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ELECTRICITY AFFORDABILITY AND EQUITY IN CANADA'S ENERGY TRANSITION

Options for rate design and electricity system funding

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Aligning Canada's electricity systems with net zero emissions will increase electricity use and has the potential to increase households' electricity expenditures. To inform policy discussion and actions for aligning electricity systems with net zero, we explore how net zero investments will affect electricity systems' costs and households' expenditures.

Our overarching research question is *how will increased electrification affect household costs by province and across the income distribution*? We find that while electricity use will increase, households' total electricity expenditures may not. These changes could exacerbate pre-existing equity issues: with a status quo approach to funding electricity system investments, the resulting system is likely to increase electricity expenditures for lower-income households relatively more than higher-income households. We explore two options for mitigating this regressivity in electricity system costs: rate-design changes and tax-system funding of system investment costs. Both approaches are tools that, in different ways, can help address regressivity and electricity affordability. Applying these tools independently or in combination provide multiple levers for policymakers to address equity and efficiency goals in the net zero transition.

This scoping paper is part of a series commissioned by the Canadian Climate Institute that explores key topics in aligning Canada's electricity systems with net zero, which culminated in the Institute report *The Big Switch*.

INTRODUCTION

Canada's commitments to reduce emissions, in line with global efforts to avert catastrophic climate change, require net zero emissions by mid-century. Achieving net zero emissions by 2050 requires changing how Canadian households and firms use energy; a large part of that change is increased electrification (Dion et al. 2021, 2022; Environment and Climate Change Canada 2022). Emissions from electricity are expected to decline by 77 per cent between 2019 and 2030, and electrification will account for 17 per cent of the expected emissions reductions between 2019 and 2030 (Environment and Climate Change Canada 2022). However, aligning electricity systems with net zero will require significant expansion of generation, transmission, and distribution infrastructure (Lee, Dion, and Guertin 2022). New investments in these fixed assets will in turn affect electricity bills. Absent policy interventions, costs of the expanded system will be borne by residential, commercial, and industrial consumers.

To inform federal and provincial policy options for aligning electricity systems with net zero, we explore how net zero investments will affect electricity system costs and costs for households. Our overarching research question is *how will increased electrification affect household costs, by province and across the income distribution*? There are three primary ways increased electrification will affect household costs. First, by changing electricity rates (the price households pay for electricity). Second, by changing electricity use. Third, by reducing expenditures on fossil fuels like gasoline, diesel, and natural gas. Electricity rates will change because of the changing composition of electricity generation (with different costs relative to the current mix) alongside increased system investments to support increased system load. Electricity use will increase due to electrification, with electricity becoming the default energy source for homes, vehicles, businesses, and industries. Correspondingly, expenditure on fossil fuels will fall as users switch to electricity in end uses. These changes may affect the affordability of electricity, though the overall costs of energy (household spending on electricity, natural gas, gasoline, heating oil, etc.) will decline (Dion et al. 2022). For lower-income households, who may not have the financial means to adjust their behaviour and energy sources, energy affordability is a key issue.

To explore the intertwined issues of electricity system change and electricity affordability, we focus on households' costs with four related research questions:

1. How much are households currently spending on electricity, and how do these costs differ across provinces and across the income distribution?
2. What will happen to households' electricity costs—both rates and total expenditure—on the path to net zero?
3. As electricity use and rates change, how will this affect Canadian households' electricity expenditure in different provinces and across the income distribution?
4. How would different rate structures and ways of funding electricity system investments change the incidence of system costs on households?

In answering our first research question, we use microdata—detailed household characteristics and expenditure data—from Statistics Canada's Social Policy Database and Model (SPSD/M).[1] Using these data, we describe current electricity expenditure patterns by province and income quintile. We then combine electricity expenditure with province-specific prices to impute household electricity use.

In answering our second research question, we use models of electricity system investments from three modelling teams— the Canada Energy Regulator (CER), ESMIA (Institut de l'énergie Trottier), and the Electric Power Research Institute (EPRI)—augmented with current utility debt costs to construct average costs of generation in 2030, 2040, and 2050. We translate these costs to a volumetric residential rate using a province-specific constant markup.[2] Using these estimated costs, we describe utility cost pressures and the volumetric and total costs for households in 2030, 2040, and 2050. We assume current electricity rate design in each province remains unchanged, and use scaling factors to increase households' volumetric and fixed charges relative to 2021.

In answering our third research question, we dive into how reference-case average household electricity expenditure, volumetric rates, fixed charges, and total household electricity costs differ across provinces and across the income distribution within each province.

[1] SPSD/M is "a non-confidential, statistically representative database of Canadian individuals in their family context, with enough information on each individual to compute taxes paid to and cash transfers received from government" (Statistics Canada 2022). We use SPSD/M version 29, which has a base year of 2017, the latest available data. The assumptions and calculations underlying the simulations were prepared by the authors and the responsibility for the use and interpretation of these data is entirely theirs.
[2] The markup is the difference between average household electricity costs ($/kWh) and modelled average generation cost ($/kWh) for the entire electricity system in 2020. The markup can result from a range of factors including return on equity, administrative costs, higher distribution costs for residential customers, and other costs for which we don't have modelling data.

DEFINITIONS

Household electricity expenditure: Total costs on an electricity bill, consisting of fixed charges and the volumetric rate (price) per kilowatt-hour (kWh) multiplied by use.

Volumetric rates: Electricity rates per kWh faced by households.

Fixed charges: Connection fees charged at a flat rate to all residential users, typically charged on a monthly or annual basis.

Electricity rates: Include monthly or annual fixed charges and the volumetric rates.

Average household electricity cost: The average cost of electricity per kWh for residential customers, constructed by dividing total household costs ($) by total household use (kWh). It combines fixed charges and volumetric rates.

Total household costs: Annual household electricity costs, including income tax increases in the scenarios where government directly funds part of net zero system investments through increased taxes.

Modelled average generation cost: The average electricity system cost. We calculate this by dividing all system costs, including amortized debt, by total modelled generation. This is measured in dollars per MWh or cents per kWh.

In answering our fourth research question, we compare different electricity rate structures and *system-funding* policies, as these are potential policy tools to mitigate equity concerns from increased system costs. Our baseline, or reference case, is that existing provincial rate structures continue. We examine three scenarios with different rate designs, and two scenarios with alternative system funding structures. These policy options are not mutually exclusive and are possible to use in combination, nor are they exhaustive of the potential policy options. They are, however, illustrative of how policy action could mitigate some of the negative equity consequences of net zero investments.

The rate-design scenarios explore different ways of levying transmission and distribution costs as a fixed charge, rather than (fully or partially) folded into volumetric rates. The scenarios are (1) a uniform fixed charge across all households; (2) a means-tested fixed charge (increasing with income) matching the progressivity of the GST's burden across the income distribution; and (3) a means-tested fixed charge matching the progressivity of federal personal income taxes. In the absence of a specific distributional goal, the three scenarios illustrate the equity considerations implicit in existing rate design versus alternatives.

We also explore two scenarios with 50 per cent government funding of the net zero investments. This reflects the notion that decarbonization through electrification and reducing emissions in the electricity sector is a policy objective rather than a system (or regulator's) objective. Moreover, governments may be better suited than private companies to absorb these costs, with the advantage of lower borrowing costs and a tax base larger than a rate base. We abstract from how government chooses to implement 50 per cent funding of the electricity system and focus on the net costs to households with 50 per cent public funding (net household costs are inclusive of their expenditure on electricity and their increased tax expenditure that results from the greater use of public funding). The two scenarios are (1) federal personal income tax increases; and (2) provincial personal income tax increases. Our choice of 50 per cent government funding of net zero system investments is arbitrary and meant to illustrate the equity and inter-provincial trade-offs of this mechanism of funding system investments.

We find that while electricity use will increase, households' total electricity expenditures may not. Major investments are necessary to align electricity systems to net zero, but the scale and scope of these investments differ by province, which has an important effect on electricity rates, and will depend on the future costs of generation, storage, and transmission technologies. Thermal provinces that currently rely on coal, natural gas, or oil for significant electricity generation—Alberta, Saskatchewan, Ontario, and the Atlantic provinces—are at greater risk of increasing volumetric rates (cents per kWh) and higher electricity expenditures. Even hydro provinces could see expenditures increase for lower-income households between 2020 and 2050. Rate design and funding approaches will be crucial in determining the distributional consequences of this change.

However, all of this will occur in the context of a changing energy system. Increased household electricity use will correspond with decreased use of gasoline, natural gas, and other fossil fuels. While spending on electricity will likely increase, total energy spending will decline (Dion et al. 2022).

Figure 1

Energy spending and electricity spending shares, 2020 to 2050

Source: Dion et al. (2022).

There are already existing policies in place—both general and targeted—to address energy affordability in Canada. Direct and targeted policies include means-tested bill rebates (for example, the Ontario Electricity Support Program (Ontario Energy Board n.d.-b)) and emergency financial assistance programs (for example, Ontario's Low-income Energy Assistance Program (Ontario Energy Board n.d.-a) or Alberta's Emergency Needs Allowance (Government of Alberta n.d.)). Other policy actions are temporary and targeted, such as Alberta's fuel tax holiday (Government of Alberta 2022). Indirect and targeted policies to address affordability include subsidies for energy-efficient investments (for example, the CleanBC Better Homes and Home Renovation Rebate Programs (CleanBC n.d.) or Manitoba's means-tested Energy Efficiency Assistance Program (Efficiency Manitoba n.d.)), and property-assessed clean energy programs (for example, Edmonton's Clean Energy Improvement Program (City of Edmonton n.d.) or Halifax's Solar City program (Halifax Regional Municipality n.d.)). The means-tested (for example, British Columbia's Climate Action Tax Credit) or lump-sum carbon tax rebates (for example, the federal Climate Action Incentive) can also be included as a general affordability policy action. However, the issue of energy poverty and energy affordability is understudied in Canada and there is no official definition of energy poverty (Shaffer and Winter 2020; Das et al. 2022; Das, Martiskainen, and Li 2022). We shed light on current and future electricity affordability and demonstrate how policy intervention can improve equity in Canada's net zero transition and address longer-term electricity affordability.

We next discuss current electricity expenditure by households, and the relative burden and affordability of electricity. We then briefly describe our methods and results for calculating residential electricity use change, modelled changes to residential rates, and modelled changes to household costs. We discuss the distributional consequences of expected household cost changes under different rate-design scenarios and the effect of different funding scenarios on electricity expenditure, variable rates, and fixed costs. We conclude by summarising our key results.

CURRENT ELECTRICITY USE AND AFFORDABILITY IN CANADA

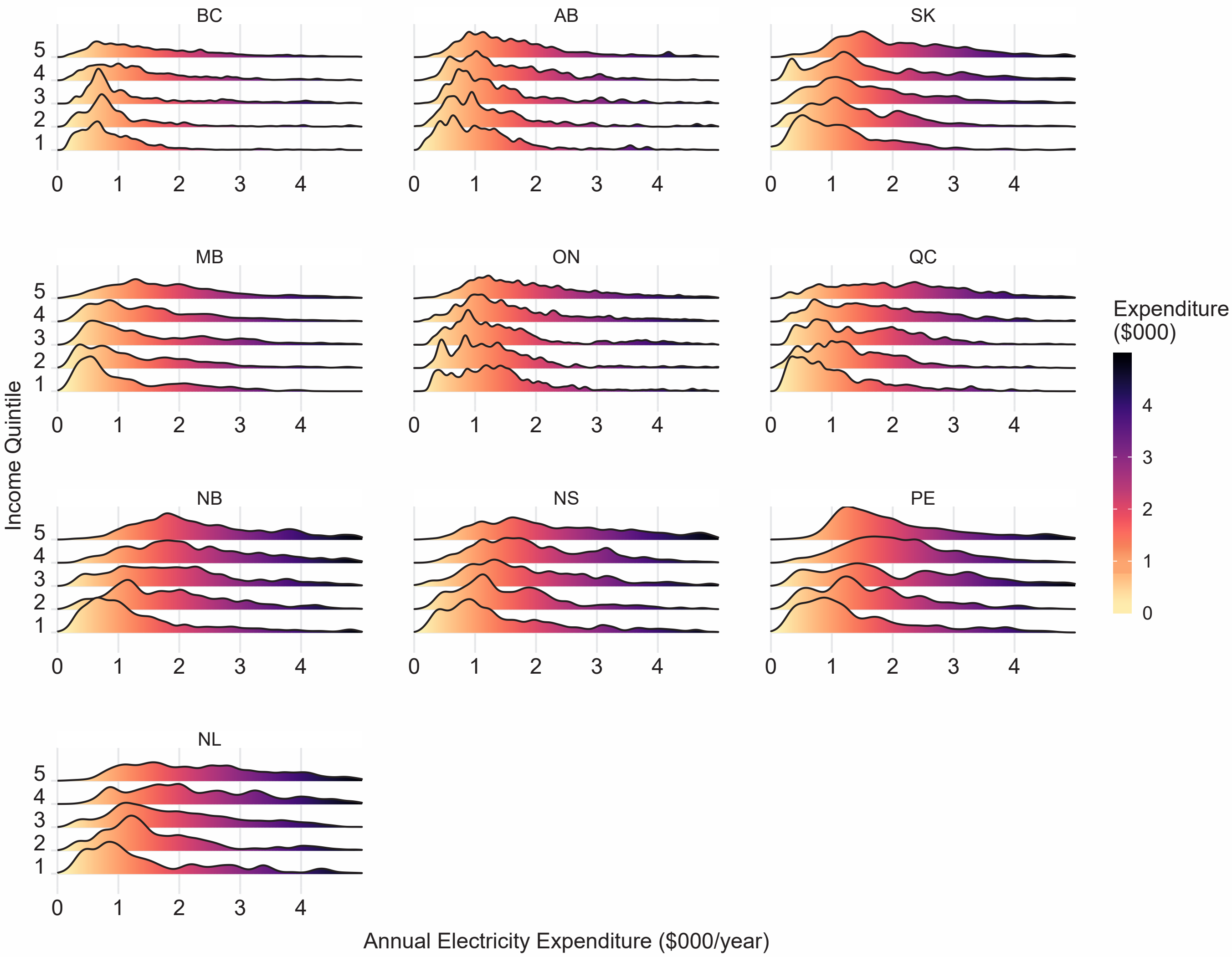
In this section, we present current household electricity expenditure using 2017 microdata from Statistics Canada's Social Policy Simulation Database and Model (SPSD/M). The database portion of SPSD/M is "a non-confidential, statistically representative database of Canadian individuals in their family context" (Statistics Canada 2018). The SPSD combines data from multiple sources and is the only integrated database with data on income, taxes, expenditure, employment information, and socio-economic characteristics.[3] These data form the basis of our analysis of how net zero investments affect households' electricity costs, the distributional consequences of a changing electricity system, and how policy choices on cost-sharing of these investments affect households. SPSD/M is a rich database of representative households in each province and ideal for our specific interests.

Figure 2 shows the distribution of households' annual electricity expenditure by province and income quintiles within each province, excluding households with no expenditure on electricity.[4] In most provinces, the majority of households in the first (lowest-income) quintile spend between $1 and $1,000 on electricity annually (as shown in the highest peak between zero and one). However, in the fifth (highest-income) quintile, annual electricity expenditures vary more as we see a relatively flat line, a nearly equal number of households spending between $500 and $3,000 on electricity expenditures annually. Importantly, this figure presents total expenditure, masking the relative roles of use, fixed costs, and volumetric rates in expenditure. We return to this issue in our analysis below.

[3] The data are synthetic, in that they are constructed from multiple sources (the Canadian Income Survey, personal income tax returns, employment insurance claimant history data, and the Survey of Household Spending), and there is no link across these datasets. However, the database is specifically constructed to be representative based on the underlying data.
[4] These are households that likely have electricity included in their housing costs, i.e., renters who do not pay utilities.

