May 30, 2023

[redacted]

Access Request: 2023-G-0003

Dear Mr. Schulz,

Re: **Final Response for *Freedom of Information and Protection of Privacy* ("FOIP Act") Request**

I am replying to your request for access to the subject records under the FOIP Act. I am pleased to advise you that partial access is being provided to the records you requested (copy enclosed).

There were a total of 180 pages of records in response to your request.

Non-responsive Information

There were pages that had non-responsive information removed in whole or in part [pages 2-3, 58-71, 73-75, 77-78, 82-84, 86-87, 91-93, 95-97, 99-102, 104-105, 108-110, 112-113].

Duplicate information

There were pages that had duplicate information removed in whole [pages 79, 85, 88, 94, 103, 106, 111].

Request Fees

On May 18, 2023, we provided you with a letter indicating final fees in the amount of $69.15. Our office received payment on May 30, 2023, and therefore, there are no additional fees owing for this request. Your receipt will follow once processing of the cheque is complete.

Third Party Records – Section 31

As communicated on May 18, 2023, pages 80-81, 89-90, 97-99 and 107-108 are subject to the parameters of a Section 31 Notice, which affords the third party an opportunity to oppose the AESO's decision for a period of 20 calendar days. As this period has not expired, portions of those pages cannot be released with the attached records package. On June 8, 2023, the AESO will contact the Information and Privacy Commissioner to determine if a request for review has been submitted. If a request has not been made, the records will be released the same day in accordance with the decision communicated in this letter. If a review has been requested, we will notify you of the status.

Right to Request a Review

If you have any questions or concerns about a decision made during the processing of your request,

Alberta Electric System Operator

Calgary Place, 2500, 330-5th Avenue SW Calgary, AB T2P 0L4

Phone: 403-539-2450 | Fax: 403-539-2949

www.aeso.ca

@theaeso

please write or call me at (403) 539-2841 so that we can look at ways to address them. You do have the right to ask the Information and Privacy Commissioner to conduct a review under section 65 of the FOIP Act. You have 60 days from the date of this notice to request a review by completing a *Request for Review* form and submitting it to:

Information and Privacy Commissioner
410, 9925 - 109 Street
Edmonton, Alberta, T5K 2J8
Fax (780) 422-5682

The form is available under the Resources tab on the Commissioner's website www.oipc.ab.ca or you can call 1-888-878-4044 to request a copy of the form.

Kindest regards,

Qaiser K.

Qaiser Kayani
Records and Information Analyst

Enclosures: Section 31; Records [pages 1-180]

June 8, 2023

[redacted]

Access Request: 2023-G-0003

Dear Ms. Schulz,

Re: <u>**Letter After Section 31 Expiry for *Freedom of Information and Protection of Privacy Act* ("FOIP Act") Request**</u>

I am writing in regards to your request **2023-G-0003** for access to records under the FOIP Act.

As communicated on May 18, 2023, pages 80-81, 89-90, 97-99 and 107-108 were subject to the parameters of a Section 31 Notice. Section 31 affords third parties an opportunity to request a review of the disclosure decision applied to the responsive records for a period of 20 calendar days.

This request period has now expired and the Office of the Information and Privacy Commissioner has confirmed no request for review has been submitted. As a result, the information in those pages can be released to you in accordance with the AESO's decision.

Exceptions to Disclosure

Portions of the records in these remaining pages contain information that is excepted from disclosure under the FOIP Act. The detailed sections supporting the severing are indicated on the face of each record. The sections used to withhold information include:

- Section 16(1)(c)(i) – the head of a public body must refuse to disclose information where disclosure could reasonably be expected to harm significantly the competitive position or interfere significantly with the negotiating position of the third party

- Section 16(1)(c)(ii) – the head of a public body must refuse to disclose information where disclosure could reasonably be expected to result in result in similar information no longer being supplied to the public body when it is in the public interest that similar information continues to be supplied

A copy of Section 16 is enclosed for your reference.

If you have any questions or concerns about a decision made during the processing of your request, please write or call me at (403) 539-2841, so that we can look at ways to address them.

Alberta Electric System Operator

Calgary Place, 2500, 330-5th Avenue SW Calgary, AB T2P 0L4

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Sincerely,

Qaiser K.

Qaiser Kayani
Records and information Analyst

Enclosures: Section 16; Records [pages 80-81, 89-90, 97-99 and 107-108]

Electric Vehicles: Applications to Alberta Drivers & Implications for the Grid

July 29, 2020

Table of Contents

Nonresponsive

Key messages

Nonresponsive

Comparing Cost: Electric Vehicles and Internal Combustion Engine Vehicles

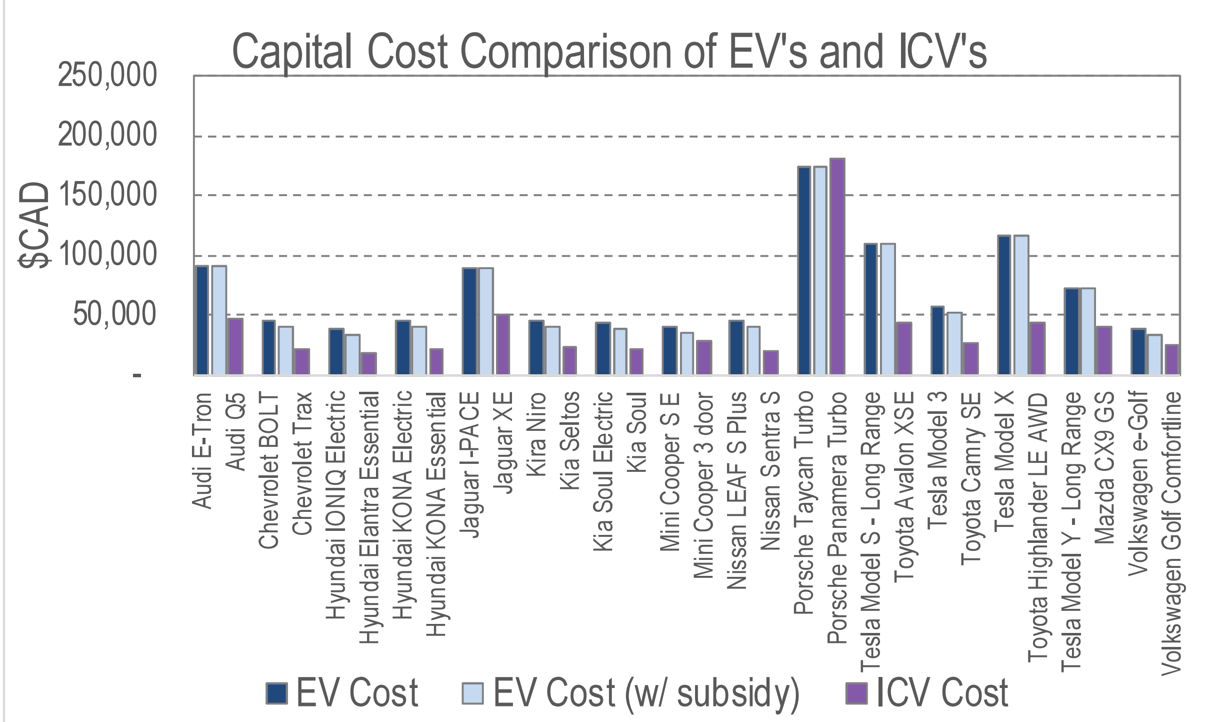
Consumer Classes

Consumer Profiles	Annual Range, km	Useful Life of Vehicle, years	Lifetime Range, km
Sunday Driver	5,200	8	41,600
Commuter	12,500	8	100,000
Daily Driver	20,000	8	160,000
Long Haul	52,000	8	416,000

- Analysis of electric vehicles (EVs) and internal combustion vehicles (ICVs) costs relies on an understanding how the vehicle is used
- Four consumer profiles were created to estimate the fixed and variable cost distribution for drivers that use vehicles for different distances and frequencies

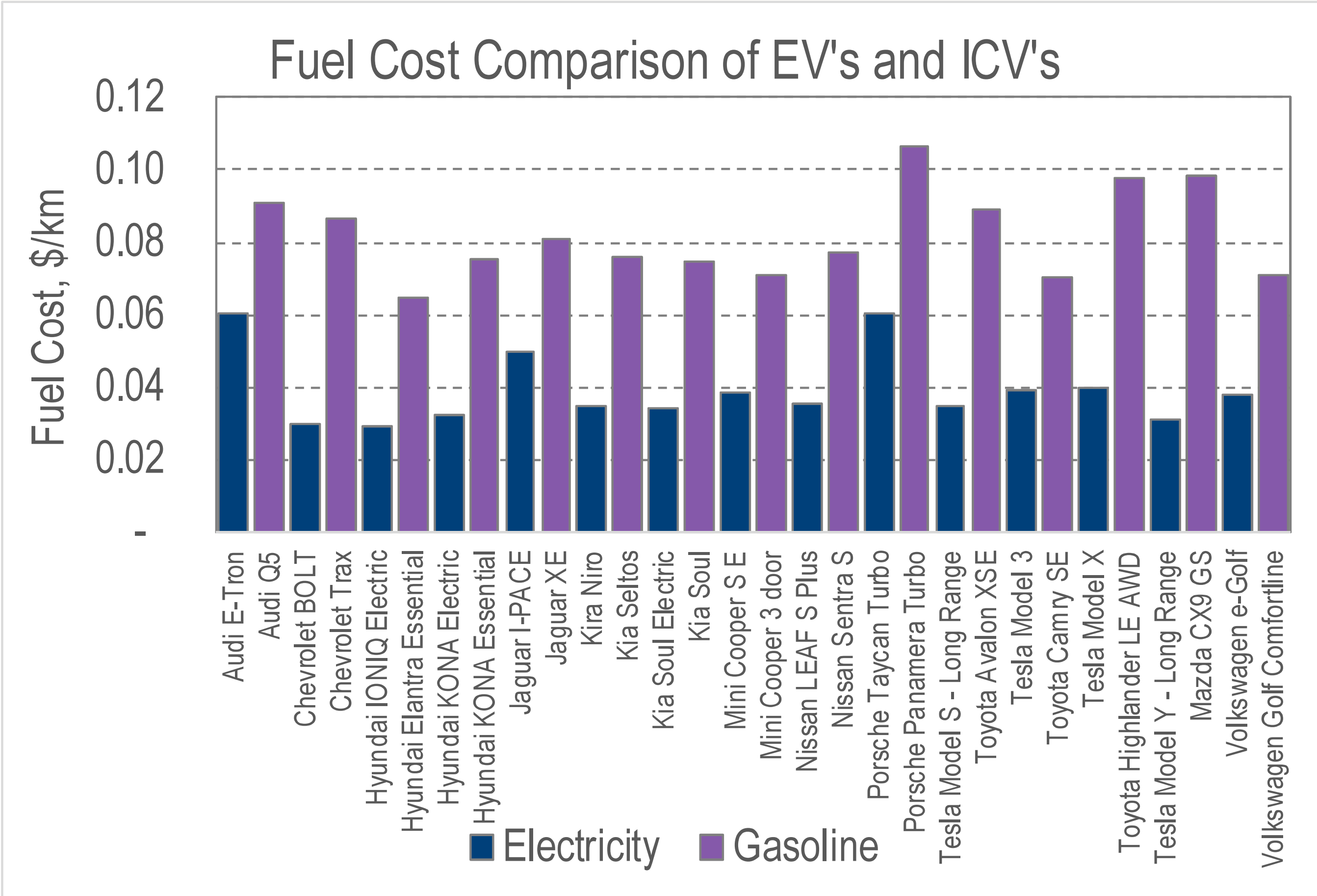
Capital Cost Comparison

Electric Vehicle	Price, CAD	Comparative Gasoline Vehicle	Price, CAD
Audi E-Tron	90,000	Audi Q5	46,300
Chevrolet BOLT	44,998	Chevrolet Trax	21,998
Hyundai IONIQ Electric	37,899	Hyundai Elantra Essential	17,149
Hyundai KONA Electric	44,999	Hyundai KONA Essential	21,249
Jaguar I-PACE	89,800	Jaguar XE	49,900
Kira Niro	44,995	Kia Seltos	22,995
Kia Soul Electric	42,595	Kia Soul	21,195
Mini Cooper S E	39,990	Mini Cooper 3 door	27,956
Nissan LEAF S Plus	44,898	Nissan Sentra S	18,798
Porsche Taycan Turbo	173,900	Porsche Panamera Turbo	179,800
Tesla Model S - Long Range	109,090	Toyota Avalon XSE	42,690
Tesla Model 3	55,990	Toyota Camry SE	26,620
Tesla Model X	116,090	Toyota Highlander LE AWD	43,490
Tesla Model Y - Long Range	72,390	Mazda CX9 GS	39,900
Volkswagen e-Golf	37,895	Volkswagen Golf Comfortline	23,970



- Electric vehicles are generally twice the capital cost of comparable internal combustion vehicles
- Many EVs qualify for federal government subsidies of $5,000 from the iZEV Program
  - Audi, Jaguar, Porsche, and some Tesla models do not qualify for the iZEV subsidy
  - Some provinces (BC and QC) have additional provincial subsidies for EVs, but not Alberta

Fuel Cost Comparison



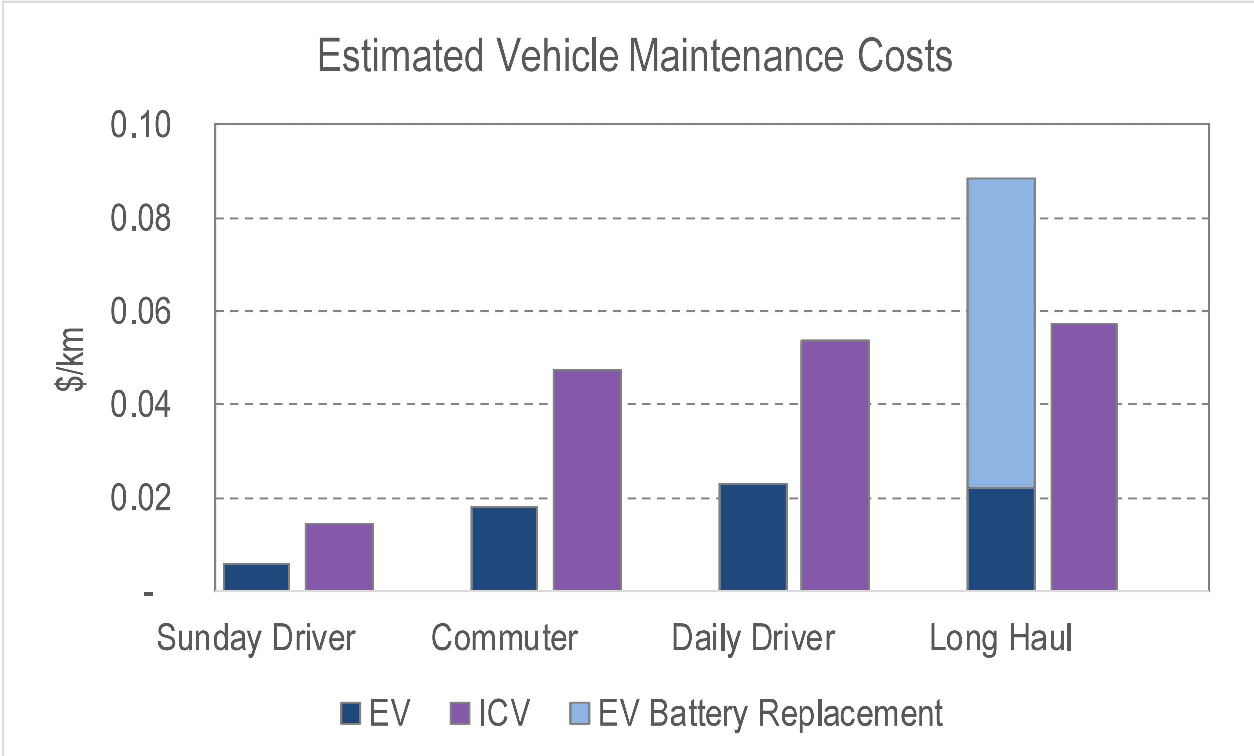
- Electric Vehicles have significantly lower fuel costs than internal combustion vehicles (based on $0.07/kW electricity commodity costs and $0.11/kW electricity delivery, administration and local access fees vs $0.95/litre gasoline costs)
  - Electricity costs per km are approximately half of the costs of internal combustion vehicles

Maintenance Schedules

Maintenance	Interval, km	Cost, $	Gas	Electric	Internal Combustion Engine, # of services required: Sunday Driver	Commuter	Daily Driver	Long Haul	Electric, # of services required: Sunday Driver	Commuter	Daily Driver	Long Haul
Oil Changes - Synthetic oil, filter, fluid	15,000	100	1	-	2	6	10	27	-	-	-	-
Spark Plugs	60,000	150	1	-	-	1	2	6	-	-	-	-
Engine Air Filter	20,000	75	1	-	2	5	8	20	-	-	-	-
Transmission Fluid	60,000	250	1	-	-	1	2	6	-	-	-	-
Timing Belt	100,000	1,000	1	-	-	1	1	4	-	-	-	-
Fuel Filter	80,000	200	1	-	-	1	2	5	-	-	-	-
Battery	100,000	200	1	-	-	1	1	4	-	-	-	-
Brake Fluid	40,000	250	1	1	1	2	4	10	1	2	4	10
Brake Pads	80,000	400	1	1	-	1	2	5	-	1	2	5
Brake Rotors	80,000	750	1	1	-	1	2	5	-	1	2	5
Coolant	100,000	150	1	1	-	1	1	4	-	1	1	4
Transmission Fluid	100,000	150	1	-	-	1	1	4	-	-	-	-
Axle Oil	150,000	200	1	1	-	-	1	2	-	-	1	2
Hoses	150,000	800	1	-	-	-	1	2	-	-	-	-
Electric Battery	250,000	27,500	-	1	-	-	-	-	-	-	-	1

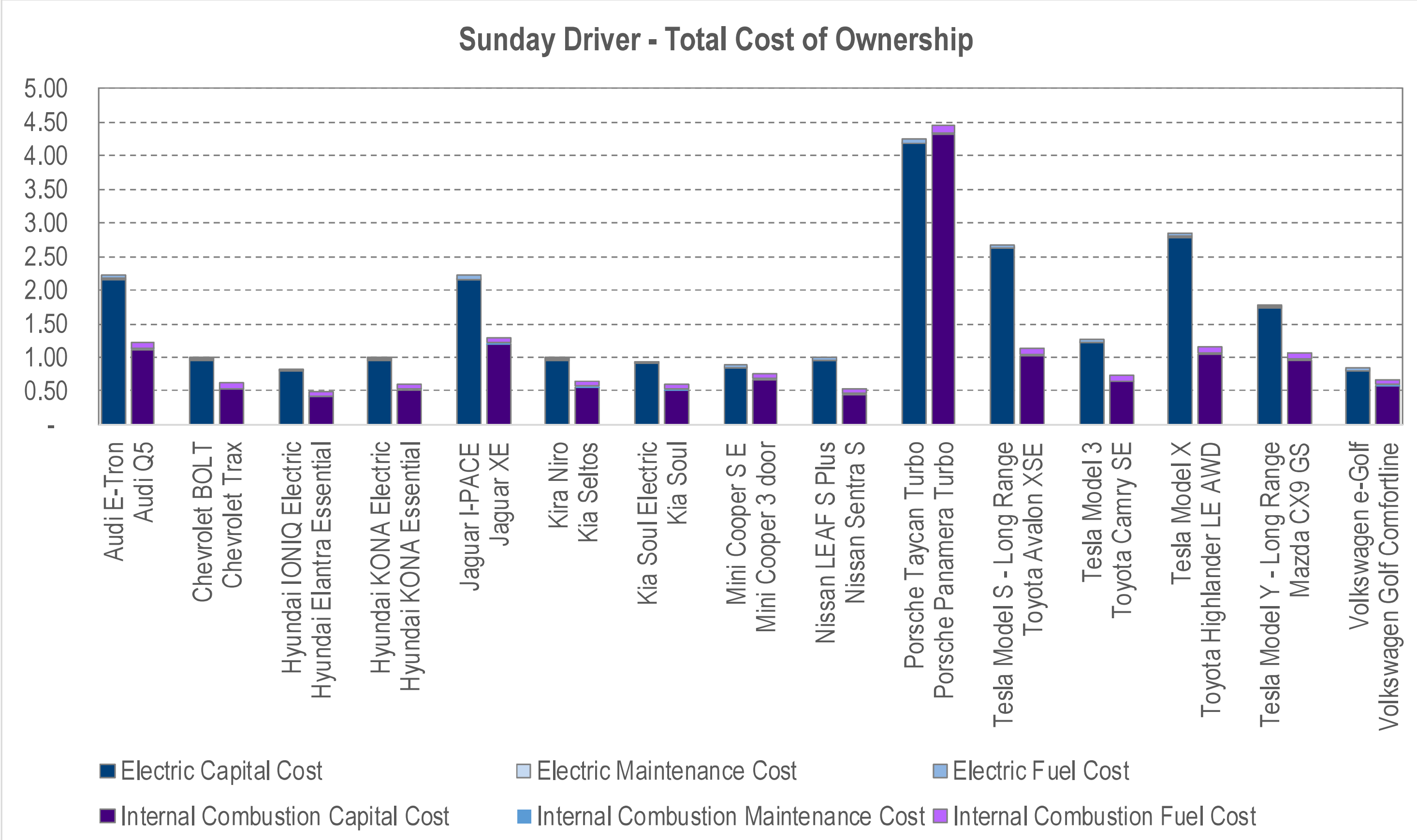
- Maintenance makes up a substantial component of the total cost of vehicle ownership
  - Some maintenance is unique to EVs and ICVs while other maintenance is common to both types of vehicles
- Maintenance varies significantly based on kilometers travelled
- EVs avoid many mechanical components including engine maintenance
- EVs may require replacement batteries ($$$) at high km intervals

Operation and Maintenance



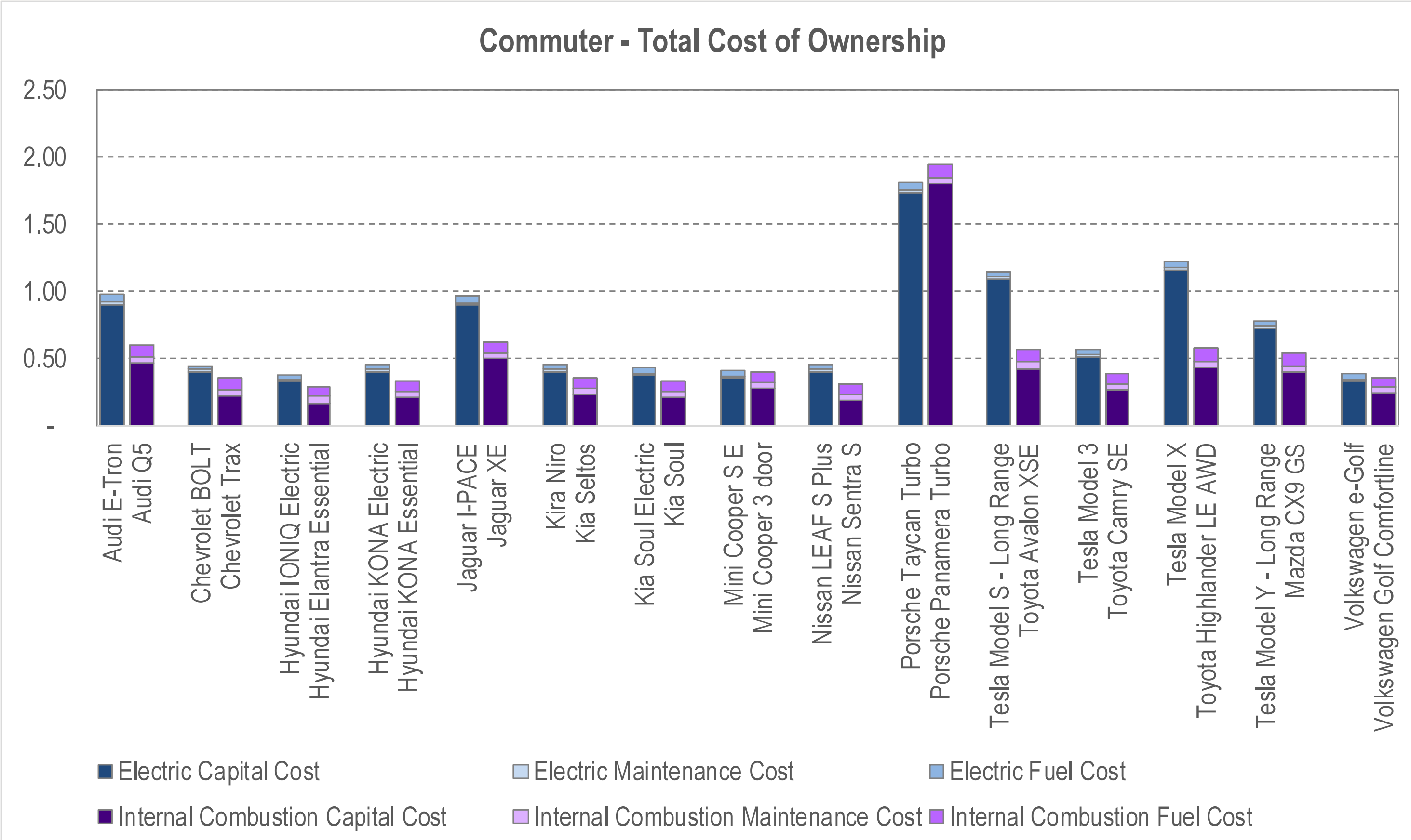
- EVs are expected to have lower maintenance costs per km of use than ICVs
  - Primarily due to simpler mechanical components (no combustion, emissions control, fuel handling, etc)
- However, EVs **may** require battery replacement after ~250,000 km, which could make them more expensive to maintain than ICVs
  - EV Battery life is largely untested in the longer term and charging/cycling may have a material impact on battery life

Total Cost of Operation – Sunday Driver



- A driver who travels 5,200 km or less per year is unlikely to switch to an EV for economic reasons
  - Unless they are a Porsche driver
- EVs are generally more expensive by ~40% for a driver who drives 100km per week or less

