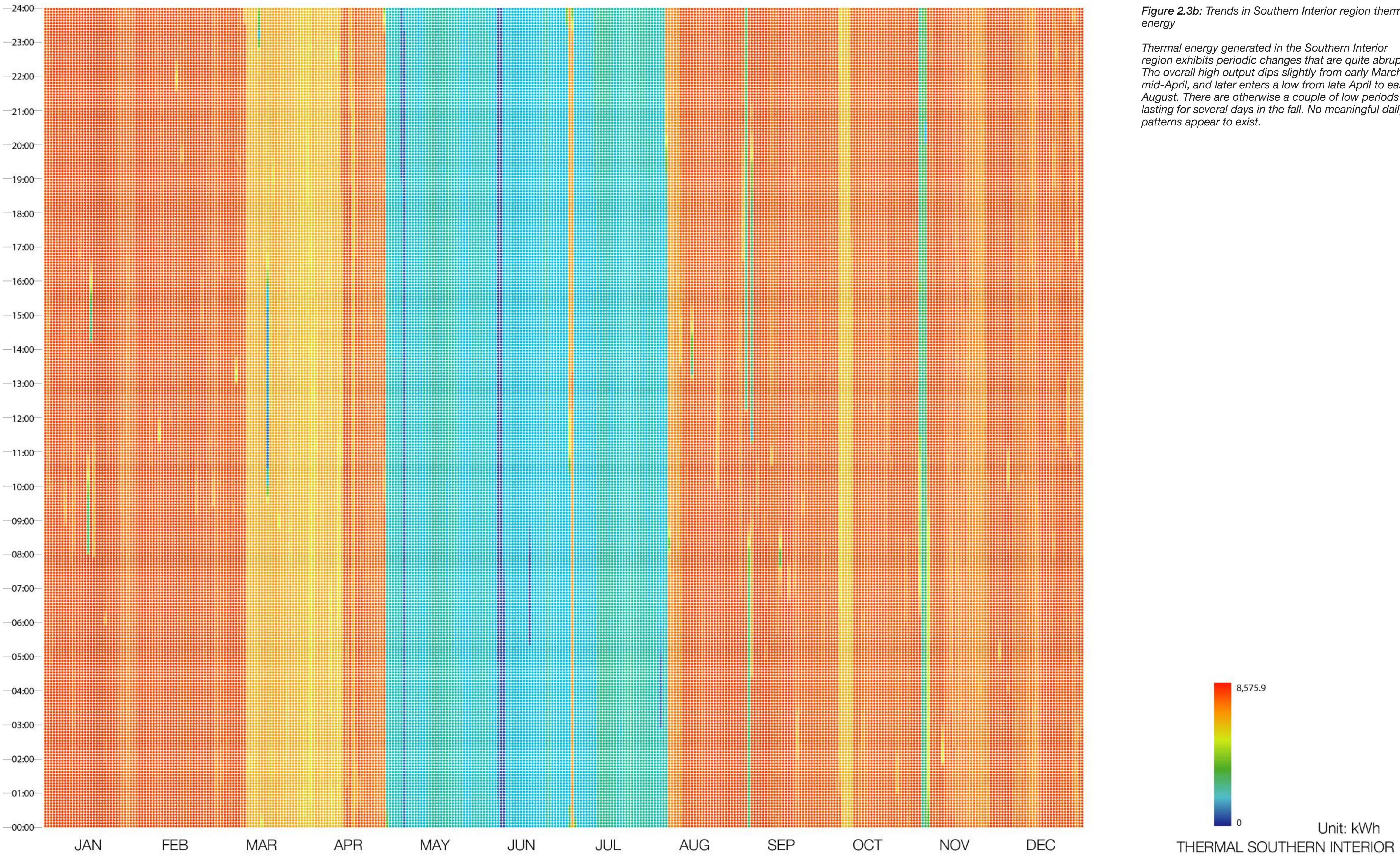


***Figure 2.3b:** Trends in Southern Interior region thermal energy*

Thermal energy generated in the Southern Interior region exhibits periodic changes that are quite abrupt. The overall high output dips slightly from early March to mid-April, and later enters a low from late April to early August. There are otherwise a couple of low periods lasting for several days in the fall. No meaningful daily patterns appear to exist.

DAILY TREND ANALYSIS BY ENERGY TYPE

To confirm and clarify the findings in the data topographies, daily samples were taken from one regional group in each of the wind, hydro and thermal categories to better ascertain the daily behaviour of these energy sources. These are shown in Figure 2.4a.

The samples were taken from the month of March for each group, from the dates of the 1, 10, 19 and 28. The daily fluctuations are shown over the full 24-hour period.