Figure 2

2017 Annual electricity expenditure by province and income quintile (thousand 2022 dollars)



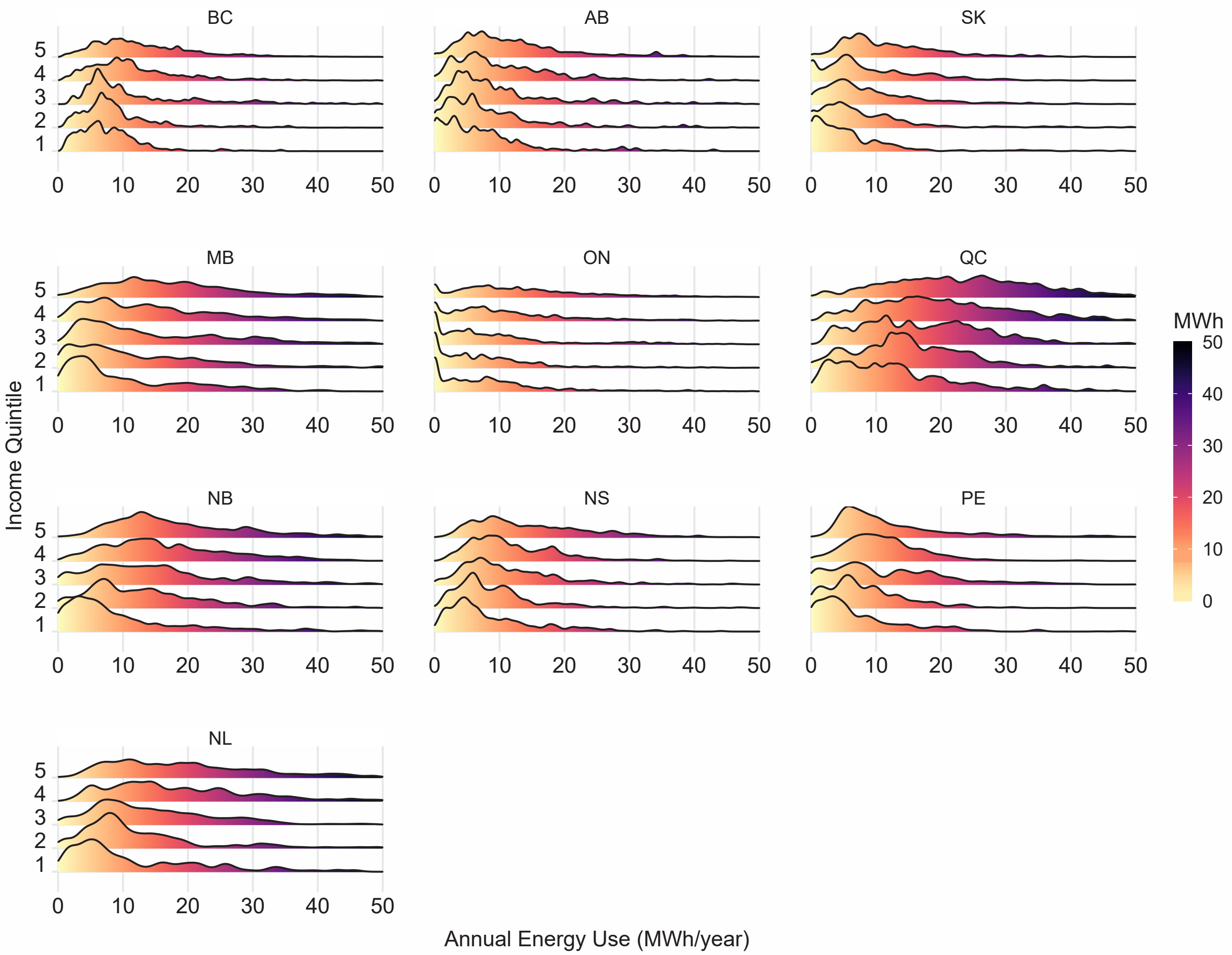
Note: The y-axis shows five income quintiles (equal groupings of households by income), where each quintile is 20 per cent of the population in each province by income. Quintile 1 is the lowest 20 per cent of the income distribution. The x-axis is annual electricity expenditure, in thousand 2022 constant dollars. We exclude households with no expenditure on electricity. The height of the curve shows the number of households that fall within a range along the x-axis. Electricity expenditure excludes commodity taxes. We use total income before taxes to define within-province income quintiles.

Figure 3 shows the distribution of households' annual electricity use in megawatt-hours (MWh) by province and income quintiles within each province, excluding households with no expenditure on electricity.[5] Most households consume 10 MWh or less per year. The pattern of distributions in Figure 2 differs from Figure 1 (expenditure), with a tighter distribution, particularly for lower-income households. Of note is that the "hydro provinces" that rely primarily on hydroelectricity—British Columbia, Manitoba, Quebec, and Newfoundland and Labrador—generally have a flatter and wider distribution of electricity use. This may reflect higher levels of existing electrification in these provinces.

[5] As we impute electricity use from expenditure, we are missing use from those households with electricity costs included in their housing costs.

Figure 3

2017 annual electricity use by province and income quintile (MWh)

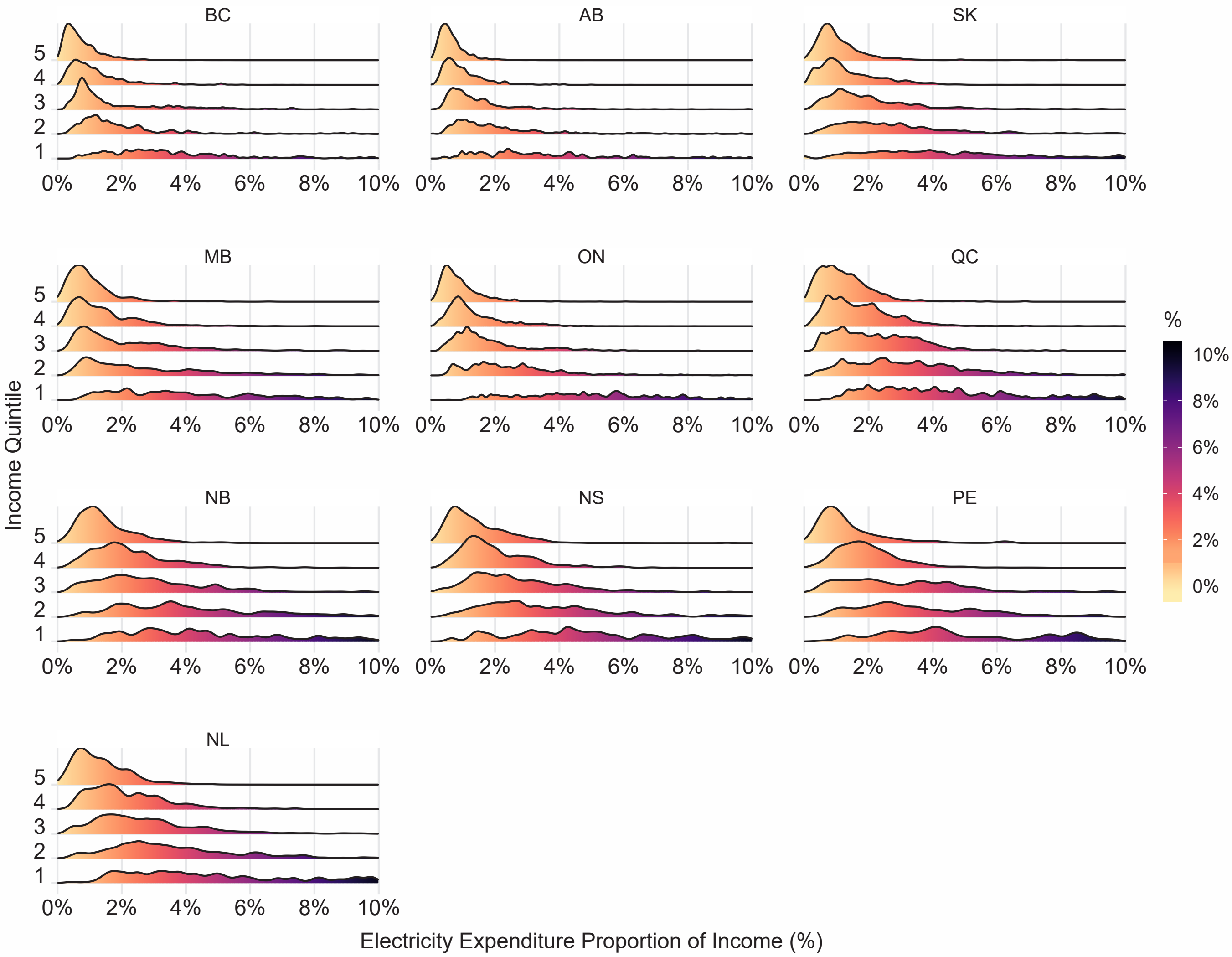


Note: The y-axis shows five income quintiles (equal groupings of households by income), where each quintile is 20 per cent of the population in each province by income. Quintile 1 is the lowest 20 per cent of the income distribution. We use total income before taxes to define income quintiles. The x-axis is annual electricity use, imputed from households' electricity expenditure and province-specific prices (see Table 1 in Appendix II for prices we use). We exclude households with no expenditure on electricity. The height of the curve shows the number of households that fall within a range along the x-axis.

Figure 4 shows households' annual electricity expenditure as a share of income by province and income quintiles within each province. This is a useful metric as it presents the relative burden of electricity expenditures. As a proportion of income, we see that electricity expenditures are a larger burden for lower income quintiles. Most of the higher-income households fall within the spending range of zero to two per cent of their income, while lower income quintiles spread across a range from two to 10 per cent and more. This implies that, all else equal, a proportional or uniform increase in electricity costs will affect lower-income households more. Without a similar increase in income, increases in electricity costs will potentially limit these households' ability to purchase other goods and services.

Figure 4

Annual electricity expenditure as a proportion of income

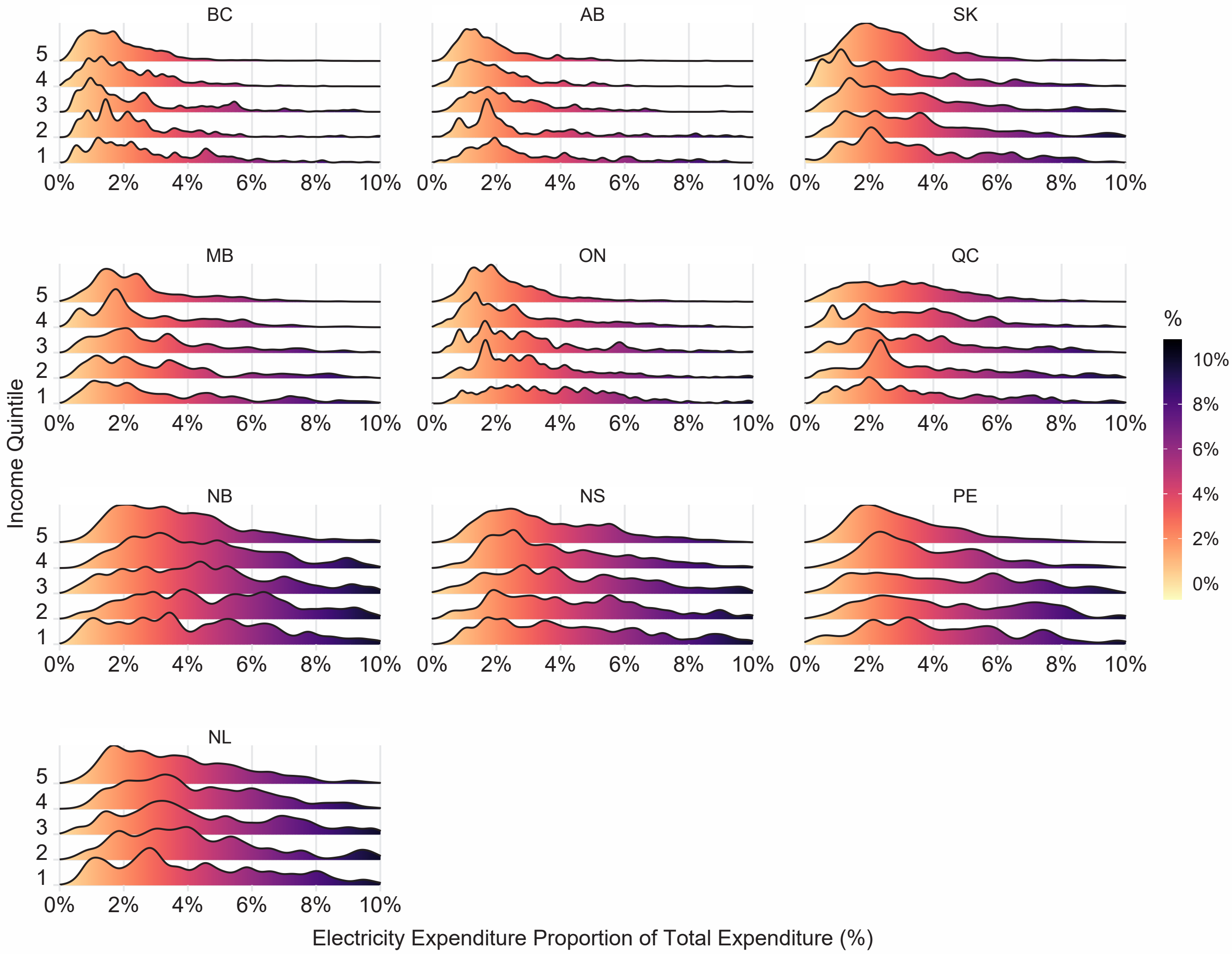


Note: The y-axis shows five income quintiles (equal groupings of households by income), where each quintile is 20 per cent of the population in each province by income. Quintile 1 is the lowest 20 per cent of the income distribution. We use total income before taxes to define income quintiles. The x-axis is annual electricity expenditure as a share of income. The height of the curve shows the number of households that fall within a range along the x-axis. We exclude households with no expenditure on electricity. Electricity expenditure excludes commodity taxes.

An alternative way to evaluate the burden of electricity costs is expenditure as a share of households' total expenditure (Figure 5). Some households may be retired, or temporarily have lower incomes (for example, parental leave), and comparing to total expenditure gives a richer sense of the relative cost burden (Poterba 1989). Using expenditure rather than income is closer to the lifetime burden of a specific type of expense. Here, electricity expenditures fall across income quintiles more equitably, compared to expenditure as a share of income in Figure 4. Importantly, however, there is still a persistent pattern of lower-income households spending more on electricity as a share of total expenditure compared to higher-income households.

Figure 5

Annual electricity expenditure as a proportion of total expenditure



Note: The y-axis shows five income quintiles (equal groupings of households by income), where each quintile is 20 per cent of the population in each province by income. Quintile 1 is the lowest 20 per cent of the income distribution. We use total income before taxes to define income quintiles. The x-axis is annual electricity expenditure as a share of income. The height of the curve shows the number of households that fall within a range along the x-axis. We exclude households with no expenditure on electricity. Electricity expenditure excludes commodity taxes.

Together, these plots show that while electricity expenditure increases with income, electricity is a higher share of both income and total expenditure for lower-income households. These households have less flexibility to adapt to increasing electricity prices. Even though modelling predicts total energy expenditure (on electricity, natural gas, gasoline, heating oil, etc.) will decrease over time (Dion et al. 2022), lower-income Canadians are vulnerable to increased costs from increased electrification in the absence of other policy intervention. We now turn to how net zero investments will affect system costs, electricity rates, and household costs.

NET ZERO AND ELECTRICITY COST PRESSURES

Here, we briefly cover our methods for and results from constructing expected electricity system investment costs, average generation costs, and the accompanying pressure on residential rates (both volumetric rates and fixed charges) and changes to household costs. We provide more detail on our methods in Appendix I.

Modelling electricity generation cost pressures

Electricity generation cost pressure is the expected change in average electricity generation cost due to changes in utility generation, distribution, transmission, and storage costs. These costs include fixed and variable elements. Fixed costs include investment costs (past, present, and future) for the electricity system itself, including power plants, wind and solar farms, hydroelectric facilities, transmission and distribution lines, and energy storage facilities. These investment costs are apportioned across users contemporaneously and over time, and funded primarily by debt. There are also fixed operations and maintenance costs that are required to keep the electricity system functioning. Variable costs include fuel for thermal plants, carbon pricing costs on fossil fuel use, and variable operations and maintenance costs.

To understand future generation costs, we use data from three electricity-system modelling groups: Canada Energy Regulator, Electric Power Research Institute, and ESMIA (Institut de l'énergie Trottier). These modelling groups created scenarios for electricity futures in provinces or regions throughout Canada. We use the modelling scenarios that are closest to achieving net zero greenhouse gas emissions by 2050. The modelling teams produce forecasts of costs that include projected capital costs for generation, transmission, and distribution; fixed operating and maintenance costs; variable operating and maintenance costs; and fuel costs.

We rely on these modelling outputs to project net zero investments in Canada's electricity system by province.[6] We do not include investment costs for making electricity systems more resilient to climate change,

[6] The EPRI model aggregates Quebec and Newfoundland and Labrador into one region, and Nova Scotia, New Brunswick and Prince Edward Island into another. We disaggregate the model results to individual provinces.

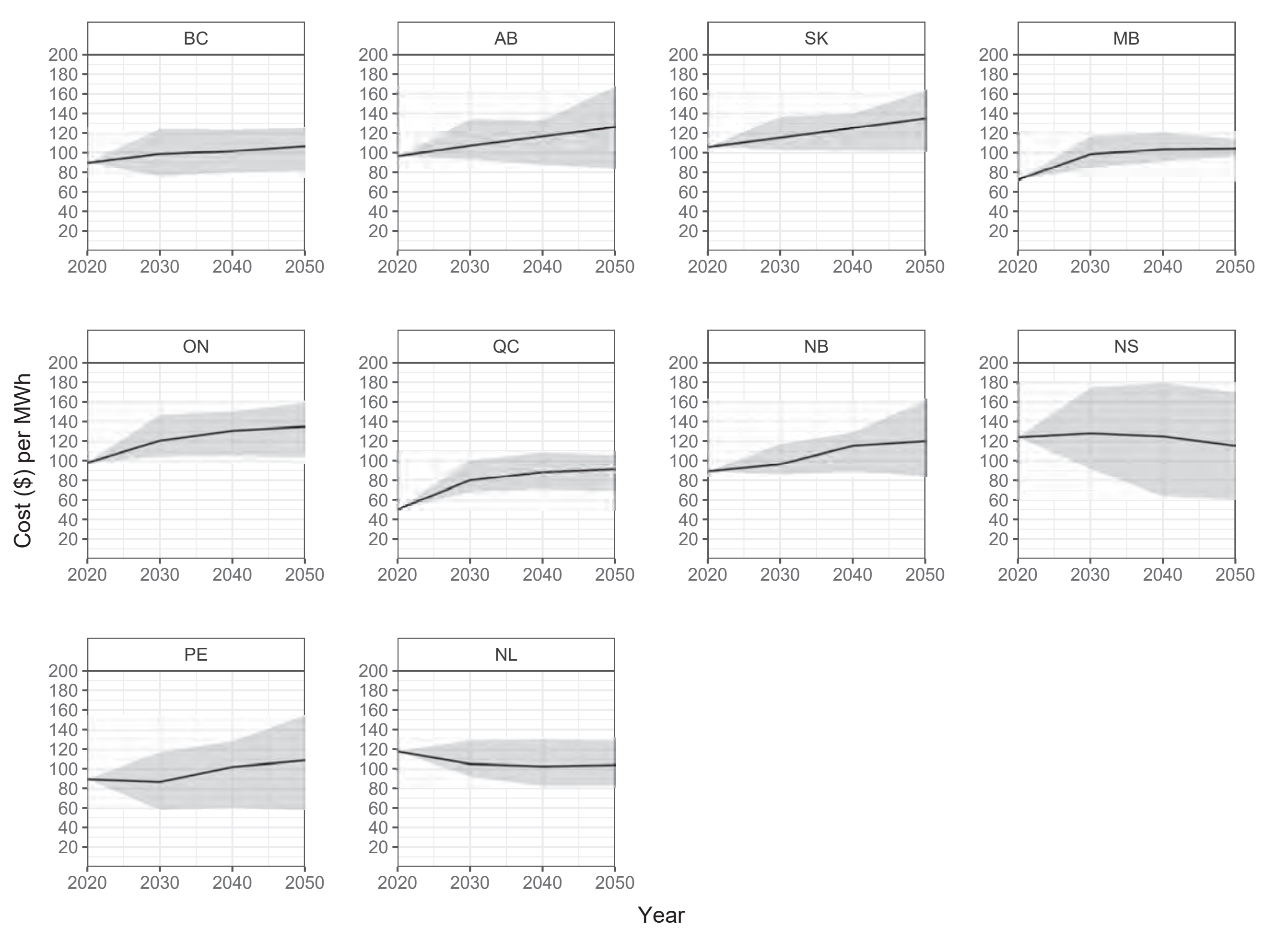
and so our analysis is a potential underestimate of total system costs between 2020 and 2050. Details on the specifics of the models and the assumptions are outlined in each modelling groups' published reports (Canada Energy Regulator 2021b; Electric Power Research Institute 2021; Langlois-Bertrand et al. 2021). The reports and assumptions are also summarised in Lee, Dion, and Guertin (2022). We augment the modelling outputs with existing and expected debt from provincial electricity utilities;[7] this creates a comprehensive measure of expected costs taking into account past investment costs. With this comprehensive cost data, we calculate average electricity-generation costs (inclusive of fixed and variable costs) for each model. These average costs are the estimated electricity generation costs for each province.