Total Cost of Operation – Commuter

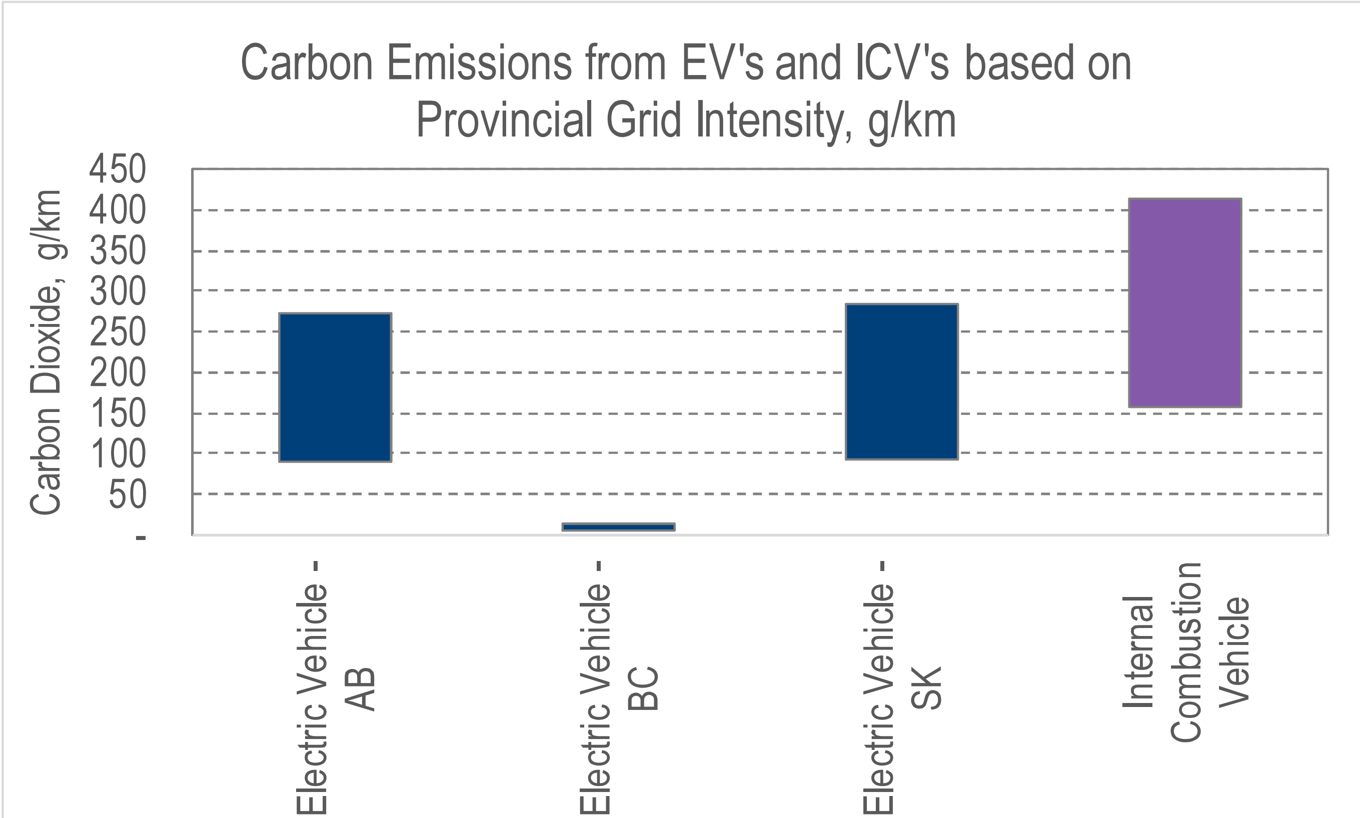


- A driver who travels 12,500 km or less per year is unlikely to switch to an EV for economic reasons
- A number of EV's become competitive when a driver puts on 240 km per week (Mini Cooper SE, Volkswagen E-Golf, Porsche Taycan Turbo)

Key Findings

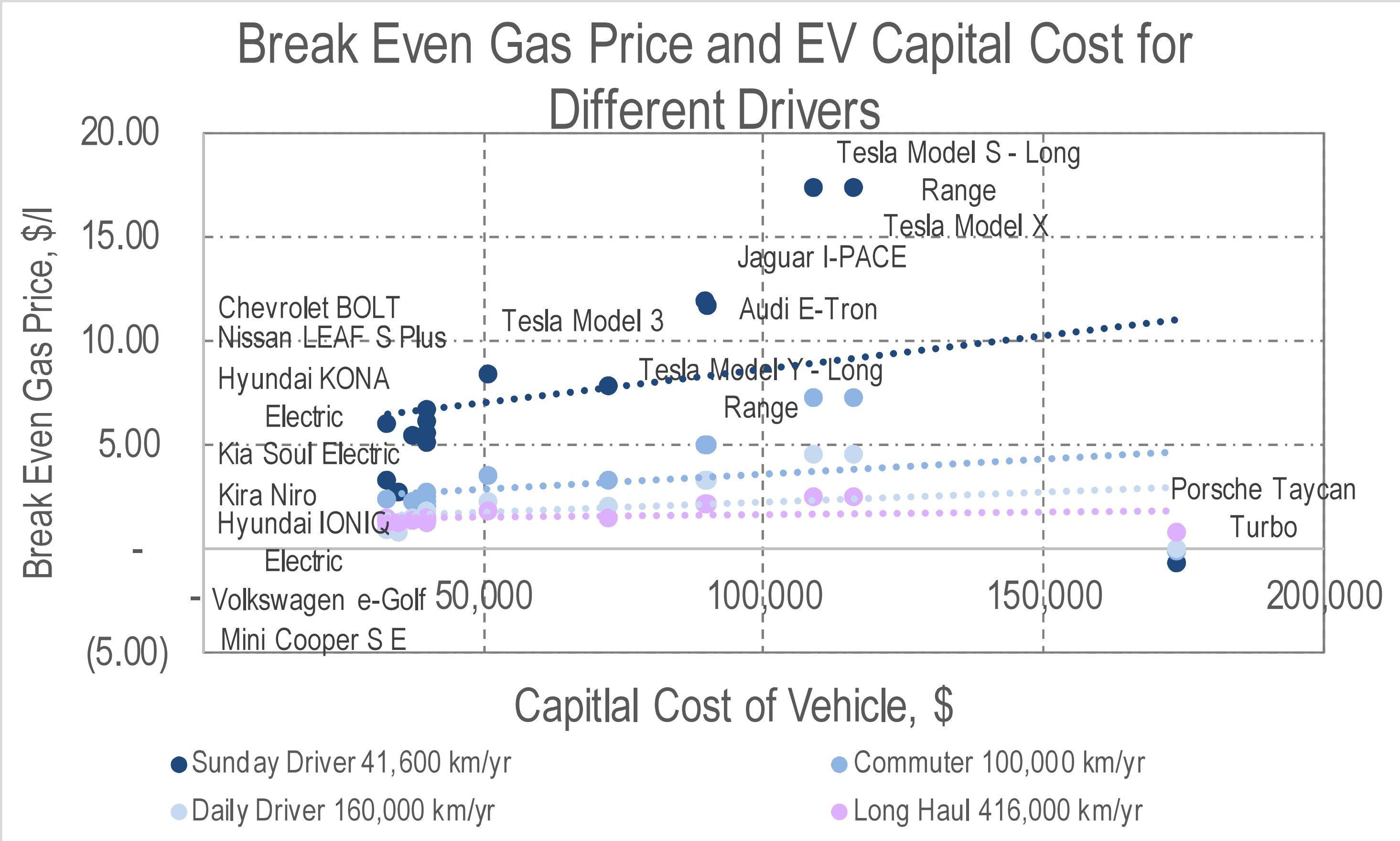
- At current capital costs, EV's are generally more expensive to own and operate than ICV's
  - Future reductions in battery technology could lead to declines in capital cost
  - Current federal subsidies are not enough to provide an economic alternative to ICV's
- EV fuel costs are meaningfully less than ICV's
- EV maintenance is generally simpler and less costly than ICV's

Key Findings - Emissions



- EVs can have a much lower emissions footprint than ICVs, depending on where they get their electricity from
  - BC's grid provides very low carbon emissions due to the high amount of hydroelectric generation in the province
  - Alberta and Saskatchewan have higher emissions associated with charging EVs
- ICVs tend to emit more carbon dioxide per km of travel than comparable EV models

How high would gasoline prices need to be in order to make EVs Economic?

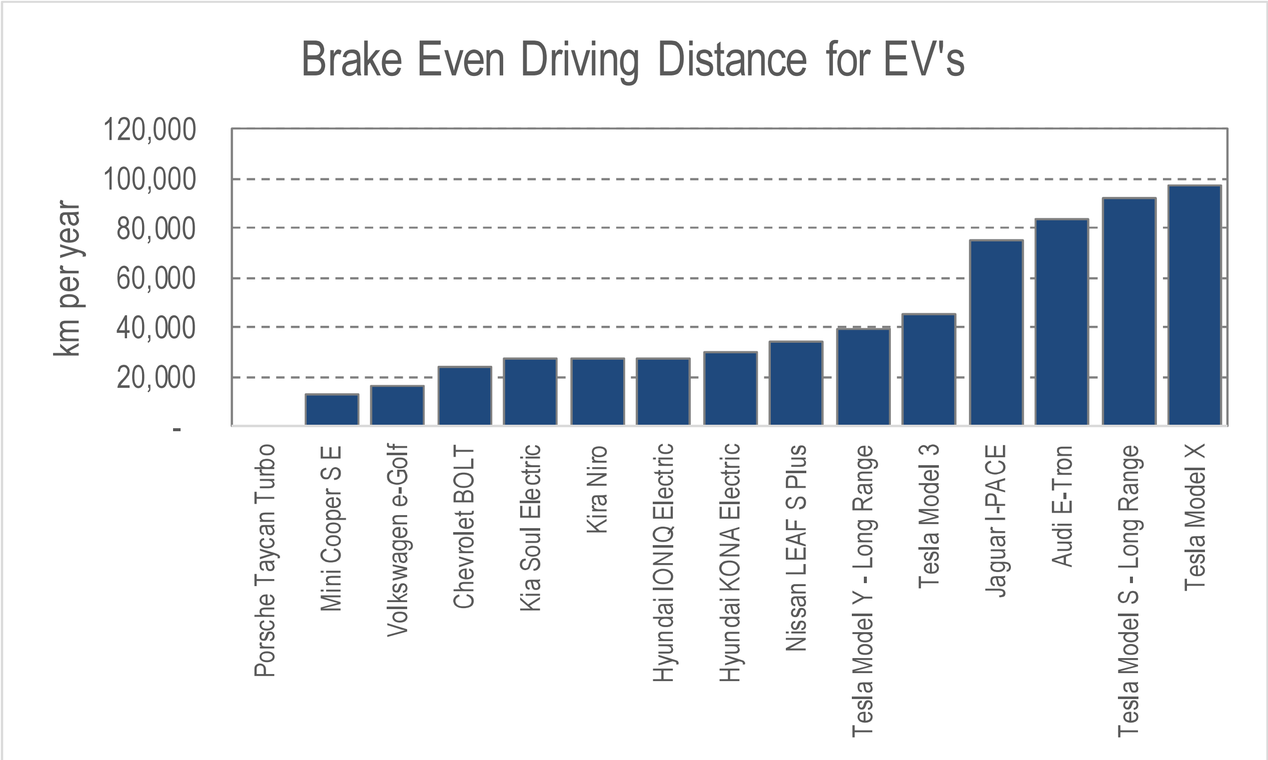


- Break-even gasoline price can be estimated based on driving distance and based on the vehicles compared:

Consumer Profiles	Annual Range, km	Average Breakeven Gas Price, $/l
Sunday Driver	5,200	7.67
Commuter	12,500	3.15
Daily Driver	20,000	1.99
Long Haul	52,000	1.56

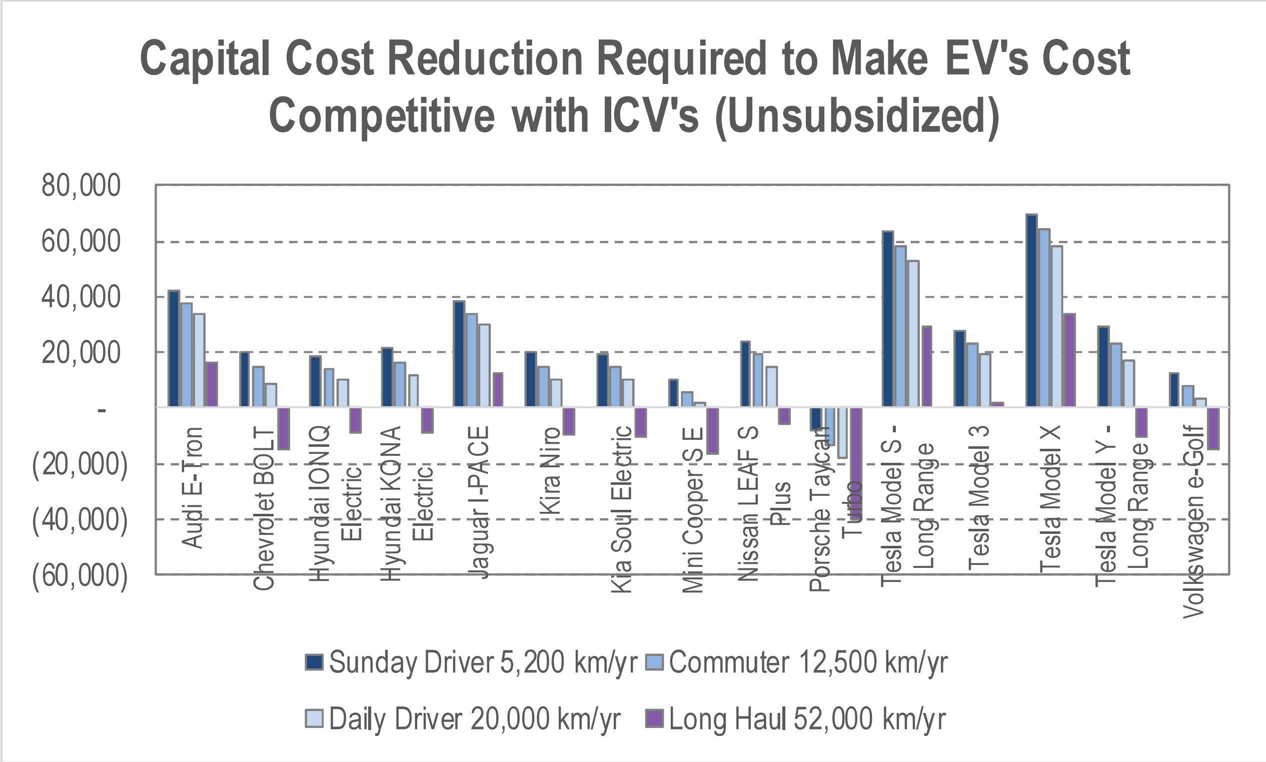
- Break-even prices are heavily influenced by EV capital cost premium

How much would a person need to drive in order to make an EV economic?



- At current electricity prices and gas prices, the break even annual driving distance ranges from zero to 97,000 km per year
  - The Porsche Taycan Turbo is priced lower than the Porsche Panamera Turbo
  - On average an EV driver would have to drive 42,000 km per year to break even vs an ICV

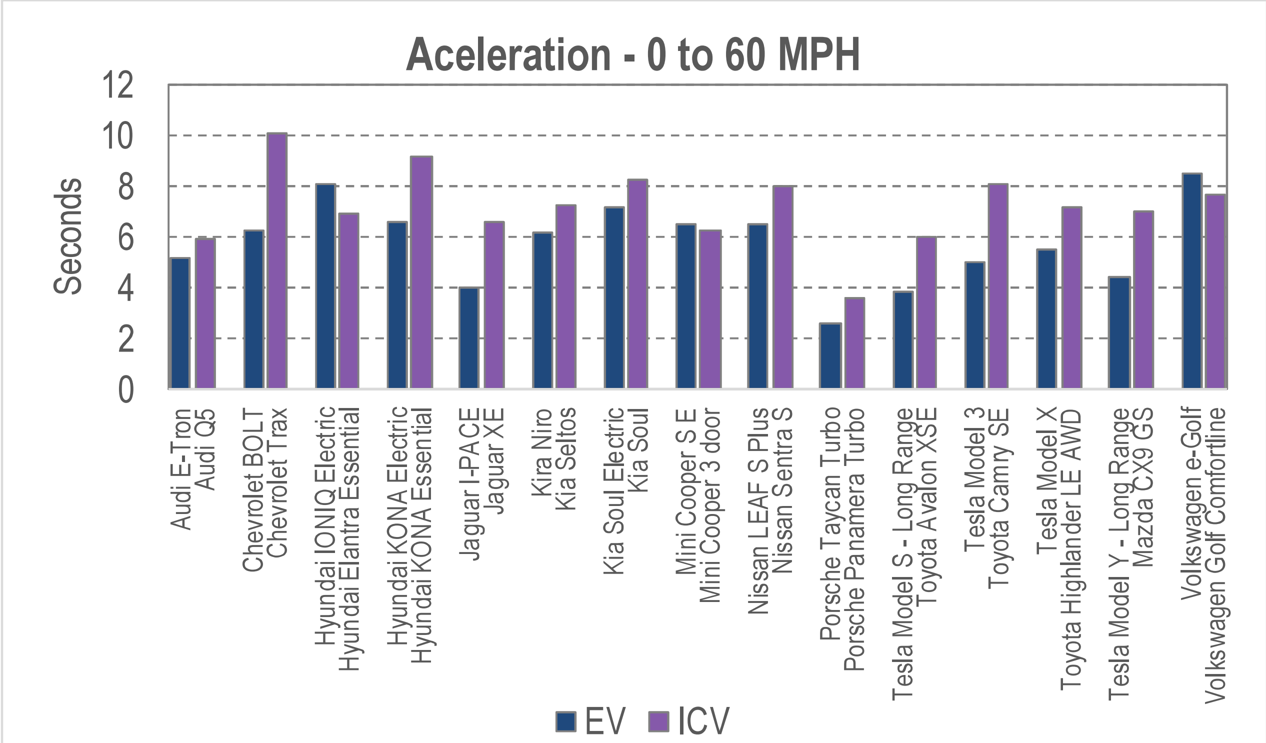
How much cheaper would EV's need to be to make them cost competitive?



- EV cost competitiveness is dependent on capital cost
- Driver's who cover more distance will receive more benefit than those who drive rarely
  - Porsche Panamera Turbo drivers can switch to a Porsche Taycan Turbo and save
  - Most other EV drivers will pay more over 8 years than ICV drivers except drivers who put on 40,000+ km per year and do not require any battery replacement in their EV

Electric Vehicle Nuances

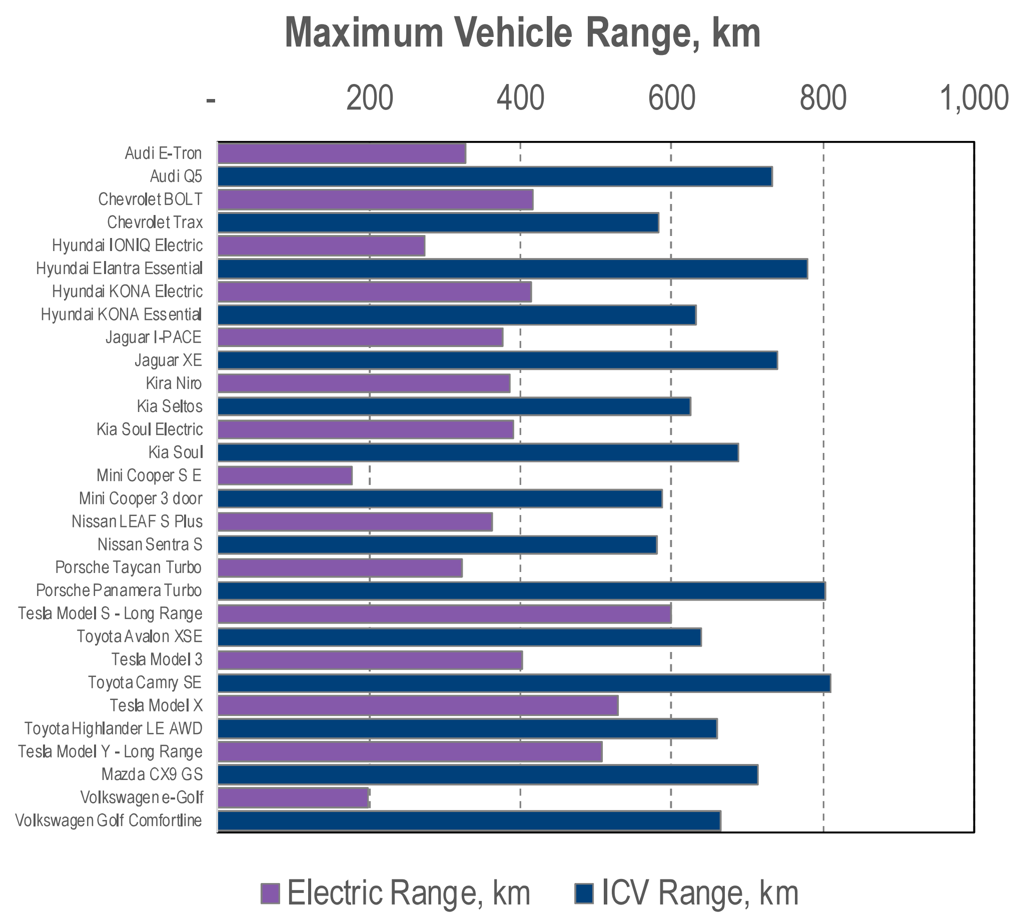
Acceleration

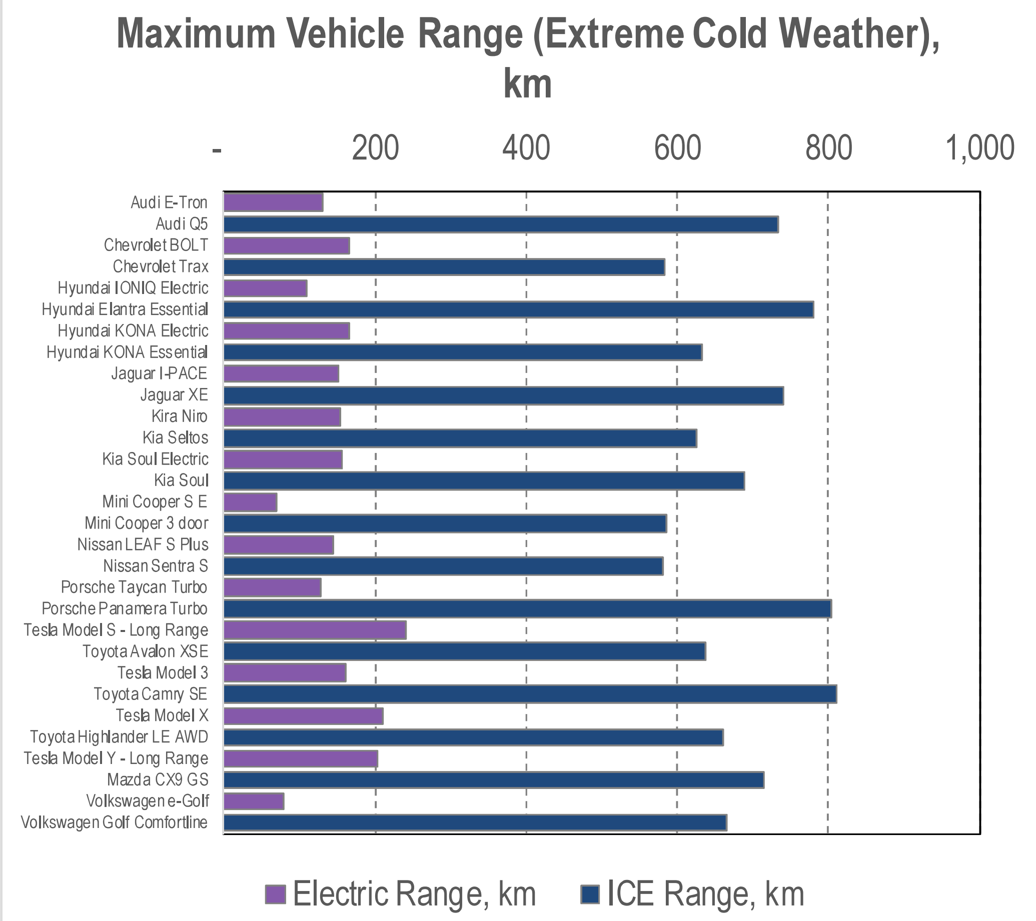


- EV's generally have faster acceleration than comparable ICV's due the instantaneous torque applied by electric motors
  - Internal combustion engine acceleration involves lag from fuel delivery, combustion, turbo spool, and losses in the mechanical transmission of power from the engine to the wheels
- There is a large variation in EV and ICV acceleration due to engine and motor size and characteristics
- Some EVs require specialized tires to accommodate the torque of their motors

Charging Speed and Capacity

Range





- Most EVs have poor range in comparison to their ICV counterparts
  - In optimal conditions, EVs have approximately 60% of the range of ICVs
  - In extreme cold weather, EVs performance degrades by up to 60% due to poor cold-weather battery performance, and heating requirements
    - For ICVs heat is a byproduct of combustion
- Range presents a challenge for EVs in Alberta's winter climate

Regenerative Braking

- Several EV's employ regenerative braking, which uses the vehicle's kinetic energy to recharge the batteries
- Regenerative braking is not an overly efficient recovery mechanism, but it will extend the range of an electric vehicle, particularly in stop-and-go traffic
  - May increase the available energy by 3% to 14% compared to vehicles without regenerative braking

Case Studies

Driving to Vancouver

- Description of route
- Refueling stops required
- Refueling time required
- Emissions footprint

Driving to Vancouver Continued

- How many refueling stops were required?
- Who long was the trip?

Driving to Vancouver

- Description of route
- Refueling stops required
- Refueling time required
- Emissions footprint
- EV or ICE

Commuting to Work

- Description of route
- Refueling stops required
- Refueling time required
- Emissions footprint
- EV or ICE

Questions?

