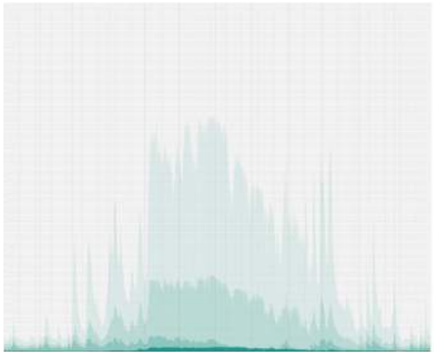

***Thumbnail of Figure 2.4:** Year-long profile of total non-storage hydro power produced in B.C. in 2013.*

YEAR-LONG PROFILES OF B.C.'S RENEWABLE HYDRO, WIND AND THERMAL POWER

Non-Storage Hydro

As discussed in a BC Hydro technical memo,[29] non-storage hydro power has no material storage capacity and is subject to the natural fluctuations in river flow throughout the year. The increased river flow begins generally in early spring and peaks around midsummer, when the high flows of the freshet allow these IPPs to generate at or near capacity. During the rest of the year, energy generation tends to be lower, except in periods of heavy rain.

Analysis

Data for the category of non-storage hydro was analyzed for seasonal fluctuations both by geographical region and in terms of the category as a whole.

For detailed analysis notes, see the following pages: Figure 2.4 shows all hydro power combined, which is followed by Figures 2.5–2.8, showing the hydro power generated in each region.

Predominant Seasonal Patterns

The graphs analyzed show an overall seasonal trend: the predominant period of the freshet is characterized by a sharp increase in early May to peak output and a gradual decline beginning in August. This overarching profile is formed by the aggregation of similar profiles for the Peace, Southern B.C. and Fraser Valley and Sunshine Coast regions on the B.C. mainland. Only the Vancouver Island region follows a different pattern: an early increase from January to May is followed by an abrupt drop-off in July, down to a low for the year in August. The island region is also characterized by much greater variability. However, it has little impact on the overall seasonal trend for hydro because it represents a small proportion of the energy generated.

Figure 2.4, below, plots total non-storage hydroelectric generation for 2013 in B.C., identifying the respective contributions of each region. Overall, the most reliable high-production months for non-storage hydro IPPs are from May through mid-August. As can be seen in this graph, run-of-river IPPs in most regions display similar seasonal patterns, which correlate in turn to the overall trend throughout the year for run-of-river hydro. To develop the analysis of this overarching seasonal trend, the power generated throughout 2013 by non-storage hydro IPPs was plotted separately for each of the four regions. This allowed correlations to be established between regional run-of-river generation patterns by season and the overall trends for non-storage hydro generation in B.C.

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29. "Response to Working Group and Public Comments on the Site C Clean Energy Environmental Impact Statement. Technical Memo: Hydro-Electric Storage and Dispatchable Energy." BC Hydro, pp. 3–4. May 8, 2013. Accessed March 15, 2016. http://www.ceaa.gc.ca/050/documents/p63919/89735E.pdf

Figure 2.5a illustrates the profile for the Peace Region. IPP power generation attributable to the freshet begins abruptly in late March to reach a near-plateau from early May to late July. Although still relatively high in August, the output becomes more variable into the fall, gradually diminishing throughout winter months. The output across the peak months appears to be the least variable of all of the hydro-producing regions.

As shown in Figure 2.5b, for the run-of-river IPPs on Vancouver Island, the freshet begins gradually in January, peaking from late March to the end of June. This high output period tapers off abruptly in early July to reach an annual low in August Despite these general trends, the graph also shows that power generation across all months exhibits a high degree of variability—the highest outputs are in fact achieved over many short periods spanning days or weeks. These high generation periods occur not only in the summer, but also in the fall and winter.

For hydro power production by IPPs in Southern B.C., Figure 2.5c reveals that the freshet begins gradually in early March but quickly reaches a peak in early May. The relatively stable high generation period lasts until early August, after which IPP power output decreases until November. While the high and low months are the most stable, there are significant fluctuations in the spring and fall.

Figure 2.5d, for the Sunshine Coast and Fraser Valley region, shows that the power generated from the freshet also begins in March, with a fairly rapid increase in early May to begin the peak period. This is followed by the more gradual decrease in output from mid August through November. Similar to the other regions, the spring and fall transition seasons are characterized by short periods of great variability, while the others are more stable.

These observations clarify that the trend of the peak period from May to July for energy generation by non-storage hydro IPPs is borne out in all regions of B.C. with relatively small differences. Although the curve up to peak generation could be made more gradual by adding capacity in differing regions (such as Vancouver Island), run-of-river hydro generation will inevitably peak in the late spring and summer and dip down to its lowest output in the winter months. This means that non-storage hydroelectric power cannot provide a constant supply over the entire year and will need to be supplemented by energy sources in other categories.

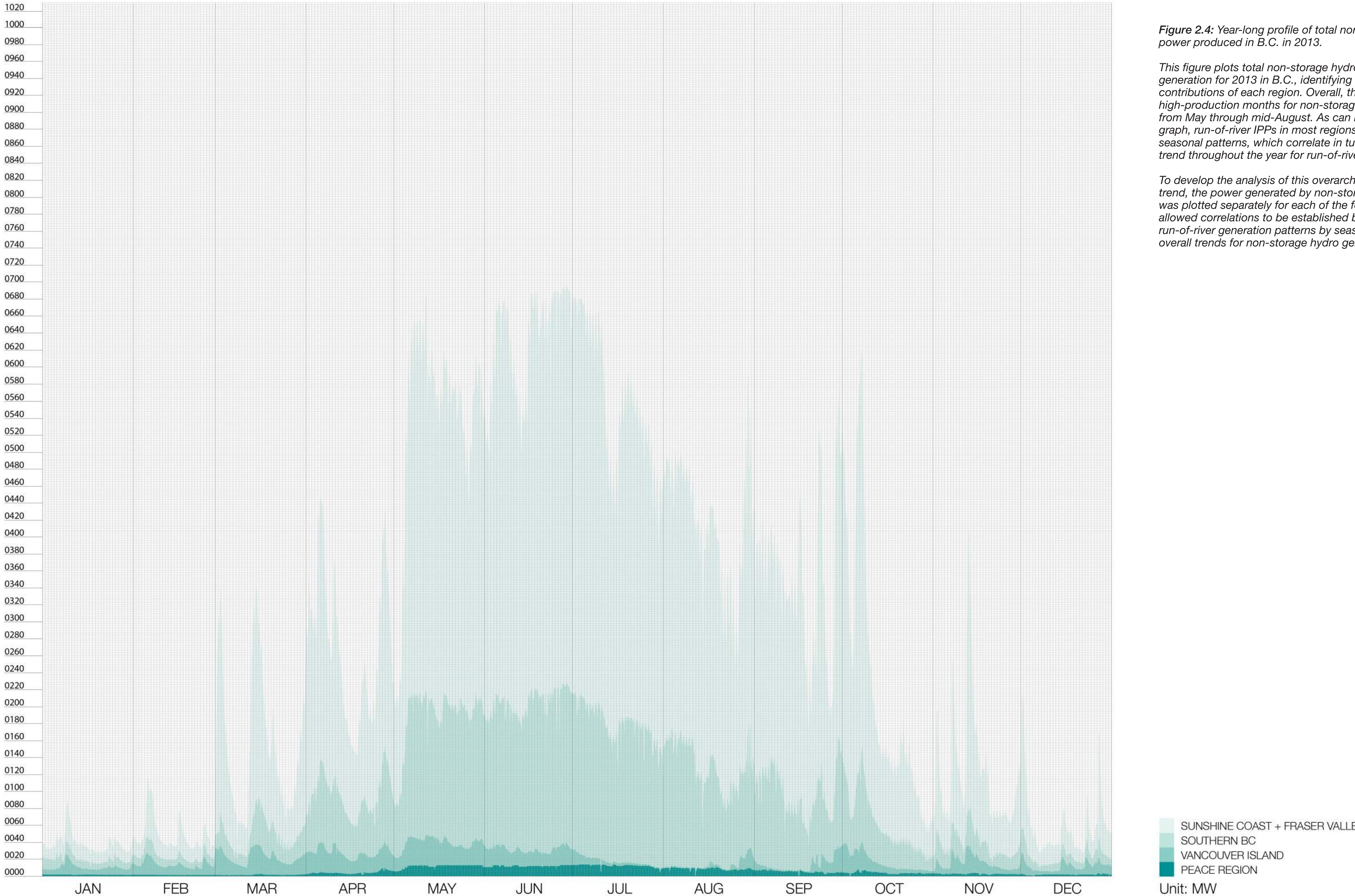


__Figure 2.4:__ Year-long profile of total non-storage hydro power produced in B.C. in 2013.

This figure plots total non-storage hydroelectric generation for 2013 in B.C., identifying the respective contributions of each region. Overall, the most reliable high-production months for non-storage hydro IPPs are from May through mid-August. As can be seen in this graph, run-of-river IPPs in most regions display similar seasonal patterns, which correlate in turn to the overall trend throughout the year for run-of-river hydro.

To develop the analysis of this overarching seasonal trend, the power generated by non-storage hydro IPPs was plotted separately for each of the four regions. This allowed correlations to be established between regional run-of-river generation patterns by season and the overall trends for non-storage hydro generation in B.C.