In Figure 6, we present our estimates of average electricity-system generation costs between 2020 and 2050. The black line is the mean of the three models' cost estimates, and the grey band reflects the maximum and minimum cost estimates in any given year. For most provinces, average electricity generation costs will likely increase, though there is also potential for costs to stay constant or decrease. The figure also demonstrates differences in current average generation costs across provinces, which also matters in considering distributional consequences. For example, Quebec and Manitoba have lower system costs. Even with new investments, the figure shows that generation costs in these provinces are only projected to increase to Ontario's current (2020) average cost. The effects of net zero investments will have differential cost implications for provinces. Thermal provinces—Alberta, Saskatchewan, New Brunswick, Nova Scotia, and Prince Edward Island as an importer of thermal electricity—whose electricity generation is currently heavily reliant on fossil fuels have the largest potential cost increases. These provinces require the greatest change in their electricity systems and so require relatively more investment. Importantly, the three models we rely on to estimate system cost increases differ in their assumptions. Specifically, some of the low-cost scenarios assume high adoption of low-cost renewables. The variation in assumptions creates larger ranges for thermal provinces, as there is more uncertainty about what the future electricity system will actually look like.

[7] This data is not comprehensive, but we identified long-term debt for the largest utilities in each province. Using these debt values, we calculate a debt per MWh annual charge by province and assign that charge to electricity rates.

Figure 6

Average electricity system generation cost, 2020 to 2050 in $/MWh (2022 constant dollars)



Note: Presents average generation cost changes over time. Average generation cost is the modelled generation cost including amortized debt, divided by total modelled generation. The black line is the mean of the three models' cost estimates, and the grey band reflects the maximum and minimum cost estimates in any given year.

Constructing residential average cost pressure

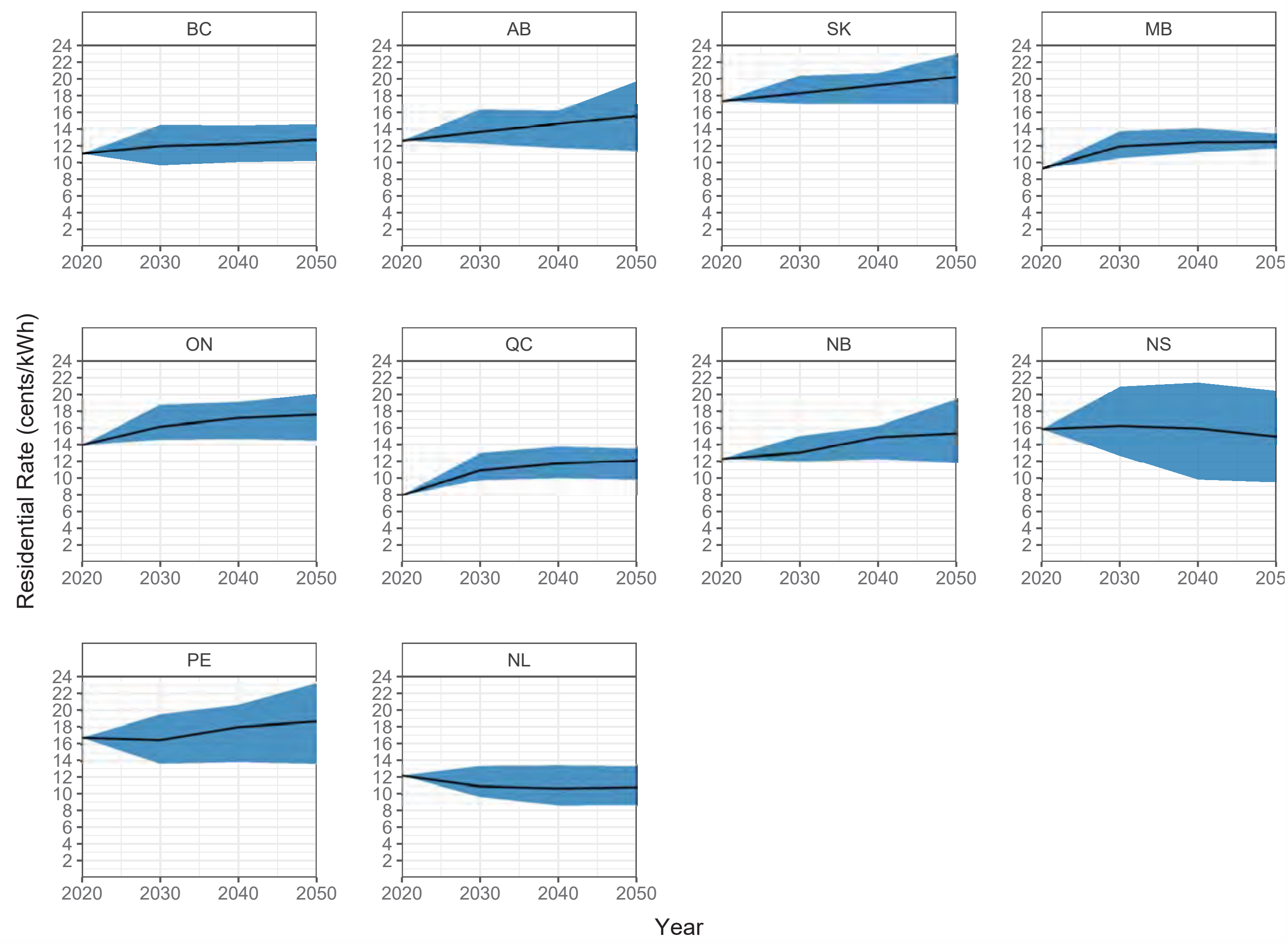
Residential cost pressure is the expected change in average residential electricity costs (both volumetric rates and fixed charges) resulting from changes in utility generation, distribution, transmission, and storage costs. This is distinct from electricity generation cost pressure as residential, commercial, and industrial ratepayers share electricity system costs, but costs are not necessarily apportioned equally across the rate classes.

Typically, residential ratepayers are slightly cross-subsidized by other ratepayer classes, in that commercial and industrial customers bear more of the costs of the electricity system relative to if costs were apportioned by share of use. Residential rates also have higher than average system generation costs due to administrative costs and other costs not included in the modelling. We adjust the cost projections in

Figure 6 by including a province-specific and constant cost-markup to account for differences in average system generation costs and average residential electricity costs. This markup is the difference between current average household electricity costs at today's rates and modelled average generation costs, and is model-specific. Figure 7 presents these changes, and has a very similar pattern to Figure 6. The black line is the mean of the three residential average cost estimates, and the blue band reflects the maximum and minimum estimates in any given year. The costs presented are average household electricity costs, and include both volumetric rates and fixed charges in the per-kWh value.

Figure 7

Residential average electricity cost pressures (constant 2022 cents/kWh), 2020 to 2050



Note: Presents the range of average residential electricity costs over time. We construct cost ranges by adding a province-specific rate inflation factor to average system cost calculated for each model and year. This rate inflation factor is calculated based on 2020 or most-recent-year comparisons of residential rates and system costs in each province. These average costs include both fixed charges and volumetric charges. The black line is the mean of the three models' cost estimates, and the blue band reflects the maximum and minimum cost estimates in any given year.

In the central estimate of the three models, the majority of provinces have minor electricity residential average cost increases, between two and four cents per kWh (2022 constant dollars). This is a small change over 30 years, and in many provinces, there is the potential that residential costs remain unchanged or even decrease. Importantly, the wide range in projected residential costs means that when holding use constant, total household costs could stay the same, decrease, or increase. With electrification, however, use is likely to increase. We turn to the joint effects in the next section.

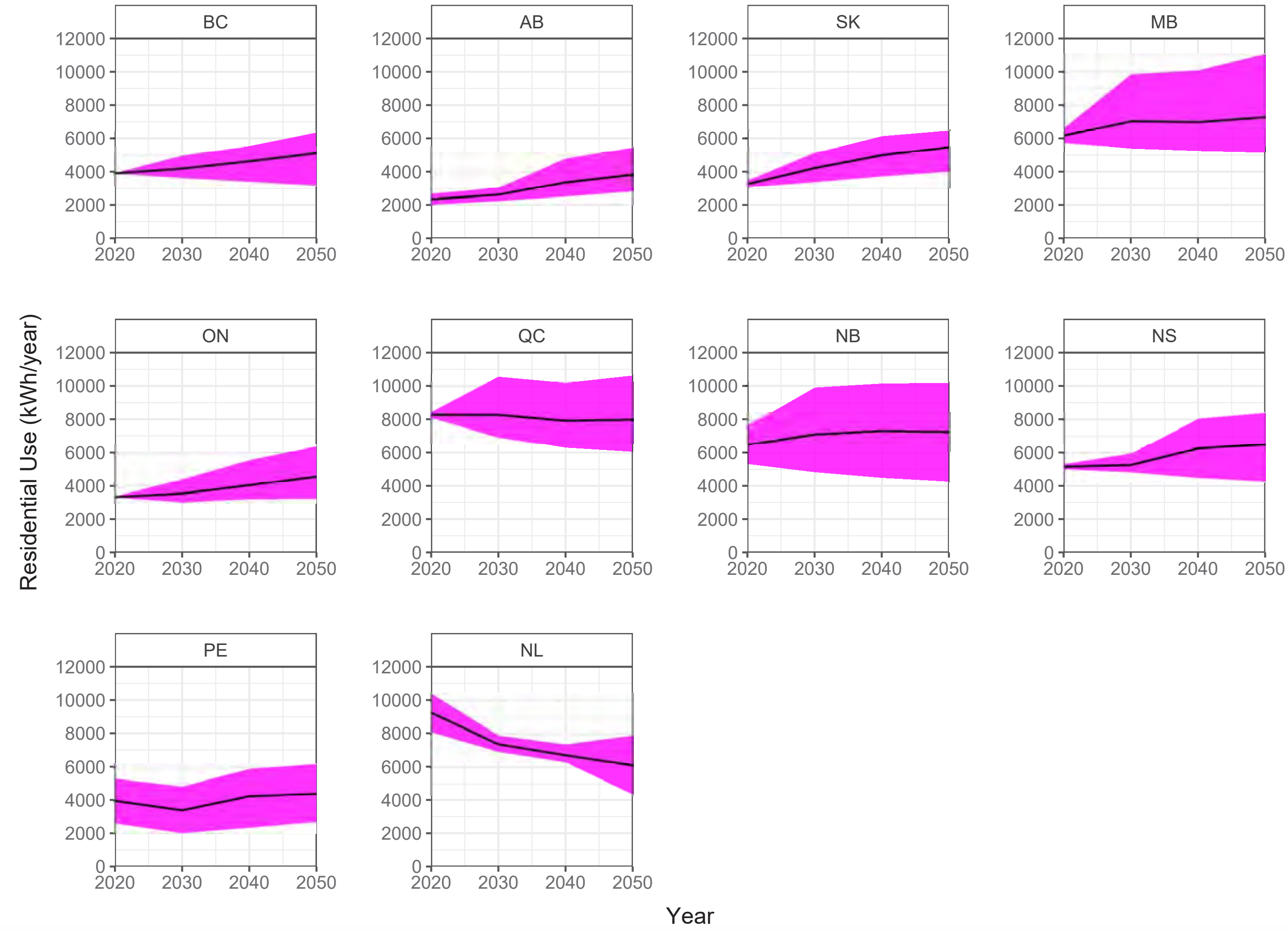
Constructing household cost estimates

Total household costs depend on both prices and use. In the previous section we describe changes to average household electricity costs; here, we describe projected electricity use changes and the total effect on household bills. The three models project that households will, on average, use more electricity as they electrify vehicles and heating. Importantly, however, there is not a one-to-one switch in energy use; electric vehicles are significantly more efficient than internal combustion engines and heat pumps are significantly more efficient than natural gas or heating oil furnaces (Canada Energy Regulator 2021a; Natural Resources Canada 2021). The higher efficiency is part of the reason total energy expenditure will likely decline for Canadian households (see Figure 1). The increased efficiency resulting from electrification has a mitigating effect on increased electricity demand. Moreover, as shown above in Figure 7, residential average electricity costs may decline.

The three models forecast residential electricity demand and population change for each province or region. We use these data to calculate per capita electricity demand in current and future years (Figure 8) and construct a growth rate for residential electricity demand. In Figure 8, the black line is the mean of the three models' projections and the pink bands reflect the maximum and minimum per-capita demand forecasts. We assume that households' composition will not change significantly between 2020 and 2050, and use per-capita growth rates to construct growth rates in household electricity use by province. This assigns the same growth rate to different households within a province, with no differentiation by income.

Figure 8

Per capita residential electricity use, 2020 to 2050



Note: Presents per capita electricity use over time. The black line is the mean of the three models' use estimates, and the pink band reflects the maximum and minimum use estimates in any given year. Per capita electricity use projections are declining in Newfoundland and Labrador, but this appears to be due to modelling assumptions.

Finally, we combine electricity use from Figure 3 and the use changes from Figure 8 with household cost pressures from Figure 7 to construct changes in households' annual electricity expenditures. We present this in Figure 9, using 2021 prices to define "current" electricity costs and normalizing to 2020 to show changes in electricity expenditure relative to 2020.[8] As before, the black line in Figure 9 is the mean across the three models' results and the purple band shows the range between the mean of the high-cost modelling results and the mean of the minimum-cost modelling results in a given year.

The figure reveals different patterns in future household electricity expenditures across provinces. Households in Alberta, Saskatchewan, Manitoba, Ontario, and Quebec will spend more on electricity, though the scale of the increase differs substantially. In contrast, British Columbia and New Brunswick may have electricity expenditures stay constant or increase. Prince Edward Island and Nova Scotia have a large range of uncertainty—households' electricity expenditures may decrease or increase. Newfoundland and Labrador is the only province with an expected decline in household electricity

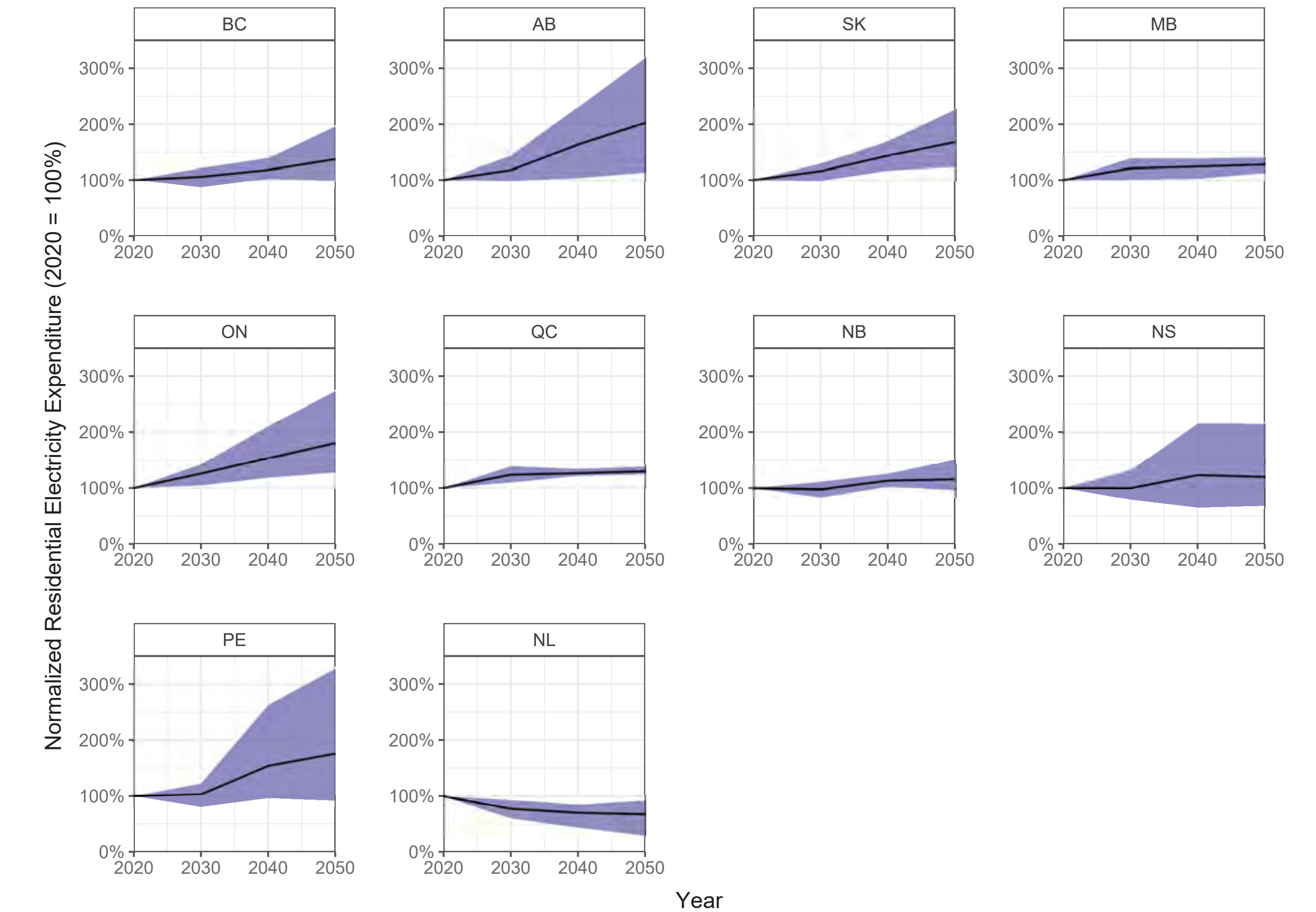
[8] We report 2021 volumetric rates and fixed charges by province in Appendix II, Table II.2.

expenditures. Several provinces—British Columbia, Saskatchewan, Ontario, and Nova Scotia—could have expenditures double, and Alberta and Prince Edward Island could even see electricity expenditures triple relative to 2020—though in all cases the lower bound has nearly unchanged expenditures.