Thank you

Electric Vehicle Modeling and Projections

January 2022

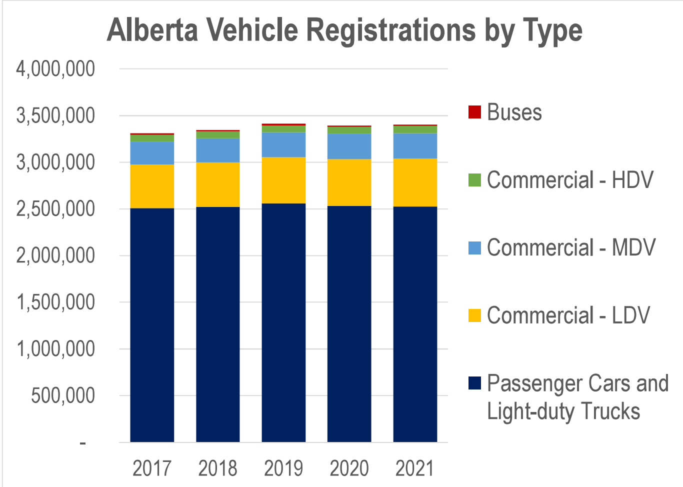
AESO Internal

AESO's Refined EV Modeling and Discussion Points

Vehicle Sales	•Stock of vehicles (based on registration numbers) have declined in the past decade, despite increase in economic drivers •Discussion point: we need to be comfortable projecting positive growth in vehicle sales despite historical trends
Electrification Targets	•EV adoption is purely based on federal (and other provincial) policies •Discussion point: policy targets ignore economic and other enablers (public infrastructure, local grid, vehicle choices) -> we should treat as ceiling/extreme penetration scenarios
EV Characteristic	•Each vehicles presents its own set of diversity – battery size, fuel efficiency, energy vs power – and each driver class has different driving patterns – short- vs long-commute, bi-modal vs random, seasonality changes, commercial factors, etc. •Discussion point: absent of transportation modeling complexities, the AESO model will at best present the average case – this needs to be made clear in each discussion/report
Charging Profiles	•Largely dependent on driving behaviour (proxied by early adopters and/or ICE driving patterns), yet it may ignore emerging EV-specific behavioural changes (unique to factors like accessibility to chargers, charger reliability, depot vs on-route charging, price signal responses) •Discussion point: charging profiles will be a key assumption that modifies peaking conditions, daily curves, (net)load variability
Geographical Allocation	•Concentration across planning regions/areas/PODs •Most impactful for LTP studies

Current breakdown of Alberta's transportation sector

- Pro-electrification policy treats vehicle classes differently
- AESO's EV model relies on multiple sources, found conflicting/mismatched data
  - Total registration comes from AB Transportation – sort of matches data from StatsCan
  - Segmentation is based on analyst judgement relying on AB Transport and NRCan's National Energy Use database
    - This allowed for splits between:
      - light-, medium-, and heavy-duty classes
      - cars, trucks or buses
      - passenger vs commercial



Summary stats

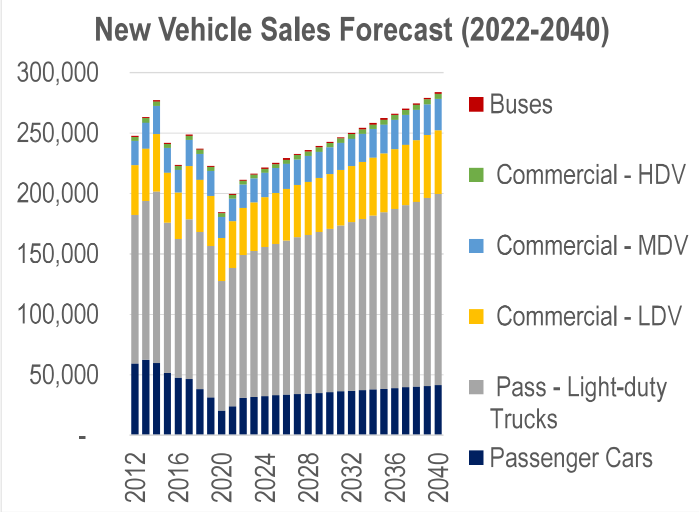
- ~3.5 million vehicles registered – 0.7% annual growth since 2017
- Composition: Passenger 76%, Commercial 24%, Buses 0.5%
- Within commercial: LDV 60%, MDV 32%, 9% HDV
- All LDVs (Pass and Comm) ~91%

New vehicle sales

- Electrification policy focuses on new vehicles with sales targets and subsidies – a forecast is required for each class

- New vehicle sales have declined in recent years
  - Pandemic added to previous negative growth – although 2021 data shows a rebound from 2020

- AESO's simplified new sales forecast is based on a hybrid model
  - Blend of 5-year persistent trend and a 10-year economic-growth correlation

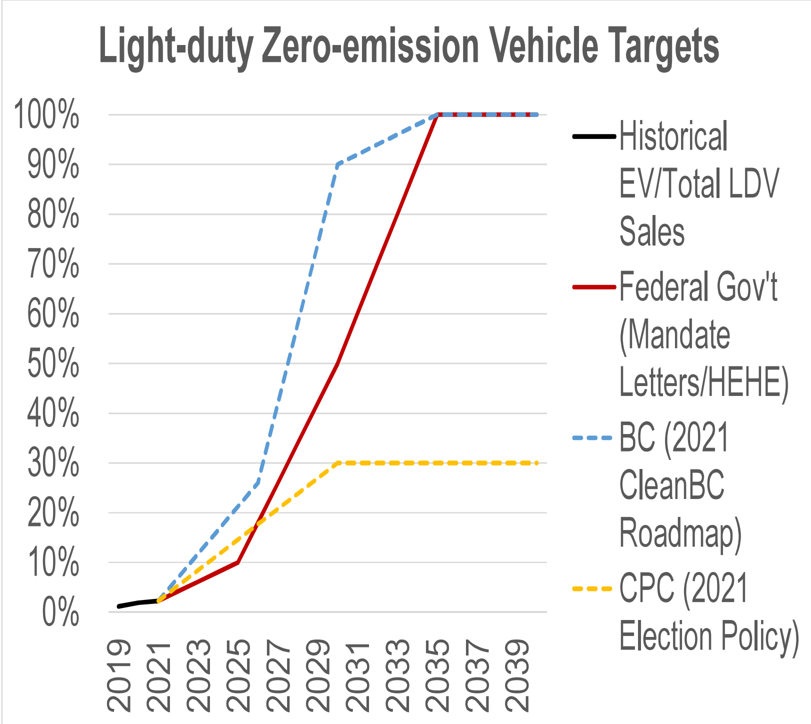


Summary stats

- Forecast (2022 onwards) growth ~1.6%/yr
- Sales composition:
  - Historical: LDV 90%, MDV 9%, HDV 1.5%, buses 0.4%
  - Forecast composition is roughly the same

EV policy uncertainty

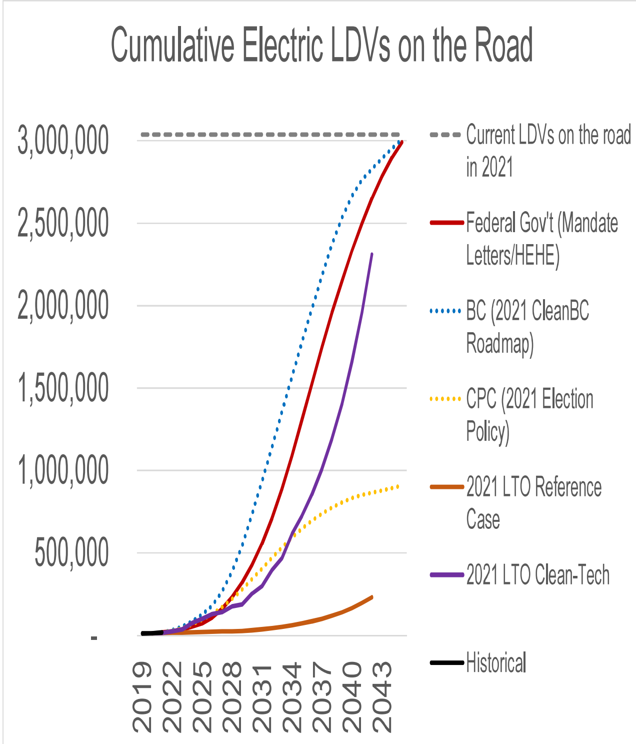
- As of January 2022, there is no sales targets for EVs (or zero-emission vehicles) in Alberta
  - The federal government announced targets for 2025, 2030 and 2035 – nothing yet in legislation
  - BC and QC are only provincial gov'ts with legislated targets – BC is most aggressive
- AESO modeling assumes federal targets dictate AB's sales:
  - By 2025, 10% of annual LDV sales
  - By 2030, 50% of annual LDV sales
  - By 2035, 100% of annual LDV sales
  - Linear annual extrapolation between target years
- Policy risk sensitivities:
  - More aggressive targets can be modelled after BC's front-end loaded plans
  - Less aggressive targets can be modelled after CPC's 30% max target



Light-duty zero-emission vehicles

- 2021 LTO had two scenarios for EV sales and cumulative estimates
  - Clean-Tech scenario presented most aggressive assumptions – around 10x greater than the Reference Case

- 2021 LTO forecast comparison
  - Although the Clean-Tech forecast pre-dates federal announcements, the first years (2022-2026) are roughly aligned
    - From 2027 onwards, the federal targets remain above previous AESO forecasts – accelerating Clean-Tech estimates by around 4-5 years



Note: the AESO's refined EV modeling now incorporates an EV life expectancy of 13 years and a subsequent replacement with another EVs; 2021 LTO forecast did not include assumptions on life expectancy or replacement ratios

THE FUTURE OF ELECTRICITY

AESO Internal

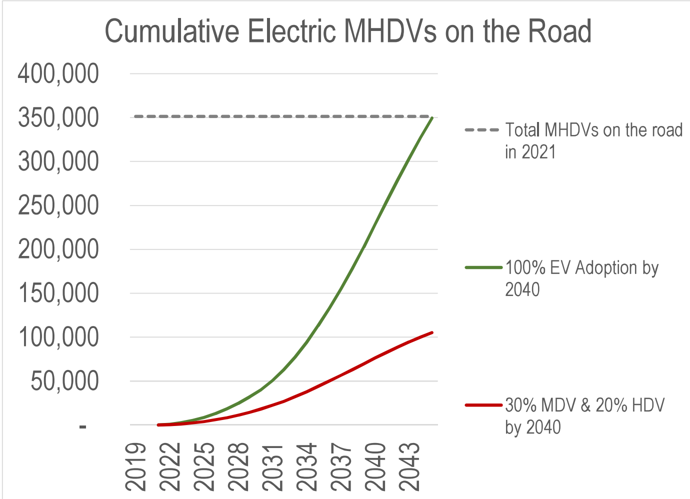
Electric LDV forecast considerations

- Meeting the federal target for LDVs represents a reasonable upper limit as mass adoption in Alberta still lacks the necessary conditions due to:
  - Cost competitiveness with ICE vehicles
  - Insufficient federal subsidies – either for each vehicle or the total funding
  - Limited public charging stations – acute issue especially outside urban centers and major corridors (main networks are ATCO/FLO's L3 chargers along the QEW[1], Southern AB-BC's Peaks to Prairies network[2])
  - Fast-charging station issues – not 100% reliable, mid-charge outages and malfunctions[3], Tesla vs standard charging ports
  - Charging constraints at multi-unit residential buildings – impacts inner-city high-density dwellers

[1] https://electric.atco.com/en-ca/community/projects/electric-alberta-ev-corridor.html
[2] https://peakstoprairies.ca/
[3] https://www.eenews.net/articles/ev-charging-stations-are-annoying-ford-wants-to-fix-them/

Medium- and Heavy-duty Vehicles

- The federal government intends to mandate a sales requirement of 100% of MHDVs to be ZEVs by 2040, where feasible
- Many potential ZEV technologies exist, some of which are not electricity-based:
  - Battery electric trucks, hydrogen fuel cell electric trucks, biodiesel, natural gas (including renewable natural gas), and high efficiency diesel engines
- The diversity of the sector means that EV adoption in this category will depend on unique commercial factors (travelled distance needs, charging infrastructure, cost parity with diesel trucks, fleet capacity and training, government funding)
- The AESO model assumes that 30% of new MDV sales and 20% of new HDV sales will be electric by 2040



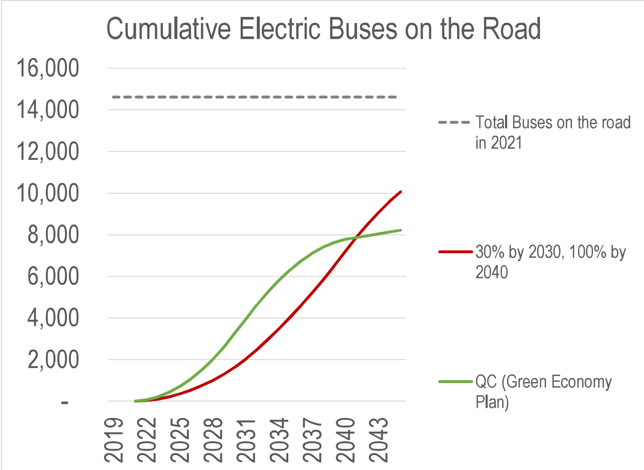
Electric MHDV forecast considerations

- The assumption of 30% of MDVs and 20% of HDVs by 2040 is defensible
  - Commercial medium-duty fleets required for short-hauls are easier to decarbonize and enjoy greater electric options
    - EV-technologies is most suitable for certain commercial vehicle usage patterns (short routes, frequent start/stops, back-to-base daily cycles)
    - Vehicle manufacturers are rushing to capitalize on this growing segment by electrifying existing models[1]
  - Heavy-haul truck technology is still in nascent stages, especially with electric options[2]
    - Heavy payloads and/or long distances travelled result in high energy demands
    - Very specialized truck configurations means fewer options available from manufacturers and/or operators' training
    - Sector tends to have a high proportion of small businesses with limited capital
    - Changing weather and unpredictable road conditions mean that operators need to rely on dependable charging/fuelling infrastructure
  - Lack of policy clarity to date
    - Federal government has only provided tax write-off treatments MDHV ZEVs but no target funding or sales target
    - There is no government programs and/or announcement at the provincial level

[1] https://www.utilitydive.com/news/electric-autonomous-delivery-vehicle-boom-expected-on-city-streets-as-inve/616839/
[2] https://www.pembina.org/reports/how-to-lighten-the-climate-load.pdf

Buses

- There is no target for the electrification of buses (transit, school buses, coach)
  - Among provinces, Quebec has announced targets for electric buses (55% transit, 65% school) by 2030
- High likelihood of complete electrification, particularly for publicly-run bus fleets:
  - Due to financial opportunity (via federal/provincial grants), economics of facility development for a return-to-base charging profile, deployment of 1+ MW fast charging technologies
- The AESO's new bus sales model assumes a path similar to Quebec's Green Economy Plan



Electric bus forecast considerations

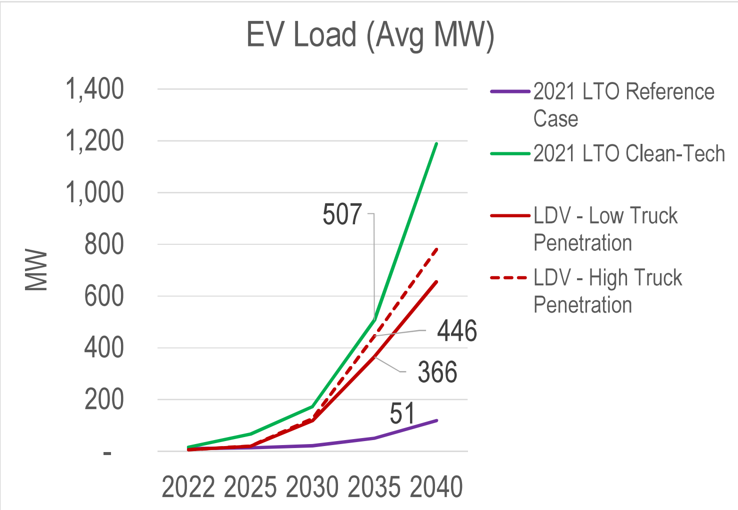
- Multiple policy/program levers exist to support the assumed electrification pathway for bus fleets in Alberta
  - Policy-motivated procurement targets – most transit agencies rely on funding and standards set by government policy
  - Increased funding from the Canadian Infrastructure Bank and Emissions Reduction Alberta
  - "Mega-chargers" are increasingly commercialized –NREL/CharIN's 3.75 MW, Tesla's 1.5 MW – will allow large trucks and buses to replenish roughly 500km of range in 30 minutes
    - This will require massive investment and coordination with DFOs

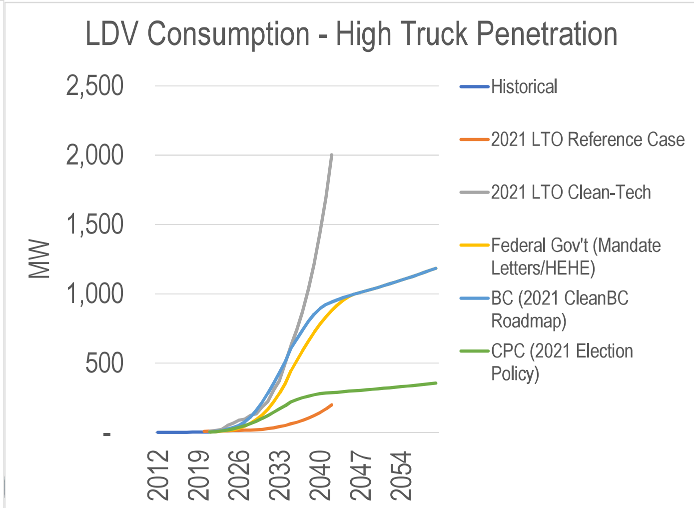
- Not all zero-emission buses are expected to be electric
  - Coach buses and transit buses that travel ranges longer than 250-300 km are not suitable for EV-technology in current state[1] – hydrogen fuel cells or other ZEV technologies already provide solutions to this segment

[1] https://vicinitymotorcorp.com/modelsm/vicinity-lightning-ev.html; min 10 https://info.burnsmcd.com/electrification/on-the-road-to-fleet-electrification-with-foothill-transit

From vehicles to energy – a tale of tech improvements

- Charging updates lead to significant decreases in LDV consumption
  - 2021 (and 2019 LTO) relied on 2016 ICF study for Yukon Energy (based on early 2010s EV data from California and adjusted for colder temperatures)
  - Updated modeling assumptions rely on Dunsky report for EPCOR based on latest EV intelligence and adjusted for Edmonton weather and driving patterns
  - Annual charging per EV declines ~60%
- Revised e-truck adoption assumption is more in line with AB preferences and technology availability – bumps load by 20%

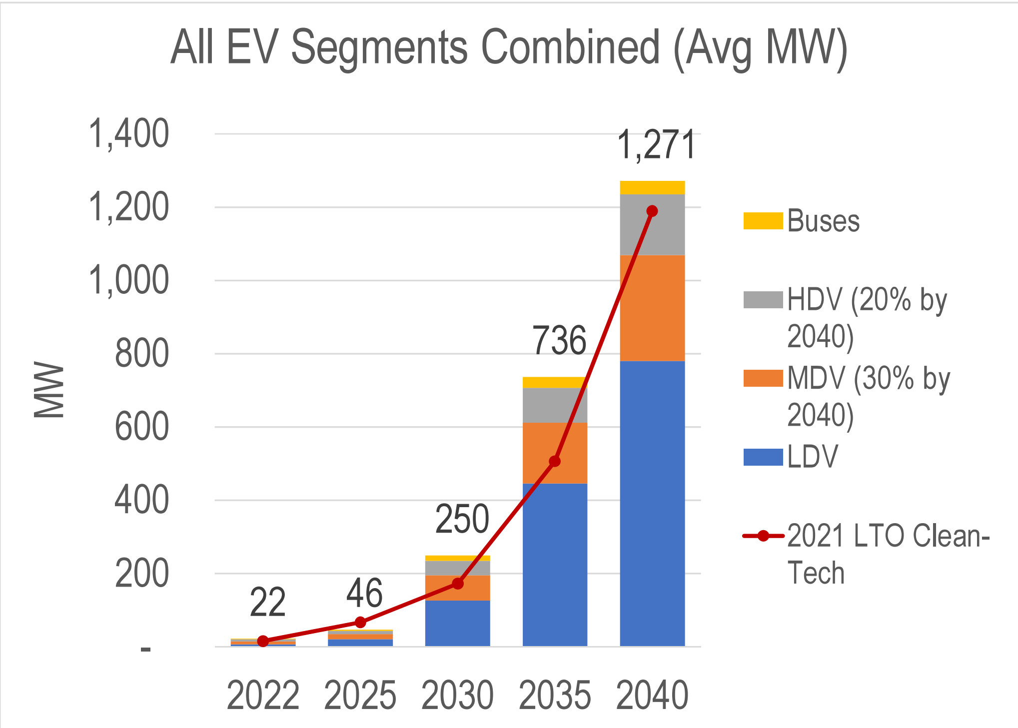




AESO Internal

Total EV energy is higher than 2021 LTO CT

- Expanding EV categories from LDVs to all segments will translate in higher EV load compared to 2021 LTO Clean-Tech – 45% higher in 2035

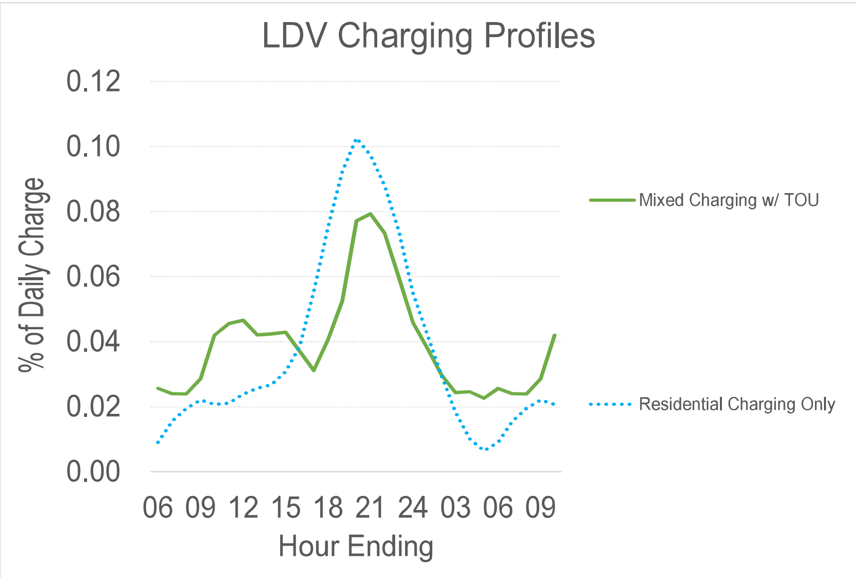


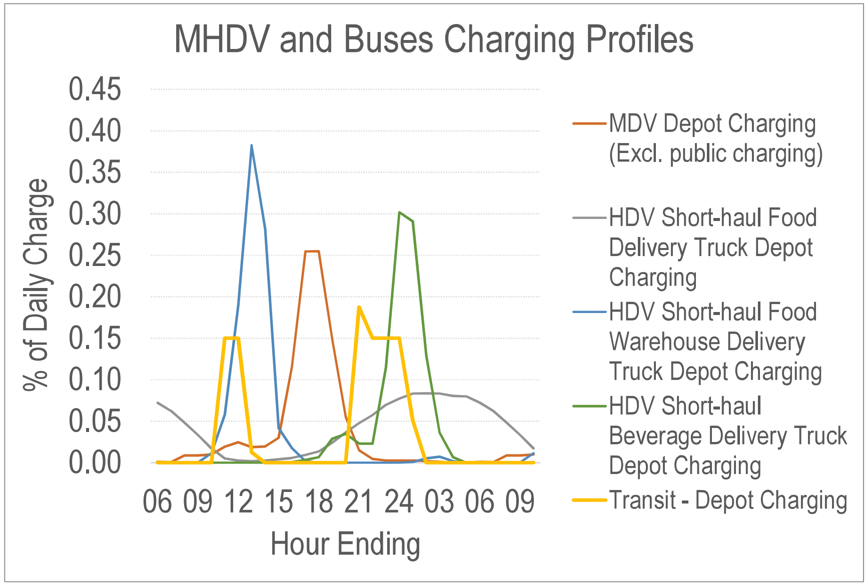
Take away

- LDVs dominate overall EV load – 40-60%
- MDVs and HDVs, despite lower adoption rates, make a significant share of EV load especially post 2035 –an upside risk if non-EV technologies (H2 in particular) doesn't pick up
- Things can still get more complex – dependent on charging profile selection

Charging behaviour will depend on retail programs and technological advancements

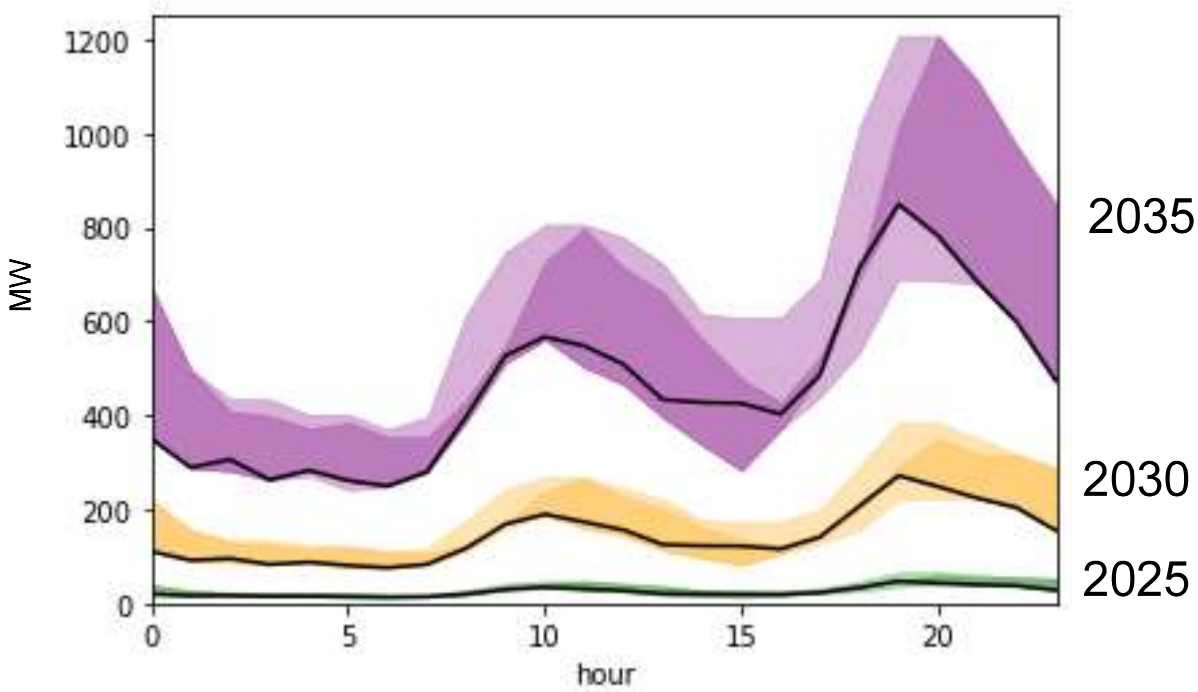
- Unmanaged charging for LDVs is unlikely to continue going forward – managed charging reduces on-peak concentration
  - In recent years, ATCO began piloting an EV fast-charging service rate (Price Schedule D23) while ENMAX's Charge Up pilot program is testing different non-rate-based managed charging approaches
- MDHV and bus charging are limited to depot charging as plans for fast-charging public charging infrastructure remains unclear – depot charging translates into concentrated, high-intensity charging during off-duty hours





The daily impact gets gradually more impactful over time

- EV charging load is limited until 2030; more pronounced by 2035 and beyond
- Range is driven by day-of-week and seasonal variations of the entire EV fleet



Note on reading this chart: this chart represents multiple percentiles within the range of load. The light-shaded areas = 1-99 pctiles, dark-shaded areas = 25-75 pctiles, black line = median.