Hydro

The daily samples of hydro energy generation were taken from the Peace Region data. They show that the output is relatively stable--on some days, over the course of the full 24-hour period; on other days, with a gradual change from hour to hour, and only very small fluctuations between five-minute increments. There is no repeated trend when comparing from day to day, except that the values for this time of year remain within a similar range.

Wind

The daily samples of wind energy generation were taken from the Peace Region (as it is the only source of actual wind energy data available to this study). They show that wind energy is quite unstable--that is, there is a good likelihood that the energy generated will be different from hour to hour, and particularly from one time of day to another. However, they also show that this energy source is not highly volatile, in that there do not appear to be large differences in the energy generated from one 5-minute increment to the next. Rather, the data reflect a continuous curve as a result of small increases and decreases. This curve is different for each day, and does not appear to follow any noticeable trends from day to day.

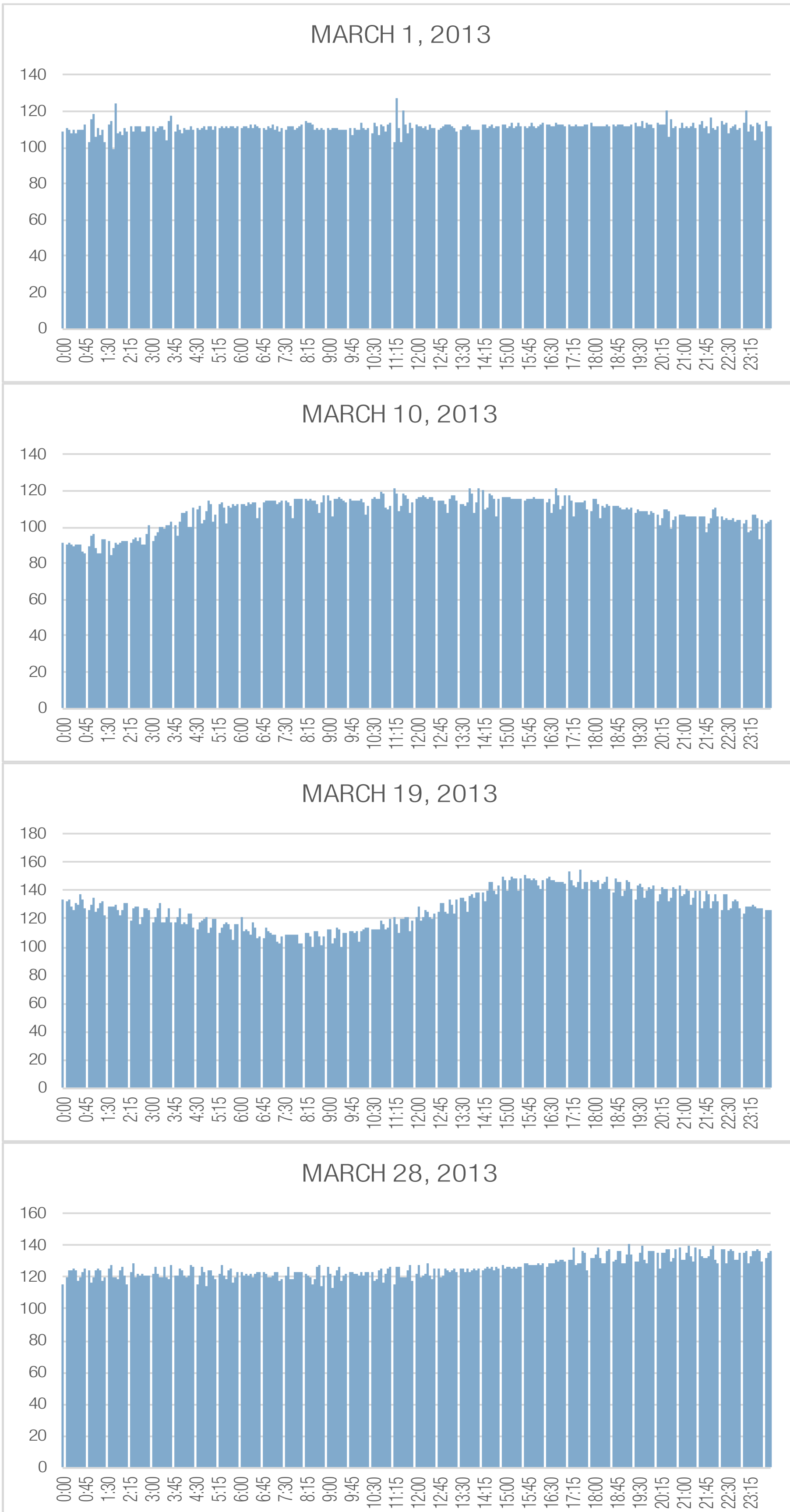
Thermal

The daily data samples for thermal energy reveal two possible behaviours. The first is an apparently regulated profile at lower levels of energy, where the output is very or entirely stable between 5-minute intervals unless subjected to some external control, which can cause significant output changes very quickly at both the five-minute and hour scales. The second behaviour shows the output varying around what appears to be the maximum output of the energy source, fluctuating either little or significantly from hour to hour. Of note is that there can also be quite a bit of change between 5-minute intervals, much more frequently than occurs for wind and also more often than for hydro. When unregulated, thermal energy outoput starts and ends in a similar range each day, but goes through some unpredictable fluctuations. These changes do not reveal a daily pattern.