However, the results presented in Figure 9 are an incomplete picture for two reasons, and should not be a *prima facie* cause for alarm. First, as we mention above, at the same time as electricity expenditure is rising, expenditure on fossil fuels will be falling, and so the expenditure changes displayed in Figure 9 are not net cost changes.[9] Second, electricity cost increases do not occur in a vacuum—we also expect incomes to grow. Nevertheless, for some provinces, these changes may be large and should provoke reflection on the ways that electricity system investments are funded and electricity rates designed. We turn now to a discussion of the distributional consequences of these electricity expenditure changes.

Figure 9

Range of changes to household electricity expenditures, 2020 to 2050



Note: Presents average household electricity expenditure changes over time, relative to 2020. This figure accounts for both use and cost changes. We impute base electricity use from 2017 expenditure using 2017 volumetric rates and fixed charges, and base electricity volumetric rates and fixed charges are from 2021. We scale both costs and use as described above. The black line is the mean of the three models' electricity expenditure estimates, and the purple band reflects the maximum and minimum expenditure estimates in any given year.

[9] Our scope is limited to assessing distributional consequences of electricity cost increases. Understanding net effects is an area ripe for future research.

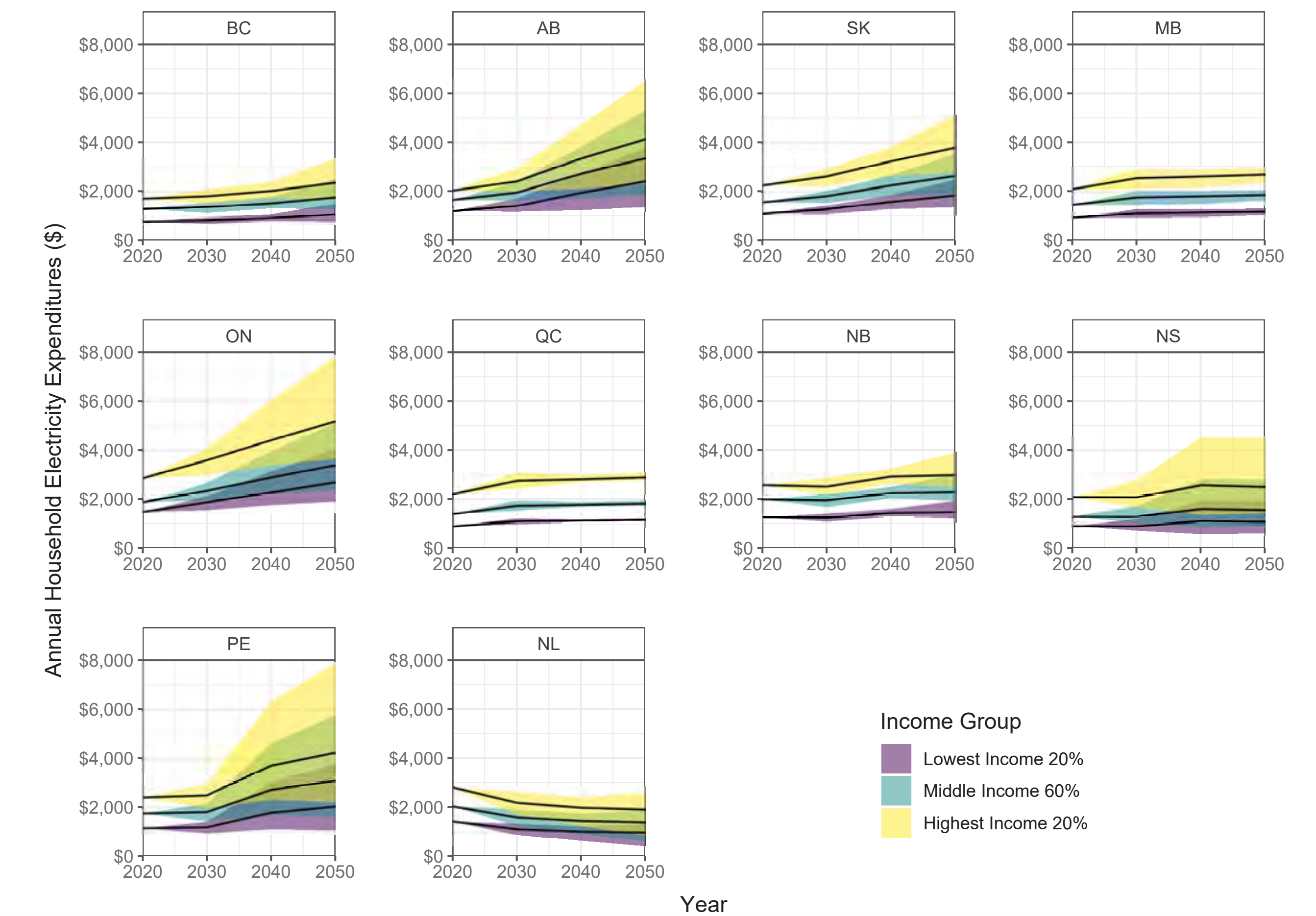
Net zero and electricity affordability: Distributional effects of electricity expenditure changes

As shown above, income groups have different electricity use and expenditure patterns. This can translate to differential distributional effects of electricity expenditure changes, particularly for more vulnerable (lower-income) households. In this section, we use the SPSD/M microdata to explore these distributional consequences, using the electricity expenditure changes in Figure 9. We apply the same relative increase to each household's current electricity expenditures, and present expenditure changes between 2020 and 2050 (Figure 10).[10] This simulates what the changes in residential use and residential rates will mean for households at different income levels. The most uncertainty for households' expenditures is in Alberta, Saskatchewan, Ontario, Nova Scotia, and Prince Edward Island.

Figure 10

Residential annual electricity expenditures by income group, 2020 to 2050

(2022 constant dollars)



Note: The y-axis shows forecast annual electricity expenditure in 2022 constant dollars for the bottom and top income quintiles and the middle three quintiles (equal groupings of households by income), where each quintile is 20 per cent of the population in each province by income. We use total income before taxes to define income quintiles. Electricity expenditure excludes commodity taxes. Baseline electricity expenditure is imputed 2017 use at 2021 volumetric rates and fixed charges. The range for each quintile is based on the mean annual household cost for each quintile and reflects the range in modelling studies. The top of the range is the quintile's mean from the model with the highest expenditure, and the bottom of the range is the quintile's mean for the model with the lowest expenditure. The black line is the within-quintile mean, averaged across all three models.

[10] The 2020 expenditure is based on imputed 2017 electricity use inflated to 2020 dollars.

To put these costs in perspective and understand the change in purchasing power, we evaluate household electricity expenditure relative to 2021 incomes in Figure 11. The figure shows average within-quintile expenditure as a share of 2021 income without income growth to cleanly identify the potential affordability challenge of electricity expenditure changes and the required income growth to keep current shares constant. The figure shows that lower-income households are most vulnerable to expenditure increases, and that the inequality in electricity expenditures will increase. Specifically, higher-income households' electricity expenditure as a share of income stays constant between 2020 and 2050. As incomes are expected to increase, this implies these households are likely to spend a smaller share of their income on electricity. In contrast, the bottom 20 per cent of each province's income distribution is particularly vulnerable to electricity expenditure increases. This quintile spends far more as a share of income and for some provinces this proportion will double. The issue is particularly acute for lower-income households in Alberta, Saskatchewan, Ontario, New Brunswick, and Prince Edward Island. Even in hydro provinces—British Columbia, Manitoba, and Quebec—lower-income households have a larger proportional increase in electricity expenditure between 2020 and 2050.

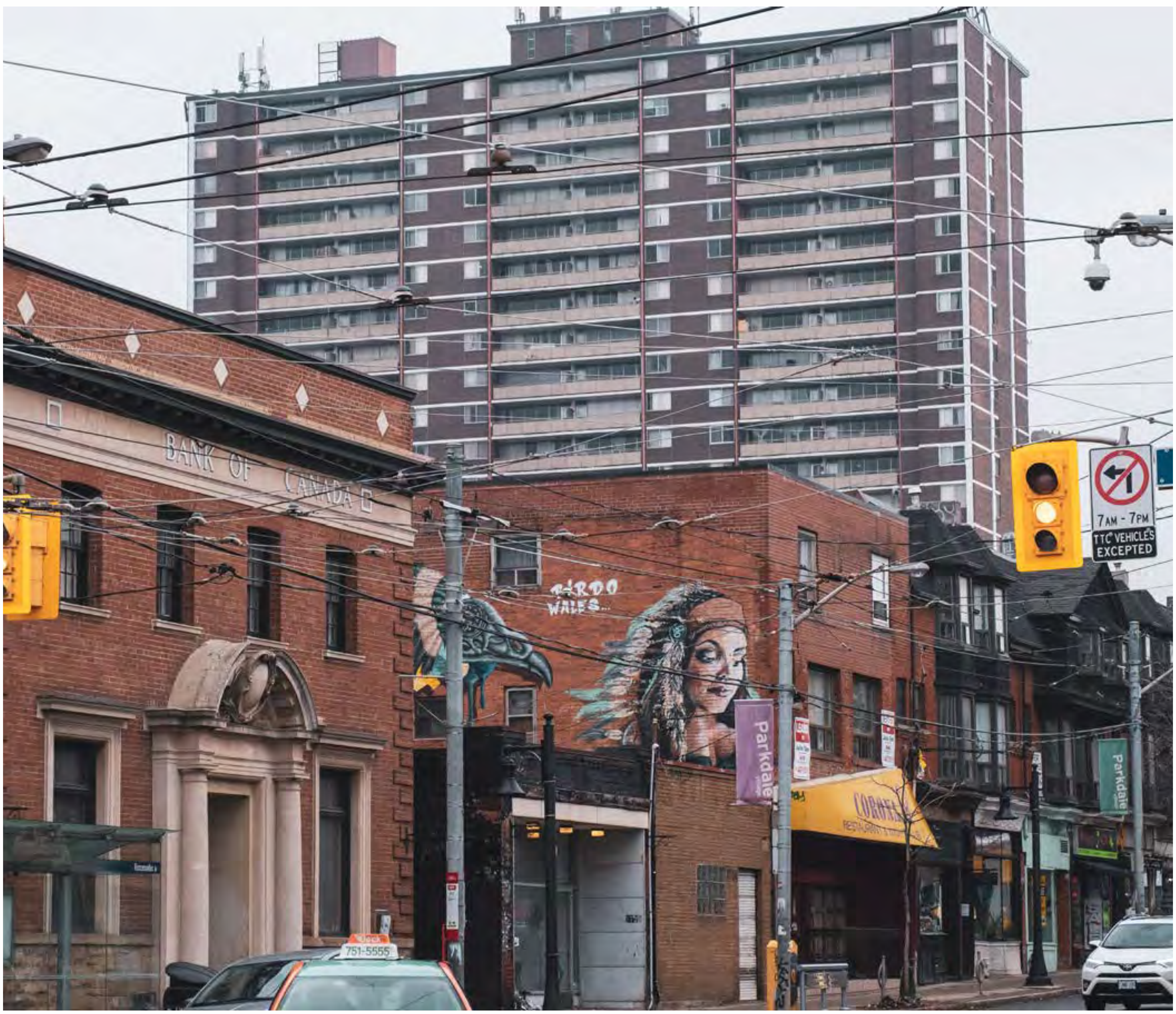


Figure 11

Total electricity expenditure as a proportion of 2021 income

Note: We separate households into five income quintiles (equal groupings of households by income), where each quintile is 20 per cent of the population in each province by income. Quintile 1 is the lowest 20 per cent of the income distribution. We use total income before taxes in 2021 to define income quintiles. Baseline electricity expenditure is 2017 use at 2021 volumetric rates and fixed charges, and excludes commodity taxes. We assume no income growth to clearly show the equity consequences of increasing household electricity expenditure.

The patterns in Figure 11 are concerning as recent evidence suggests income inequality in Canada is increasing (Green, Riddell, and St-Hilaire 2017), intergenerational mobility is decreasing (Connolly, Haeck, and Lapierre 2021), and wages are growing more slowly than economic growth and productivity (Ashwell 2021; Greenspon, Stansbury, and Summers 2021; Williams 2021). If past patterns hold, income growth for lower-income households may be insufficient to compensate for increases in electricity bills, exacerbating the current burden and relative inequity. Policymakers may wish to consider additional policy action to address this problem and specifically insulate lower-income households from net zero transition costs. We turn to these policy options in the next section.

POLICY OPTIONS FOR FUNDING NET ZERO ELECTRICITY SYSTEM INVESTMENTS

We demonstrate above that an electricity system supporting net zero emissions targets in Canada will likely increase electricity expenditures for some households, assuming a status quo approach to funding the electricity system. While this increase occurs in the context of falling energy costs overall (Dion et al. 2022), funding the costs of electricity investments differently could affect this distributional incidence. To this end, we explore options to mitigate cost pressures on low-income households.

Rate-design choices and government supports will have different distributional consequences. We compare several counterfactual scenarios modifying rate design and reducing system investment costs through tax financing. Our reference case is the status quo described above, using 2021 electricity rates and estimated future rates with current rate design. We assess the relative cost burden faced by households under five counterfactual scenarios. The first three scenarios are alternative rate-design options, while the latter two are alternatives for funding net zero investments. We distinguish between the two approaches in our discussion below. For ease of interpretation we present distinct policy scenarios, but these policy choices are not mutually exclusive and it may be desirable to adjust both rate design and system funding.

Rate design choice and equity

In this section, we explore how utilities can change rate structures to address the issue of distributional equity, and other concerns. An acknowledged challenge in rate design is the apportionment of fixed system costs into volumetric rates and fixed charges (Borenstein 2016). In most provinces the majority of fixed costs are folded into volumetric charges (cents per kWh), making the monthly or annual fixed charges users pay on their electricity bills smaller than would be the case if they truly reflected fixed costs. This increases volumetric charges above the true marginal cost of generation, and reduces incentives to switch to electric vehicles, electric heat, and electric industrial processes (Borenstein, Fowlie, and Sallee 2021).

The disjoint between volumetric prices and marginal costs makes distributed solar generation a challenge for utilities: solar self-generators under net-metering plans receive the volumetric retail rate of electricity, while only saving the utility the marginal cost of generation. This means that solar self-generators are cross-subsidized by other customers. A potential solution is increasing fixed charges to ensure solar self-generators pay the real system costs for having the grid as a backup (Borenstein 2011; Borenstein, Fowlie, and Sallee 2021). This has the benefit of shifting electricity volumetric rates closer to marginal cost, which is more efficient, and desirable for encouraging electrification of vehicles and buildings. However, while transmission and distribution as a fixed charge is desirable from an efficiency and rate design perspective, it creates equity challenges due to the uniform and fixed nature of the fixed charges. Specifically, an increase in fixed charges is regressive and negatively affects low-income ratepayers. If fixed charges increase to address the cross-subsidization of solar and move volumetric rates closer to marginal cost, then utilities can consider means-tested fixed costs to address equity concerns.

We examine three scenarios for different approaches to fixed charges:

1) **Transmission and distribution as fixed charge:** This scenario modifies the reference case and bases the fixed monthly charge on the cost of transmission and distribution; all remaining costs are covered via residential volumetric electricity rates. Specifically, we remove amortized transmission and distribution costs from total system costs and assign these costs as uniform fixed charges.[11] The fixed monthly charge is added to household costs but not reflected in the volumetric price per kWh. This rate design could improve incentives for electrification by reducing volumetric rates and help rates better approximate actual marginal generation costs, but it would affect cost incidence.

2) **Means-tested fixed charge (GST targeted):** This scenario modifies the uniform fixed-charge scenario by making fixed charges income-dependent and increasing with income. The fixed charge matches the progressivity of the GST. We model this by calculating the proportion of GST paid by each income quintile in Canada, and then designing uniform within-quintile fixed charges that match those proportions. For example, the lowest income quintiles across all provinces pay 10 per cent of GST in aggregate, and we apportion this percentage of transmission and distribution costs to the lowest income quintile, and split the proportion equally across households in the quintile. This scenario involves cross-subsidization of electricity-system fixed costs between income groups within a province.