Why isn't bi-directional charging in the model?

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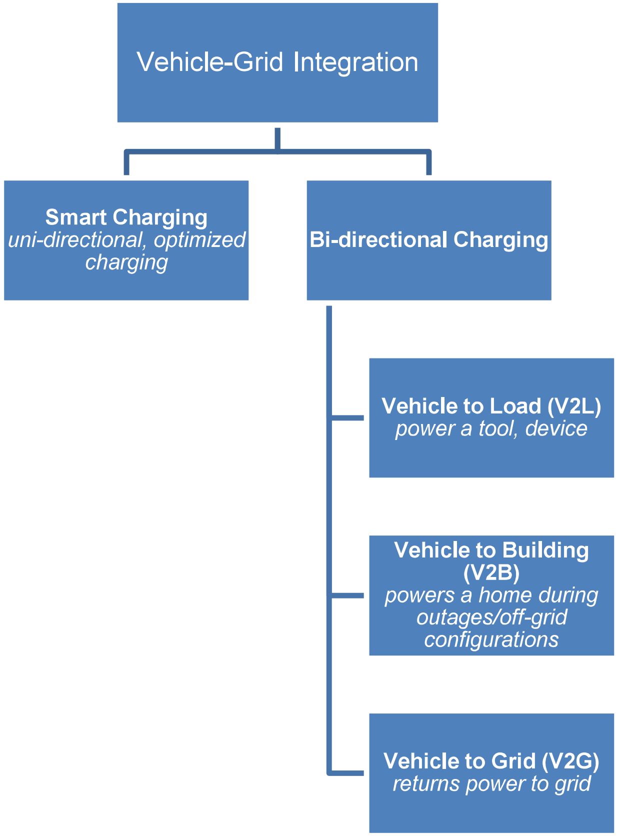
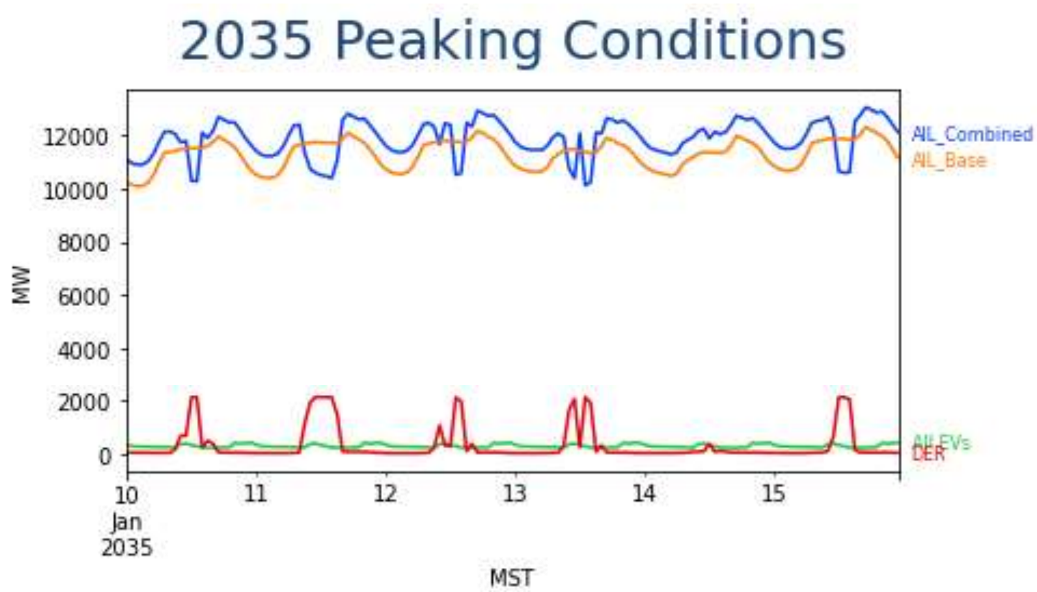
- Vehicle-grid integration could potentially turn EVs into distributed energy resources[1]
  - Benefits include opportunities to alleviate or manage peak load or congestion impacts, synchronize charging with renewables, enable energy arbitrage, defer grid investments, etc.
- Near-term widespread adoption of VGI technology is unlikely due to
  - Limited utility process/policies – limited residential time-of-use rates[2] or V2G charging processes
  - Technological limitations – limited vehicle selection that can perform bi-directional charging configurations (Ford's F-150 can do V2L/V2B at most)
  - Lack of industry standards – DC/AC bi-directional charger/inverters can be integrated into the vehicle or the station, each presenting its own set of interoperability and safety issues
- Due to these uncertainties, the AESO modelling assumes smart charging for certain segments but no bi-directional VGI



1 For more details, see https://www.dunsky.com/scaling-vehicle-to-grid-v2g-technology-benefits-and-considerations/
2 Only aware of ATCO's TOU pilot in Grande Prairie (Price Schedule D13 included in 2019 Dx Tariff Application and approved by AUC)

Flat LDV charging profile

- Extreme case with 100% managed charging



THE FUTURE OF ELECTRICITY

Drafting slides

Connector Types and Power Ratings

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- Connectors can vary between current type and power ratings

AC connector type	Typical Power Ratings
Type 1	3.7kW 7kW
Type 2	3.7kW 7kW 22kW (three-phase)*

* Three-phase power is relatively rare. There is almost no three-phase in homes, but there is some in a few larger commercial buildings. Most public stations are single-phase 7kW devices.

DC connector type	Typical Power Ratings
CHAdeMO	50kW 100kW
Combined Charging System (CCS)	50kW 150kW** 350kW***
Type 2	150kW 250kW****

** 150kW CCS rapid chargers will become very common, but most are just 50kW.
*** 350kW CCS is not yet common place.
**** 250kW Tesla Superchargers are starting to be rolled out.

Visualizations and notes are from UK-based charging station provider Pod Point: https://pod-point.com/guides/driver/ev-connector-types-speed

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Public Charging Stations

- Alberta data from NRCan's ZEV station finder* - *static data only, no utilization*
  - 250 existing + 9 planned (data downloaded in Dec 2021)
  - 66 municipalities: ~50% in Calgary, Edmonton, Med Hat, Red Deer
    - *Although urban centers dominate, there is no geographic/regional/DFO concentration*
- Charging stations can have multiple EVSE ports (akin to gas fuel pumps) which in turn can have multiple connectors (akin to hoses at a pump)
  - 601 EVSE ports
    - 5 Level 1 (Slow AC), 418 Level 2 (Fast AC), 178 Level 3 (Fastest DC)
    - Connector types**:
      - 5 NEMA250 (Level 1-all EVs)
      - ~240 J1772 (Level 2-all EVs)
      - ~120 CHAdeMO/SAE combo (Level 3-all EVs)
      - 235 Tesla-exclusive connectors (Level 2 and 3)

More than half of EVSE ports are considered super-charger – with ratings 50+ kW

  - ~500 of EVSE ports are associated with at least 1 of 8 different networks (i.e., Tesla, PetroCan, SWTCH); ~100 are non-networked (i.e., set-up by facility owner)
  - Most EVSE ports are sited at hotels, shopping and retail locations, car dealers, and office buildings and are free to use (no fee for charging) – *expected to lead to segmented charging profiles*

* Data can be downloaded from https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles/zero-emission-vehicle-charging-stations#/find/nearest
** For a plain explanation of connector type standards and usability, see https://chargehub.com/en/electric-car-charging-guide.html

Federally subsidized EVs

- Since 2019, the Incentives for ZEV (iZEV) program* has subsidized 1,980 EV purchases in Alberta – around $8.2 million up to October 2021

* Data can be downloaded from https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles/program-statistics

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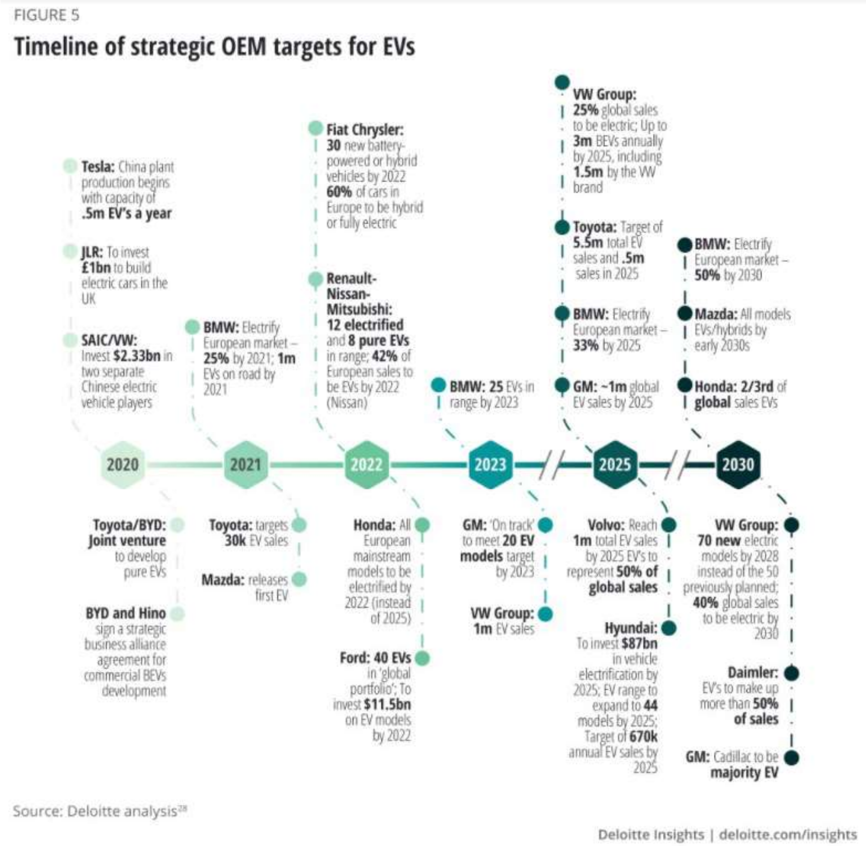
Supply side targets



Source: https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html

- Most manufactures have targets for EV production
- Still raises questions whether all these options will be available in Alberta, especially with issues around:
  - Supply chain challenges (battery manufacturing capacity, pandemic impact on global logistics of semiconductors and so on)
  - Design suitability for colder jurisdictions
  - Affordability and alignment with Alberta consumer preferences

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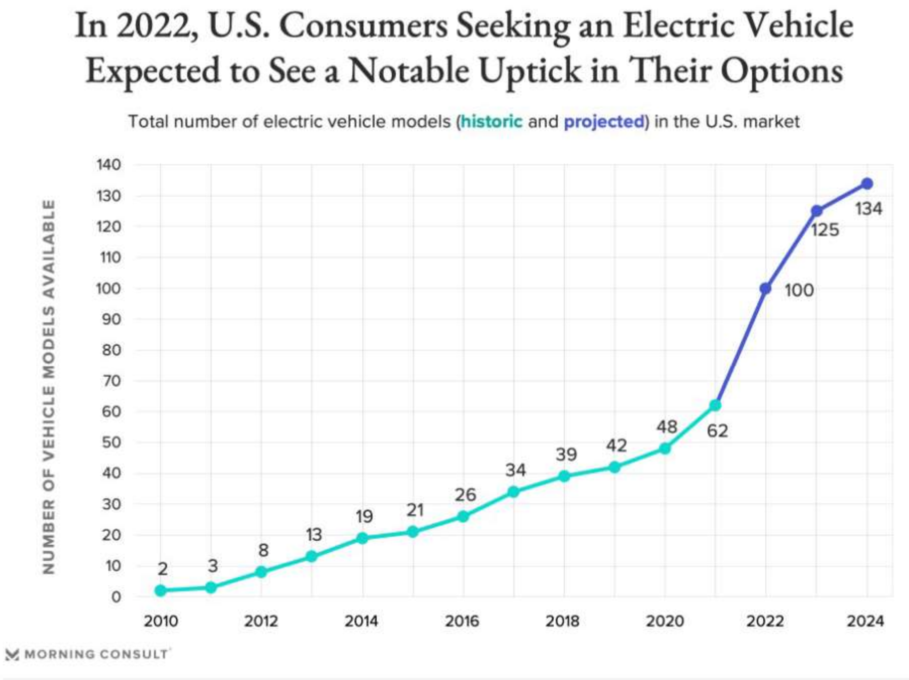
AESO Internal

Supply side targets



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Source: https://morningconsult.com/2021/12/22/electric-vehicles-consumers-2022/

Electric buses

LESSONS LEARNED

- In-route charged buses are inflexible.
- In-route charging stations require off-
- In-route charging stations are costly. F
  planners for plan review and permittir
- Requires maintenance contract with charger provider.
- HVAC has negative impact on bus range
- Not a one-to-one bus replacement.
- Driver training is very important

CAPITAL & OPERATING COST

- Electric bus costs are $250,000/bus more than CNG bus.
- Infrastructure is $120M over next decade with escalation
- Electricity costs are much less than CNG fuel costs
- Electric bus O&M costs are less than CNG bus
- Charger O&M and future replacements factored in
- Electric fleet cost is $15.4M more per year

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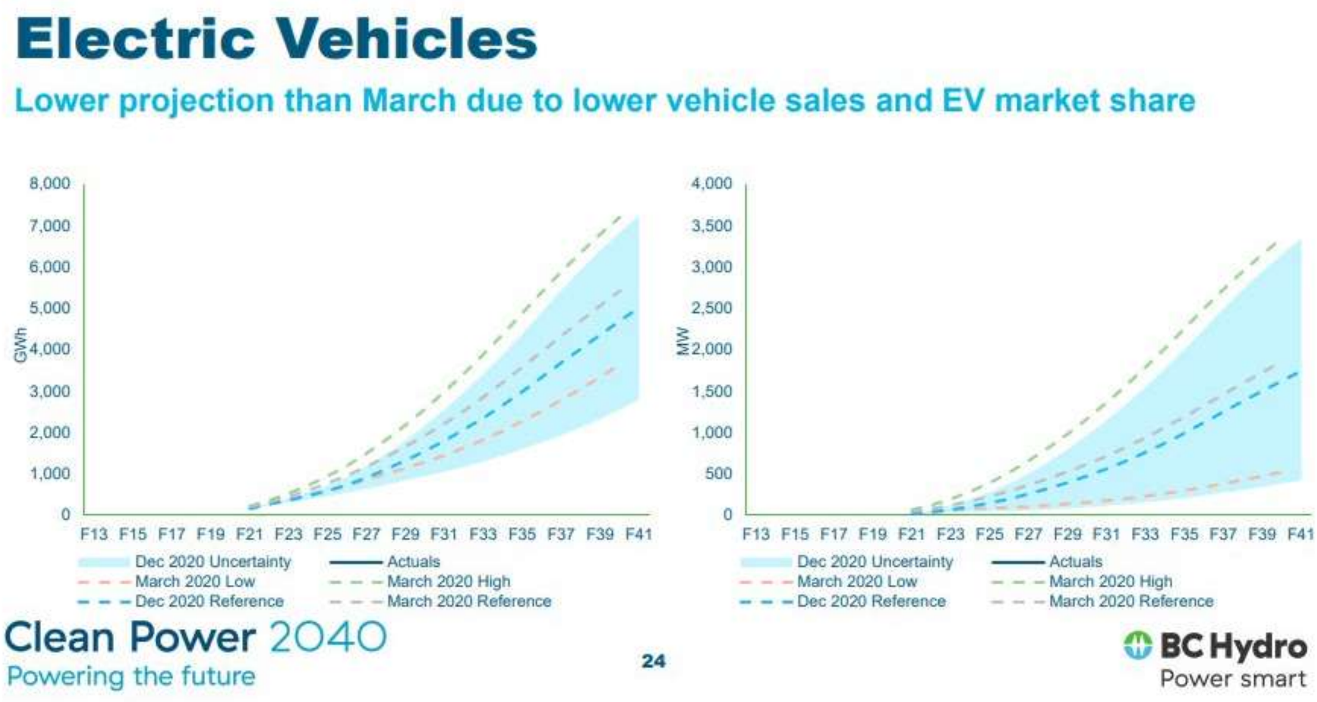
- Charging profile considerations
  - Static behaviour – no changes or learnings applied overtime
  - No adjustments to accommodate “preparatory charging” (anticipatory charging ahead of storm or weather system that could threaten the reliability of the grid)
  - No adjustment for high driving seasons (winter and summer holidays)

BC Hydro Comparison

- as

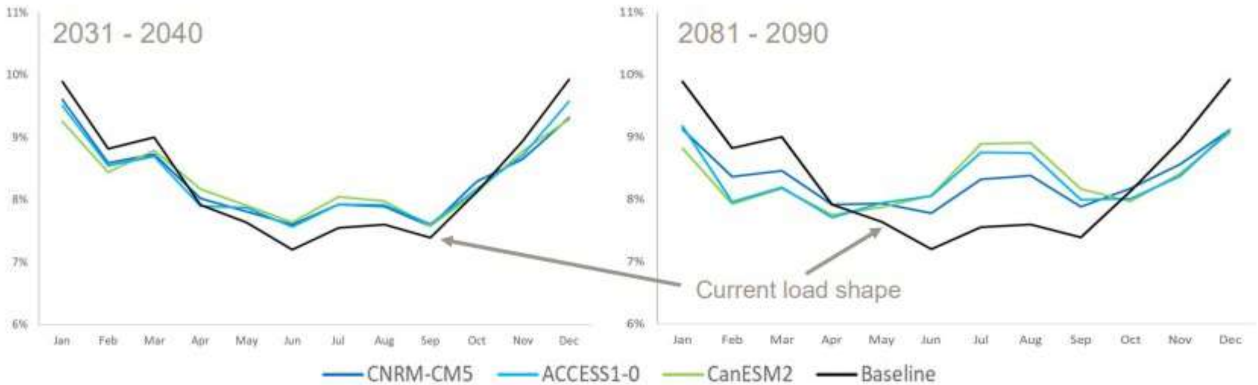


Source: https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/regulatory-planning-documents/integrated-resource-plans/current-plan/2021-irp-tac-mtg8-20210127-slides.pdf

BC Hydro's climate adaptation study

Impact on Load Shape

Projections indicate load shape shifting from a winter peak to a dual peak (winter and summer peak) in the long-term as heating / cooling load decreases / increases



Average monthly Load Shape (% of annual) for baseline and three Global Climate Models under the RCP 8.5 emission scenario

Clean Power 2040
Powering the future

41

BC Hydro
Power smart

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Context

In October/November 2022, the AESO met with DFOs at the Executive level to increase coordination on the impact of grid transformation resulting from net-zero emission policies and technological trends.

- AESO-DFO collaboration was a recommendation identified by the AESO in its Net-Zero Emissions (NZE) Pathways report (released in June 2022).[1] The report focused on transmission-level impact to market, cost and operations; distribution system impacts were highlighted as a gap to be addressed via further engagement with DFOs.
- Objectives of AESO-DFO engagement agreed at the Executive level include:

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  - Understand current state of DFO planning for impacts of a net-zero transition including electrification of transportation

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Net-Zero Scenario Assumptions

In the NZE report, the AESO produced a single 20-year load forecast that included key sectors that will be impacted by net-zero and carbon policies from 2022 to 2042. Each of these sectors and the modelling assumptions are explained below. Please review and be prepared to comment on degree of alignment between AESO assumptions and your organization's, how your organization is tracking/modeling development in these sectors and how you rely on these types of projections for business decisions.

[1] NZE Pathways report can be found here: https://www.aeso.ca/assets/Uploads/net-zero/AESO-Net-Zero-Emissions-Pathways-Report pdf

Transportation Decarbonization

The AESO's model focuses on a sub-set of transportation (i.e., excludes air, marine, and even rail transport) modes based on the most likely to electrify based on policy incentives and technological readiness. These are light-duty (passenger cars and trucks), freight (medium- and heavy-duty transport vehicles), and buses (transit, school, coach).[2]

Modelling EV adoption and charging demand largely depends on a set of key assumptions:

- Adoption drivers – government subsidies, mandated sales targets, comparative cost against internal combustion engine vehicles, stock turnover rate
  - The NZE report assumes federal policy targets drive EV adoption in Alberta
- Driving patterns – driver behaviour, typical mileage, weekend and holiday effects
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Tables 1 and 2 in the Appendix show the results from the EV model produced for the NZE report.

Discussion questions

- Can you share your most recent EV forecast (# of vehicles, charging load estimates, charging profile assumptions)?
  - Discuss the extent to which the AESO approach is consistent or not with your forecast
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  - Discuss current and future work plans, methodological approach, key assumptions driving results, in-house vs consultant modeling, the extent to which the AESO results are leveraged
- Do you see/expect the impact of EV charging to be different depending on location – i.e., residential vs commercial/institutional buildings vs warehouse vs commercial charging stations?
  - Discuss types of analysis conducted on accommodating EV charging for different purposes and at a different locations

[2] Details on the modelling of each sub-sector are explained in PDF pages 19-22 of the NZE report.

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  - Discuss charging load-shifting mitigation options discussed, what would makes most sense for your service territory or business goals, barriers to implementation of different options
- From a collaboration perspective, how can the AESO support your EV load monitoring and modelling?

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Appendix

Table 1: EV Adoption and Charging Load Projections

	Average	Peak	LDV Cars and Trucks[1]		MDV Trucks		HDV Trucks		Buses	
Year	MWa	MW	#	% / Total	#	% / Total	#	% / Total	#	% / Total
2022	9	19	29,491	0.9%	341	0.1%	37	0.0%	67	0.4%
2023	18	39	49,458	1.4%	1,034	0.3%	112	0.1%	202	1.2%
2024	31	71	77,375	2.1%	2,089	0.6%	227	0.3%	408	2.3%
2025	48	114	112,448	3.1%	3,511	1.0%	382	0.4%	686	3.9%
2026	70	168	155,706	4.3%	5,307	1.6%	577	0.6%	1,037	5.8%
2027	99	239	221,783	6.1%	7,485	2.2%	814	0.9%	1,463	8.2%
2028	138	328	311,312	8.5%	10,049	2.9%	1,093	1.2%	1,964	10.9%
2029	186	434	424,305	11.6%	13,006	3.7%	1,414	1.6%	2,542	14.0%
2030	243	558	560,914	15.2%	16,366	4.7%	1,780	2.0%	3,198	17.5%
2031	313	706	716,785	19.3%	20,138	5.7%	2,190	2.4%	3,881	21.1%
2032	394	874	892,364	23.6%	24,330	6.8%	2,646	2.9%	4,590	24.5%
2033	486	1,064	1,088,038	28.3%	28,950	7.9%	3,148	3.4%	5,260	27.7%
2034	588	1,274	1,295,949	33.4%	34,010	9.2%	3,698	3.9%	5,888	30.8%
2035	700	1,505	1,517,730	38.9%	39,516	10.6%	4,297	4.5%	6,474	33.6%
2036	798	1,615	1,734,059	44.1%	45,134	12.1%	4,908	5.2%	7,017	36.2%
2037	894	1,817	1,944,928	49.1%	50,865	13.5%	5,531	5.8%	7,515	38.4%
2038	989	2,019	2,150,311	53.9%	56,711	14.9%	6,167	6.4%	7,969	40.5%
2039	1,077	2,216	2,335,744	58.1%	62,679	16.4%	6,816	7.1%	8,379	42.3%
2040	1,160	2,408	2,500,943	61.7%	68,772	17.8%	7,478	7.7%	8,743	43.8%
2041	1,233	2,587	2,645,486	64.8%	74,573	19.1%	8,109	8.3%	8,856	44.0%
2042	1,299	2,751	2,768,929	67.3%	80,081	20.4%	8,708	8.9%	8,951	44.1%

Note: [1] LDVs assume 50% of the current Alberta hybrid vehicle fleet are plug-in electric vehicles

Table 2: EV Daily Charge Assumptions

Type	Daily Charge (kWh-day)
Car	5.9
LDV Truck	8.2
MDV Truck	70.6
HDV Truck	351.0
Buses	114.0

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* subject to Section 31 Notice period

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* subject to Section 31 Notice period

- Battery specifications – representative EV type, charging capacity under different seasonal conditions (winter vs summer; for instance, the AESO assumes a 35% deterioration in battery range in the winter compared to summer conditions)

* subject to Section 31 Notice period

- Charging profile – representative daily driving and charging patterns, impact of incentives/penalties for charging in certain time-blocks (daytime vs evening vs overnight), deployment of managed charging technologies, vehicle-to-grid functionality
  - The NZE report relies on charging profile sensitivities that shift evening peaks to other time blocks
  - Vehicle-to-grid is not modelled in the NZE report
- Geographical concentration – residential vs on-road charging, workplace or commercial building charging, charging facilities for freight and bus EVs, EV-specific rates vs general rates, differences across DFO service territories
  - The NZE report did not include regional allocation of EVs, which means there's no service area differentiation. However, this will be addressed for the 2023 LTO

* subject to Section 31 Notice period

[2] Details on the modelling of each sub-sector are explained in PDF pages 19-22 of the NZE report.

* subject to Section 31 Notice period

Tables 1 and 2 in the Appendix show the results from the EV model produced for the NZE report.

Discussion questions

- Can you share your most recent EV forecast (# of vehicles, charging load estimates, charging profile assumptions)?
  - Discuss the extent to which the AESO approach is consistent or not with your forecast
- What is the state of modeling of EV adoption and charging profiles in your service territory?
  - Discuss current and future work plans, methodological approach, key assumptions driving results, in-house vs consultant modeling, the extent to which the AESO results are leveraged
- Do you see/expect the impact of EV charging to be different depending on location – i.e., residential vs commercial/institutional buildings vs warehouse vs commercial charging stations?
  - Discuss types of analysis conducted on accommodating EV charging for different purposes and at a different locations
- What are your key sources of intelligence or monitoring mechanisms to track EVs?
  - Discuss whether customer (residential, commercial or industrial) requests feed into your modeling, whether AMI data or other internal resources have been used for EV analysis
- Is your organization considering charging management mitigation options (e.g., time of use, centralized management, financial/punitive incentives etc.) to avoid concentration of EV charging during the evening peak?
  - Discuss charging load-shifting mitigation options discussed, what would makes most sense for your service territory or business goals, barriers to implementation of different options

* subject to Section 31 Notice period

- From a collaboration perspective, how can the AESO support your EV load monitoring and modelling?