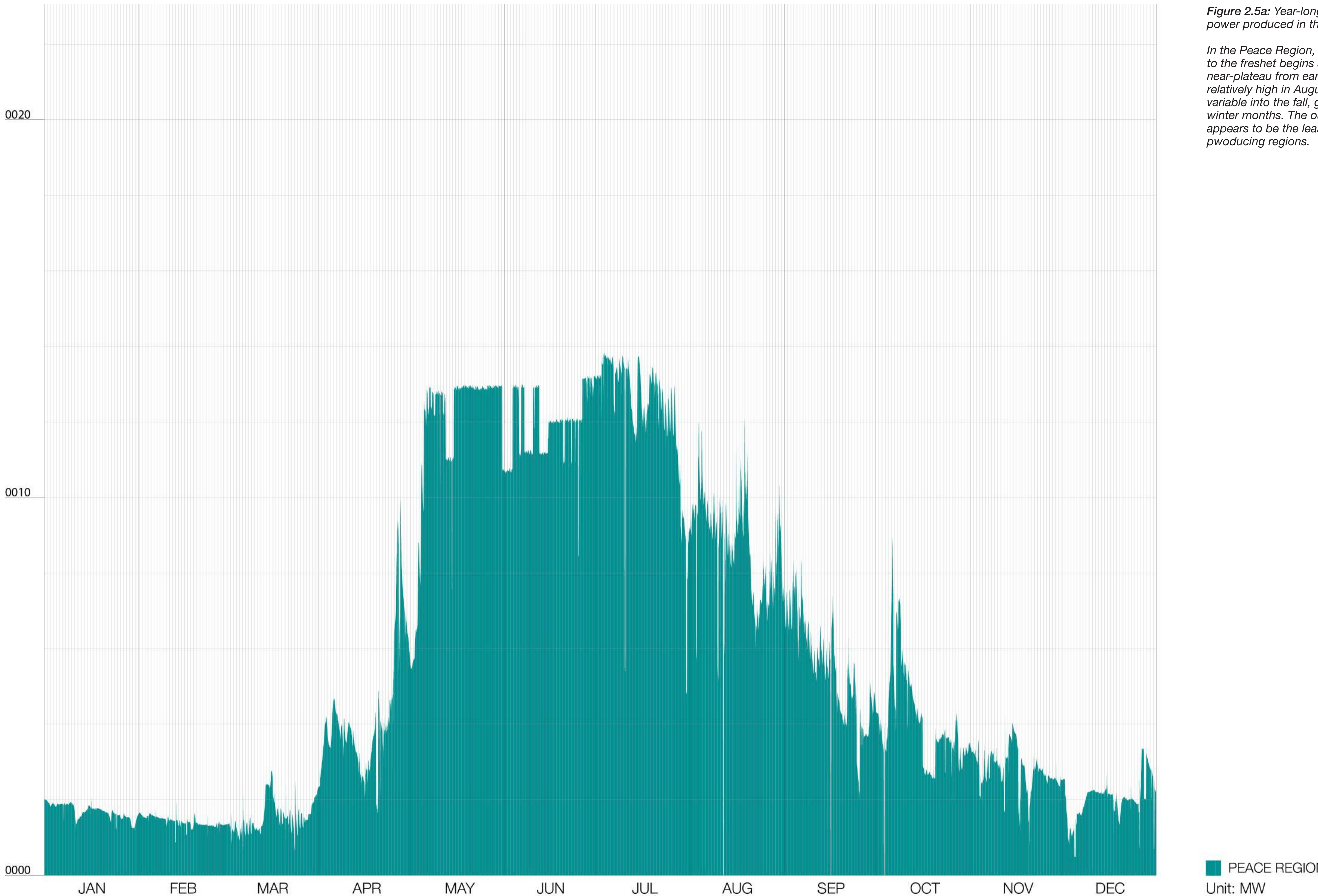


Figure 2.5a: *Year-long profile of non-storage hydro power produced in the Peace Region in 2013.*

In the Peace Region, IPP power generation attributable to the freshet begins abruptly in late March to reach a near-plateau from early May to late July. Although still relatively high in August, the output becomes more variable into the fall, gradually diminishing throughout winter months. The output across the peak months appears to be the least variable of all of the hydro-pwoducing regions.

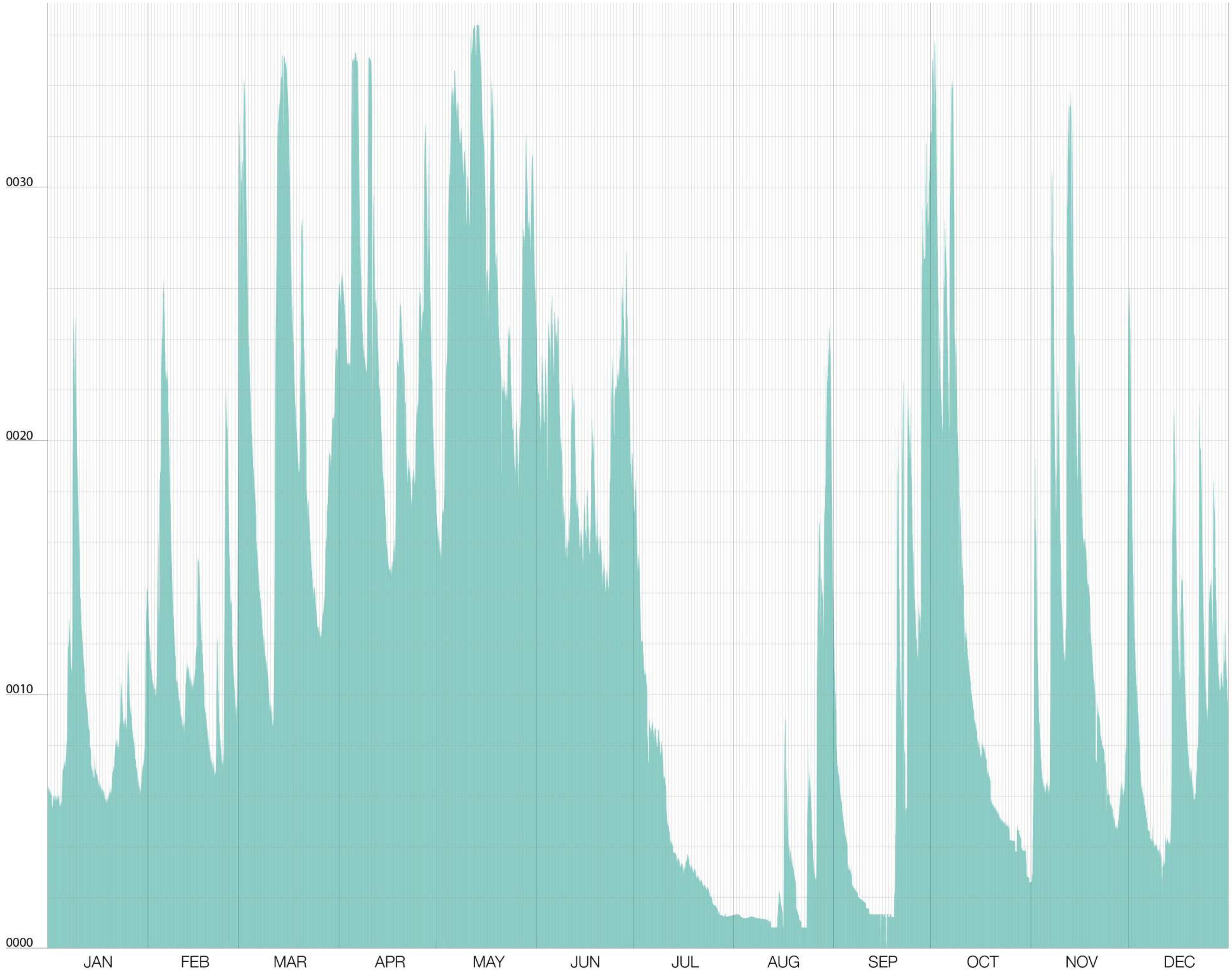


Figure 2.5b: *Year-long profile of non-storage hydro power produced in the Vancouver Island region in 2013.*

For the run-of-river IPPs on Vancouver Island, the freshet begins gradually in January, peaking from late March to the end of June. This high output period tapers off abruptly in early July to reach an annual low in August.

Despite these general trends, the graph also shows that power generation across all months exhibits a high degree of variability—the highest outputs are in fact achieved over many short periods spanning days or weeks. These high generation periods occur not only in the summer, but also in the fall and winter.