3) **Means-tested fixed charge (personal income tax targeted):** Like policy 2) above, this policy modifies the uniform fixed-charge scenario by making fixed charges income-dependent and increasing with income. The fixed charges match the progressivity of the federal personal income tax system. We model this by calculating the proportion of personal income taxes paid by each income quintile in Canada, and then designing uniform within-quintile fixed charges that match those proportions. For example, the lowest income quintiles across all provinces pay 0.5 per cent of personal income taxes in aggregate, and so we apportion this percentage of transmission and distribution costs to the lowest

[11] To calculate the volumetric rates we remove fixed transmission and distribution cost components and then divide the remaining system costs by aggregate household electricity use to find an adjusted volumetric rate.

income quintile, and split the proportion equally across households in the quintile. Conversely, the highest income quintile households pay 63 per cent of personal income taxes and so are charged correspondingly higher fixed charges on these modelled electricity bills. This scenario also involves cross-subsidization of electricity-system fixed costs between income groups within a province.

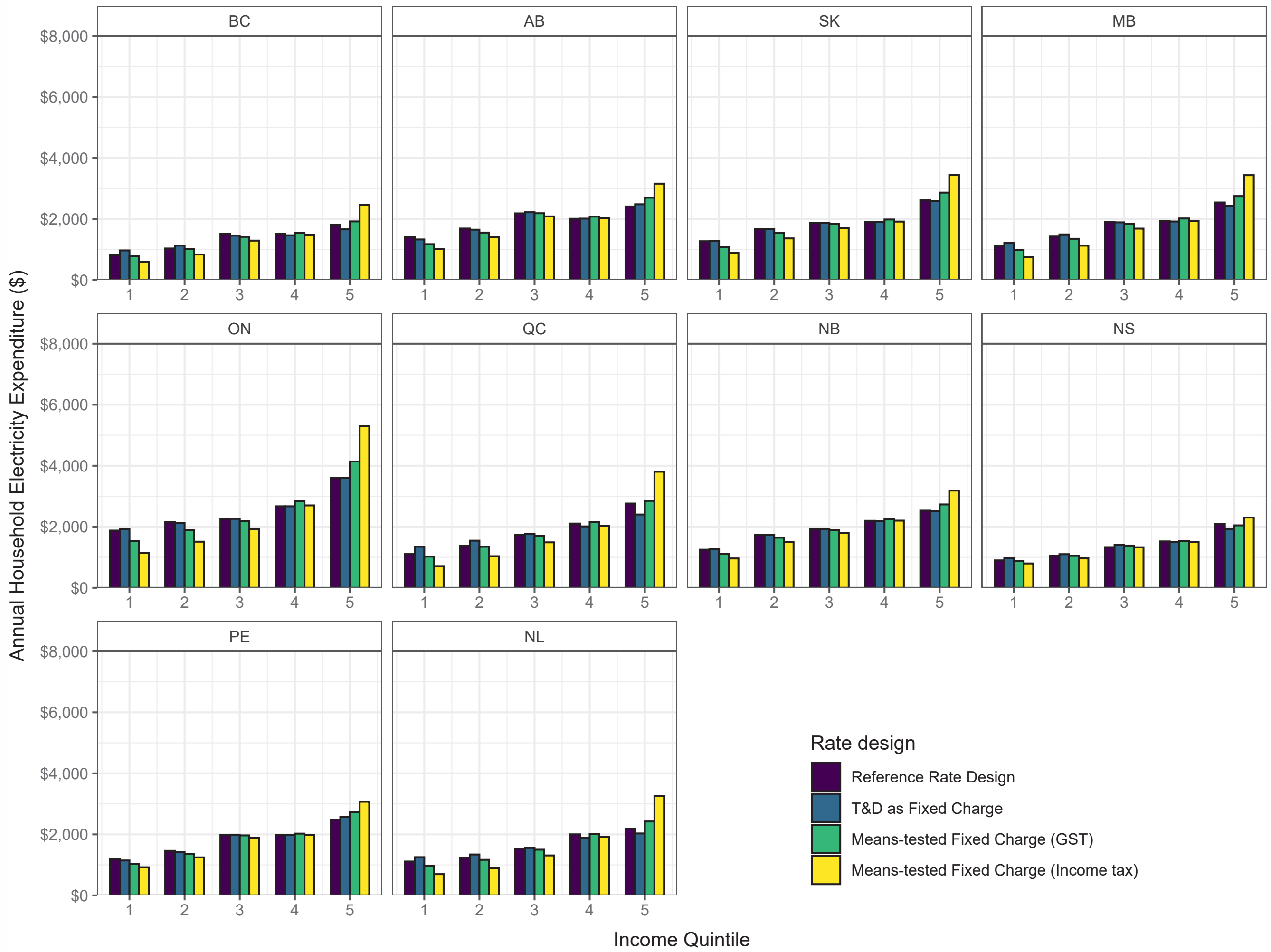
Figure 12 shows within-province quintile-average total household electricity costs in 2030 for the different rate-design scenarios. Figure 13 shows 2040 results, and Figure 14 shows 2050 results. The pattern across scenarios remains the same, though costs increase over time. All rate design scenarios show total household costs increase with income. In most provinces, the alternative scenarios generate roughly equivalent costs for the third and fourth income quintiles. The most visible differences in costs and the effect of rate-design choices on costs are in the first and fifth quintiles—the lowest-income and highest-income households. In most provinces, households in the lowest two quintiles face higher costs when transmission and distribution is a fixed charge relative to the reference case. The higher-income households are generally better off with the uniform fixed charge relative to the reference case. This is not surprising, as a uniform fixed charge is more burdensome on lower-income households with lower use. Exceptions are Alberta, New Brunswick, and Prince Edward Island, due to a relatively close alignment with our estimated transmission and distribution costs and existing fixed charges. Some utilities have higher fixed charges, perhaps reflecting a desire to charge ratepayers for transmission and distribution independently of volumetric rates.[12] For these provinces, our modelled adjustments in rate design have very little effect on total household electricity expenditures.

The figures show the means-tested fixed charge matched to the progressivity of income taxes is the most effective policy for lowering lower-income households' total costs; this results in higher-income households cross-subsidizing electric system costs for lower-income households in each province. The means-tested fixed charge pinned to the GST is also progressive, but expenditures are higher for all but the fifth income quintile.

[12] Alberta has relatively high fixed charges, and Prince Edward Island has somewhat high fixed charges. In contrast, British Columbia only has a daily fixed charge and all other residential charges are volumetric (Bishop, Ragab, and Shaffer 2020).

Figure 12

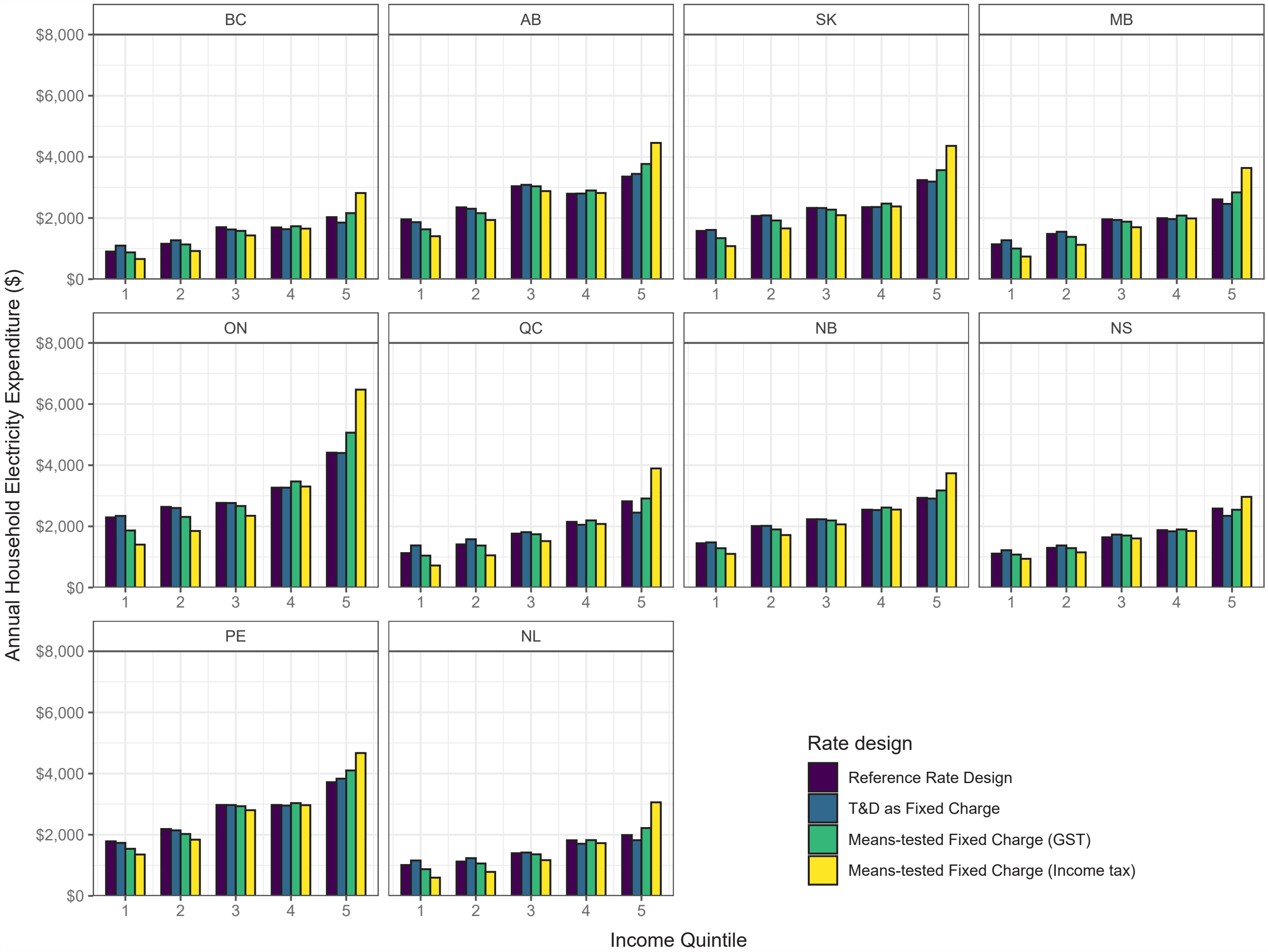
2030 total annual household electricity expenditures under different equity and rate-design scenarios (2022 dollars)



Note: Presents total annual household electricity expenditure in 2030 by income quintile, for different rate-design scenarios. This figure accounts for both use and cost changes; the rate-design scenarios modify how system costs are apportioned between the reference case (existing rate formats) and alternative fixed charges. Cost and use changes are based on the mean of the three modelling studies.

Figure 13

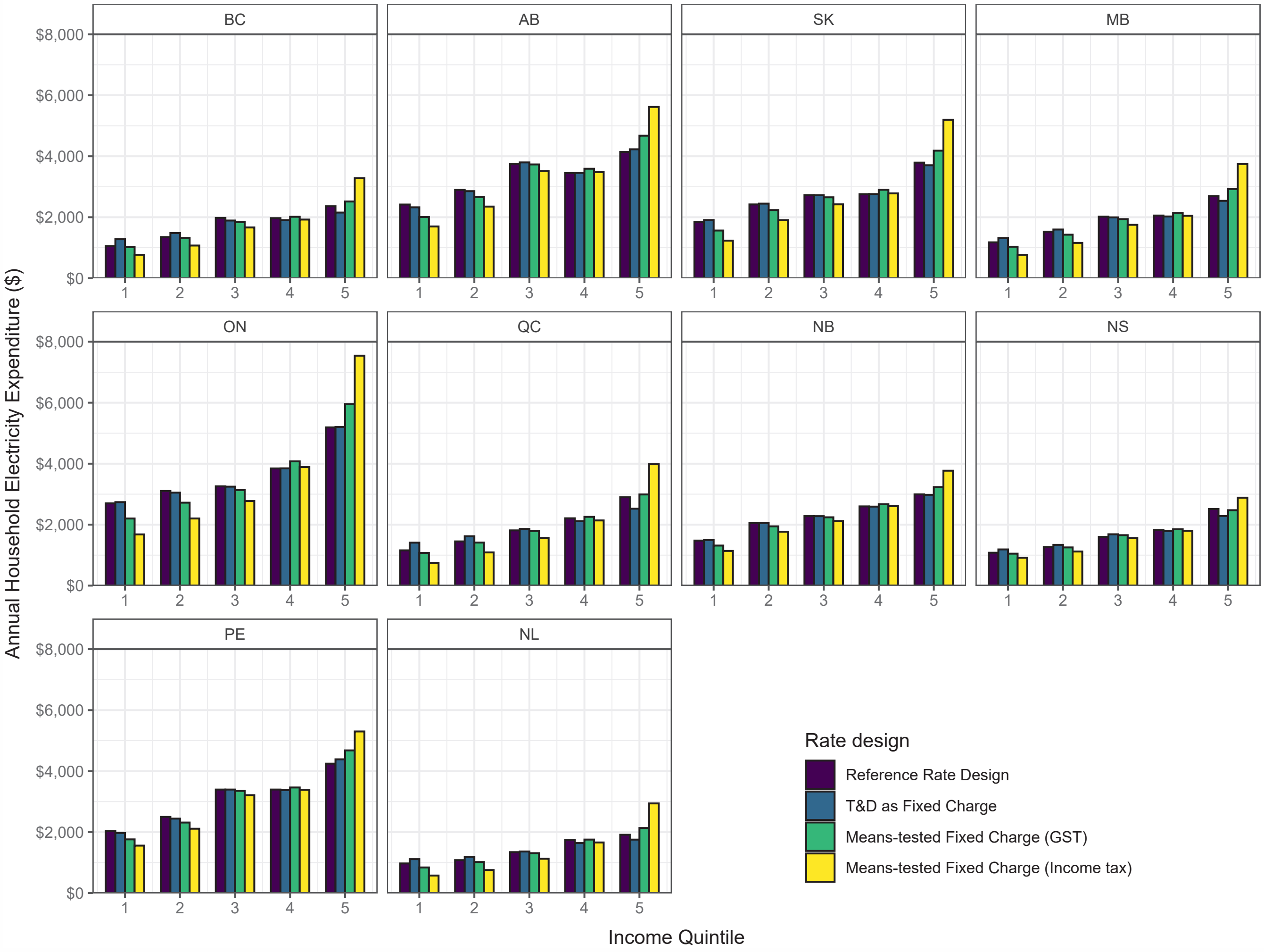
2040 total household electricity expenditures under different equity and rate-design scenarios



Note: Presents total annual household electricity expenditure in 2040 by income quintile, for different rate-design scenarios. This figure accounts for both use and cost changes; the rate-design scenarios modify how system costs are apportioned between the reference case (existing rate formats) and alternative fixed charges. Cost and use changes are based on the mean of the three modelling studies.

Figure 14

2050 total household electricity expenditures under different equity and rate-design scenarios



Note: Presents total annual household electricity expenditures in 2050 by income quintile, for different rate-design scenarios. This figure accounts for both use and cost changes; the rate-design scenarios modify how system costs are apportioned between the reference case (existing rate formats) and alternative fixed charges. Cost and use changes are based on the mean of the three modelling studies.

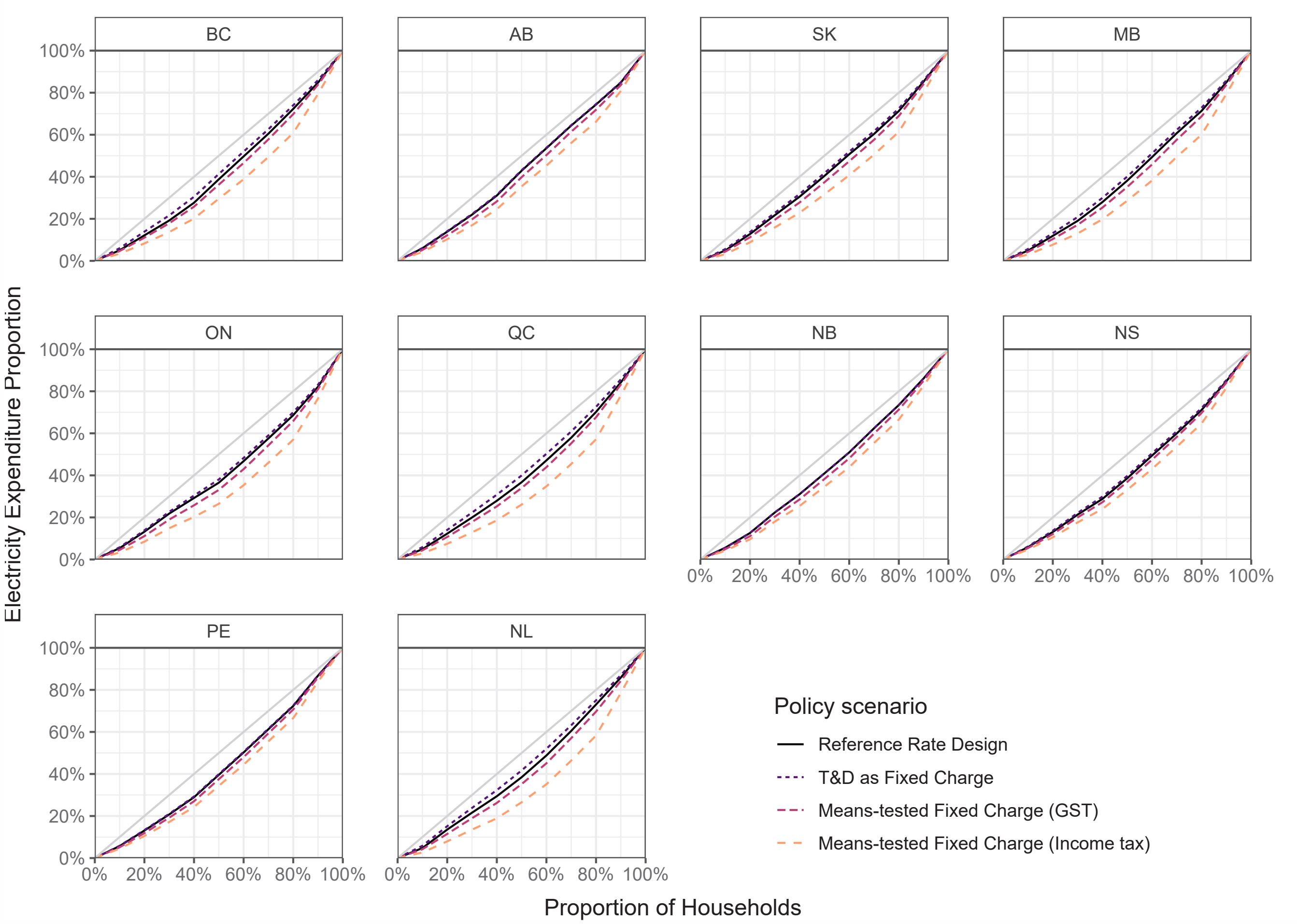
Figure 15 presents a Lorenz curve for the different rate-design scenarios; Lorenz curves show the distribution of costs against the population distribution ordered from lowest income to highest income households. This curve has a different interpretation from a standard Lorenz curve as it presents expenditures rather than income on the y-axis.[13] The thin grey line is the line of perfect equality (the 45-degree line), where electricity costs are equal across the population and independent of income and use. Lines further below the 45-degree line are more progressive, representing larger shares of total electricity costs paid by households that use more electricity (Levinson and Silva 2022).[14]

[13] Lorenz curves are typically used to show the distribution of income or wealth, but can be applied to show the distribution of costs.
[14] This is the opposite interpretation of a standard, income-based, Lorenz curve, where moving away from the line of perfect equality implies a less progressive (more regressive) income distribution with higher income inequality.