* subject to Section 31 Notice period

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Transportation Decarbonization

The AESO's model focuses on a sub-set of transportation (i.e., excludes air, marine, and even rail transport) modes based on the most likely to electrify based on policy incentives and technological readiness. These are light-duty (passenger cars and trucks), freight (medium- and heavy-duty transport vehicles), and buses (transit, school, coach).[2]

Modelling EV adoption and charging demand largely depends on a set of key assumptions:

- Adoption drivers – government subsidies, mandated sales targets, comparative cost against internal combustion engine vehicles, stock turnover rate
  - The NZE report assumes federal policy targets drive EV adoption in Alberta
- Driving patterns – driver behaviour, typical mileage, weekend and holiday effects
  - The NZE report does not include holiday effects (i.e., impact of July-August or December holidays on typical driving distances)
- Battery specifications – representative EV type, charging capacity under different seasonal conditions (winter vs summer; for instance, the AESO assumes a 35% deterioration in battery range in the winter compared to summer conditions)
- Charging profile – representative daily driving and charging patterns, impact of incentives/penalties for charging in certain time-blocks (daytime vs evening vs overnight), deployment of managed charging technologies, vehicle-to-grid functionality
  - The NZE report relies on charging profile sensitivities that shift evening peaks to other time blocks
  - Vehicle-to-grid is not modelled in the NZE report
- Geographical concentration – residential vs on-road charging, workplace or commercial building charging, charging facilities for freight and bus EVs, EV-specific rates vs general rates, differences across DFO service territories
  - The NZE report did not include regional allocation of EVs, which means there's no service area differentiation. However, this will be addressed for the 2023 LTO

Tables 1 and 2 in the Appendix show the results from the EV model produced for the NZE report.

Discussion questions

- Can you share your most recent EV forecast (# of vehicles, charging load estimates, charging profile assumptions)?
  - Discuss the extent to which the AESO approach is consistent or not with your forecast
- What is the state of modeling of EV adoption and charging profiles in your service territory?
  - Discuss current and future work plans, methodological approach, key assumptions driving results, in-house vs consultant modeling, the extent to which the AESO results are leveraged

[2] Details on the modelling of each sub-sector are explained in PDF pages 19-22 of the NZE report.

- update standards: 13.8 kV standard, 120/208 V (apartamnet) 347/600 V (commercial); 480 V transformer is more American (not a lot of 480 V transformers) – now they need to stock more transformer (no impact to training); supply chain delays for transformers of all voltage levels; cyber-security challenges
- traditional standard service of 100 amps; newer developments sized to 200 amps;
- council mostly focused on doing at commercial malls

– Do you see/expect the impact of EV charging to be different depending on location – i.e., residential vs commercial/institutional buildings vs warehouse vs commercial charging stations?
  - Discuss types of analysis conducted on accommodating EV charging for different purposes and at a different locations
– What are your key sources of intelligence or monitoring mechanisms to track EVs?
  - Discuss whether customer (residential, commercial or industrial) requests feed into your modeling, whether AMI data or other internal resources have been used for EV analysis

* subject to Section 31 Notice period

– Is your organization considering charging management mitigation options (e.g., time of use, centralized management, financial/punitive incentives etc.) to avoid concentration of EV charging during the evening peak?
  - Discuss charging load-shifting mitigation options discussed, what would makes most sense for your service territory or business goals, barriers to implementation of different options
– From a collaboration perspective, how can the AESO support your EV load monitoring and modelling?

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Electric Vehicle Modeling and Projections

December 2022

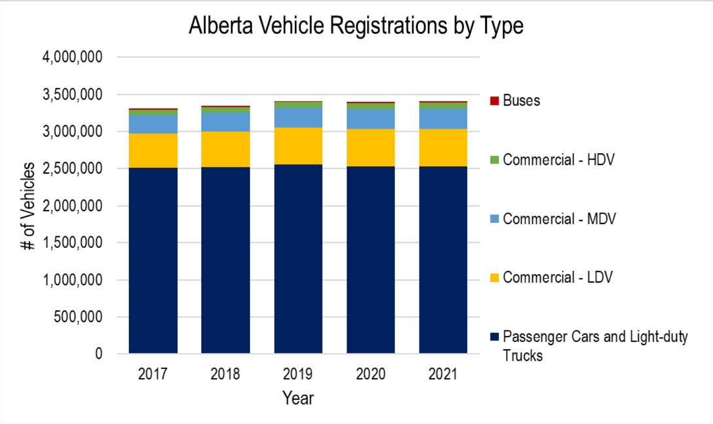
Outline

- Review (AIL Level)
  - Type of registered vehicles
  - Policies
  - Electrification forecast (vehicles number and loads)

- Geographical Allocation (Area and Substation Levels)
  - Allocate vehicles forecast to AESO planning area
  - Allocate loads forecast to AESO planning area
  - Allocate vehicles forecast to substations
  - Allocate loads forecast to substations

- DFO Allocation (ENMAX, EPCOR, ATCO, Fortis)

Review



Type	Policy	Description (Percentage of new sales)
LDV	2030 ERP Targets	60% by 2030, 100% by 2035
MDV Truck	2030 ERP Targets	35% by 2030, 100% by 2041
HDV Truck	2030 ERP Targets	35% by 2030, 100% by 2041
Buses	2030 ERP / QC Plan	60% 2030 onward (QC coach)+55% 2030 by onward (QC school)+100% transit 2040

Summary stats

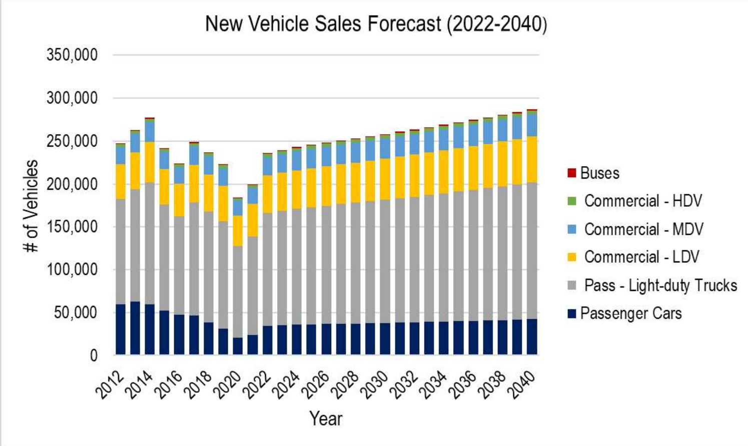
- ~3.5 million vehicles registered – 0.7% annual growth since 2017
- Composition: Passenger ~76%, Commercial ~24%, Buses ~0.5%
- Within commercial: LDV ~60%, MDV ~32%, ~9% HDV
- All LDVs (Pass and Comm) ~91%

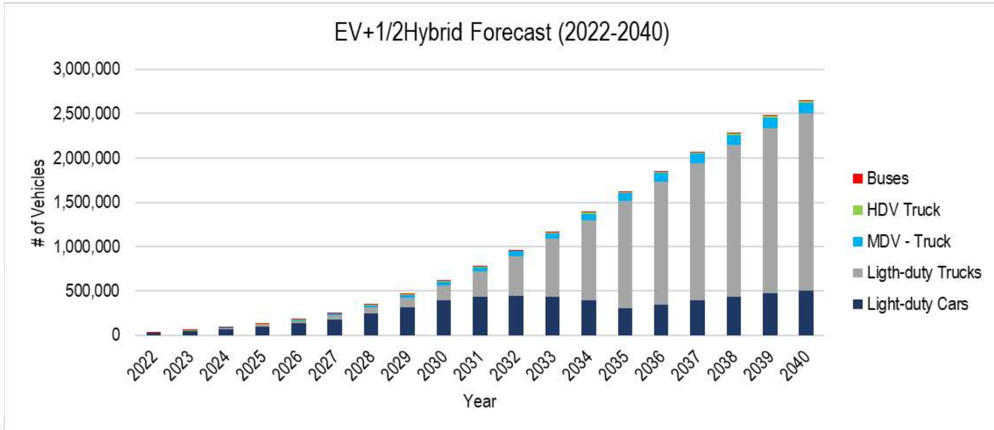
Review

- AESO's simplified new sales forecast is based on a hybrid model
  - Blend of 5-year persistent trend and a 10-year economic-growth correlation

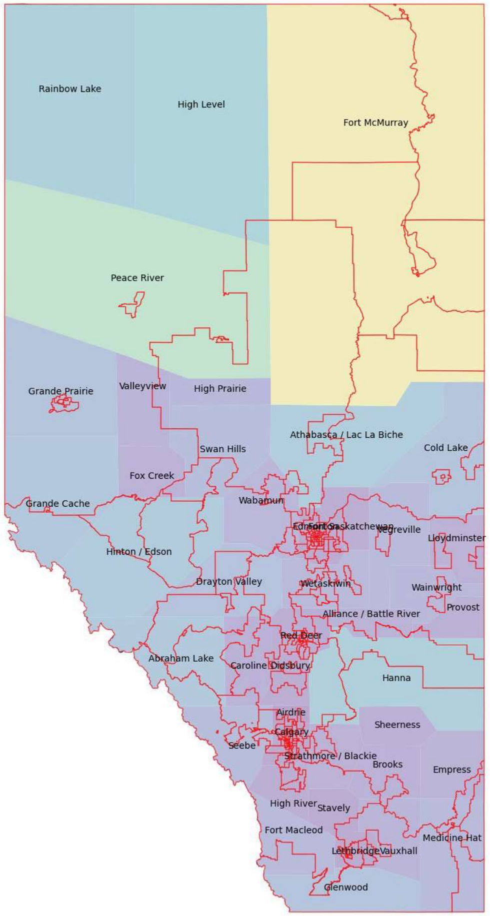
- New vehicle sales forecast (2022 onwards) growth ~1.6%/yr
  Sales composition:
  - Historical: LDV ~90%, MDV ~9%, HDV ~1.5%, Buses ~0.4%
  - Forecast composition is roughly the same

- In 2040, the number of EV+1/2Hybrid will be extremely higher than in 2022:
  - LDV 84 times, MDV 145 times, HDV 145 times, Buses 131 times





Geographical Allocation : Area

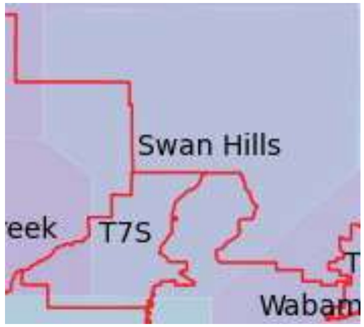


Steps:

- Map Forward Sortation Area (FSA) to AESO planning area.
- Determine the FSA's area of each polygon distributed in the different planning areas.
- Calculate the EVs number for each polygon part located in different areas.
- Calculate the total number of EVs in each area.
- Forecast EV number and load related to each area for different assumptions and various types of registered vehicles for the next 20 years.

Notes:

- Total number of the electric vehicle until March 2021 is 3,527.
- Original data was provided by the Alberta Ministry of Transportation.
- Data is for BEVs, and PHEVs data are missing.
- A few FSA data are missing.
- In the forecast, electric+1/2 hybrid vehicles are taken into consideration.

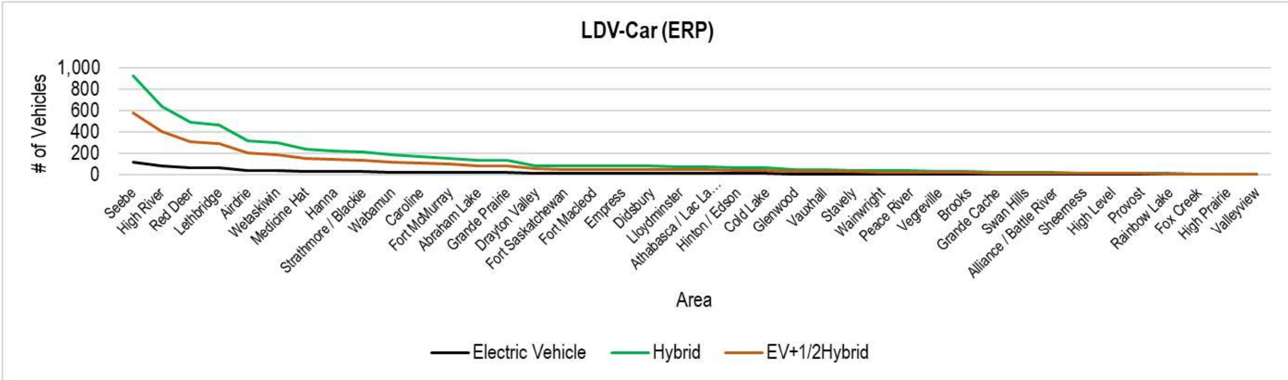


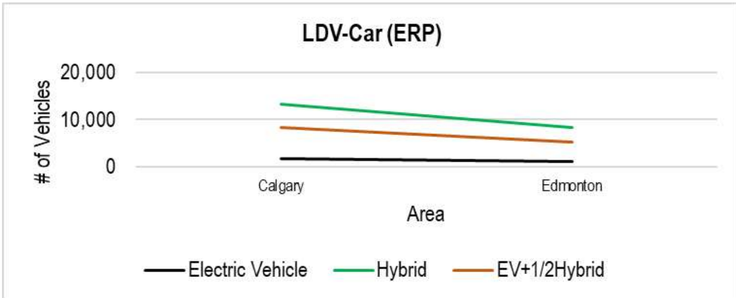
THE FUTURE OF ELECTRICITY

Number of Electric Vehicle and Hybrid by Area in 2021

Summary stats

- ~ 3,500 EV and ~27,200 Hybrid are registered
- Total EV+1/2 Hybrid is ~17,000
- Composition:
  - Calgary 48.70%
  - Edmonton 30.69%
  - Seebe 3.39%
  - High river 2.33%
  - Red deer 1.79%.



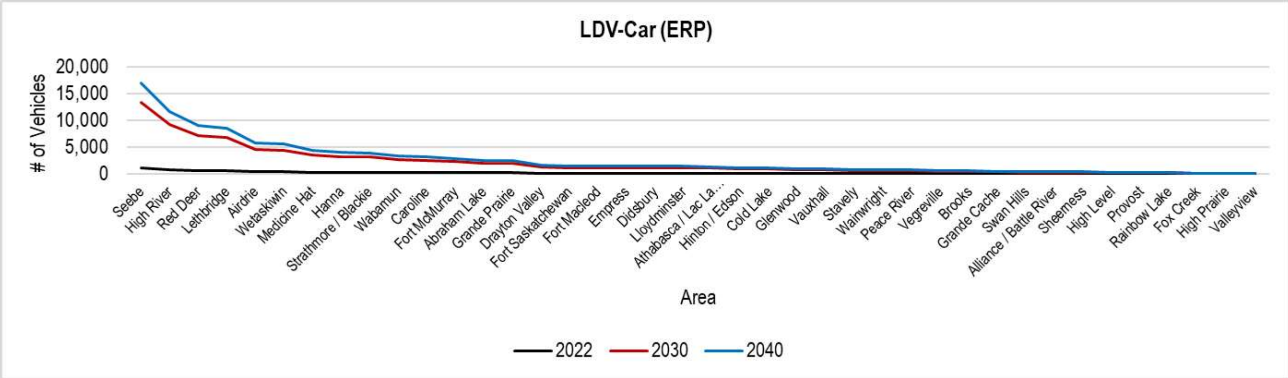


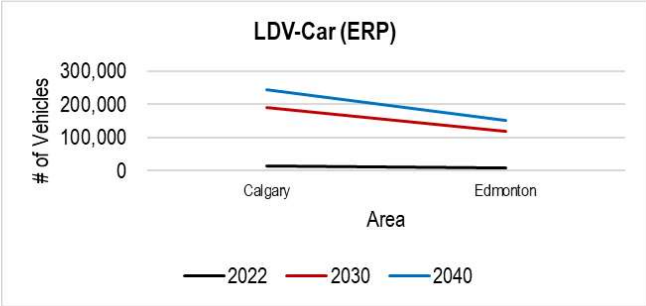
THE FUTURE OF ELECTRICITY

LDV-Car Forecast by Area

Summary stats

- Forecast growth from 2022 to 2030 is ~ 1,200%.
- Forecast growth from 2030 to 2040 is ~22%.
- Number of EV+1/2 Hybrid in Calgary, Edmonton, and Seebe will be ~14,400, ~9,000, and ~998 in 2022, respectively.
- Number of EV+1/2 Hybrid in Calgary, Edmonton, and Seebe will reach to ~244,000, ~153,000, and ~17,000 in 2040, respectively.



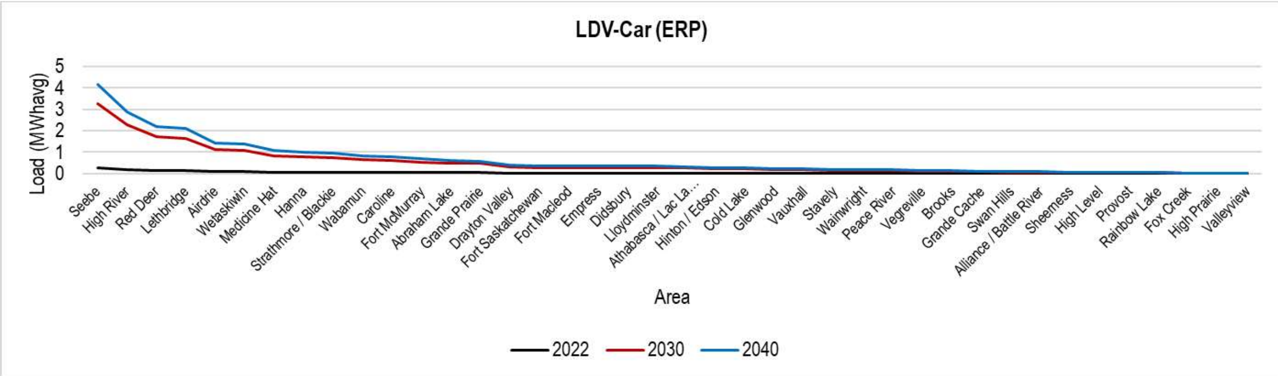


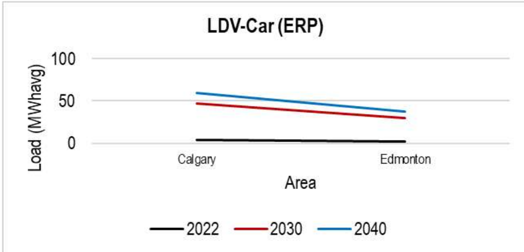
LDV-Car Forecast by Area

Summary stats

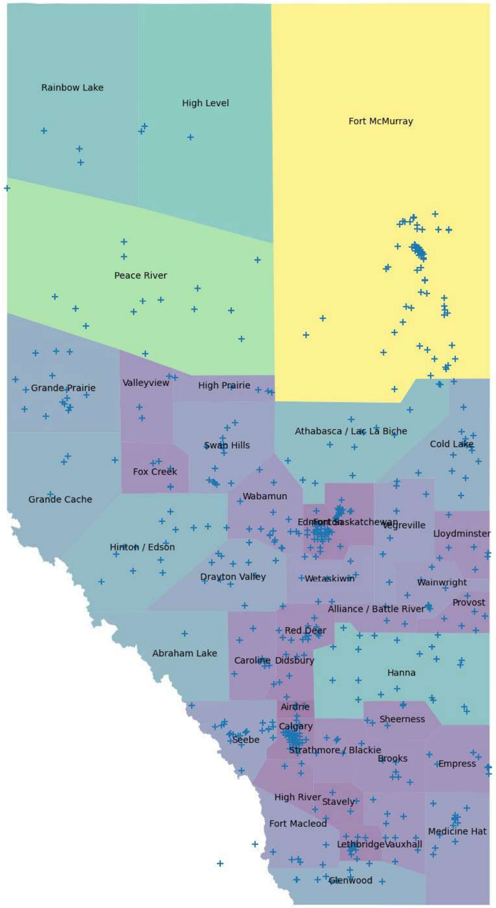
- Load (MWhavg) results from EV+1/2Hybrid:

Area	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary	3.5	47	60
Edmonton	2	30	38
Seebe	0.3	3	4





Geographical Allocation : Substations



Scenario 1: Allocate EV charging stations to substations.

- Considerations:
  - The residential charging loads are not considered.
  - There are no information about future EV charging stations' locations.

Scenario 2: Allocate center of FSA to substations.

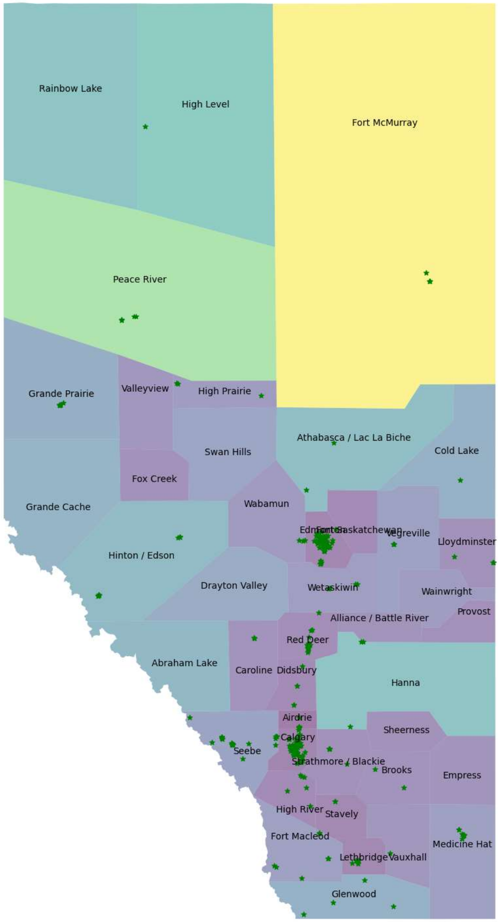
- Considerations:
  - Assumes car registration addresses are where EVs will be charged going forward
  - EV owners charge their vehicles at home or the closest EV stations.

Scenario 3: Blended scenarios 1 and 2 (preferred).

Notes:

- Total number of substations in October 2022 is 716.
- Substations number supplying load less than 3 MW is 92 and excluded from the substations. list; these are mostly service stations (i.e., substations serving generation assets load).
- Substations with no MPIDs connection are excluded from the list of substations.

Geographical Allocation : Substations (Scenario 1- EV stations allocation)

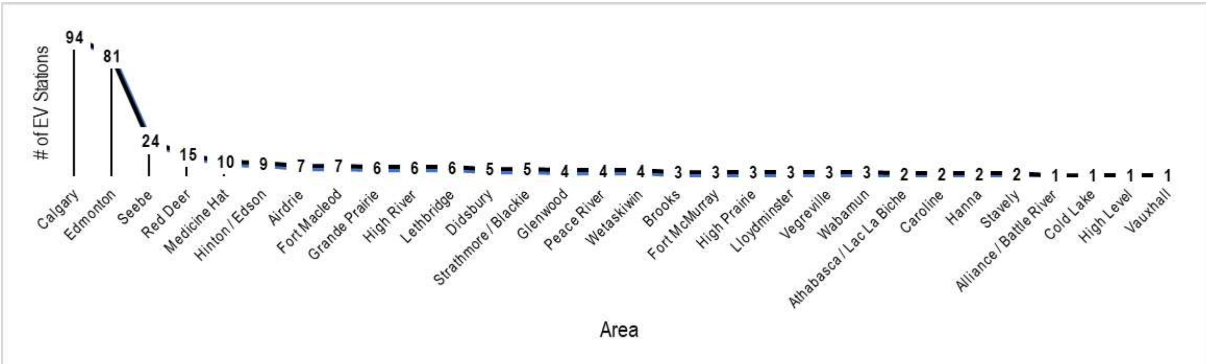


Steps:

- Apply spatial join to match points (EV stations) to areas' polygons.
- Calculate the Haversine distance of each EV station with each substation in each area and assign each EV station to the closet substation.

Notes:

- Total number of EV charging stations is 322 in Alberta.
- Assumption: The number of EV stations stays same for the future.