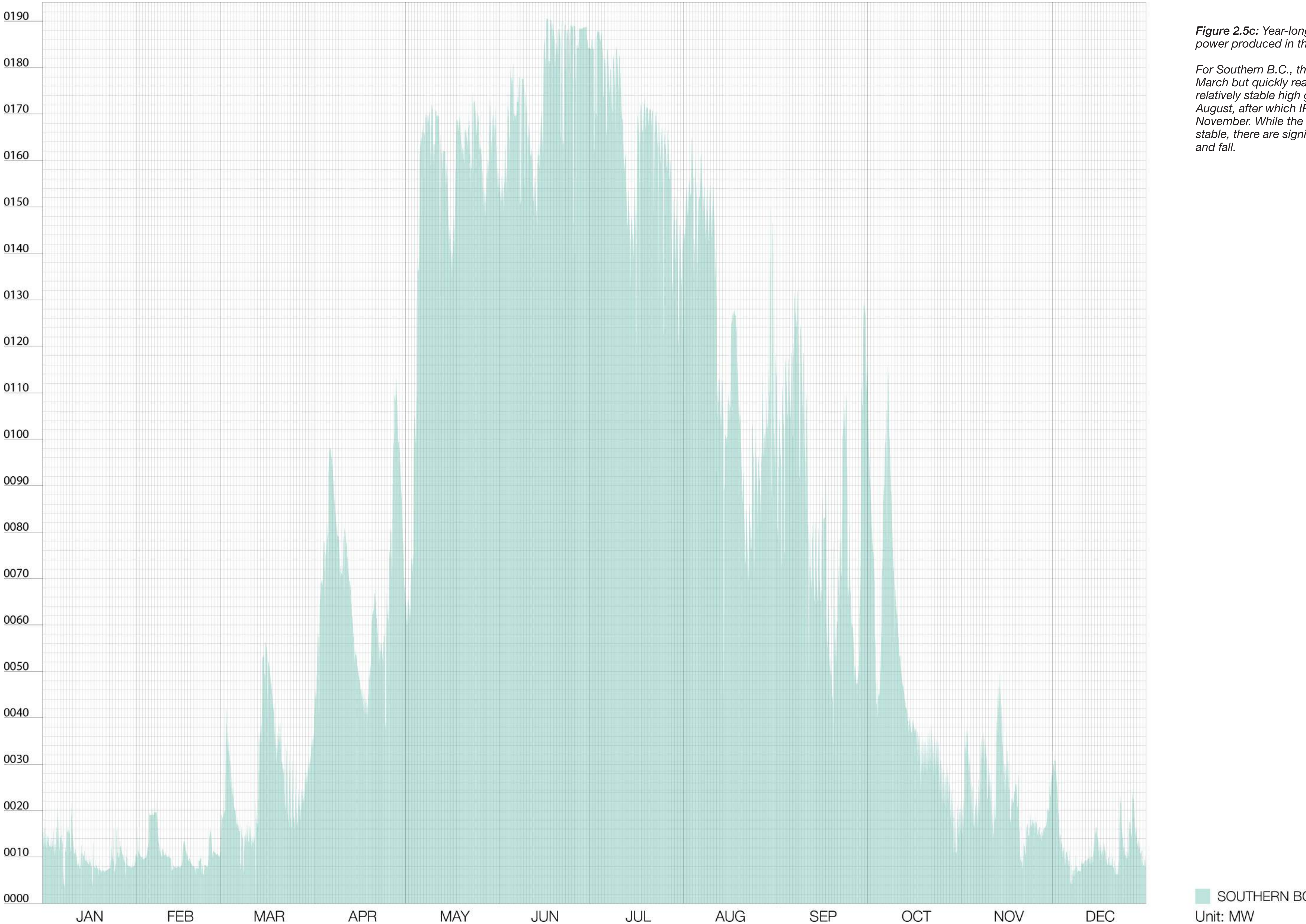


Figure 2.5c: *Year-long profile of non-storage hydro power produced in the Southern B.C. region in 2013.*

For Southern B.C., the freshet begins gradually in early March but quickly reaches a peak in early May. The relatively stable high generation period lasts until early August, after which IPP power output decreases until November. While the high and low months are the most stable, there are significant fluctuations in the spring and fall.

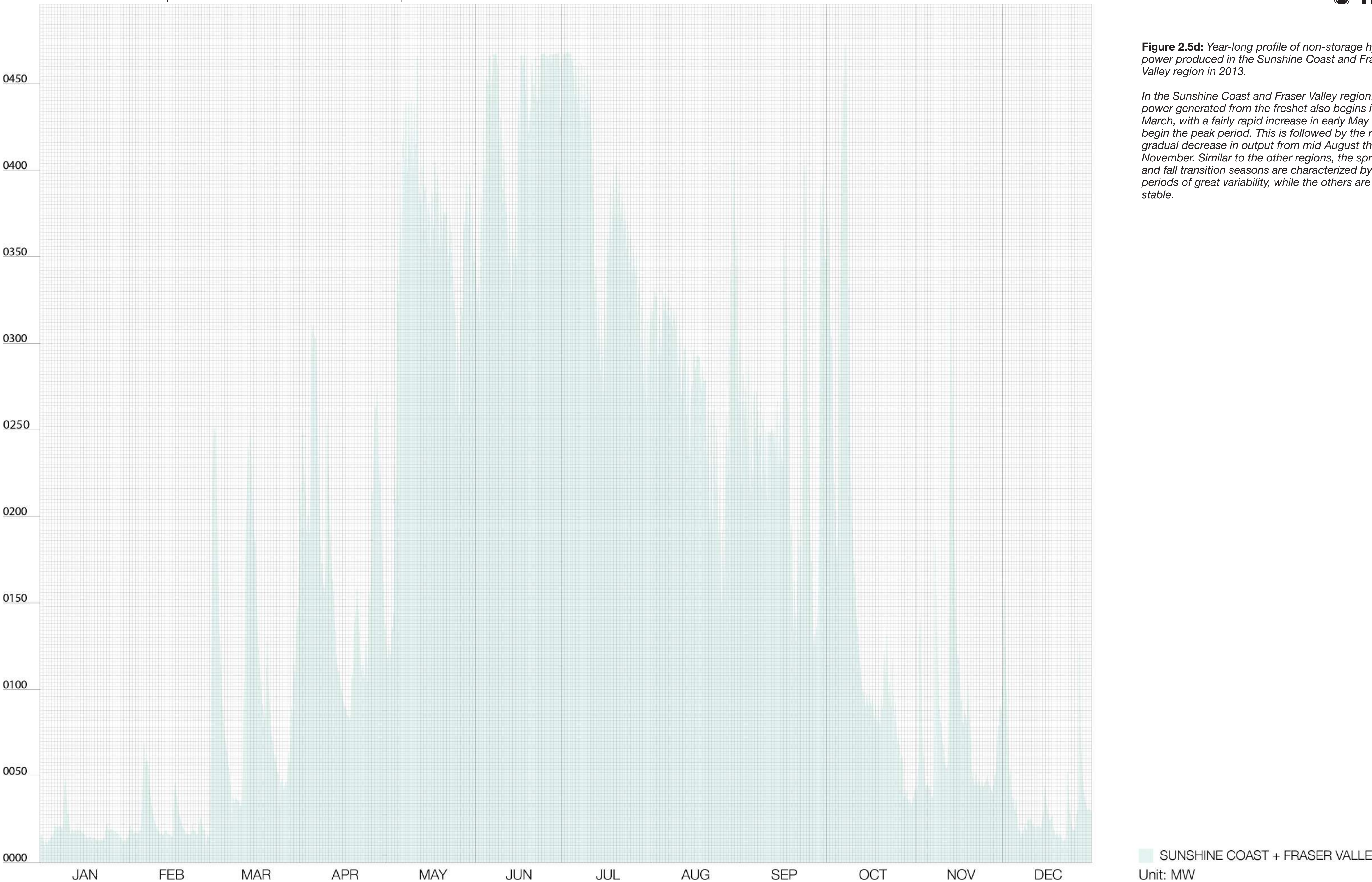
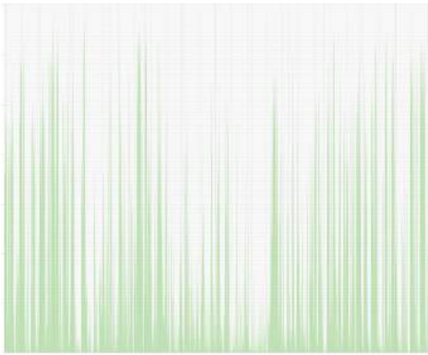


Figure 2.5d: *Year-long profile of non-storage hydro power produced in the Sunshine Coast and Fraser Valley region in 2013.*

In the Sunshine Coast and Fraser Valley region, the power generated from the freshet also begins in March, with a fairly rapid increase in early May to begin the peak period. This is followed by the more gradual decrease in output from mid August through November. Similar to the other regions, the spring and fall transition seasons are characterized by short periods of great variability, while the others are more stable.



Thumbnail of Figure 2.6a:
Year-long profile of wind power produced in the Peace Region in 2013.

Wind

BC Hydro has assessed potential wind power generation projects for four distinct regions in British Columbia: the Peace Region, the Vancouver Island Region, the Southern Interior Region and the North Coast Region.[30] The data obtained for wind power is for IPPs in the Peace Region, where 80 percent of B.C.'s wind energy is currently generated. Figure 2.6a illustrates the wind energy trends for this region.

The only other region in B.C. in which wind power IPPs currently operate is Vancouver Island.[31] For that region, energy generation profiles projected by BC Hydro for the year 2024 have been obtained from the Western Electricity Coordinating Council's Transmission Expansion Planning[32] and analyzed for comparison with the available Peace Region data. This projected data for the existing wind IPP on Vancouver Island is visualized in Figure 2.6b. In Figure 2.6c, they are combined to show the probable total energy profile of wind power IPPs operating in B.C. in 2013.

Analysis

From Figure 2.6a, it can be seen that the wind generation profile for IPPs in the Peace Region shows that power output is extremely variable throughout the year, to the extent that it is difficult to identify strong seasonal trends. From the data topography analysis in Figure 2.2, we know that wind power is on average less in early to mid-March and in the summer months from May to August, and tends to reach higher peaks in late April, late August and the remaining months through the fall and winter. However, these periods of high output are short and seemingly unreliable, interspersed with equally sporadic periods of low output.

The projected profile in Figure 2.8b for the Vancouver Island wind IPPs shows that the power output for this region is also highly variable, but exhibits clearer seasonal trends. Energy generation is at its highest from the beginning of December to early February, and at its lowest in early April and the second half of August. The summer months are low overall, except that power generation from late April to mid-May is somewhat higher.

Figure 2.6c shows that in the combined power generation profile for the Peace Region and Vancouver Island wind IPPs, both regions share seasonal trends of higher output in the winter and lower output in the summer, but most of their short-term fluctuations throughout the year do not precisely coincide.