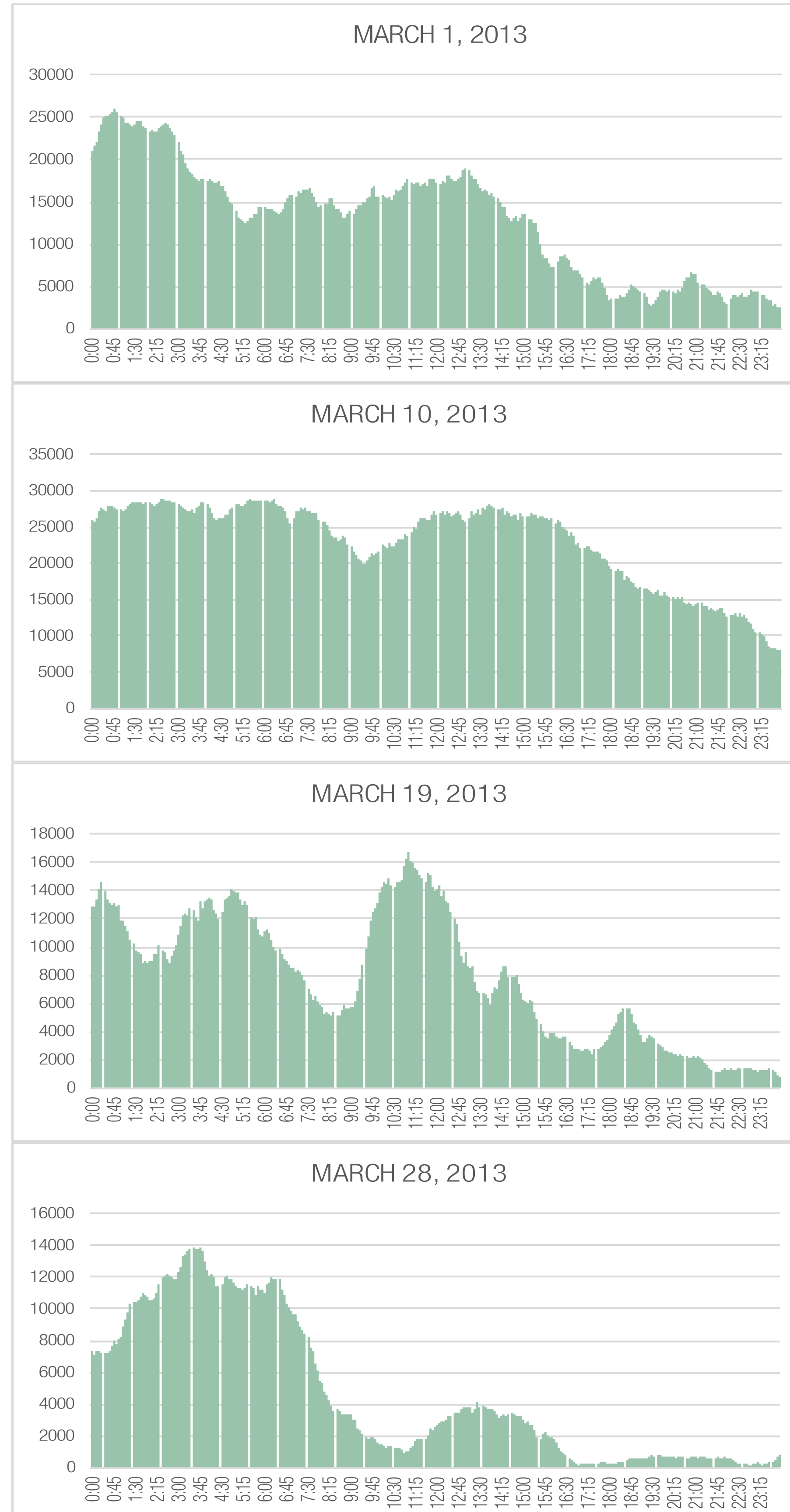
Observations

The daily sample graphs for energy output of hydro, wind and thermal IPPs in Figure 2.4a show in particular that the variations between consecutive 5-minute intervals are small. These variations can be managed by digital charging interfaces, reinforcing the appropriateness of these energy sources for electric vehicle charging.

HYDRO: PEACE REGION



WIND: PEACE REGION



THERMAL: METRO VANCOUVER