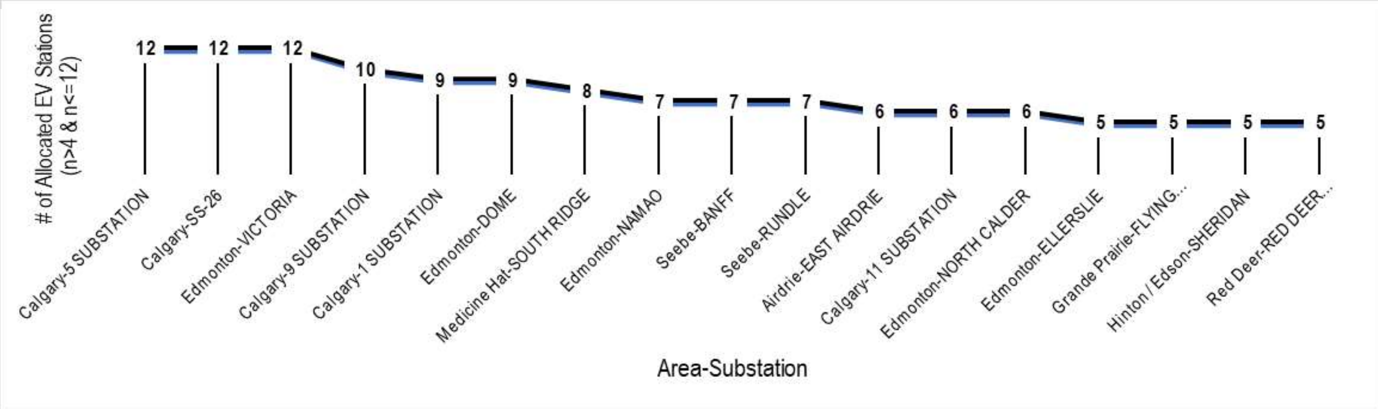


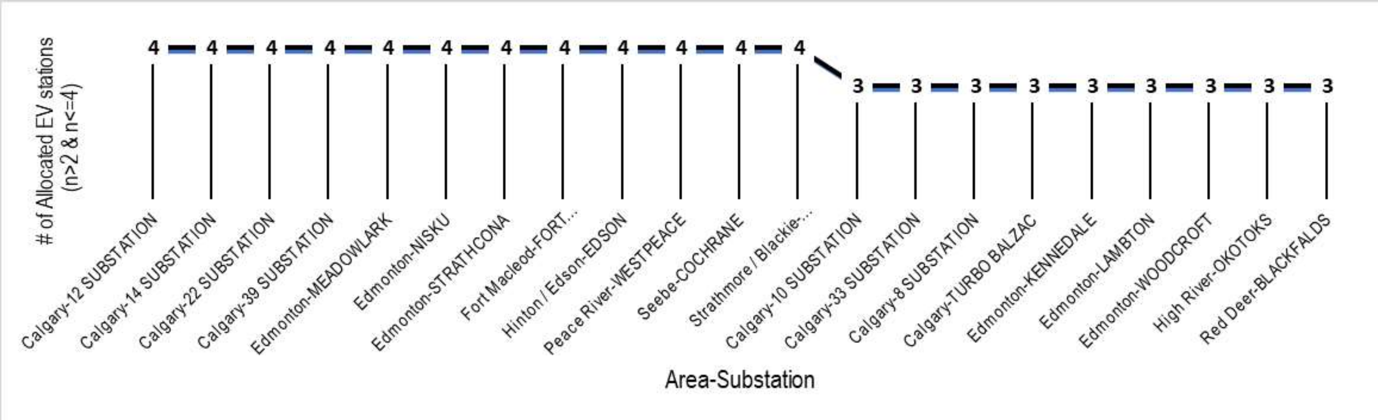
THE FUTURE OF ELECTRICITY

Geographical Allocation : Scenario 1- EV Stations Allocation in 2021

Summary stats

- The highest number of EV charging stations is allocated to :
  - 5-SUBSTATION (Calgary)
  - SS-26 (Calgary)
  - VICTORIA (Edmonton)





THE FUTURE OF ELECTRICITY

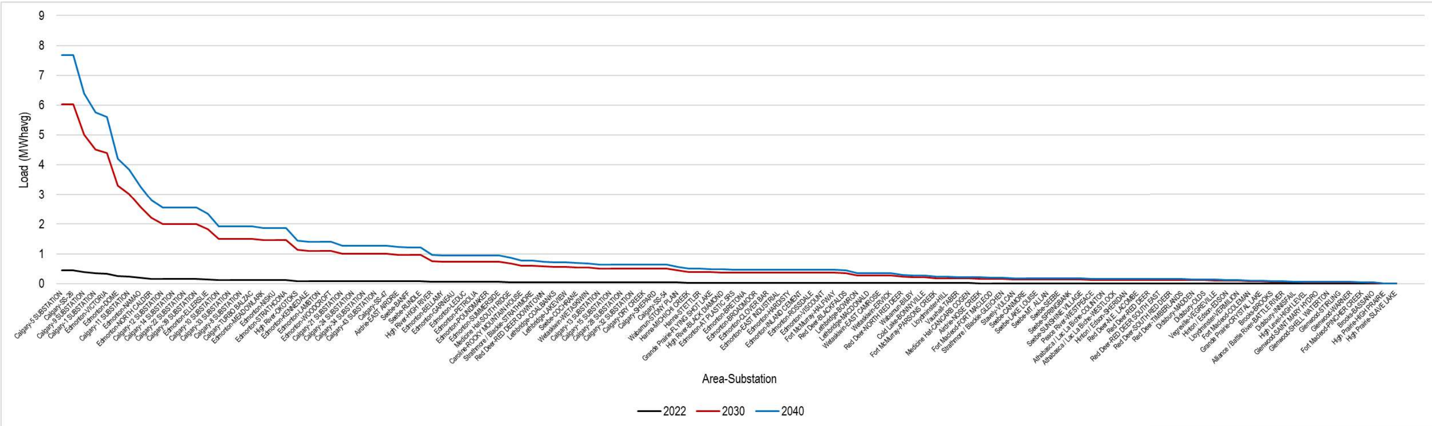
Geographical Allocation : Scenario 1- EV Stations Allocation

Summary stats

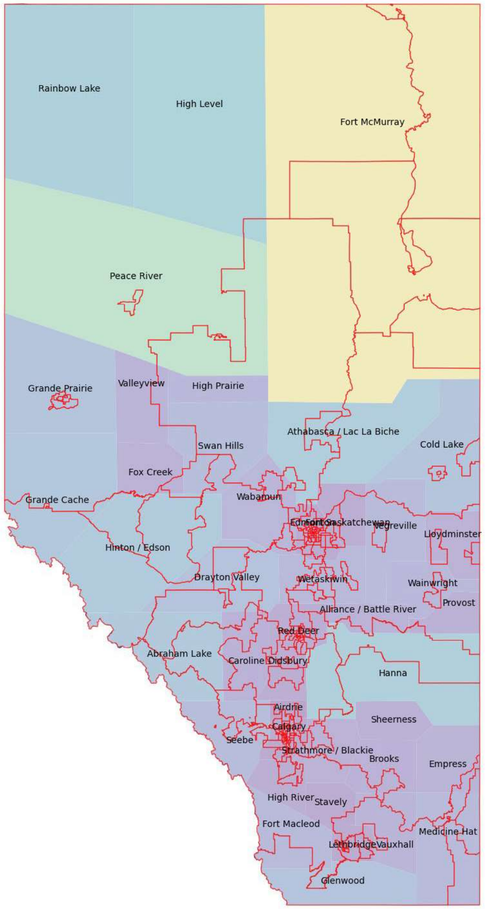
- Load results from EV stations in 2040 is ~17 times higher than 2022.

- First 3 highest load (MWhavg) results from Scenario 1:

Area-Substation	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary-5 SUBSTATION	0.45	6.02	7.67
Calgary-SS-26	0.45	6.02	7.67
Calgary-9 SUBSTATION	0.38	5.02	6.39



Geographical Allocation : Scenario 2- FSA Allocation



Step(s):

- Calculate the Haversine distance between center of each Polygon/multi-polygon and substations and assign each forward sortation area (FSA) to a substation.

Notes:

- Total number of FSA is 154.

THE FUTURE OF ELECTRICITY

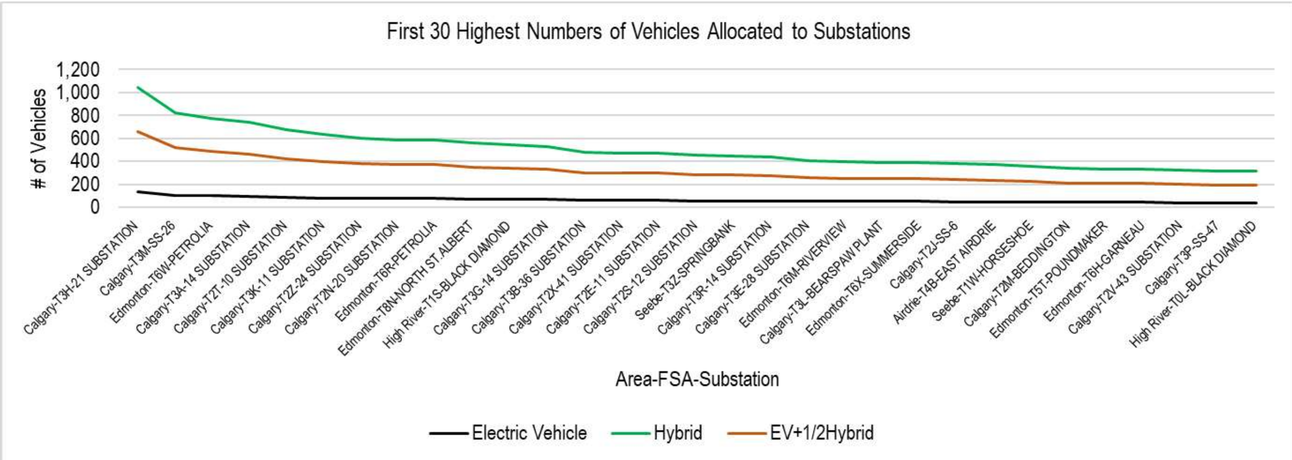
Geographical Allocation : Scenario 2- FSA Allocation in 2021

Summary stats

- Highest number of EV, Hybrid, and EV+1/2Hybrid are 134, 1,044, and 656, respectively, in 2021.

- The first 5 highest numbers of EV+1/2Hybrid are allocated to:

Area-FSA-Substation	#
Calgary-T3H-21 SUBSTATION	656
Calgary-T3M-SS-26	518
Edmonton-T6W-PETROLIA	488
Calgary-T3A-14 SUBSTATION	464
Calgary-T2T-10 SUBSTATION	424



THE FUTURE OF ELECTRICITY

Geographical Allocation : Scenario 2- FSA Allocation in 2021

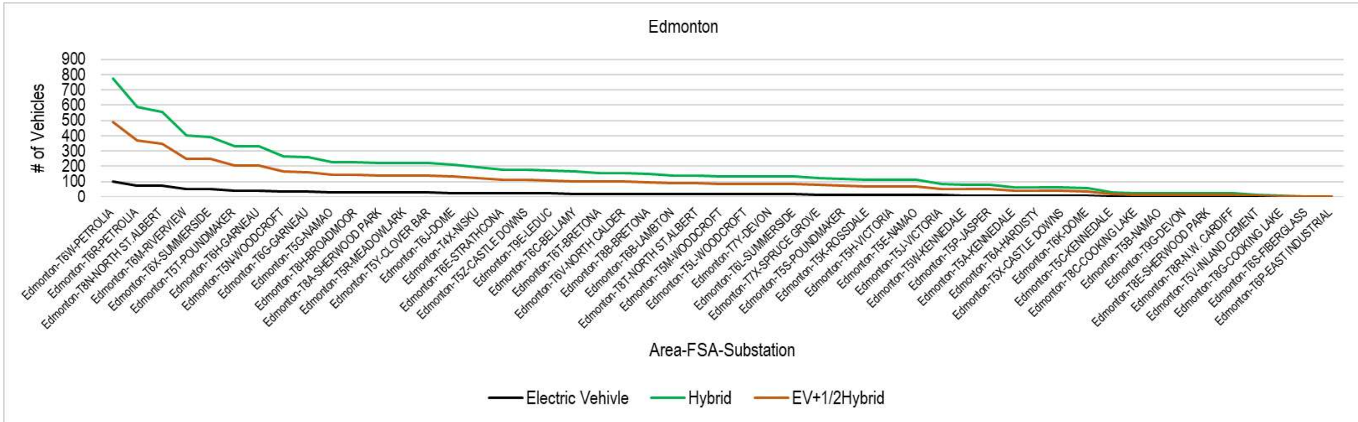
Summary stats

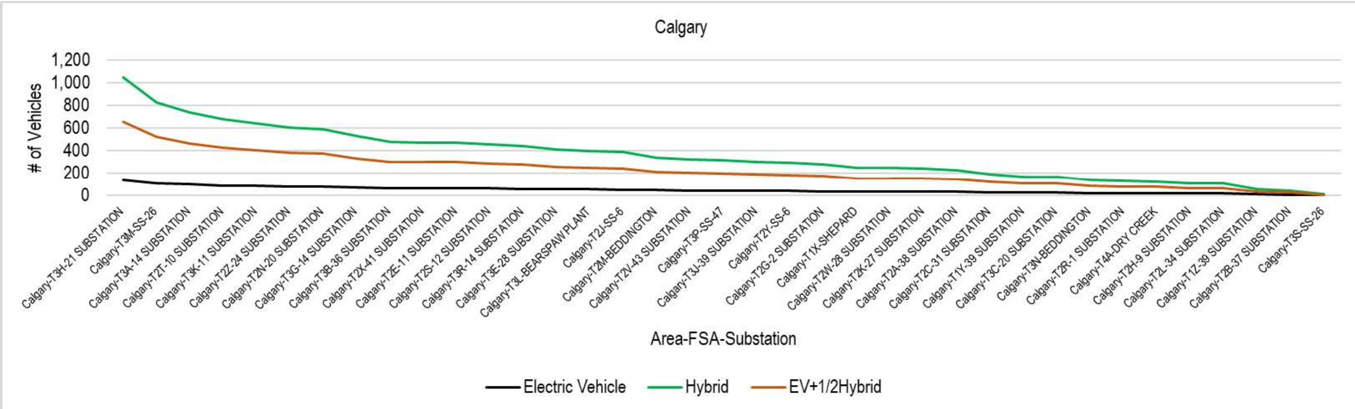
- First 5 highest numbers of vehicles (EV+1/2Hybrid) in Edmonton according to FSA allocation to substations:

Edmonton-FSA-Substation	#
Edmonton-T6W-PETROLIA	488
Edmonton-T6R-PETROLIA	370
Edmonton-T8N-NORTH ST.ALBERT	350
Edmonton-T6M-RIVERVIEW	252
Edmonton-T6X-SUMMERSIDE	247

- First 5 highest numbers of vehicles (EV+1/2Hybrid) in Calgary according to FSA allocation to substations:

Calgary-FSA-Substation	#
Calgary-T3H-21 SUBSTATION	656
Calgary-T3M-SS-26	518
Calgary-T3A-14 SUBSTATION	464
Calgary-T2T-10 SUBSTATION	424
Calgary-T3K-11 SUBSTATION	399



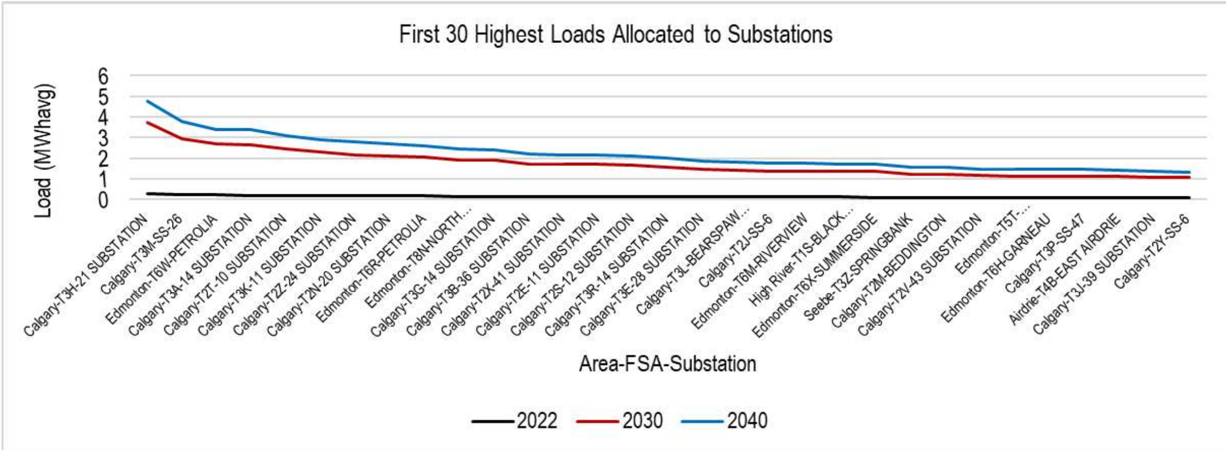


Geographical Allocation : Scenario 2- FSA Allocation

Summary stats

- First 5 highest loads (MWhavg) results from vehicles:

Area-FSA-Substation	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary-T3H-21 SUBSTATION	0.28	3.75	4.78
Calgary-T3M-SS-26	0.22	2.96	3.77
Edmonton-T6W-PETROLIA	0.20	2.67	3.41
Calgary-T3A-14 SUBSTATION	0.20	2.65	3.38
Calgary-T2T-10 SUBSTATION	0.18	2.42	3.09



Geographical Allocation : Scenario 2- FSA Allocation

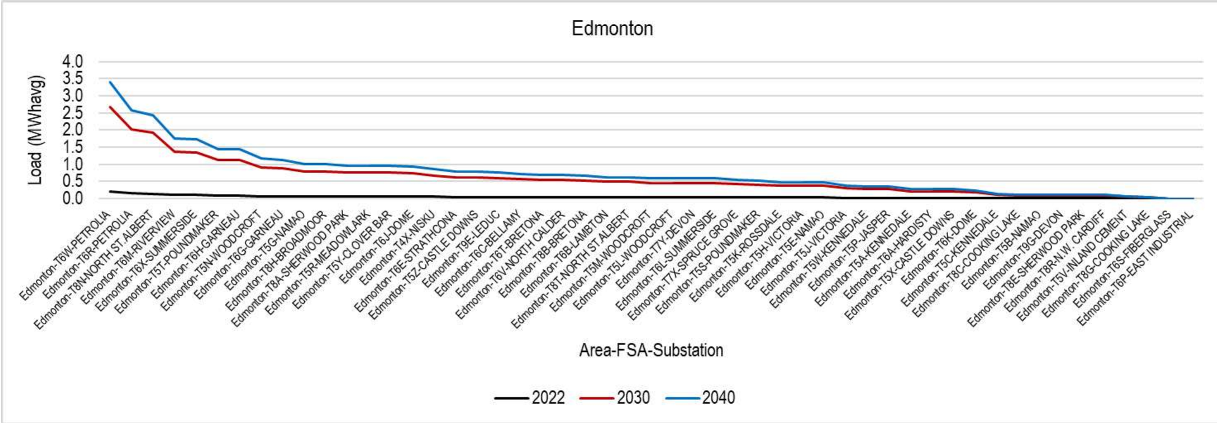
Summary stats

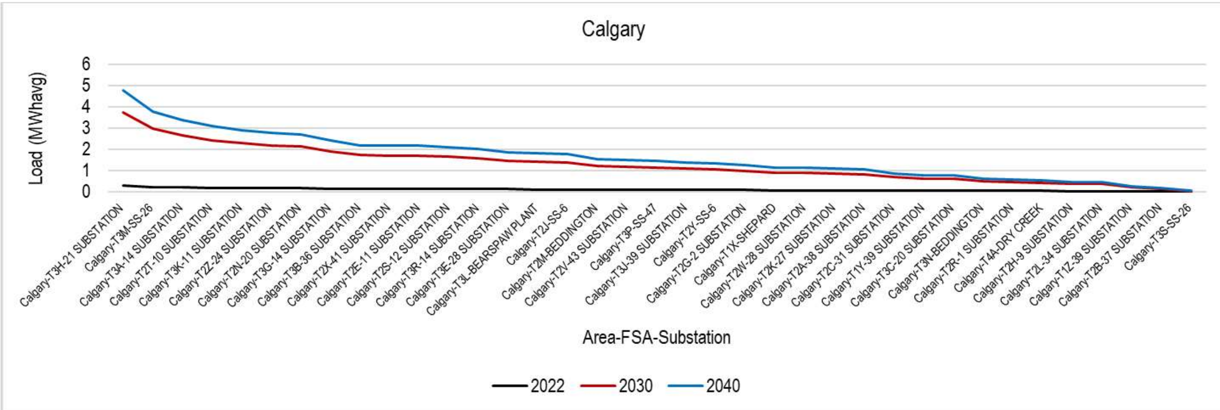
- First 5 highest loads (MWhavg) results from FSA allocation to substations in Edmonton:

Edmonton-FSA-Substation	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Edmonton-T6W-PETROLIA	0.20	2.67	3.41
Edmonton-T6R-PETROLIA	0.15	2.03	2.58
Edmonton-T8N-NORTH ST.ALBERT	0.14	1.92	2.44
Edmonton-T6M-RIVERVIEW	0.10	1.38	1.75
Edmonton-T6X-SUMMERSIDE	0.10	1.35	1.72

- First 5 highest loads (MWhavg) results from FSA allocation to substations in Calgary:

Calgary-FSA-Substation	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary-T3H-21 SUBSTATION	0.28	3.75	4.78
Calgary-T3M-SS-26	0.22	2.96	3.77
Edmonton-T6W-PETROLIA	0.20	2.67	3.41
Calgary-T3A-14 SUBSTATION	0.20	2.65	3.38
Calgary-T2T-10 SUBSTATION	0.18	2.42	3.09



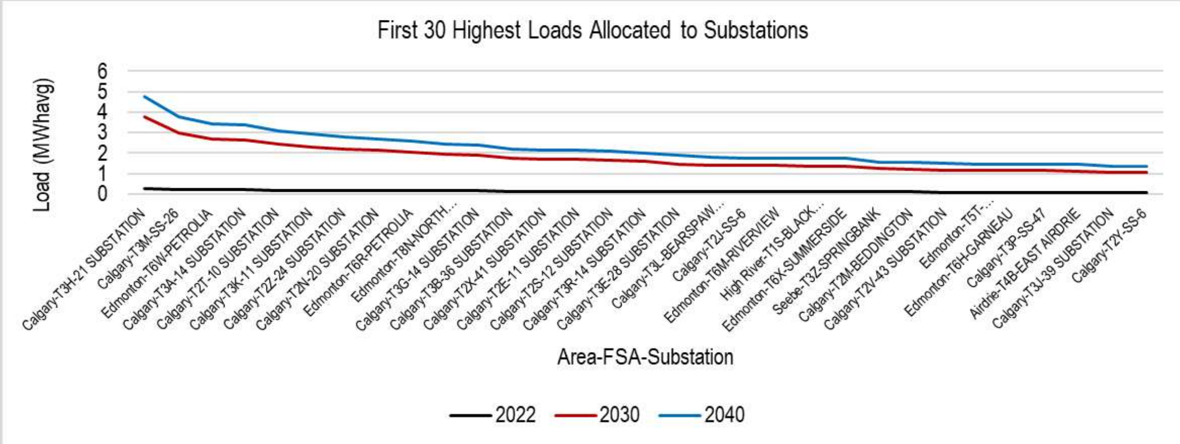


Geographical Allocation : Blended Scenario

Summary stats

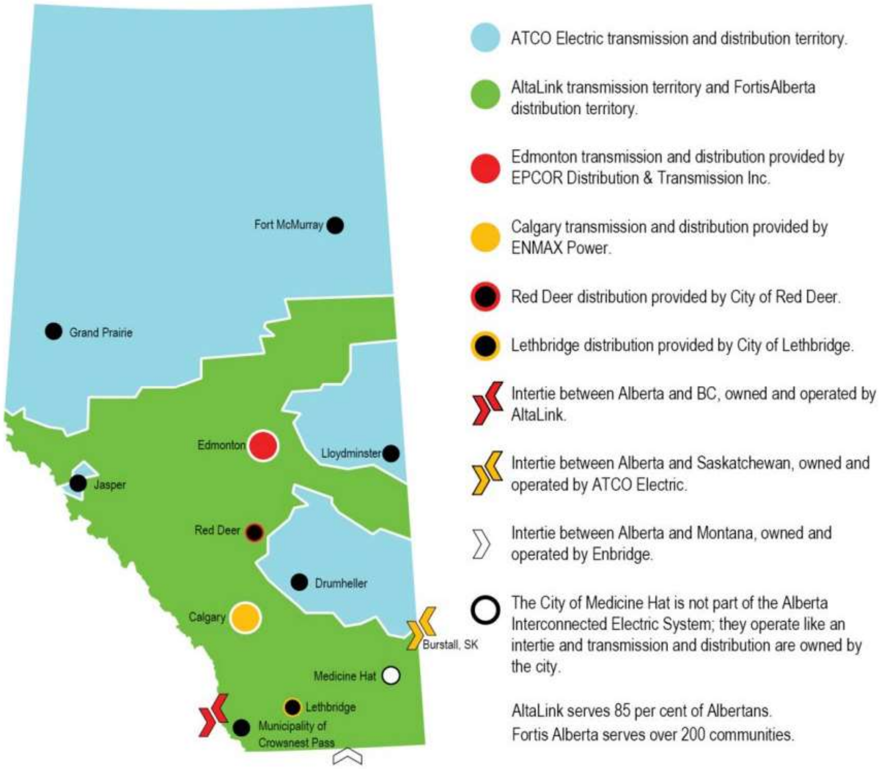
- First 5 highest loads (MWhavg) results from FSA allocation to substations:

Area-FSA-Substation	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary-T3H-21 SUBSTATION	0.28	3.75	4.78
Calgary-T3M-SS-26	0.22	2.96	3.77
Edmonton-T6W-PETROLIA	0.20	2.67	3.41
Calgary-T3A-14 SUBSTATION	0.20	2.65	3.38
Calgary-T2T-10 SUBSTATION	0.18	2.42	3.09



THE FUTURE OF ELECTRICITY

DFO Allocation



Source: Electricity Distribution [Fact Sheet], Government of Alberta

Represent EV forecast based on DFO territories:

- Scenario 1 - Allocate EV charging stations to substations.
- Scenario 2 - Allocate center of FSA to substations.