Therefore, the combination of wind energy from these two regions helps to reinforce

30. GEC. "BC Hydro Wind Data Study." Prepared for BC Hydro. May 1, 2009. Accessed February 29, 2016. https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/environment/winddata/pdf/wind_data_study_report_may1_2009.pdf
31. "Independent Power Producers (IPPs) currently supplying power to BC Hydro." BC Hydro. October 1, 2015. Accessed April 19, 2016. https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/independent-power-producers-calls-for-power/independent-power-producers/ipp-supply-list-in-operation.pdf
32. "Wind Profiles" [2024 projected]. WECC-TEP (Western Electricity Coordinating Council's Transmission Expansion Planning). Accessed April 19, 2016. https://www.wecc.biz/TransmissionExpansionPlanning/Pages/Datasets.aspx

common seasonal trends and reduce some of the volatility that characterizes the regions individually, even though the second region of Vancouver Island only comprises about 20% of the total energy. The seasonal trends of wind power generation appear slightly more predictable than for the Peace Region on its own, but wind energy overall remains extremely variable.

The observed tendency for greater wind power generation in the winter months and lower generation in the summer seems to hold some potential to offset the opposite seasonal trend observed in the output of non-storage hydro IPPs. However, the non-seasonal variability in wind energy would need to be mitigated significantly.

In an attempt to further this analysis, wind roses for each of BC Hydro's four wind regions[33] were analyzed in Figure 2.6d to determine whether wind could become a more stable energy source through the development of capacity in a greater number of regions. In all regions, higher average wind speeds in the predominant wind direction do occur in the winter months, i.e., in the first and last quarters of the year.

More specifically, Figure 2.6d compares wind roses showing long-term trends in average windspeed, frequency and direction for municipalities in B.C.'s four wind regions. The annual wind roses for each region, generated using the Climate Consultant software program, show predominant wind directions and speeds, while the quarterly wind roses show to what extent seasonal trends support or negate the yearly patterns.

Significant wind average speeds for the purposes of this analysis are from 6 m/s, the lowest speed at which energy can viably be generated by a wind turbine.[34]

The municipalities chosen for wind rose data were determined by the town for which wind data was available that was either the closest to operating wind farms (for regions in which wind IPPs supplying power to BC Hydro currently operate) or located most centrally within the region (for regions in which no IPPs supplying power to BC Hydro currently operate).

Peace Region (Fort St. John): Highest average windspeeds occur more frequently from October to March in the predominant northerly and southwesterly directions.

Vancouver Island (Port Hardy): Highest average windspeeds occur more frequently from October to March in the predominant southeasterly direction.

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33. "All Regions - North and Central America WMO Region 4 - Canada - British Columbia." *EnergyPlus*. U.S. National Renewable Energy Laboratory (NREL). Accessed April 19, 2016. https://energyplus.net/weather-region/north_and_central_america_wmo_region_4/CAN/BC. Data for Canada is from 1953-1995 period of record, sourced from *Canadian Weather for Energy Calculations*, Numerical Logics. Downsview, Ontario: Environment Canada, 1999.

34. GEC. "BC Hydro Wind Data Study." Prepared for BC Hydro. May 1, 2009, p. 17. Accessed February 29, 2016. https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/environment/winddata/pdf/wind_data_study_report_may1_2009.pdf

S.E. Interior (Summerland): Highest average windspeeds occur more frequently from October to March in the predominant southerly direction.

North Coast (Prince Rupert): Highest average windspeeds occur more frequently from October to March in the predominant southeasterly direction.

Based on these observations, wind energy generation capacity should be developed in the two remaining regions that do not yet have IPPs producing for B.C. Hydro, namely the Southeast Interior and the North Coast. This recommendation is based on two hypotheses: (1) that wind power generated in a greater number of regions will help mitigate regional in-season variations and unpredictability, reinforcing the observed seasonal trend of high production in winter; and (2) that wind patterns in these particular regions, illustrated by their respective wind roses, indicate a greater potential than the Peace Region and Vancouver Island region for greater energy generation in the first, and last quarters of the year when hydro energy generated in most regions is at its lowest, with additional potential in the third quarter when hydro begins to decrease.

These assertions are based on the percentage of time that wind is recorded in the dominant direction and its average speed in that direction according to the wind roses for the Southeast Interior and North Coast regions. These two regions complement each other well.

The Southeast Interior region experiences above 30% of its wind along the dominant north-south axis in the first quarter of the year and above 20% of its wind along that axis in the third and fourth quarters. The highest average wind speeds, between 6 and 8 m/s, are in the first and fourth quarters, in the south direction only. This means that the energy production in this region will strongly reinforce the seasonal trend for greater wind generation in the winter months, with a low expected from April to June, and less production from July to September, opposite to the observed peak of hydro production from May to July.

The North Coast region experiences above 20% of its wind in the dominant southeast direction in the first quarter of the year and just below 20% of its wind in that direction in the fourth quarter. Average wind speeds in the southeast direction are at 6 m/s during these times of year, also reinforcing the seasonal trend opposite to hydro. This region could also supply some power in the second quarter, namely through April and early May when hydro is still prone to fluctuations, since while only 10% of the wind is in the dominant direction, it does reach the average speed of 6 m/s require for turbine generation, as noted previously.

Therefore, if wind power could be supplied by IPPs in a number of different regions, developing capacity in the Southeast Interior and North Coast specficially, it might be possible to reduce the non-seasonal variability inherent in this energy source and reinforce the trend of higher energy production in winter. Careful management and study could produce a reliable energy source that follows a seasonal trend opposite to that observed for non-storage hydro energy generation in B.C.

Figure 2.6a: *Year-long profile of wind power produced in the Peace Region in 2013.*

The wind generation profile for IPPs in the Peace Region shows that power output is extremely variable throughout the year, to the extent that it is difficult to identify strong seasonal trends.

From the data topography analysis in Figure 2.2, we know that wind power is on average less from early to mid-March and in the summer months from May to August, and tends to reach higher peaks in late April, late August and the remaining months through the fall and winter. However, these periods of high output are short and seemingly unpredictable, interspersed with equally sporadic periods of low output.

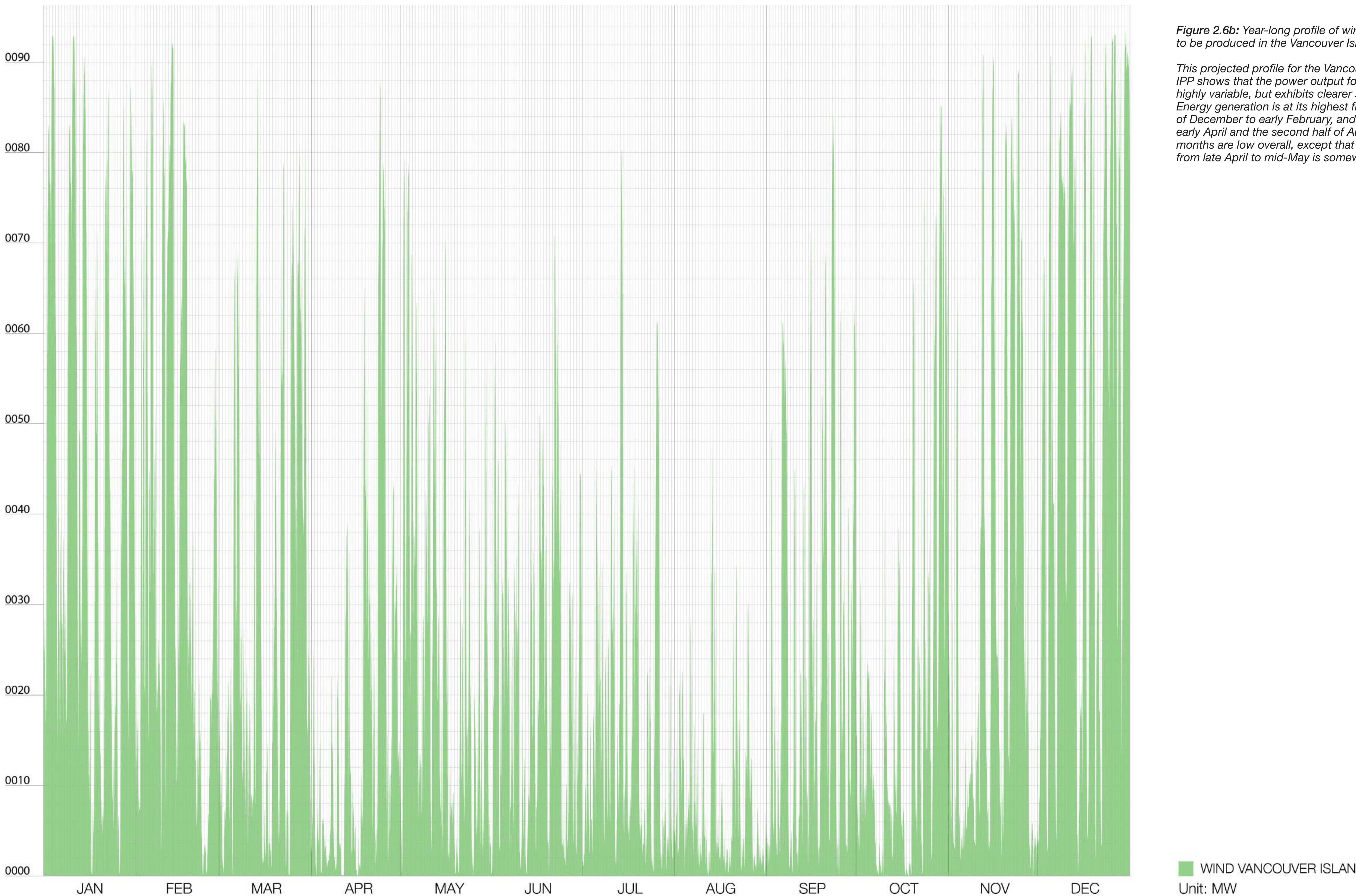


***Figure 2.6b:** Year-long profile of wind power projected to be produced in the Vancouver Island region in 2024.*

This projected profile for the Vancouver Island wind IPP shows that the power output for this region is also highly variable, but exhibits clearer seasonal trends. Energy generation is at its highest from the beginning of December to early February, and at its lowest in early April and the second half of August. The summer months are low overall, except that power generation from late April to mid-May is somewhat higher.