Figure 15 shows that the choice of rate-design scenario matters the most for the top and bottom 20 per cent of the income distribution. Basing the fixed charge on the cost of transmission and distribution moves volumetric rates closer to the marginal cost of electricity generation, and improves the price signal to users. However, it increases costs for lower-income households, which may have limited ability to absorb these increased costs or may tip into energy poverty.[15] Means-testing fixed charges is an effective way of mitigating the distributional and equity implications of fixed charges. Matching the fixed charges to the income tax system results in the most progressive rate system.

Figure 15

Lorenz curve for average household electricity costs by rate design option and province, 2050



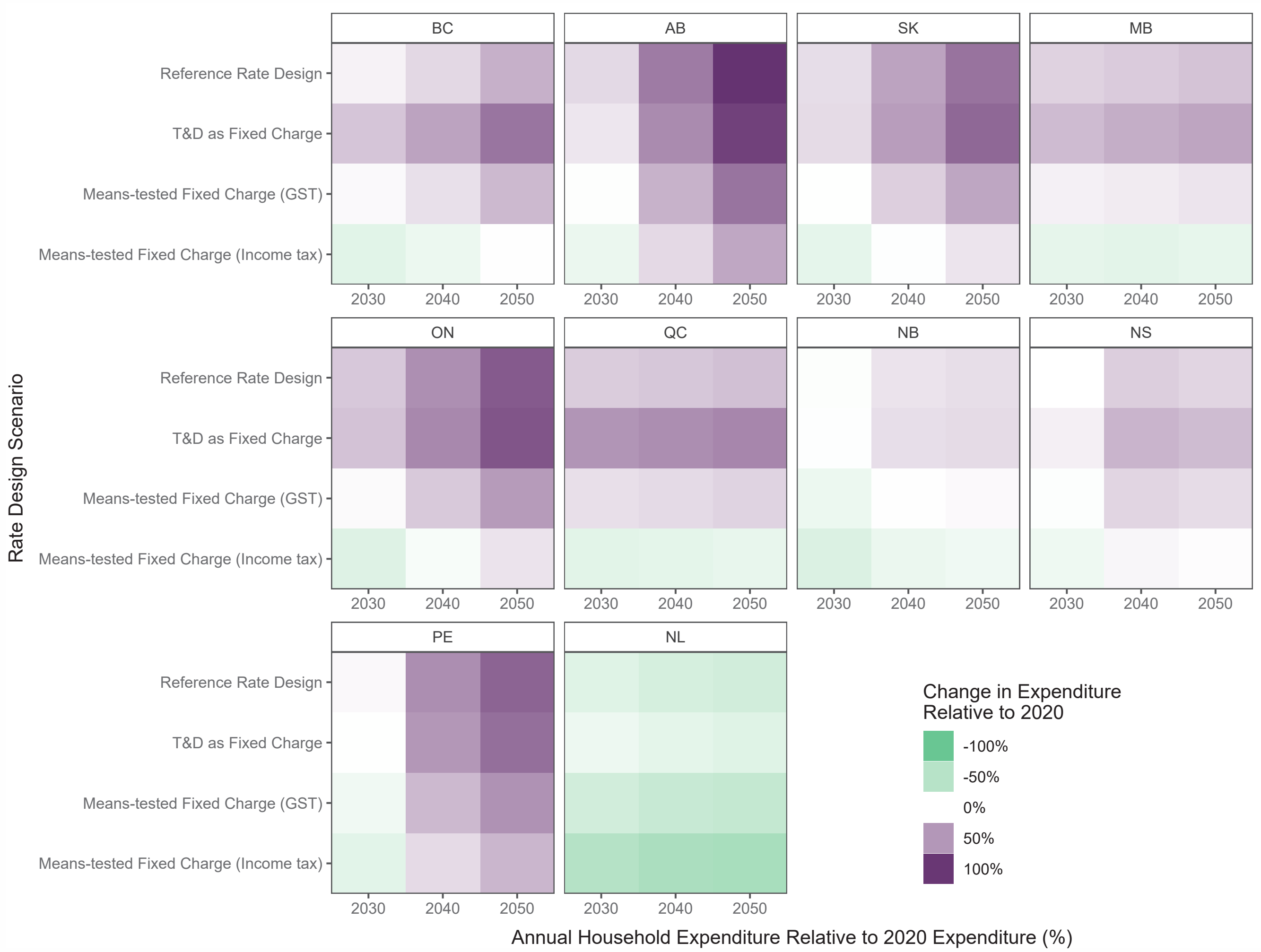
Note: Presents the Lorenz curve for household electricity expenditures, plotting proportion of expenditure by household (y-axis) against cumulative share of households arranged from lowest to highest incomes (x-axis). The thin grey line is the line of equality, where electricity expenditure is equal and independent of income and use. Lines further below the line of perfect equality are more progressive rate designs.

[15] Energy poverty is households' inability to afford energy services; it may manifest as a heat-or-eat dilemma, self-imposed brownouts for financial reasons, or keeping home temperature at lower-than-comfortable room temperature. For a discussion of definitions of energy poverty, see Shaffer and Winter (2020).

Figure 16 presents the lowest income quintile's average total household electricity expenditures in 2030, 2040, and 2050 relative to expenditures in 2020 for the different rate-design scenarios. A means-tested fixed charge is most effective at insulating low-income households from potential rate increases; when the fixed charge is pegged to the progressivity of the federal income tax system, total expenditures decline relative to 2020 for low-income households in most provinces. Expenditure increases are particularly acute for households in Alberta, Saskatchewan, and Ontario due to the major system investments to be compliant with net zero and larger forecast increases in electricity usage. Overall, insulating lower-income households from cost pressures will require rate-design changes or some other cost-offset mechanism. We turn to alternative funding approaches in the next section.

Figure 16

Lowest income quintile's average annual household electricity expenditures relative to 2020 under different equity and rate scenarios



Note: Presents the percentage change in average annual electricity expenditures in 2030, 2040, and 2050 relative to 2020 under different rate-design structures, for the lowest income quintile in each province. The reference case is status quo rate-design systems in each province. .

Electric federalism: Options for funding net zero investments

Addressing climate change is a responsibility for all of society, not just electricity ratepayers (Borenstein, Fowlie, and Sallee 2021; Kanduth and Dion 2022). Government can acknowledge that achieving net zero emissions is a social and political goal, and can partially fund the electricity system's transition to ensure the move does not unduly increase electricity costs. This approach spreads the burden of net zero investments—generation, transmission, distribution, and storage—amongst a larger group.

We model 50 per cent government funding of system investment costs (reducing both volumetric rates and fixed charges for households), and compare the net household financial results of provincial versus federal funding via personal income tax increases.[16] Our choice of 50 per cent government funding is arbitrary and meant to illustrate the distributional consequences of direct government subsidies of net zero investments rather than a prescriptive policy position. We use the existing rate structure to calculate aggregate household electricity costs for each province, and then model the rates required if government funded 50 per cent of new system investments. The investment required varies by province and by modelling team. Provinces that must invest more receive proportionately more government funding, and reduce their electricity system costs by more. For each province we scale fixed charges by the change in total electricity system costs that result from 50 per cent funding of new investment. For example, if new investment comprises 50 per cent of electricity system costs, and it is reduced by 50 per cent, then total cost is 75 per cent of what it would have been otherwise. We then scale fixed charges by multiplying by 0.75. After we subtract the new

[16] Recall that the cost pressures we model are for residential electricity rates and use only. Implicit in our analysis is that commercial and industrial customers will also bear their share of system costs. We do not assume any government support of commercial and industrial electricity consumers.

fixed charges from the total system cost covered by residential customers, we divide the remaining costs by aggregate household electricity use in that province to calculate the new required volumetric rate. This means we reduce both fixed charges and volumetric rates equally. The two scenarios are:

1) **Reduced bills and federal tax increases:** finances the 50 per cent of new investments in generation, transmission, distribution, and storage costs via contemporaneous federal personal income tax increases. This scenario subsidizes the net zero electricity-system investments and involves cross-subsidization between income groups; when federal taxes are used to fund system investments there is also cross-subsidization across provinces. Specifically, provinces with higher investment costs receive greater federal funding as the 50 per cent subsidy is within-province costs. The income tax increase parameters are reported in Appendix II: Supplementary Tables.

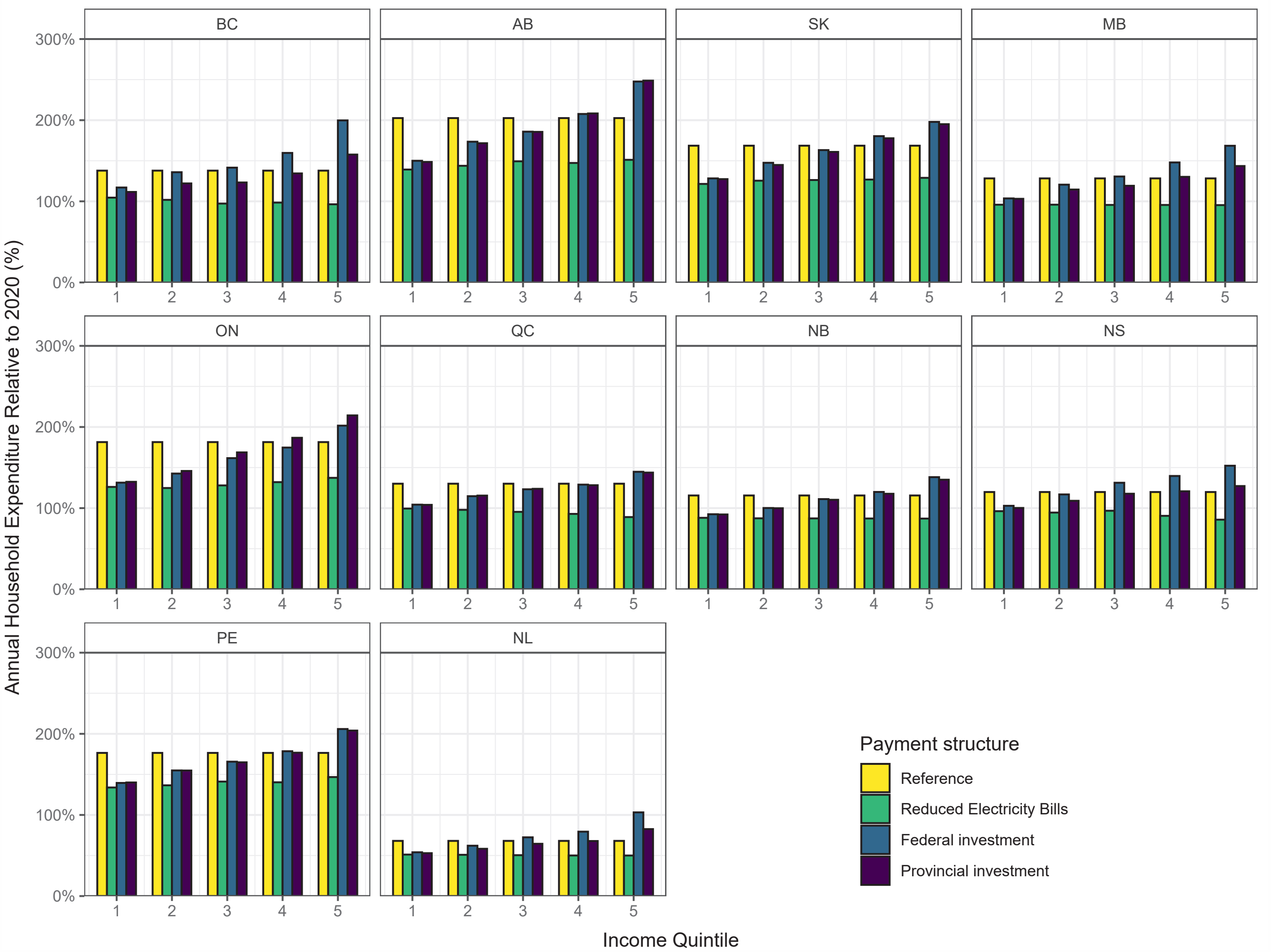
2) **Reduced bills and provincial tax increases:** finances the 50 per cent of generation, transmission, distribution, and storage costs via contemporaneous provincial personal income tax increases. This scenario subsidizes the net zero electricity system investments and involves cross-subsidization between income groups within provinces. We report the income tax increase parameters in Appendix II: Supplementary Tables.

We also show the effect on electricity expenditures, exclusive of income tax changes ("Reduced electricity bills"). This demonstrates how government funding would affect electricity expenditures relative to the reference case ("Reference").

Figure 17 shows 2050 total household costs relative to 2020 under the two system funding scenarios, inclusive of the income tax burden from funding 50 per cent of system costs via federal or provincial personal income taxes. The reference case, shown by the yellow bar, is a province-specific uniform scaled increase in costs across all households. The green bar shows the change in electricity bills without adding income taxes; as with the reference case, costs scale uniformly within provinces. Notably, lower-income households (the bottom two quintiles) are better off when system costs are subsidized through tax changes, and the highest-income households are worse off. Importantly, however, there are stark differences in the relative burden between provinces. Provinces with predominantly low-emission grids like British Columbia, Quebec, and Manitoba have higher costs when federal funding subsidizes system costs relative to provincial funding. In contrast, thermal provinces—Alberta, Saskatchewan, New Brunswick, and Prince Edward Island (as an importer of thermal electricity)—have very similar costs under provincial versus federal income-tax financing. Federal income-tax financing shifts costs from higher-emissions provinces to lower-emission provinces. Moreover, the provinces that contribute more to federal income taxes fund more, in relative terms, another source of cross-subsidization.

Figure 17

2050 total household electricity expenditures relative to 2020 under system funding scenarios

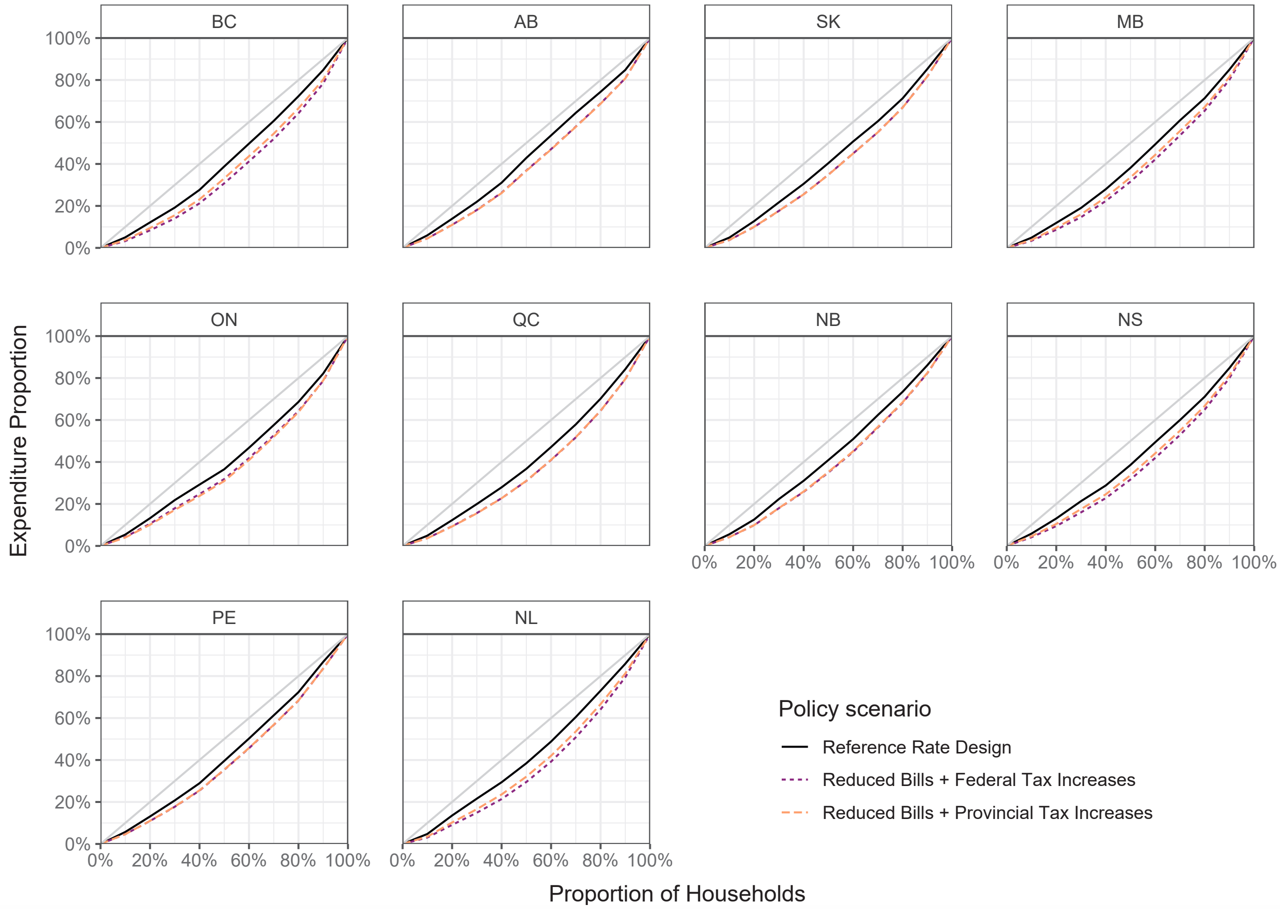


Note: Presents the percentage change in average annual household electricity expenditures in 2050 relative to 2020 under different rate-design structures, for income quintiles in each province. The figure accounts for both changes in costs and changes in use. The reference case (yellow) is status quo rate-design systems in each province, with uniform scaled cost increases across the income distribution. The reduced electricity bills scenario shows the effect on electricity expenditures exclusive of income tax increases. Federal investment assumes 50 per cent of new investments in generation, transmission, distribution, and storage costs within a province are funded by federal personal income tax changes. Provincial investment assumes 50 per cent of new investments in generation, transmission, distribution, and storage costs within a province are funded by provincial personal income tax changes.