DFO Allocation- Scenario 1- EV Stations Allocation

Summary stats

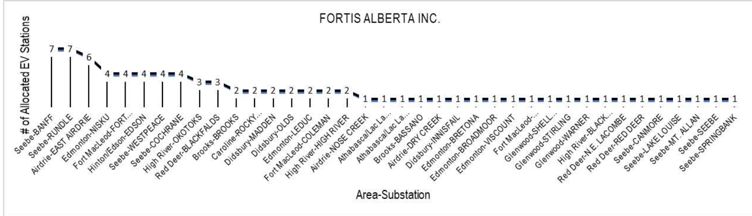
- The highest number of EV charging stations is allocated to:

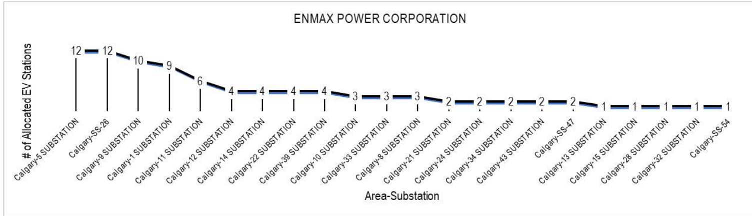
Fortis Alberta Inc. (Area- Substation)	# EV Stations
Seebe-BANFF	7
Seebe-RUNDLE	7

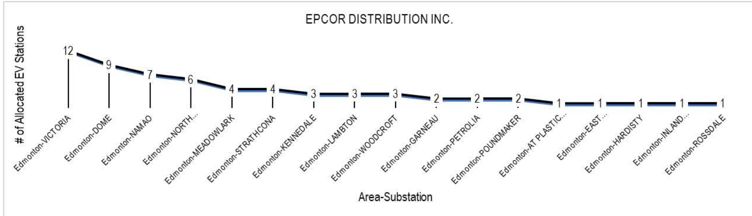
ENMAX Power Corporation (Area-Substation)	# EV Stations
Calgary-5 SUBSTATION	12
Calgary-SS-26	12

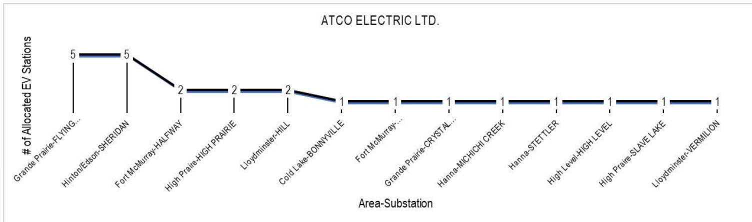
EPCOR Distribution Inc. (Area- Substation)	# EV Stations
Edmonton-VICTORIA	12

ATCO Electric Ltd. (Area-Substation)	# EV Stations
Grande Prairie-FLYING SHOT LAKE	5
Hinton/Edson-SHERIDAN	5









DFO Allocation: Scenario 1- EV Stations Allocation

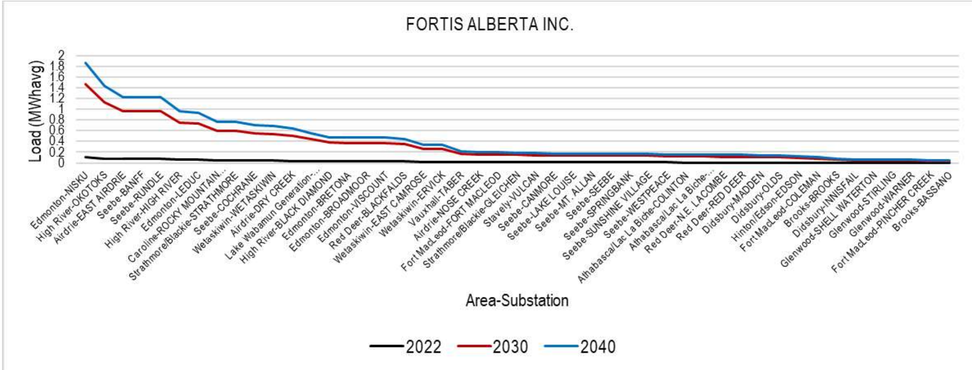
aeso

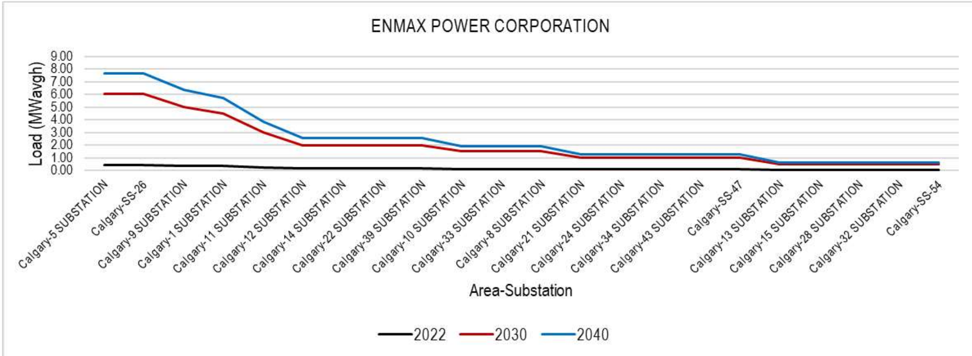
Summary stats

- First 3 highest load (MWhavg) results from Scenario 1:

Fortis Alberta Inc. (Area- Substation)	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Edmonton-NISKU	0.11	1.47	1.87
High River-OKOTOKS	0.08	1.13	1.44
Airdrie-EAST AIRDRIE	0.07	0.96	1.23

Enmax Power Corporation (Area- Substation)	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary-5 SUBSTATION	0.45	6.02	7.67
Calgary-SS-26	0.45	6.02	7.67
Calgary-9 SUBSTATION	0.38	5.02	6.39





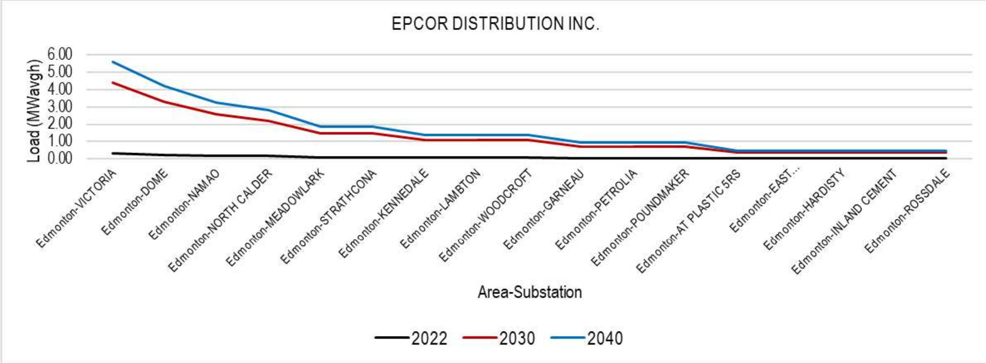
DFO Allocation: Scenario 1- EV Stations Allocation

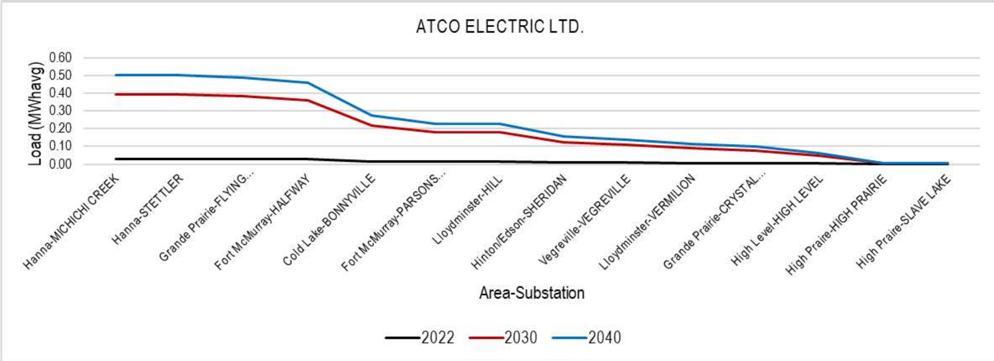
Summary stats

- First 3 highest load (MWavg) results from Scenario 1:

EPCOR Distribution Inc. (Area- Substation)	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Edmonton-VICTORIA	0.33	4.40	5.61
Edmonton-DOME	0.25	3.30	4.21
Edmonton-NAMAO	0.19	2.57	3.27

ATCO Electric Ltd. (Area-Substation)	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Hanna-MICHICHI CREEK	0.03	0.39	0.50
Hanna-STETTLER	0.03	0.39	0.50
Grande Prairie-FLYING SHOT LAKE	0.03	0.38	0.49





THE FUTURE OF ELECTRICITY

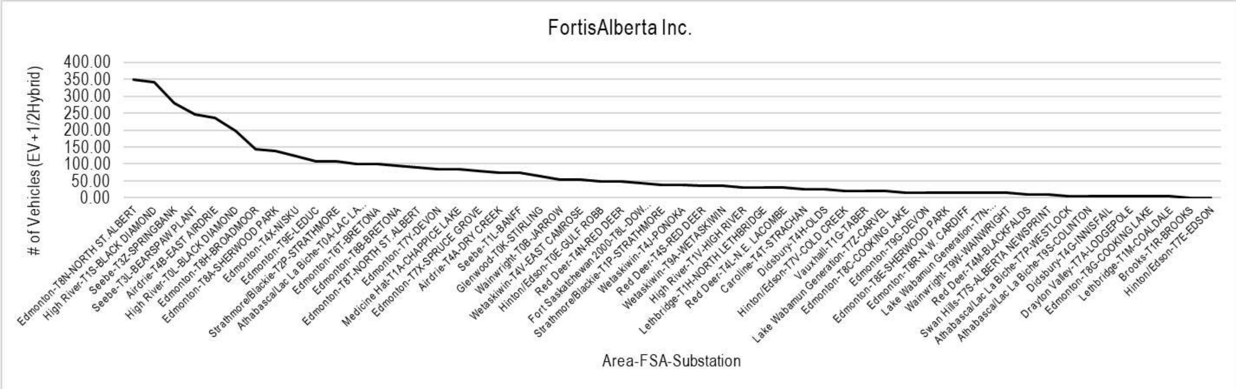
DFO Allocation: Scenario 2- FSA Allocation

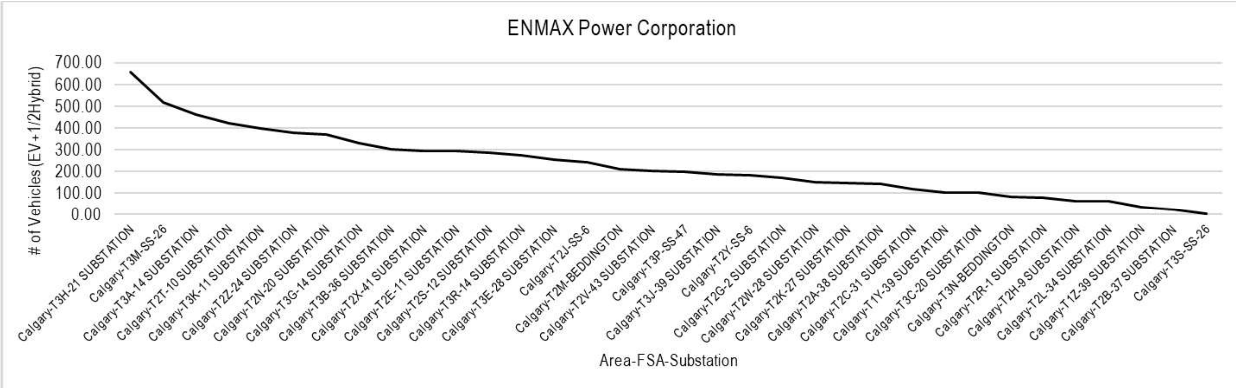
Summary stats

- First 3 highest numbers of vehicles (EV+1/2Hybrid):

Fortis Alberta Inc. (Area- FSA-Substation)	# of Vehicles (EV+1/2Hybrid)
Edmonton-T8N-NORTH ST.ALBERT	350
High River-T1S-BLACK DIAMOND	340
Seebe-T3Z-SPRINGBANK	281

ENMAX Power Corporation (Area-FSA-Substation)	# of Vehicles (EV+1/2Hybrid)
Calgary-T3H-21 SUBSTATION	656
Calgary-T3M-SS-26	518
Calgary-T3A-14 SUBSTATION	464





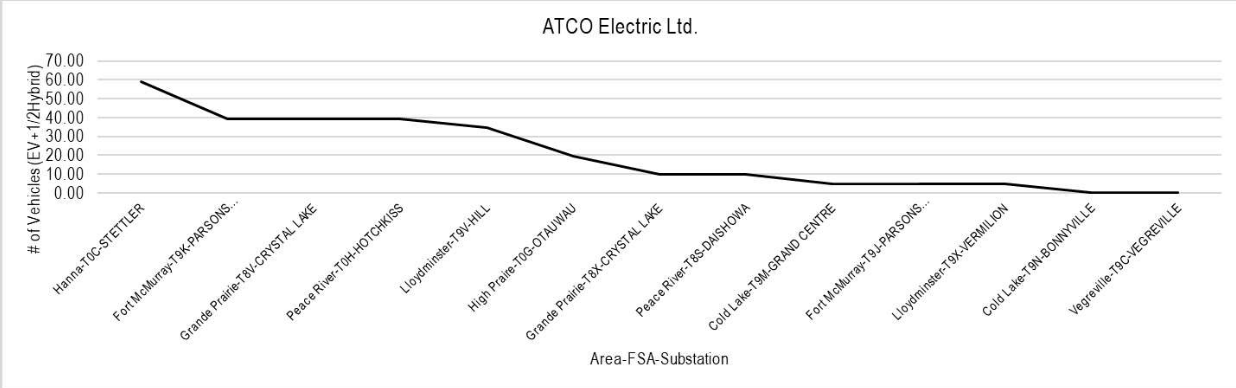
DFO Allocation: Scenario 2- FSA Allocation

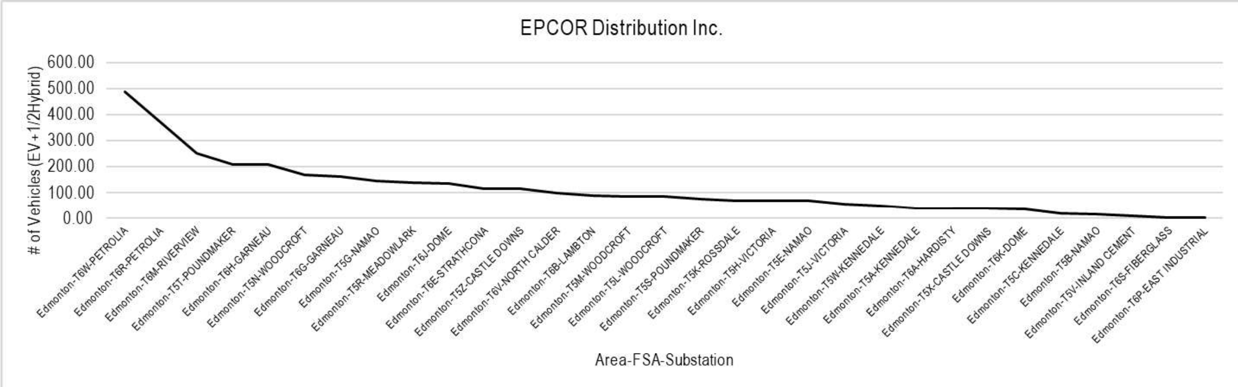
Summary stats

- First 3 highest numbers of vehicles (EV+1/2Hybrid):

ATCO Electric Ltd. (Area-FSA-Substation)	# of Vehicles (EV+1/2Hybrid)
Hanna-T0C-STETTLER	59
Fort McMurray-T9K-PARSONS CREEK	39
Grande Prairie-T8V-CRYSTAL LAKE	39

EPCOR Distribution Inc. (Area- FSA-Substation)	# of Vehicles (EV+1/2Hybrid)
Edmonton-T6W-PETROLIA	488
Edmonton-T6R-PETROLIA	370
Edmonton-T6M-RIVERVIEW	252



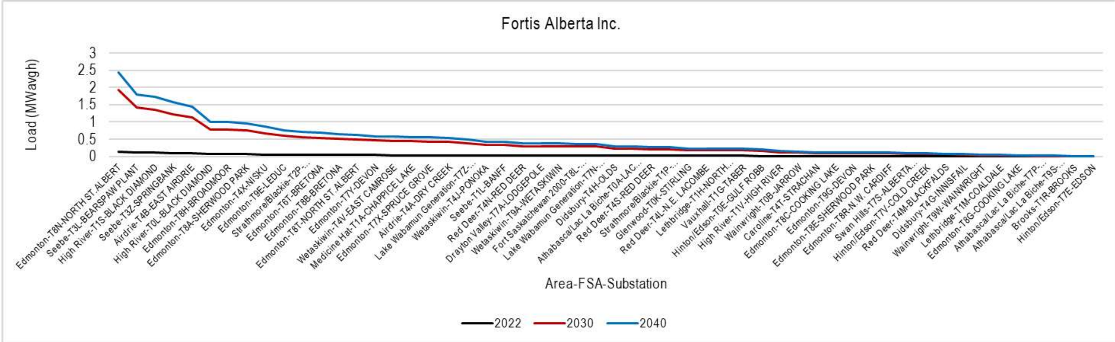


DFO Allocation: Scenario 2- FSA Allocation

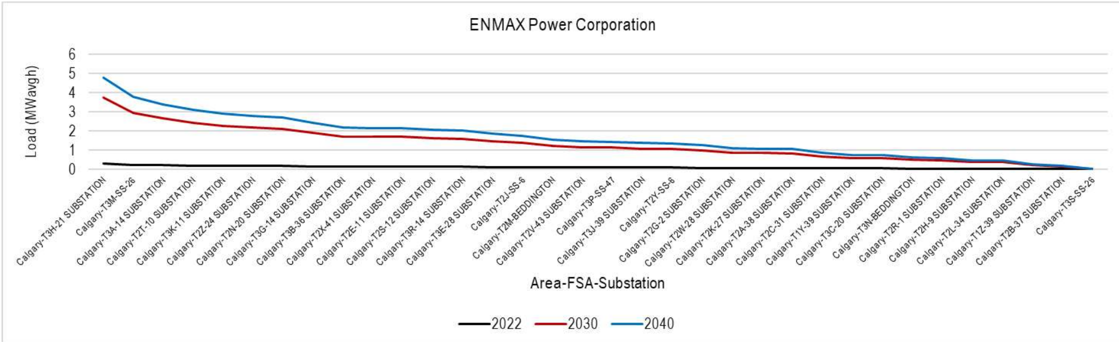
Summary stats

- First 3 highest load (MWhavg) results from Scenario 2:

Fortis Alberta Inc. (Area- FSA-Substation)	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Edmonton-T8N-NORTH ST.ALBERT	0.14	1.92	2.44
Seebe-T3L-BEARSPAW PLANT	0.11	1.41	1.80
High River-T1S-BLACK DIAMOND	0.10	1.36	1.73



ENMAX Power Corporation (Area-FSA-Substation)	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary-T3H-21 SUBSTATION	0.28	3.75	4.78
Calgary-T3M-SS-26	0.22	2.96	3.77
Calgary-T3A-14 SUBSTATION	0.20	2.65	3.38



THE FUTURE OF ELECTRICITY

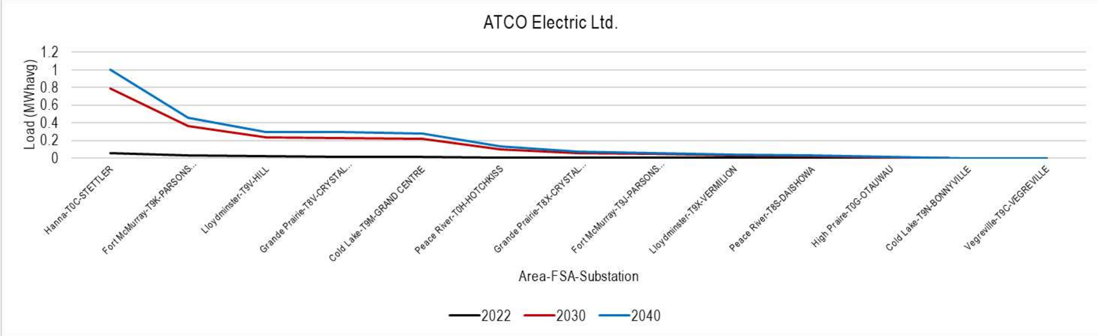
DFO Allocation: Scenario 2- FSA Allocation

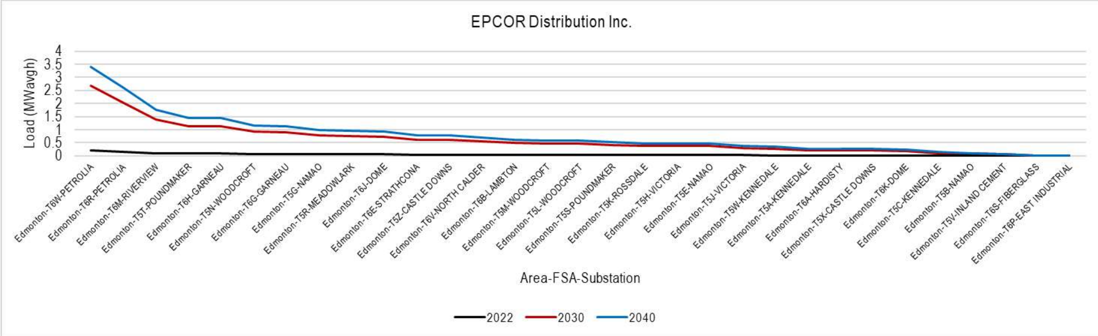
Summary stats

- First 3 highest load (MWavg) results from Scenario 2:

ATCO Electric Ltd. (Area-FSA-Substation)	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Hanna-T0C-STETTLER	0.06	0.79	1.00
Fort McMurray-T9K-PARSONS CREEK	0.03	0.36	0.46
Lloydminster-T9V-HILL	0.02	0.23	0.30

EPCOR Distribution Inc. (Area- FSA-Substation)	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Edmonton-T6W-PETROLIA	0.20	2.67	3.41
Edmonton-T6R-PETROLIA	0.15	2.03	2.58
Edmonton-T6M-RIVERVIEW	0.10	1.38	1.75





Summary

- Forecast is based on average of flat growth (5 years) and economic growth.
- ~3,500 EVs and ~27,200 Hybrid are registered in 2021, according to the data provided by the Alberta Ministry of Transportation.
- The highest number of EV allocations belongs to Calgary and Edmonton with 48.70% and 30.69%, respectively.
- Number of EVs in 2040 is ~17 times higher than in 2022.
- From 2022 to 2040, loads resulting from EVs, will increase from 3.5 MWhavg to 60 MWhavg and 2 MWhavg to 38 MWhavg in Calgary and Edmonton, respectively.
- Three scenarios are considered for the allocation to substations: 1) EV charging stations allocation, 2) FSA allocations, and 3) blended scenario.
- The highest number of charging EV stations (#12) is allocated to Calgary-5-SUBSTATION and increased from 0.47 MWhavg to 7.67 MWhavg.
- The highest numbers of EV+1/2 Hybrid in scenario 2 (FSA allocation) is allocated to Calgary-T3H-21 SUBSTATION (# 651).
- Highest load in scenario 2 (FSA allocation) is allocated to Calgary-T3H-21 SUBSTATION, and from 2022 to 2040 it will increase from 0.28 MWhavg to 4.78 MWhavg.
- The highest number of charging EV stations and loads allocation is related to ENMAX Power Corporation.

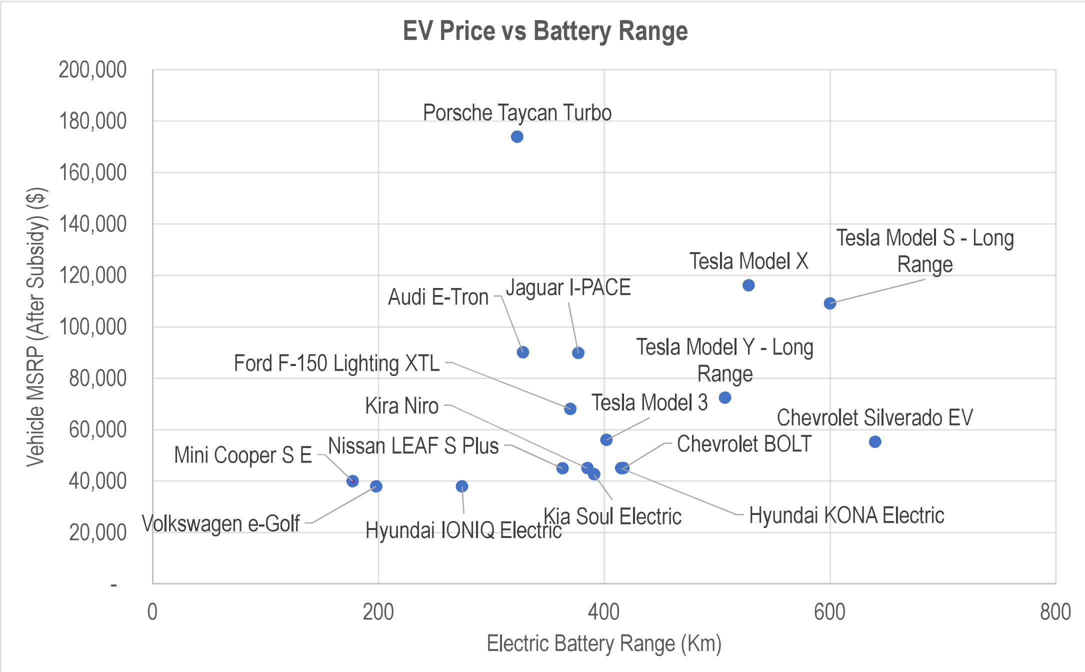
Thank you

EV Projections: Simplified Economic Analysis

Comparative analysis approach

- EV classification is based on range and paired up with a most-likely substitute internal combustion vehicle

Battery Electric Vehicle	Internal Combustion Alternative
Short-range BEV (< 200 km)	
Mini Cooper S E	Mini Cooper 3 door
Volkswagen e-Golf	Volkswagen Golf Comfortline
Mid-range BEV (200-400 km) Under $50,000	
Hyundai IONIQ Electric	Hyundai Elantra Essential
Kira Niro	Kia Seltos
Hyundai KONA Electric	Hyundai KONA Essential
Nissan LEAF S Plus	Nissan Sentra S
Kia Soul Electric	Kia Soul
Chevrolet BOLT	Chevrolet Trax
Mid-range BEV (200-400 km) Over $50,000	
Ford F-150 Lighting XTL	Ford F-150 XTL
Tesla Model 3	Toyota Camry SE
Jaguar I-PACE	Jaguar XE
Audi E-Tron	Audi Q5
Porsche Taycan Turbo	Porsche Panamera Turbo
Long-range BEV (400+ km)	
Tesla Model Y - Long Range	Mazda CX9 GS
Tesla Model X	Toyota Highlander LE AWD
Tesla Model S - Long Range	Toyota Avalon XSE
Chevrolet Silverado EV	Chevrolet Silverado LD



Vehicle specifications

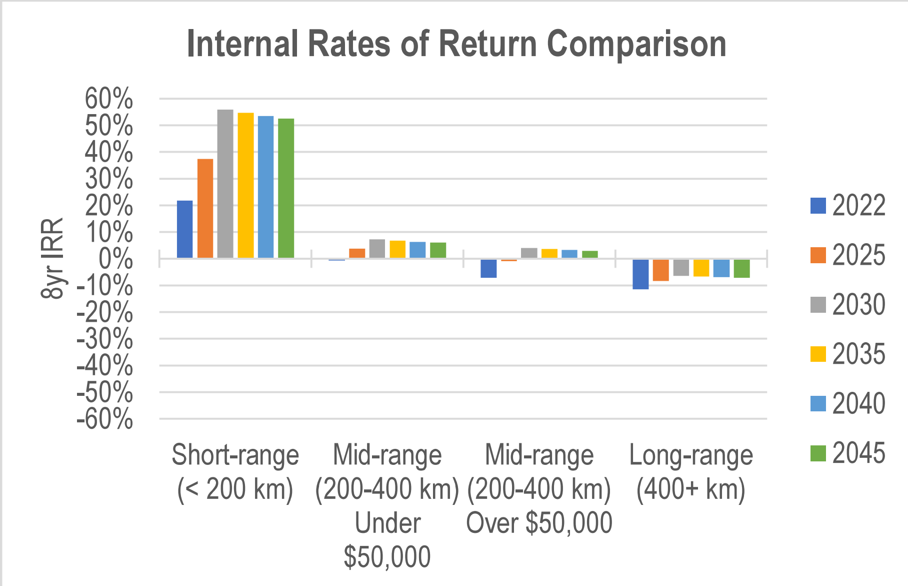
- Total cost of ownership depends on initial purchase price (minus applicable subsidies), fuel charges and maintenance costs
  - Initial purchase expense is a barrier to adoption
  - Fuel cost differential is a key advantage to EV ownership

Category	BEV Purchase Cost ($)	ICV Purchase Cost ($)	Purchase Cost Differential ($)	BEV Efficiency (kWh/100km)	ICV Efficiency (Liters/100km)
Short-range (< 200 km)	32,000-35,000	24,000-28,000	7,980	18.1-18.4	7.5
Mid-range (200-400 km) Under $50,000	33,000-40,000	17,000-23,000	17,833	14.0-17.1	6.8-9.1
Mid-range (200-400 km) Over $50,000	51,000-174,000	26,000-180,000	25,191	18.7-29.0	7.4-11.8
Long-range (400+ km)	55,000-117,000	40,000-46,000	45,223	14.8-31.3	9.4-18.5

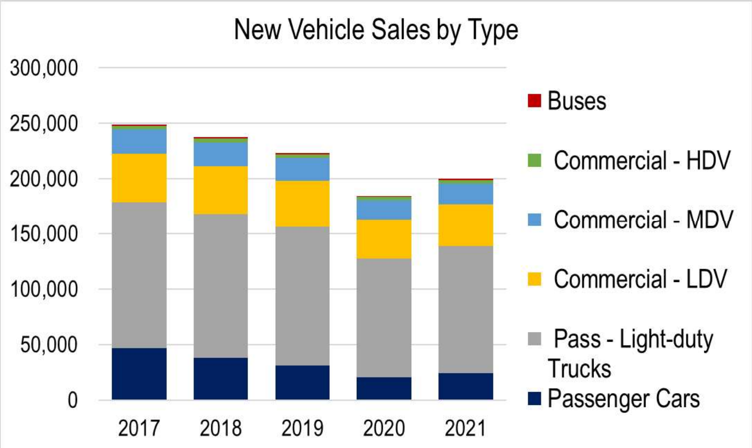
Notes: BEV purchase cost do not include home charger device and installation costs. BEV purchase estimates are net of federal incentives for zero-emission vehicles where applicable (in this case, those in the short- and . Fuel efficiency estimates are manufacturer's specifications and may not factor Alberta-specific weather conditions. Some estimates are based on pre-production rollout announcements which could change.