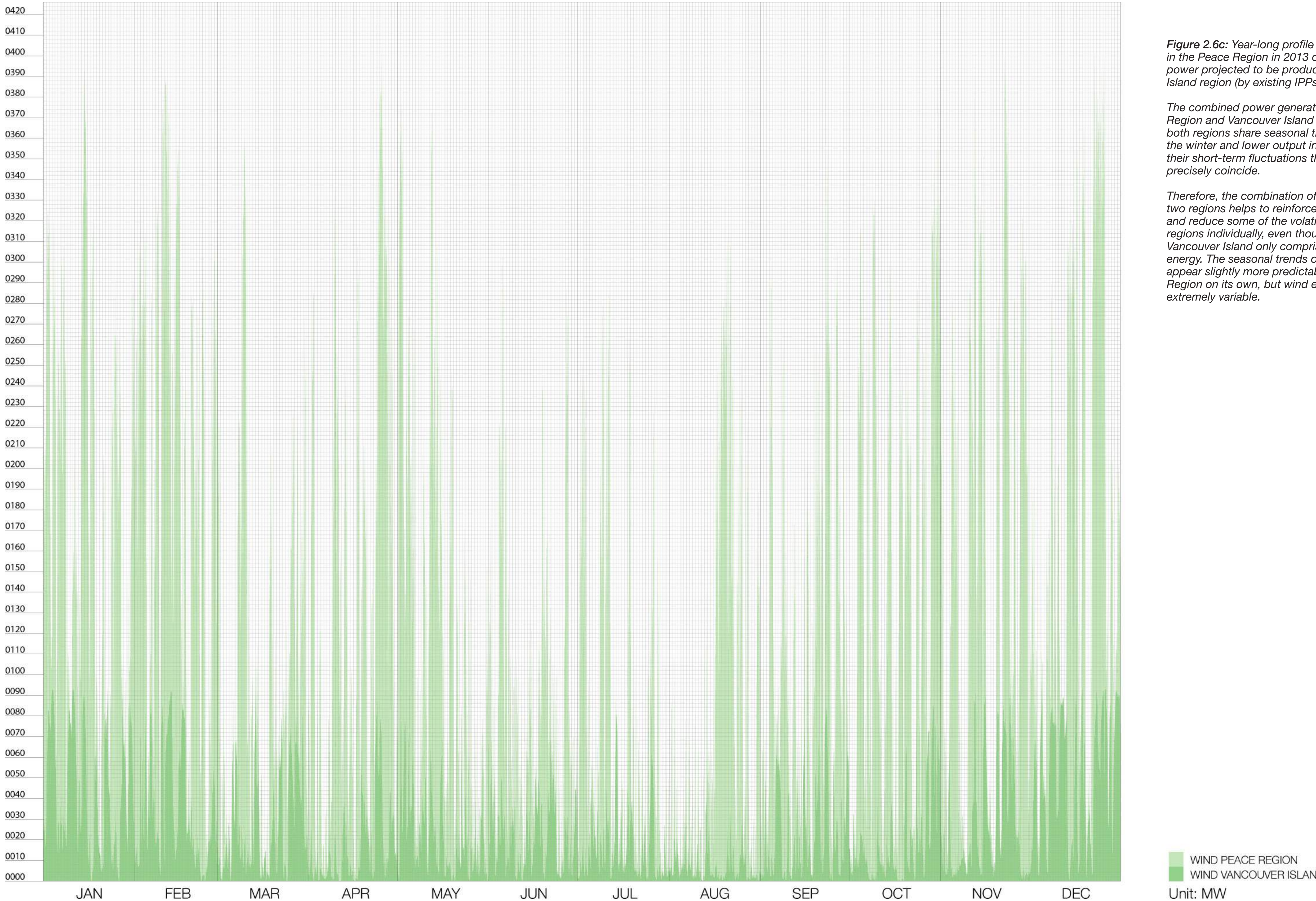


Figure 2.6c: *Year-long profile of wind power produced in the Peace Region in 2013 combined with wind power projected to be produced in the Vancouver Island region (by existing IPPs) in 2024.*

The combined power generation profile for the Peace Region and Vancouver Island wind IPPs shows that both regions share seasonal trends of higher output in the winter and lower output in the summer, but most of their short-term fluctuations throughout the year do not precisely coincide.

Therefore, the combination of wind energy from these two regions helps to reinforce common seasonal trends and reduce some of the volatility that characterizes the regions individually, even though the second region of Vancouver Island only comprises about 20% of the total energy. The seasonal trends of wind power generation appear slightly more predictable than for the Peace Region on its own, but wind energy overall remains extremely variable.

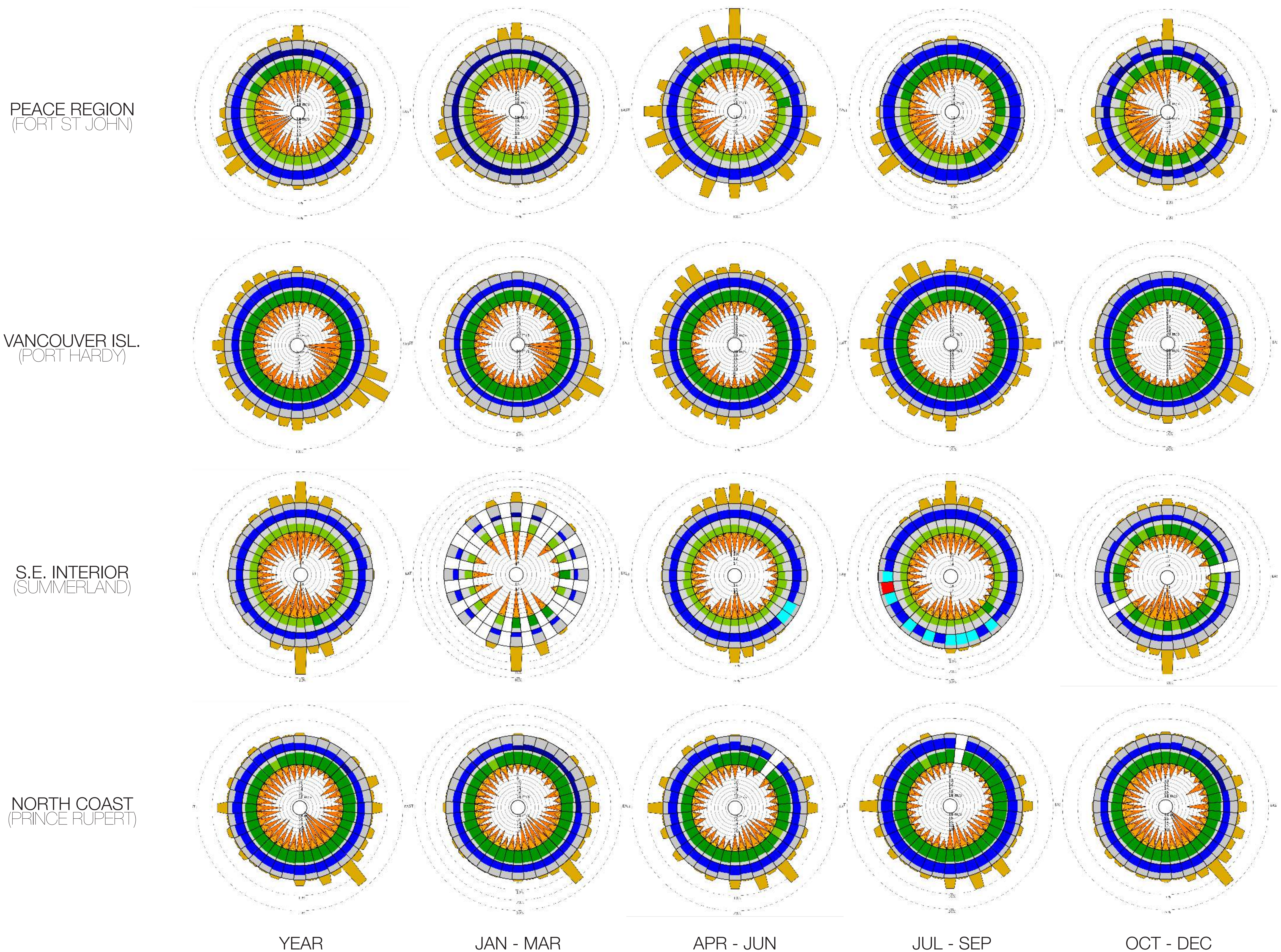


Fig. 2.6d: *Wind roses showing long-term trends in average windspeed, frequency and direction for municipalities in B.C.'s four wind regions.*

The annual wind roses, generated using the Climate Consultant software program, show predominant wind directions and speeds, while the quarterly wind roses show to what extent seasonal trends support or negate the yearly patterns.

Significant average wind speeds for the purposes of this analysis are from 6 m/s, the lowest speed at which energy can viably be generated by a wind turbine.[1]

The municipalities chosen for wind rose data were determined by the town for which wind data was available that was either the closest to operating wind farms (for regions in which wind IPPs supplying power to BC Hydro currently operate) or located most centrally within the region (for regions in which no IPPs supplying power to BC Hydro currently operate).