Figure 18 shows the Lorenz curve for the two tax-funded scenarios against the reference case or status quo. As expected, funding new system investment costs with increases to income taxes increases the progressivity of electricity costs. Interestingly, for most provinces there is very little difference between federal funding and provincial funding via income taxes. However, for British Columbia, Manitoba, Nova Scotia, and Newfoundland and Labrador, a federal tax increase is slightly more progressive. In contrast, in Ontario federal funding is very slightly less progressive than provincial funding. Also of note in Figure 18 is that the Lorenz curves for the two funding scenarios are quite close to the reference case Lorenz curve. This indicates that funding net zero system investments via government funds rather than through rates has a limited effect on the progressivity of household electricity costs. This is in contrast to Figure 15, where a means-tested fixed charge had a larger progressivity improvement for some provinces. This indicates rate design is likely a more powerful tool for addressing equity concerns as it is a more targeted and precise policy tool; tax-base funding of system investments benefits all ratepayers whereas means-tested fixed charges explicitly target distribution concerns.

Figure 18

Lorenz curve for average household electricity expenditures by system funding option and province, 2050



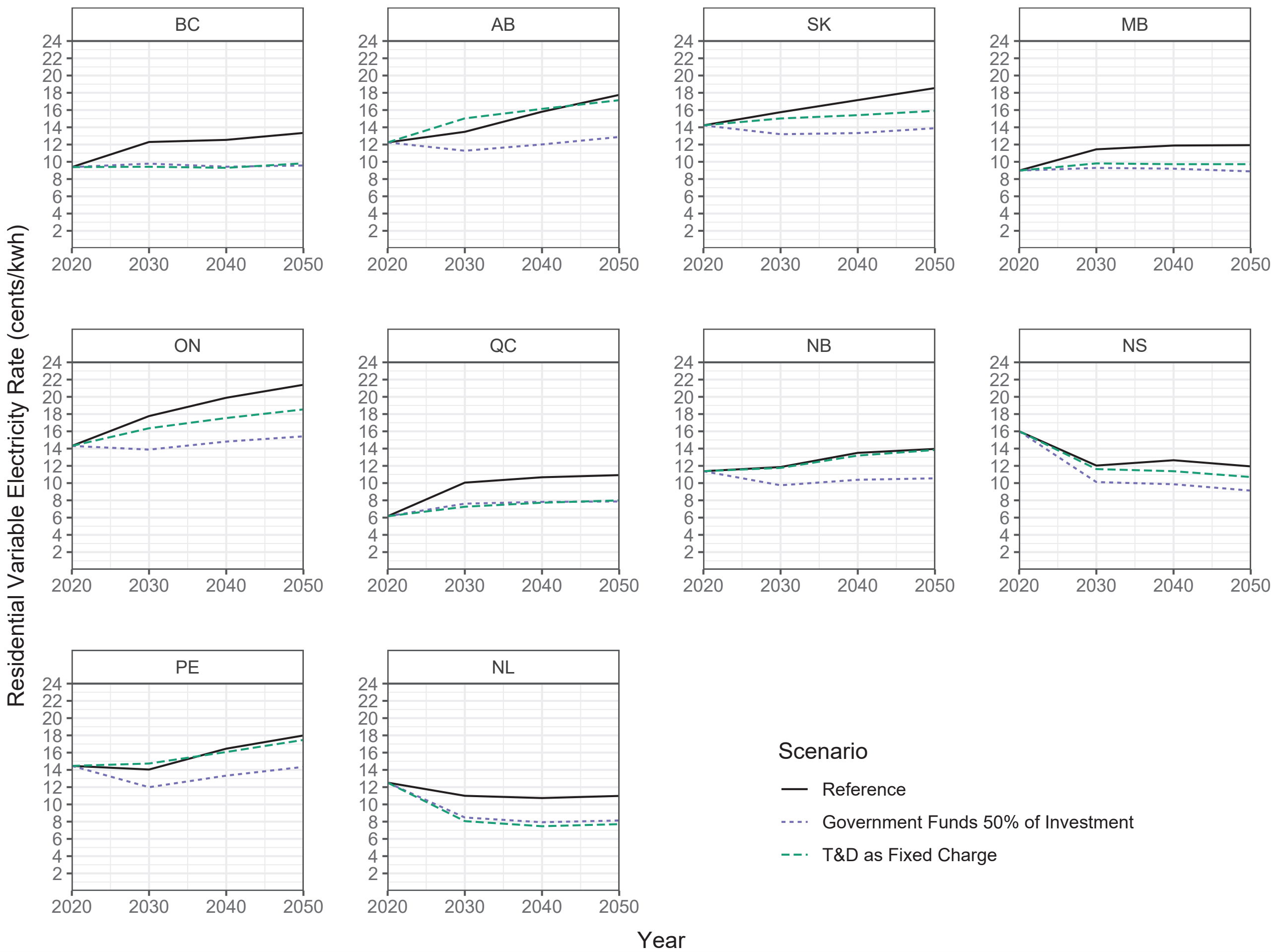
Note: Presents the Lorenz curve for total household electricity expenditures under different system funding scenarios, plotting proportion of costs by household (y-axis) against cumulative share of households arranged from lowest to highest incomes (x-axis). The thin grey line is the line of equality, where electricity expenditure is equal and independent of income and use. Lines further below the line of perfect equality are more progressive distributions of electricity costs. The electricity costs are based on the mean of the three modelling studies.

While rate design changes may be better suited to addressing progressivity of electricity costs, government funding of new system investments is a powerful tool for reducing electricity rate pressures. Figure 19 shows variable (per kWh) electricity costs under three different scenarios: the reference case, where investment costs are included in variable rates; the *system-funding* scenario where government funds 50 per cent of investment costs; and the rate-design scenario where transmission and distribution costs are allocated to households' bills as a province-specific uniform fixed charge (not means-tested).

For the majority of provinces, the reference case has the highest volumetric electricity rates and government funding 50 per cent of costs results in the lowest variable rates. However, in some provinces, like Alberta, New Brunswick, and Prince Edward Island, the fixed charge scenario is largely the same as the reference case. As noted above, in our discussion of Figure 12 through Figure 14, exceptions are in provinces with a relatively close alignment with our estimated transmission and distribution costs and existing fixed charges. In contrast, several provinces—British Columbia, Quebec, and Newfoundland and Labrador—have nearly identical variable electricity costs in the two alternative scenarios. This is due to these provinces' lower investment requirements to meet zero-emissions electricity targets. Hydro provinces are well-positioned with legacy emissions-free assets. The difference across provinces is also due to variation in modelling assumptions around high adoption of low-cost renewables, with more uncertainty about what the future electricity system will actually look like.

Figure 19

Volumetric electricity rates (cents/kWh) under different rate-design and system-funding scenarios

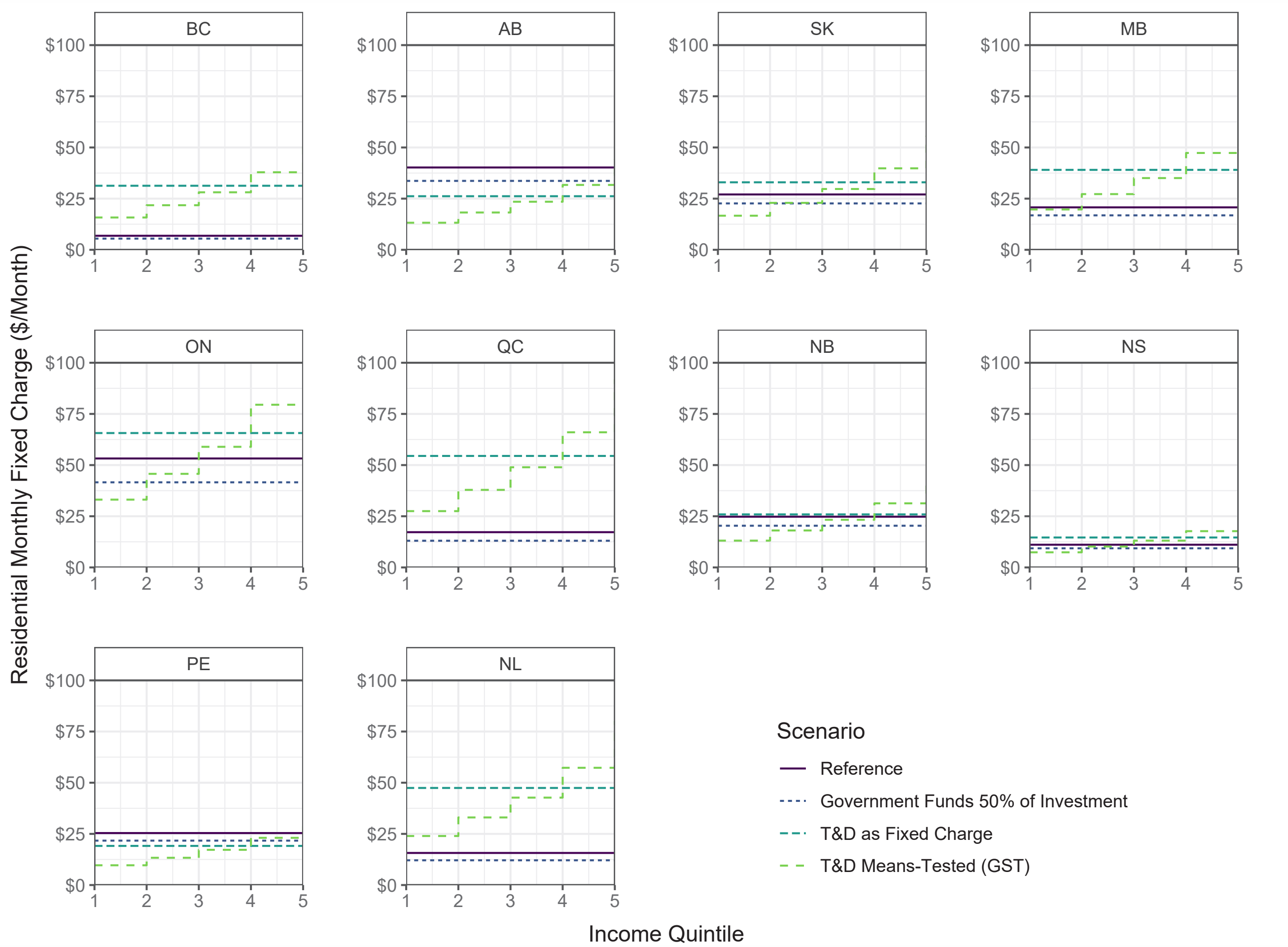


Note: Presents average residential volumetric electricity rates between 2020 and 2050 in each province. The figure is not representative of total household costs, as fixed charges are omitted (see Figure 20), and the figure does not account for changes in use. The reference case is status quo rate-design systems in each province, with uniform scaled cost increases across the income distribution. The "Government Funds 50 per cent of Investment" scenario assumes government funds 50 per cent of new investment in generation, transmission, distribution, and storage costs within a province. The "Transmission and distribution as fixed charge" scenario removes some system costs from volumetric rates and creates a fixed monthly charge based on the cost of transmission and distribution; residential volumetric electricity rates are determined by the remaining costs based on the current rate structure (fixed operations and maintenance, variable operation and maintenance, fuel, existing debt, and amortized capital cost of investments in generation and storage).

Figure 20 shows different fixed-cost scenarios in 2030 by province and income quintile. (Fixed costs are increasing over time but the patterns remain the same.) The difference in fixed charges is stark for hydro provinces—British Columbia, Manitoba, Quebec, and Newfoundland and Labrador—with a reference-scenario fixed charge close to when government funds 50 per cent of investment. There is a clear difference in rate designs across provinces.[17] For example, British Columbia and Quebec currently absorb the majority of fixed systems costs into variable rates, and so the reference case fixed costs are quite low compared to when transmission and distribution costs are a fixed charge. This is reflected in the relatively higher volumetric charge for these provinces shown in Figure 18. Also notable in Figure 20 is the difference between large and smaller thermal provinces. New Brunswick, Nova Scotia, and Prince Edward Island all have relatively similar fixed charges across the scenarios, compared to Ontario, Alberta, and Saskatchewan with a greater distribution.

Figure 20

2030 monthly fixed charges under different rate-design and system-funding scenarios



Note: Presents households' monthly fixed charges in 2030 in each province. The figure is not representative of total household electricity expenditures, as volumetric rates are omitted (see Figure 19). The reference case is status quo rate-design systems in each province, with uniform scaled cost increases across the income distribution. The "Government Funds 50 per cent of Investment" scenario assumes government funds 50 per cent of new investment in generation, transmission, distribution, and storage costs within a province. The "T&D as Fixed Charge" scenarios remove some system costs from volumetric rates and creates a fixed monthly charge based on the cost of transmission and distribution. Residential volumetric electricity rates are determined by the remaining costs based on the current rate structure (fixed operations and maintenance, variable operation and maintenance, fuel, existing debt, and amortized capital cost of investments in generation and storage).

[17] See Bishop, Ragab, and Shaffer (2020) for a discussion of different provincial rate-design systems.

CONCLUSION

Aligning electricity systems with Canada's net zero commitments could increase electricity rates in some provinces, and increased electrification will increase households' electricity use. The combination could increase households' overall electricity expenditure. However, these changes correspond with decreased use of and spending on gasoline, natural gas, and other fossil fuels. While spending on electricity will likely increase, total energy spending will decline (Dion et al. 2022).

Complicating this *big switch* from fossil fuels to low- or no-emissions electricity, however, is the fact that electricity costs are currently borne regressively: lower-income households spend a higher proportion of their incomes and total expenditure on electricity compared to higher-income households. This regressivity could be exacerbated under the net zero transition, particularly if lower-income households experience slow or stagnant income growth. For this reason, policymakers concerned about distributional fairness should consider measures like we analyse above to protect lower-income households and ensure electricity costs from Canada's net zero transition are borne fairly.

Importantly, the types of rate design that improve incentives for electrification—apportionment of electricity system costs into volumetric rates and fixed charges, with volumetric rates closer to marginal costs of electricity—also risk exacerbating regressivity. This is due to fixed charges being uniform, placing a disproportionate burden on lower-income households that typically consume less electricity.

Addressing cost regressivity on the path to net zero can take many forms; we present two options that governments can use alone or in combination. The first is adjusting fixed charges to be income-tested. This approach addresses the concerns around equity in fixed charges, but only moves costs around within the ratepayer base. A second approach is for governments to assume some or all of these system costs. Federal and provincial income tax systems are progressive, meaning that higher incomes are taxed at a higher rate. Government funding for electricity system investments addresses regressivity by reducing electricity users' exposure to total electricity system cost increases, and instead paying for a portion of Canada's climate commitments using the progressive tax system. This mitigates increases to both fixed charges and volumetric rates in the electricity sector. When such system funding is federal rather

than provincial, it also adjusts for the unequal investment burdens that different regions face (which is largely a function of the relative availability of hydro versus fossil fuel resources).

Both approaches are tools that can help address regressivity and electricity affordability, and they do so in different ways. Changing fixed charges can be implemented by regulators independently, or by provincial or territorial governments via policy intervention. Government funding of system investments is solely the purview of federal, provincial, and territorial governments. Applying these tools in combination is a viable option for policymakers interested in multiple levers to address equity and efficiency goals in the net zero transition.

Acknowledgments

We thank Christopher Roney, Electric Power Research Institute; Ganesh Doluweera, the Canada Energy Regulator (CER); John Bistline, Electric Power Research Institute (EPRI); Kathleen Vaillancourt, ESMIA Consultants; Brienne Riehl, Navius Research; and Ryan Ness, Canadian Climate Institute, for their input into our analysis. We thank EPRI, CER, and ESMIA for sharing their modelling data, which makes this work possible.

This analysis uses Statistics Canada’s Social Policy Simulation Database and Model version 29.0. The assumptions and calculations underlying the simulation results were prepared by the authors and the responsibility for the use and interpretation of these data is entirely theirs.