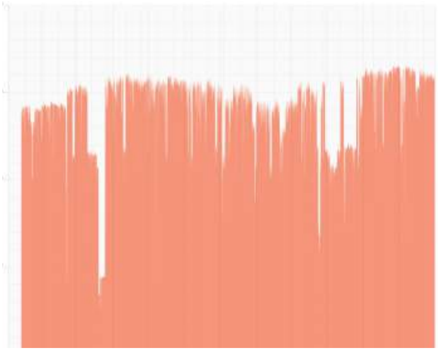
Peace Region *(Fort St. John): Highest average windspeeds occur more frequently from October to March in the predominant northerly and southwesterly directions.*

Vancouver Island *(Port Hardy): Highest average windspeeds occur more frequently from October to March in the predominant southeasterly direction.*

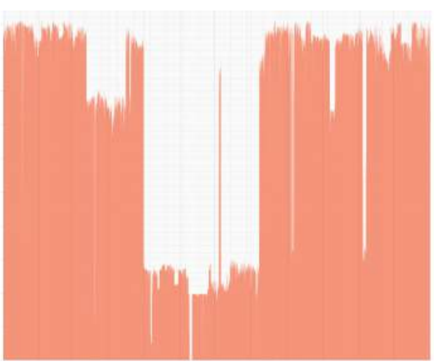
S.E. Interior *(Summerland): Highest average windspeeds occur more frequently from October to March in the predominant southerly direction.*

North Coast *(Prince Rupert): Highest average windspeeds occur more frequently from October to March in the predominant southeasterly direction.*

1. GEC. "BC Hydro Wind Data Study." Prepared for BC Hydro. May 1, 2009, p. 17. Accessed February 29, 2016. https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/environment/winddata/pdf/wind_data_study_report_may1_2009.pdf



Thumbnail of Figure 2.7a: *Year-long profile of thermal power produced in the Metro Vancouver region in 2013.*



Thumbnail of Figure 2.7b: *Year-long profile of thermal power produced in the Southern Interior region in 2013.*

Thermal

Analysis

The thermal power generation profiles for the Metro Vancouver and Southern Interior regions show that this energy source provides a relatively constant power output throughout the year.

Figure 2.7a shows that the power generated by thermal IPPs in the Metro Vancouver region varies relatively little over the course of the year. On the whole, output is just slightly greater from late March to early June and then again throughout November and December. The thermal sources, consisting of about 71% municipal solid waste and the remainder of biogas, seem therefore to produce an overall stable energy output. (N.B.: The period of apparent zero output in early January should be ignored as it is caused by a lack of data for this period.)

Figure 2.7b, shows that the power generated by thermal IPPs in the Southern Interior region is also quite stable for most of the year. However, the exception is a low period for this region from May to early August, during which output is also quite stable, but reduced. This low output is only associated with the IPPs in the Southern Interior region, which rely on biomass and energy recovery generation, as opposed to the Metro Vancouver thermal IPPs, which rely on solid municipal waste and biogas.

Given that this thermal source's composition is approximately 61% biomass and 29% energy recovery generation and therefore not seasonal by nature, it seems possible that one or both sources encountered a lack of resources during this time. In order to draw any further conclusions, it would be necessary to know if this period of reduced output happens consistently every year in this IPP group or if it was an anomaly for the year 2013.

The reasons for this seasonal low in the energy generated remain unknown. However, if BC Hydro were to develop additional thermal power capacity following a similar energy profile, these resources could increase the renewable energy available in the fall, winter and early spring months when run-of-river hydro output is low. The relative stability of the power output of thermal IPPs could also help to mitigate the frequent fluctuations in B.C.'s current renewable energy profile, particularly in the early spring and fall months when the power output from non-storage hydro becomes more variable.

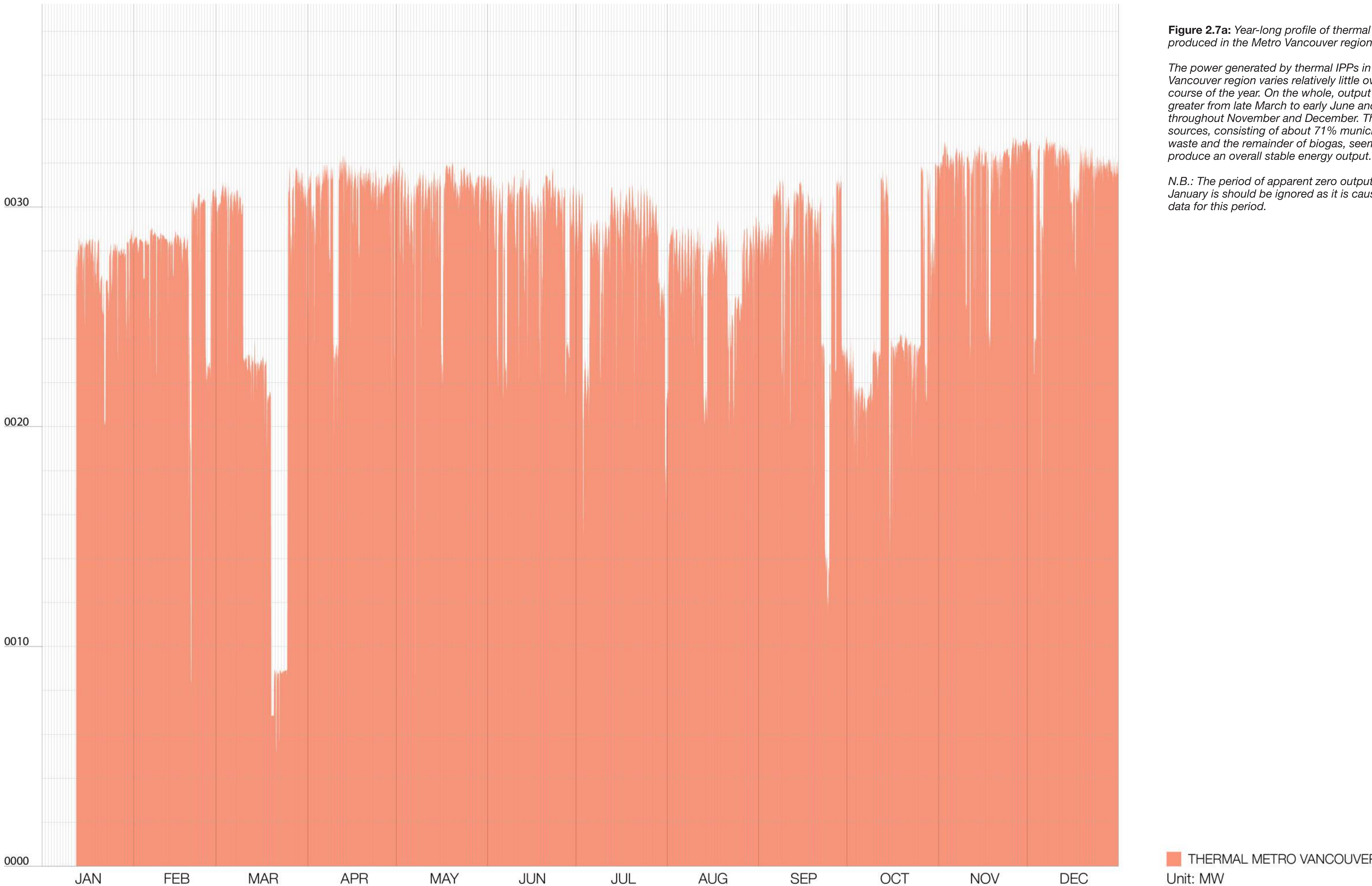


Figure 2.7a: *Year-long profile of thermal power produced in the Metro Vancouver region in 2013.*

The power generated by thermal IPPs in the Metro Vancouver region varies relatively little over the course of the year. On the whole, output is just slightly greater from late March to early June and then again throughout November and December. The thermal sources, consisting of about 71% municipal solid waste and the remainder of biogas, seem therefore to produce an overall stable energy output.

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

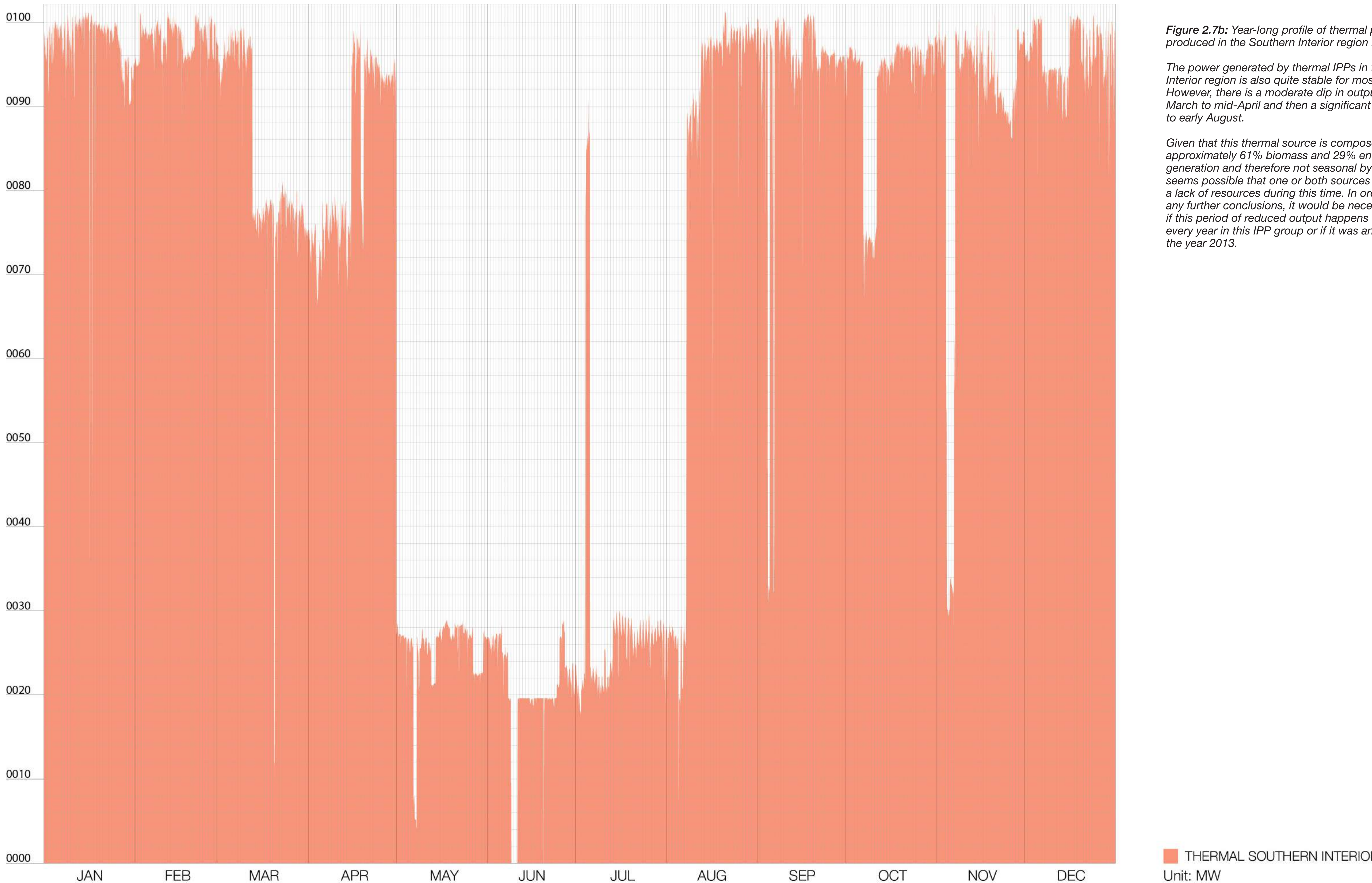


Figure 2.7b: *Year-long profile of thermal power produced in the Southern Interior region in 2013.*

The power generated by thermal IPPs in the Southern Interior region is also quite stable for most of the year. However, there is a moderate dip in output from mid-March to mid-April and then a significant low from May to early August.

Given that this thermal source is composed of approximately 61% biomass and 29% energy recovery generation and therefore not seasonal by nature, it seems possible that one or both sources encountered a lack of resources during this time. In order to draw any further conclusions, it would be necessary to know if this period of reduced output happens consistently every year in this IPP group or if it was an anomaly for the year 2013.

Summary: all renewable sources combined

To provide a clearer picture of B.C.'s renewable energy production overall, Figure 2.8 provides a visualization of the combined energy profile from the data currently available for B.C.'s renewable thermal, hydro and wind IPPs.

As shown in this figure, the combined profile shows a strong seasonal variation that is somewhat tempered by complementary trends of various energy types.

In particular, hydro power, comprising the majority of B.C.'s renewable energy, creates the greatest seasonal differential and accounts for the peak output from early May into August and low output from November to February.

Power from thermal energy sources offsets some of the peak through its relative low from the beginning of May to early August.

The addition of wind at first glance merely seems to increase the variability of the overall power output throughout the year; however, more wind power is actually produced in the months from late fall to early spring.

(N.B.: The period of lower thermal power output in early January is should be ignored as it is caused by a lack of data for this period.)

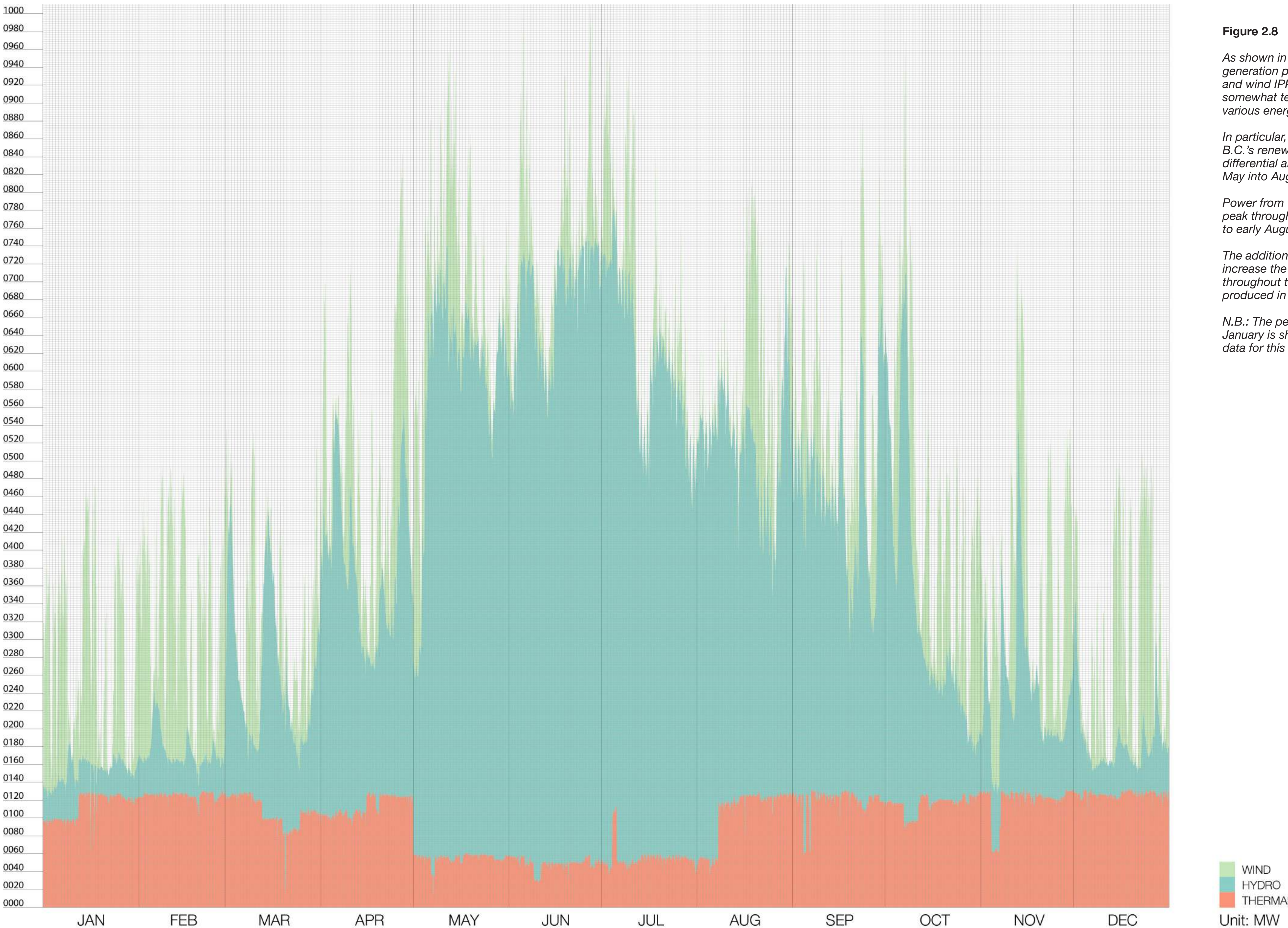


Figure 2.8

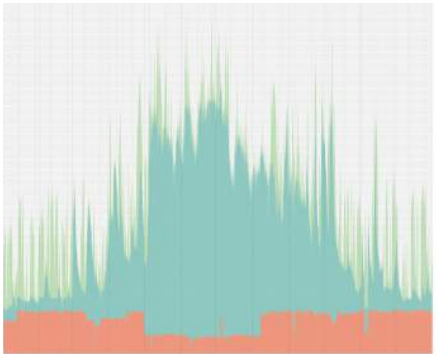
As shown in this figure, the combined yearly power generation profiles of B.C.'s renewable thermal, hydro and wind IPPs show a strong seasonal variation that is somewhat tempered by the complementary trends of various energy types.

In particular, hydro power, comprising the majority of B.C.'s renewable energy, creates the greatest seasonal differential and accounts for the peak output from early May into August and low from November to February.

Power from thermal energy sources offsets some of the peak through its relative low from the beginning of May to early August.

The addition of wind at first glance merely seems to increase the variability of the overall power output throughout the year, although more wind power is produced in the months from late fall to early spring.

N.B.: The period of lower thermal power output in early January is should be ignored as it is caused by a lack of data for this period.



Thumbnail of Figure 2.8

III. CORRELATIONS BETWEEN CURRENT AND PROJECTED RENEWABLE ENERGY GENERATION AND EV CHARGING

ANALYSIS

In order to correlate B.C.'s renewable energy output with the charging demands of B.C.'s current and projected electric vehicle fleet, a middle ground must be reached between the seasonal trends of one and the daily trends of the other.

Currently, B.C.'s renewable energy power generation profile varies seasonally, as shown clearly in Fig. 2.8. The implications of this variation for EV charging are illustrated in Fig. 3.1. As previously mentioned, the approximate size of B.C.'s 2013 passenger vehicle fleet was estimated at 2,738,785.[35] B.C.'s current renewable energy profile could meet the future charging demands of EVs comprising up to 8.8% of the current provincial vehicle fleet.

To support a greater proportion of EVs in B.C.'s vehicle fleet with renewable energy generated in the province, either demand or supply must be modified.

On the demand side, EV charging varies predominantly during the day, as seen in Fig. 1.2. Data from Idaho National Laboratory's report shows only minor changes in overall peak energy demand from charging as a result of TOU incentivization schemes; despite some seasonal changes to TOU rates, these programs succeed mainly in moving peak charging times out of peak grid load times.

This suggests that changes may be made most productively to B.C.'s supply of renewable energy to accommodate more EVs. However, rather than simply increasing the total power output from all renewable energy sources to meet the demand for more EV charging in the future, the overall profile could be more productively adjusted so that the seasonal variation is not as great.