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APPENDIX I: METHODS

Estimating household electricity use

We estimate household electricity use with SPSD/M synthetic microdata. The SPSD is a detailed representative database of Canadian individuals including their economic and family characteristics, expenditure by commodity type, and tax and transfer information. The model part of SPSD/M allows for counterfactual analysis of tax and transfer policy. SPSD/M version 29.0 uses 2017 Survey of Household Spending data as a base for the expenditure data.

We compile 2017 electricity prices (volumetric rates and fixed charges) for each province and sub-provincial region in Canada (see Table 1 in Appendix II). We then divide annual household electricity expenditure (exclusive of taxes) by the electricity price, adjusting for fixed monthly charges, provincial subsidies, and two-tiered rate systems. This gives us imputed electricity use:

$$\mathrm{use}_{\mathrm{hp}} = \frac{\mathrm{exp}_{\mathrm{hp}} - f_{\mathrm{p}}}{\mathrm{c}_{\mathrm{p}}}$$

where h denotes household and p denotes province, f denotes fixed monthly charges, and c is the cost (price) of electricity faced by residential consumers.

We use this imputed electricity use to re-estimate current electricity expenditures using 2021 electricity volumetric rates and fixed charges (2021 prices multiplied by imputed electricity use, plus 2021 fixed charges); see Table 2 in Appendix II for the values we use. To calculate a gross average cost of electricity (per kWh) paid by households in each province, we sum the households' electricity expenditure in each province to construct aggregate household expenditure, and divide aggregate expenditure by aggregate use, where aggregate use is the sum of household electricity use in each province. This gross average cost folds in the fixed charges, which vary by province, to make the values comparable across provinces. We refer to this as the *average household electricity cost.*

Calculating utility cost pressure

The Canadian Climate Institute provided us with the modelling results from three modelling teams: EPRI, ESMIA (Institut de l'énergie Trottier), and CER (Canada Energy Regulator). These teams provided results from simulations of the Canadian electricity between 2020 and 2050 (and beyond). Modelling results include electricity demand growth; installed electricity capacity in megawatts (MW); generation shares in gigawatt-hours (GWh); capital investment costs for investments in generation, distribution, transmission, and storage; fixed and variable operations and maintenance (O&M) costs; fuel use; and carbon pricing charges. We do not include investment costs for making electricity systems more resilient to climate change. We worked with the modelling teams to ensure compatibility between the cost estimates. As the CER and ESMIA models do not include intra-provincial transmission and distribution investment, we add intra-provincial distribution and transmission costs from EPRI to both the CER and ESMIA cost results to ensure comparability.

All three models forecast system investments and do not include the value of existing debt from past investments. As existing debt is amortized and included in households' electricity rates (both volumetric rates and fixed charges), any cost estimates from these models will understate potential costs to households. To better reflect the financial situation of utilities across Canada, we compile data on long-term debt held by the utilities. Not knowing the exact debt schedule of long-term debt held by utilities across Canada, we amortize this long-term debt over 30 years at an interest rate of six per cent, and divide by model-specific future provincial generation estimates to calculate an expected debt payment per megawatt-hour (MWh) for each province. Similarly, we amortize all capital investments in new generation, transmission, distribution, and storage over 25 years at an interest rate of six per cent.

For 2020 (or the closest available year), 2030, 2040, and 2050 we calculate the modelled average cost of generation in each province for each model (including our modifications to ensure comparability). The average cost of generation is total system costs (including amortized debt and new capital investments) divided by modelled generation.

We calculate each province's electricity markup for residential ratepayers with the difference between average household electricity cost and the average cost of generation. This mark-up can result from a range of factors including return on equity, administrative costs, higher distribution costs for residential customers, and other costs for which we don't have modelling data. We make the simplifying assumption that the markup is time-invarying and province-specific.

$$\text{Gross average cost}_{\text{p2020}} - \text{Modelled average cost}_{\text{Mp2020}} = \text{Markup}_{\text{Mp}}$$

where, p refers to province, and M refers to model (CER, EPRI, ESMIA, or the mean of the three).

To calculate residential rates in future years, we add the time-invarying, provincial markup to average cost estimates calculated using the modelling results for the years 2030, 2040, and 2050.

$$\text{Residential rate}_{\text{Mpt}} = \text{Modelled average cost}_{\text{Mpt}} + \text{Markup}_{\text{Mp}}$$

Calculating future electricity demand

The three models forecast residential electricity demand and population change for each province or region, in 10-year increments between 2020 and 2050 (ESMIA forecasts to 2060). We use these data to calculate per capita electricity demand in current and future years. We compare these per capita electricity consumption estimates to Natural Resources Canada's Comprehensive Energy Use Database and our imputed energy use from SPSD/M synthetic microdata. The match is quite good for most provinces, giving us confidence in our own per capita electricity estimates, and those of the models. We assume that the composition of households will not change significantly between now and 2050, and so assume that the growth of household electricity consumption will closely match the growth of per capita electricity in each province.

Estimating future household electricity costs

We estimate future household electricity costs using results from all three models and the mean of the three models.

We assume that households at all income levels within a province will increase their electricity use at the same growth rate. That is, growth rates are province- and time-invariable. We normalize provincial electricity consumption estimates at unity with 2020 as our base year. We then scale electricity use for each household by this province- model- and time-specific electricity growth factor.

$$\text{Electricity use}_{\text{hpMt}} = \text{Imputed electricity use}_{\text{hp2020}} * \text{Normalized growth factor}_{\text{pMt}}$$

where *h* refers to household h in the SPSD/M synthetic microdata, p refers to province, M refers to model (CER, EPRI, ESMIA, or the mean of the three), and t refers to year (2020, 2030, 2040, and 2050).

We then create a scaling factor for residential average costs, normalized with 2021 residential average costs equal to 1.0.

$$\frac{\text{Estimated residential average cost}_{\text{pMt}}}{\text{Current residential average}_{\text{p2021}}} = \text{Normalized residential rate pressure}_{\text{pMt}}$$

We multiply the normalized electricity use growth factor and the normalized residential rate pressure factor to create an overall scaling factor:

$$\text{Scaling}_{\text{pMt}} = \text{Normalized residential rate pressure}_{\text{pMt}} * \text{Normalized growth factor}_{\text{pMt}}$$

We then multiply household cost in 2021 (previously calculated using 2021 electricity rates and imputed electricity 2017 use) by the scaling factor to estimate future household electricity cost from volumetric rates.

$$\text{Household cost}_{\text{hpMt}} = \text{Scaling}_{\text{pMt}} * \text{Imputed electricity use}_{\text{hp2020}}$$

We can then calculate mean household cost by income quintile in each province to compare the effect of future electricity scenarios.

Rate design and payment structure simulations

We modify rate designs to understand how different variations would affect electricity affordability for low-income households. Energy, and specifically electricity affordability, is of increasing interest in policy circles. There are two issues of concern here related to system design and increased costs and the ability of lower-income households to bear these costs. Electricity bills do not always distinguish between purely marginal costs of production and the overall system costs, folding in fixed capital costs into volumetric rates. Some systems do distinguish between fixed costs and set volumetric rates close to marginal costs. However, uniform increases in either case will fall disproportionately on lower-income households with less disposable income to absorb cost increases. Moreover, lower-income households may have limited ability to adapt to energy system changes, putting them at increased risk of a heat-or-eat dilemma. As electricity rate design is a policy choice, analysis of design alternatives and these alternatives' distributional consequences is an important part of evaluating the consequences of net zero electricity investments.

We examine five different design variations. First, setting monthly fixed charges equal to estimated transmission and distribution costs for the household. This is often proposed as a way to better reflect the cost structure of delivering electricity to households. Households must be served with a fixed connection regardless of electricity use. Often, utilities pay for some of the residential transmission and distribution costs using revenues from the volumetric rates (cents/kWh). Separating the variable costs of generation from the fixed cost of service is a way to present a more efficient price signal.[18] Increasing fixed costs is also suggested as a way to avoid cross-subsidizing rooftop solar photovoltaics (PV). When solar producers are paid at the retail rate of electricity, and that retail rate includes fixed components like transmission and distribution and the generation capacity that must be available at peak times, solar is over-compensated and non-solar customers cross-subsidize residential solar producers (Dolter and Boucher 2018). If solar deployment is high enough, this means electricity rates must increase to compensate for the revenues lost to self-generation of solar. However, increasing fixed rates is also highly regressive, impacting low-income households that on average use less electricity. Conversely, increasing fixed charges allows volumetric rates to be lowered, and this is desirable to encourage electrification of vehicles, buildings, business, and industry (Borenstein, Fowlie, and Sallee 2021).

To avoid negatively impacting low-income households, fixed charges can be means-tested, varying with income. They can be made as progressive as a sales tax (in Canada, the GST or HST) or income tax (Borenstein and Bushnell 2021; Borenstein, Fowlie, and Sallee 2021). We model both options by first calculating the proportion of GST and income tax paid, respectively, by each income quintile in Canada, and then designing uniform within-quintile fixed charges that match those proportions. These simulations form our second and third scenarios.

Achieving climate goals by pursuing a zero-emissions electricity grid is an activity that is initiated by government and consequently could be funded by government (Borenstein, Fowlie, and Sallee 2021). We model government funding 50 per cent of required new investments in each province. Here, we only model government funding 50 per cent of the residential portion of new system investments. In all government-funding scenarios, the remaining electricity system costs in each province are modelled as in our reference case, using existing provincial rate systems. The choice of 50 per cent government funding is arbitrary and meant to illustrate the interprovincial and inter-household consequences of government funding of net zero investments.

We model two separate government funding scenarios. First, we model a scenario where the federal government pays 50 per cent of required new investments in all provinces, and funds this with increases to federal personal income taxes. Second, we model a scenario where each provincial government funds the 50 per cent of new investments with increases in provincial personal income taxes. We model the two scenarios using the tax simulation capabilities of SPSD/M.

[18] This is particularly relevant in the case of small-scale rooftop solar or electric technology investments.

APPENDIX II: SUPPLEMENTARY TABLES

Table 1

Provincial electricity rates for imputing electricity use (2017 dollars)

Prov	Location	Annual fixed charge ($)	Volumetric charge, cents per kWh (Tier 1)	Volumetric charge, cents per kWh (Tier 2)
BC	Rural	73.91	0.10280	0.1767
	Population under 30,000	69.31	0.08580	0.1287
	Population 30,000 to 99,999	69.31	0.08580	0.1287
	Population 100,000 to 499,999	69.31	0.08580	0.1287
	Vancouver	69.31	0.08580	0.1287
AB	Rural	293.48	0.06060	
	Population under 30,000	293.48	0.06060	
	Population 30,000 to 499,999	293.48	0.06060	
	Edmonton	293.48	0.06060	
	Calgary	257.64	0.06060	
SK	Rural	381.24	0.13741	
	Population under 100,000	264.12	0.13741	
	Saskatoon	300.84	0.15650	
	Regina	264.12	0.13741	
MB	Rural	193.92	0.08200	
	Population under 100,000 and Brandon	96.96	0.08200	
	Winnipeg	193.92	0.08200	
ON	Rural	1953.72	0.09450	
	Population under 30,000	1953.72	0.09450	
	Population 30,000 to 99,999	828.98	0.09450	
	Population 100,000 to 499,999	612.12	0.09450	
	Ottawa	208.92	0.09450	
	Hamilton and Burlington	275.16	0.09450	
	Toronto	342.72	0.09450	
QC	Rural	148.34	0.05710	0.0868
	Population under 30,000	148.34	0.05710	0.0868
	Population 30,000 to 99,999	148.34	0.05710	0.0868
	Population 100,000 to 499,999	148.34	0.05710	0.0868
	Quebec City	148.34	0.05710	0.0868
	Montreal	148.34	0.05710	0.0868

Prov	Location	Annual fixed charge ($)	Volumetric charge, cents per kWh (Tier 1)	Volumetric charge, cents per kWh (Tier 2)
NB	Rural	284.4	0.10840	
	Population under 30,000	259.44	0.10590	
	Population 30,000 to 99,999 and Fredericton	259.44	0.10590	
	Saint John and Moncton	259.44	0.10590	
NS	Rural	129.96	0.14646	
	Population under 100,000	129.96	0.14646	
	Halifax	129.96	0.14646	
	Cape Breton	129.96	0.14646	
PEI	Rural and population under 30,000	309.48	0.13890	0.1103
	Charlottetown	309.48	0.13890	0.1103
NL	Rural	254.28	0.10900	
	Population under 100,000	194.28	0.10900	
	St John's	194.28	0.10900	

Table 2

Reference case electricity rates (2021 dollars)

Province	Annual fixed charge ($)	Volumetric charge, cents per kWh (Tier 1)	Volumetric charge, cents per kWh (Tier 2)
BC	75.81	0.0939	0.1408
Alberta	478.08	0.0743	
Saskatchewan	273.48	0.14228	
Manitoba	212.64	0.08983	
Ontario	462.36	0.1221	
Quebec	150.26	0.06159	0.09502
New Brunswick	273.84	0.1138	
Nova Scotia	129.96	0.16008	
PEI	309.91	0.1437	0.1142
Newfoundland and Labrador	192	0.1252	

Table 3

Federal personal income tax rate changes

2021 tax rate	2030 simulation	2040 simulation	2050 simulation	Tax bracket
15.0%	15.48%	15.67%	15.83%	On the first $49,020 of taxable income
20.5%	20.98%	21.17%	21.33%	On the portion of taxable income over $49,020 up to $98,040
26.0%	26.48%	26.67%	26.83%	On the portion of taxable income over $98,040 up to $151,978
29.0%	29.48%	29.67%	29.83%	On the portion of taxable income over $151,978 up to $216,511
33.0%	33.48%	33.67%	33.83%	On taxable income over $216,511

Table 4

British Columbia personal income tax rate changes

2021 tax rate	2050 simulation	Tax bracket
5.06%	5.56%	On the first $42,184 of taxable income
7.7%	8.20%	On the portion of taxable income over $42,184 up to $84,369
10.5%	11.00%	On the portion of taxable income over $84,369 up to $96,866
12.29%	12.79%	On the portion of taxable income over $96,866 up to $117,623
14.7%	15.20%	On the portion of taxable income over $117,623 up to $159,483
16.8%	17.30%	On the portion of taxable income over $159,483 up to $222,420
20.5%	21.00%	On the portion of taxable income over $222,420

Table 5

Alberta personal income tax rate changes

2021 tax rate	2050 simulation	Tax bracket
10%	10.83%	On the first $131,220 of taxable income
12%	12.83%	On the portion of taxable income over $131,220 up to $157,464
13%	13.83%	On the portion of taxable income over $157,464 up to $209,952
14%	14.83%	On the portion of taxable income over $209,952 up to $314,928
15%	15.83%	On the portion of taxable income over $314,928

Table 6

Saskatchewan personal income tax rate changes

2021 tax rate	2050 simulation	Tax bracket
10.5%	11.31%	On the first $45,677 of taxable income
12.5%	13.31%	On the portion of taxable income over $45,677 up to $130,506
14.5%	15.31%	On the portion of taxable income over $130,506

Table 7

Manitoba personal income tax rate changes

2021 tax rate	2050 simulation	Tax bracket
10.8%	11.35%	On the first $33,723 of taxable income
12.75%	13.30%	On the portion of taxable income over $33,723 up to $72,885
17.4%	17.95%	On the portion of taxable income over $72,885

Table 8

Ontario personal income tax rate changes

2021 tax rate	2050 simulation	Tax bracket
5.05%	5.994%	On the first $45,142 of taxable income
9.15%	10.094%	On the portion of taxable income over $45,142 up to $90,287
11.16%	12.104%	On the portion of taxable income over $90,287 up to $150,000
12.16%	12.16%	On the portion of taxable income over $150,000 up to $220,000
13.16%	13.16%	On the portion of taxable income over $220,000

Table 9

Quebec personal income tax rate changes

2021 tax rate	2050 simulation	Tax bracket
15%	15.7%	On the first $45,105 of taxable income
20%	20.7%	On the portion of taxable income over $45,105 up to $90,200
24%	24.7%	On the portion of taxable income over $90,200 up to $109,755
25.75%	26.5%	On the portion of taxable income over $109,755

Table 10

New Brunswick personal income tax rate changes

2021 tax rate	2050 simulation	Tax bracket
9.40%	10.20%	On the first $43,835 of taxable income
14.82%	15.62%	On the portion of taxable income over $43,835 up to $87,671
16.52%	17.32%	On the portion of taxable income over $87,671 up to $142,534
17.84%	18.64%	On the portion of taxable income over $142,534 up to $162,383
20.30%	21.10%	On the portion of taxable income over $162,383

Table 11

Nova Scotia personal income tax rate changes

2021 tax rate	2050 simulation	Tax bracket
8.79%	9.32%	On the first $29,590 of taxable income
14.95%	15.48%	On the portion of taxable income over $29,590 up to $59,180
16.67%	17.20%	On the portion of taxable income over $59,180 up to $93,000
17.5%	18.03%	On the portion of taxable income over $93,000 up to $150,000
21%	21.53%	On the portion of taxable income over $150,000

Table 12

Prince Edward Island personal income tax rate changes

2021 tax rate	2050 simulation	Tax bracket
9.8%	10.59%	On the first $31,984 of taxable income
13.8%	14.59%	On the portion of taxable income over $31,984 up to $63,969
16.7%	17.49%	On the portion of taxable income over $63,969

Table 13

Newfoundland personal income tax rate changes

2021 tax rate	2050 simulation	Tax bracket
8.7%	9.23%	On the first $38,081 of taxable income
14.5%	15.03%	On the portion of taxable income over $38,081 up to $76,161
15.8%	16.33%	On the portion of taxable income over $76,161 up to $135,973
17.3%	17.83%	On the portion of taxable income over $135,973 up to $190,363
18.3%	18.83%	On taxable income over $190,363