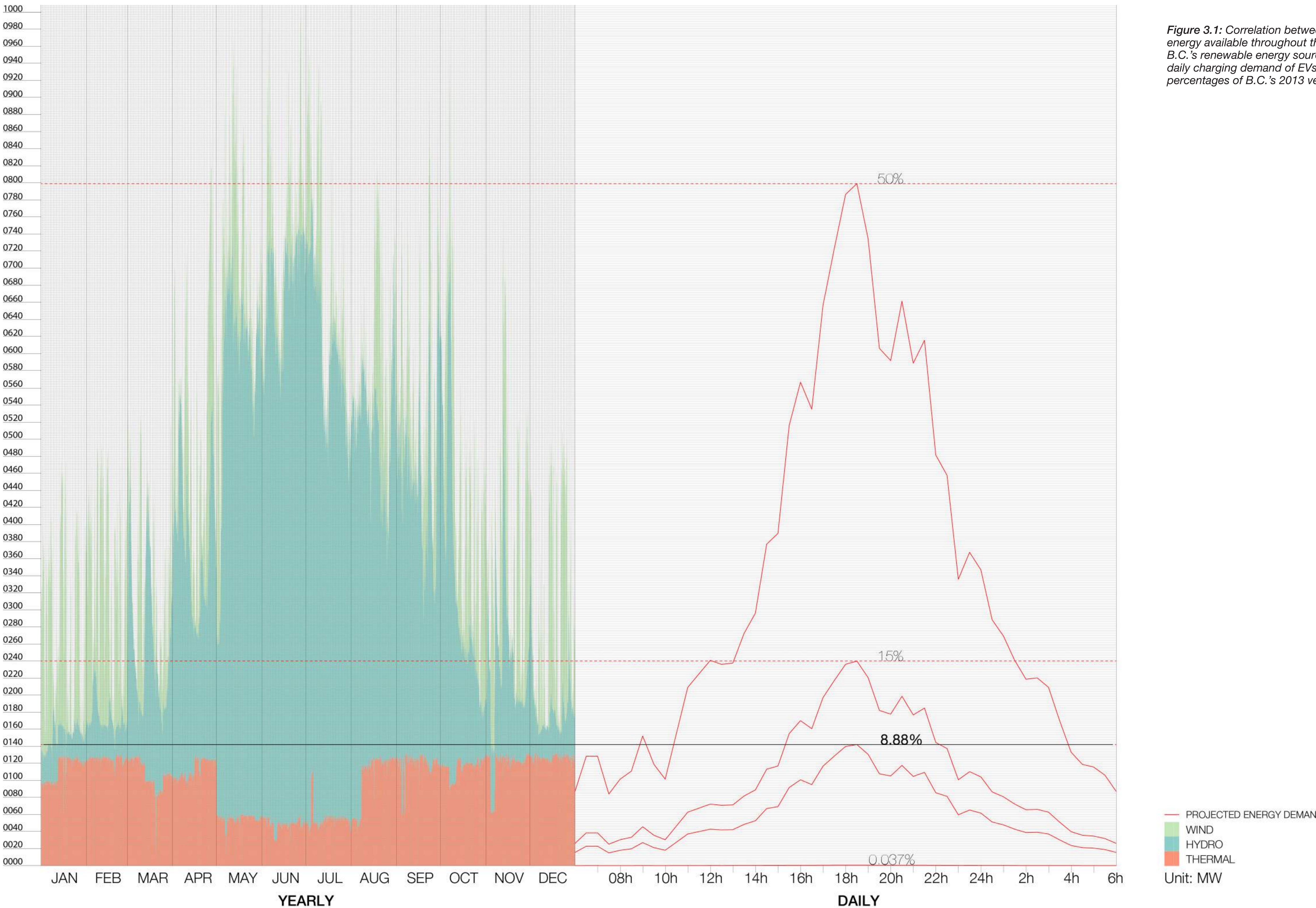
From the energy analysis conducted in Part II of this report, it can be seen that the energy profile of all non-storage hydro IPPs combined is complementary to those of the two other energy types: first, the combined Peace Region and Vancouver Island (projected) wind IPPs and, second, the thermal IPPs in the Southern Interior region. It is equally clear from Figure 2.8 that B.C.'s lowest energy output occurs from late fall to early spring. Therefore, targeting investment in renewable energy sources to either wind or thermal IPPs would increase energy production during that period and reduce the seasonal variation in B.C.'s year-round renewable energy profile.

To posit whether wind or thermal energy should be increased to best achieve this goal, it is important to consider the factors of reliability, availabiilty and sustainability. While the wind energy profile for the Peace and Vancouver Island regions is a product of regional weather patterns, as demonstrated in the wind roses of Figure 2.6d, the thermal energy produced by IPPs in the Southern interior region is reliant on human systems.

At first glance, from the daily samples in Figure 2.6c, thermal energy seems more

35. "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 (the figure used was for "Vehicles weighing less than 4 500 kilograms").

Figure 3.1: *Correlation between the minimum energy available throughout the year in 2013 from B.C.'s renewable energy sources and the maximum daily charging demand of EVs comprising different percentages of B.C.'s 2013 vehicle fleet.*



reliable in light of its largely steady output, but the energy sources of biomass and biofuel that it relies on may not always be available. The lower energy output recorded from May to July for the thermal IPPs in the Southern Interior region could, as previously stated, indicate a lack of resources, which may not always occur at such a favourable time. More information is needed to determine both the actual reliability and availability of this energy source, particularly in relation to time of year.

In terms of sustainability, the use of biomass and biofuel may produce some greenhouse gases, both in the steps leading to their production and in their combustion.[36]

Wind energy is arguably less reliable at hourly, daily and inter-seasonal timescales, as both the daily and year-long visualizations of its power output show. However, it is based on wind, which follows verifiable patterns year after year in each region. With high output most likely to occur in the first and fourth quarters of the year, and low output predominating in the second and third quarters, wind energy is more certain in its seasonal availability, which is opposite to the generation patterns for hydro energy. Since all of the regions analyzed in this report and considered by BC Hydro for future power projects follow these same overall wind patterns, developing more wind farm projects may well begin to offset shorter timescale fluctuations in wind energy, as shown in Figure 2.6c of the combined wind energy generated in the Vancouver Island and Peace regions, making wind energy more reliable overall. This supposition is supported by a U.K. study showing that as wind generation locations increase in number and distance from one another, fluctuations in overall power decrease.[37]

With regard to sustainability, wind energy is considered to have a low environmental impact, with "some of the lowest global warming potential per unit of electrical energy generated."[38] This resource therefore seems to offer the most positive outlook in terms of availability, sustainability and, if enough IPPs in different regions are brought online, reliability.

Currently, as illustrated in Figure 3.1, B.C.'s total yearly renewable energy meets the charging needs of 8.8% of B.C.'s current vehicle fleet if they converted to EVs. Increasing the output of wind energy IPPs from all regions studied (see Fig. 2.6d) would help balance the profile between seasons, increasing the proportion of renewable energy that can be relied upon year-round, to support a greater segment of B.C.'s vehicle fleet becoming EVs.

A targeted change in one energy source allows proportionally more of the overall en-

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36. "Biofuel." *Wikipedia*. 19 July 2016. Web. <https://en.wikipedia.org/wiki/Biofuel> Accessed on 30 July 2016.

37. From "Wind power." Wikipedia. 29 July 2016. Web. < https://en.wikipedia.org/wiki/Wind_power#cite_note-Diesendorf-110 > Accessed on 30 July 2016. Footnote 108: Diesendorf, Mark (2007). "Greenhouse Solutions with Sustainable Energy": 119. "Graham Sinden analysed over 30 years of hourly wind speed data from 66 sites spread out over the United Kingdom. He found that the correlation coefficient of wind power fell from 0.6 at 200 km to 0.25 at 600 km separation (a perfect correlation would have a coefficient equal to 1.0.) There were no hours in the data set where wind speed was below the cut-in wind speed of a modern wind turbine throughout the United Kingdom, and low wind speed events affecting more than 90 per cent of the United Kingdom had an average recurrent rate of only one hour per year."

38. "Environmental impact of wind power." Wikipedia. 9 July 2016. Web. < https://en.wikipedia.org/wiki/Environmental_impact_of_wind_power > Accessed on 30 July 2016.

ergy generated to be used, suggesting that this an effective strategy for making more of B.C.'s renewable energy available for EV charging in the future.

CONCLUSION

This report has produced a more nuanced understanding of EV charging demands and the potential for their alignment with renewable energy generation in B.C.

The analysis of EV charging habits in B.C. and other North American jurisdictions has clarified that TOU incentivization, as it is currently implemented in the researched area, does not have a strong seasonal influence on maximum energy demand at peak charging times; it mainly affects the time of day at which EV charging peaks.

The analysis of B.C.'s reneweable energy generation shows that the power produced by non-storage hydro, wind, and thermal IPPs in the province are overall subject to seasonal trends rather than daily ones. In the case of wind energy sources, frequent fluctuations in output at the present time tend to overshadow the seasonal trend. Hydro is less subject to unpredictable fluctuations and in aggregate follows a pronounced seasonal winter low and summer high. Thermal energy shows very little seasonal change except for a low in the midsummer months in one region. Since renewable thermal energy is dependent more on human systems than natural systems, the reasons for this trend are difficult to ascertain. Wind energy naturally follows a seasonal trend opposite to hydro, and greater development of this resource is needed to create a reliable baseline capacity during times of year when little hydro energy is produced.r

Therefore, investing in renewable energy types in proportions that will tend to reduce the seasonal variation in B.C.'s total renewable power output appears to be the most effective strategy for the development of renewable energy sources to support future EV energy needs in B.C.