Cost differential analysis

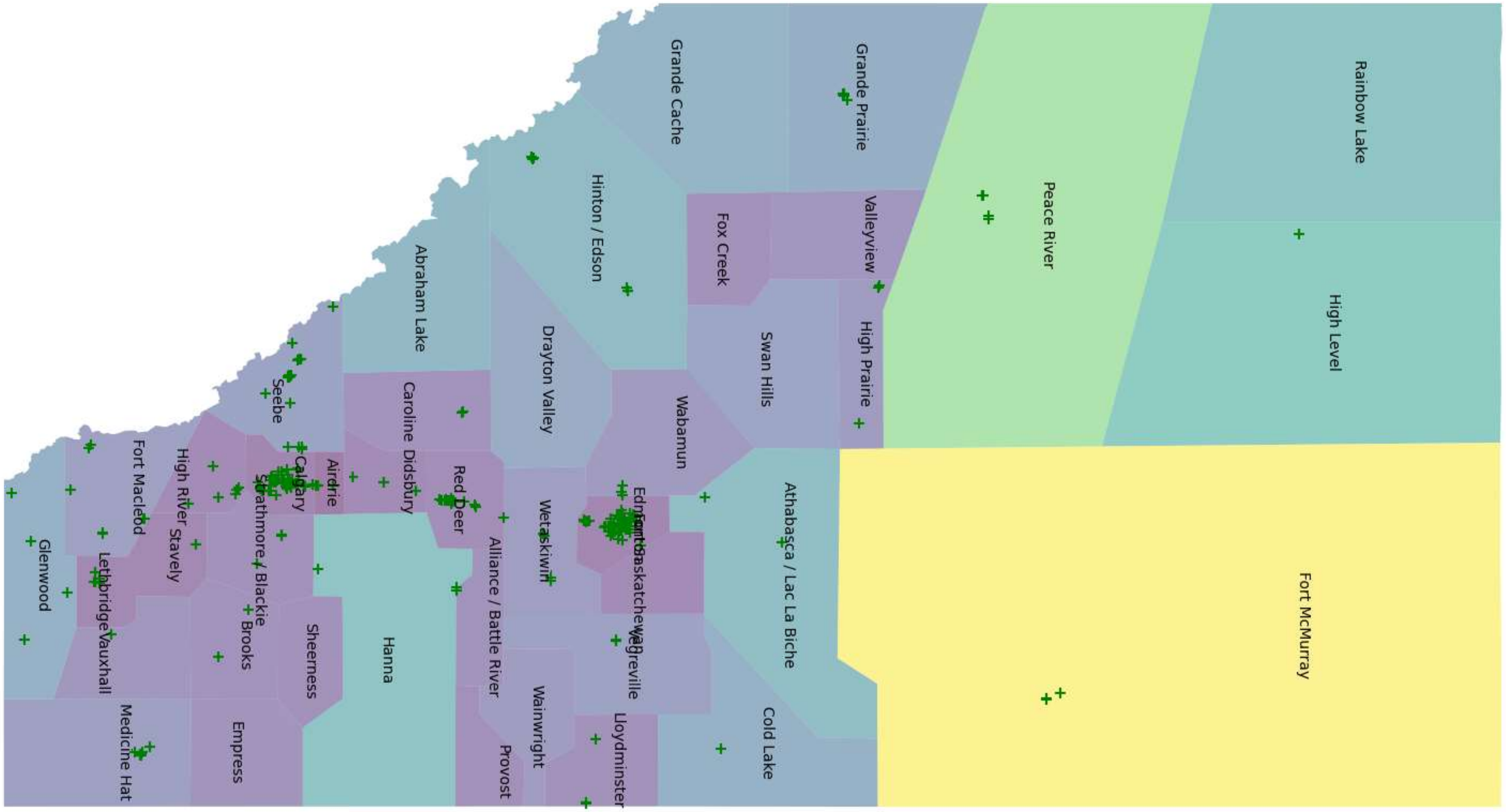
- The differential in vehicle cost is assessed by different purchase years to assess economic viability of opting for EVs over IC vehicle at different periods
  - Positive returns (IRR) supports EV ownership over an ICV substitute
- Analysis focuses on “typical” driver behaviour
  - Assume a daily driving profile of 50km (20,000 km/yr) and an 8-year financial life
- Results suggests short- to mid-range BEV are most economic-attractive options



THE FUTURE OF ELECTRICITY

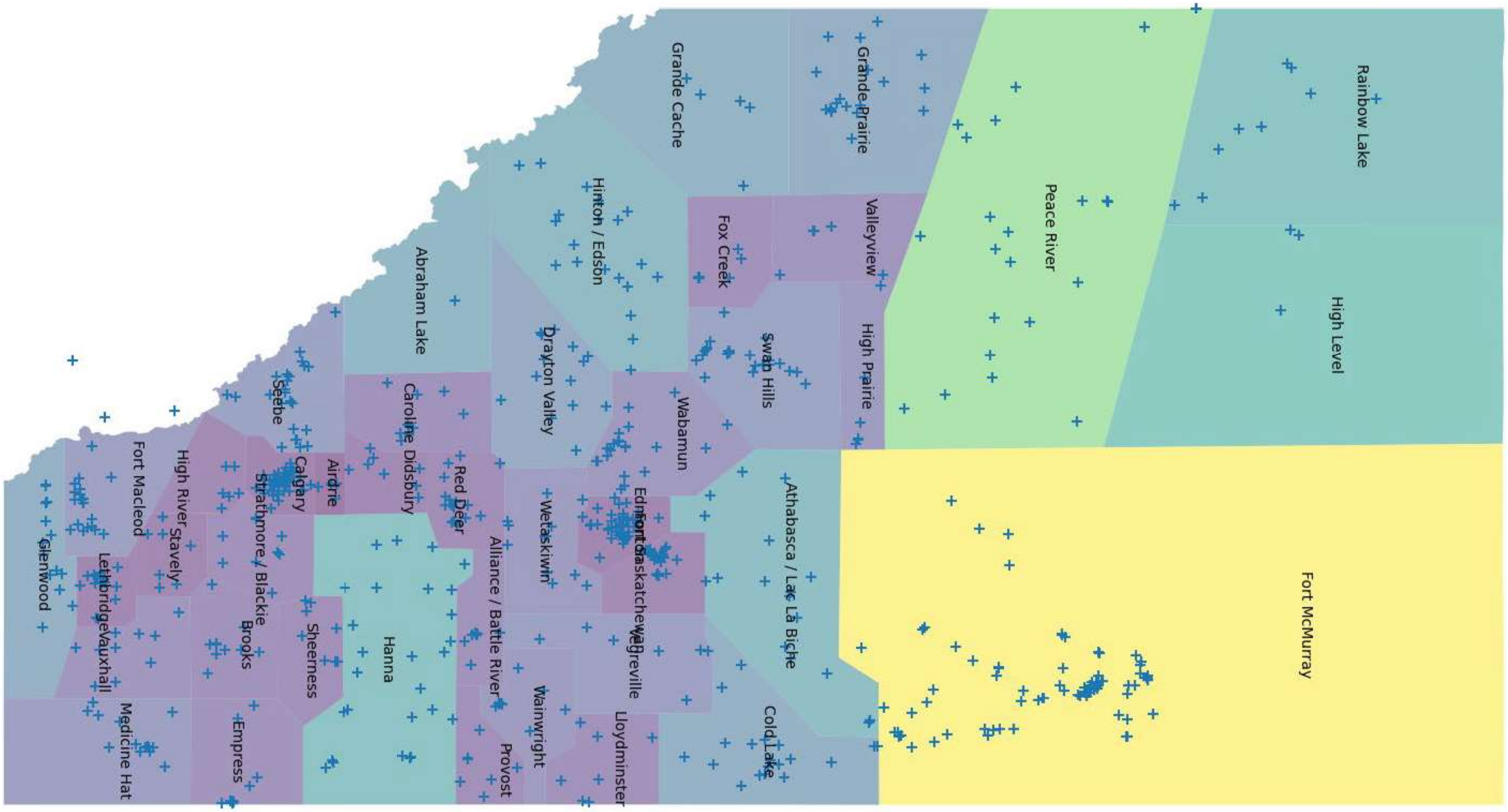

New Vehicle Sales by Type
300,000
250,000
200,000
150,000
100,000
50,000
0
2017
2018
2019
2020
2021
Buses
Commercial - HDV
Commercial - MDV
Commercial - LDV
Pass - Light-duty Trucks
Passenger Cars

Distribution of EV Stations on AESO Planning Area

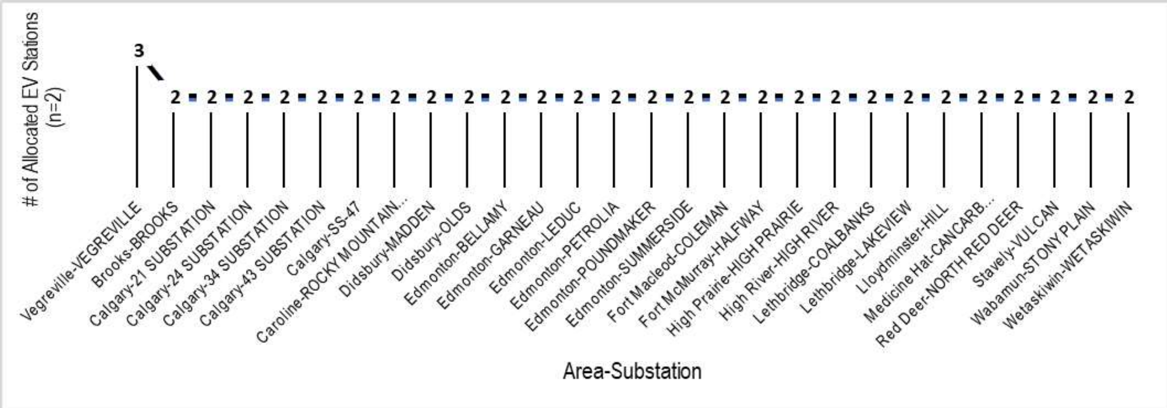


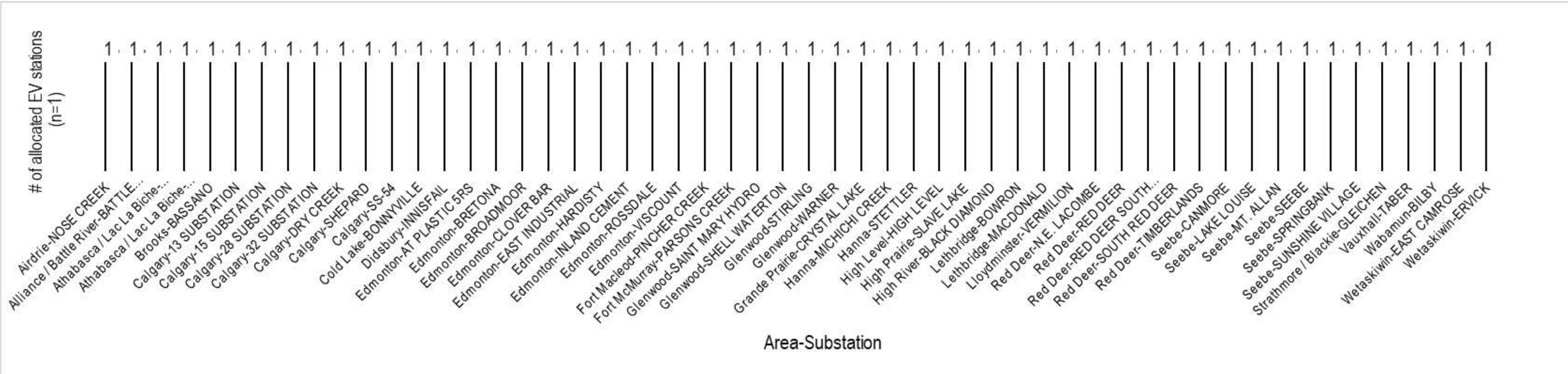
THE FUTURE OF ELECTRICITY

Distribution of Substations on AESO Planning Area

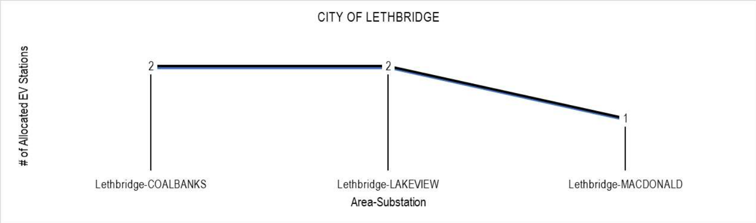


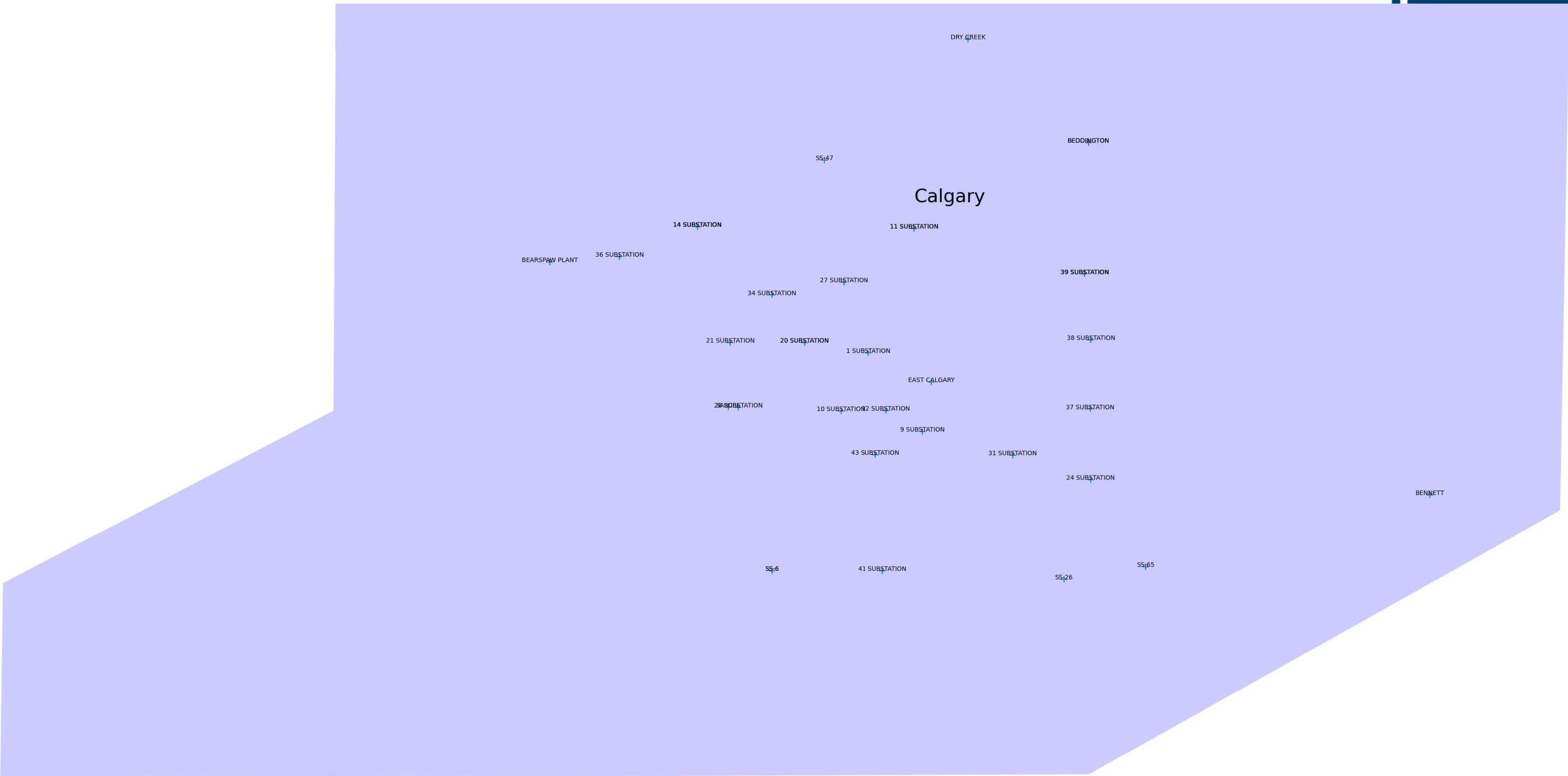
THE FUTURE OF ELECTRICITY



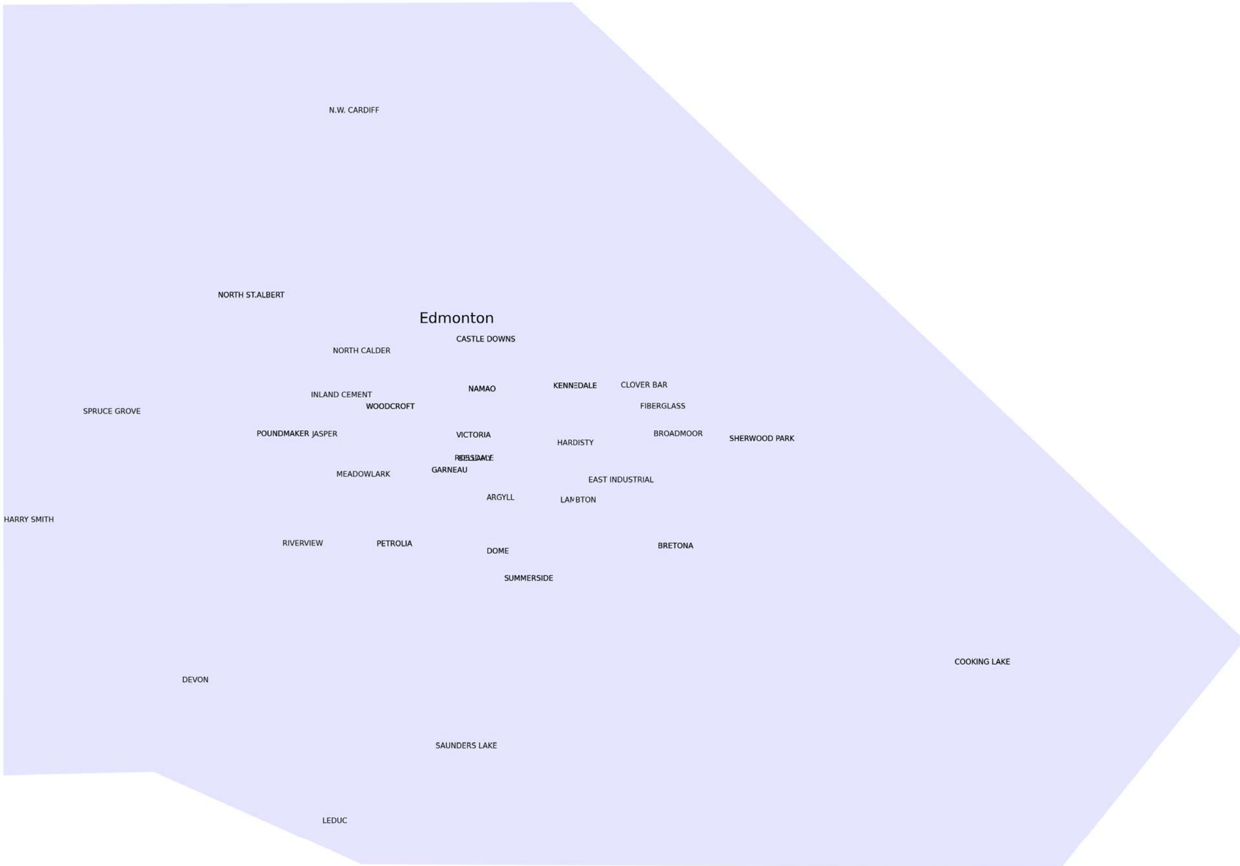


THE FUTURE OF ELECTRICITY


CITY OF LETHBRIDGE
# of Allocated EV Stations
2
2
1
Lethbridge-COALBANKS
Lethbridge-LAKEVIEW
Lethbridge-MACDONALD
Area-Substation



THE FUTURE OF ELECTRICITY


N.W. CARDIFF
NORTH ST.ALBERT
Edmonton
CASTLE DOWNS
NORTH CALDER
INLAND CEMENT
WOODCROFT
NAMAO
KENNEDALE
CLOVER BAR
FIBERGLASS
SPRUCE GROVE
POUNDMAKER
JASPER
VICTORIA
HARDISTY
BROADMOOR
SHERWOOD PARK
GARNEAU
MEADOWLARK
EAST INDUSTRIAL
ARGYLL
LAMBTON
HARRY SMITH
RIVERVIEW
PETROLIA
DOME
BRETONA
SUMMERSIDE
COOKING LAKE
DEVON
SAUNDERS LAKE
LEDUC

Public Charging Stations

- Alberta data from NRCan's ZEV station finder* - *static data only, no utilization*
  - 250 existing + 9 planned (data downloaded in Dec 2021)
  - 66 municipalities: ~50% in Calgary, Edmonton, Med Hat, Red Deer
    - *Although urban centers dominate, there is no geographic/regional/DFO concentration*
- Charging stations can have multiple EVSE ports (akin to gas fuel pumps) which in turn can have multiple connectors (akin to hoses at a pump)
  - 601 EVSE ports
    - 5 Level 1 (Slow AC), 418 Level 2 (Fast AC), 178 Level 3 (Fastest DC)
    - Connector types**:
      - 5 NEMA250 (Level 1-all EVs)
      - ~240 J1772 (Level 2-all EVs)
      - ~120 CHAdeMO/SAE combo (Level 3-all EVs)
      - 235 Tesla-exclusive connectors (Level 2 and 3)

    More than half of EVSE ports are considered super-charger – with ratings 50+ kW
  - ~500 of EVSE ports are associated with at least 1 of 8 different networks (i.e., Tesla, PetroCan, SWTCH); ~100 are non-networked (i.e., set-up by facility owner)
  - Most EVSE ports are sited at hotels, shopping and retail locations, car dealers, and office buildings and are free to use (no fee for charging) – *expected to lead to segmented charging profiles*

* Data can be downloaded from https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles/zero-emission-vehicle-charging-stations#/find/nearest
** For a plain explanation of connector type standards and usability, see https://chargehub.com/en/electric-car-charging-guide.html

Connector Types and Power Ratings

ae

- Connectors can vary between current type and power ratings

AC connector type	Typical Power Ratings
Type 1	3.7kW 7kW
Type 2	3.7kW 7kW 22kW (three-phase)*

DC connector type	Typical Power Ratings
CHAdeMO	50kW 100kW
Combined Charging System (CCS)	50kW 150kW** 350kW***
Type 2	150kW 250kW****

* Three-phase power is relatively rare. There is almost no three-phase in homes, but there is some in a few larger commercial buildings. Most public stations are single-phase 7kW devices.

** 150kW CCS rapid chargers will become very common, but most are just 50kW.
*** 350kW CCS is not yet common place.
**** 250kW Tesla Superchargers are starting to be rolled out.

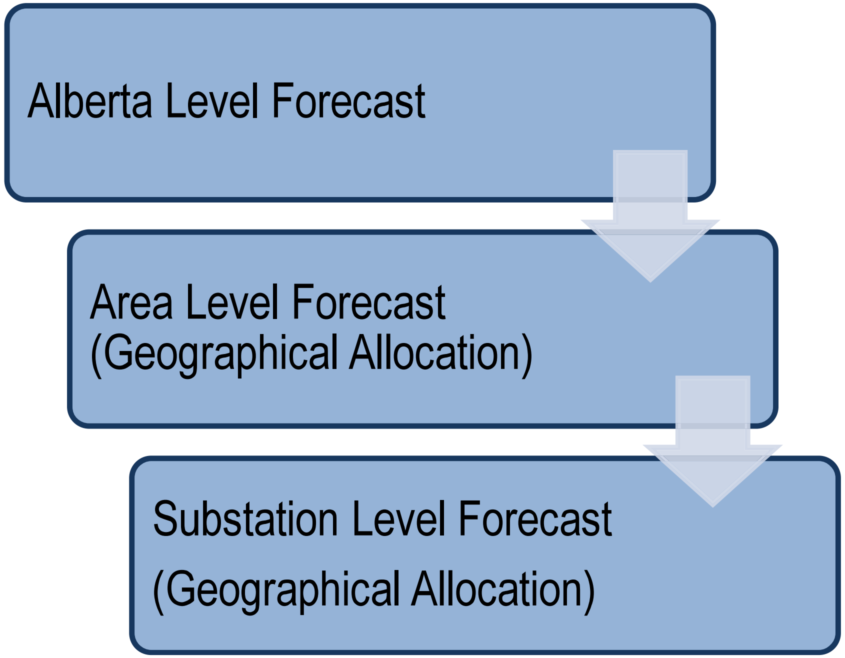
Visualizations and notes are from UK-based charging station provider Pod Point: https://pod-point.com/guides/driver/ev-connector-types-speed

THE FUTURE OF ELECTRICITY

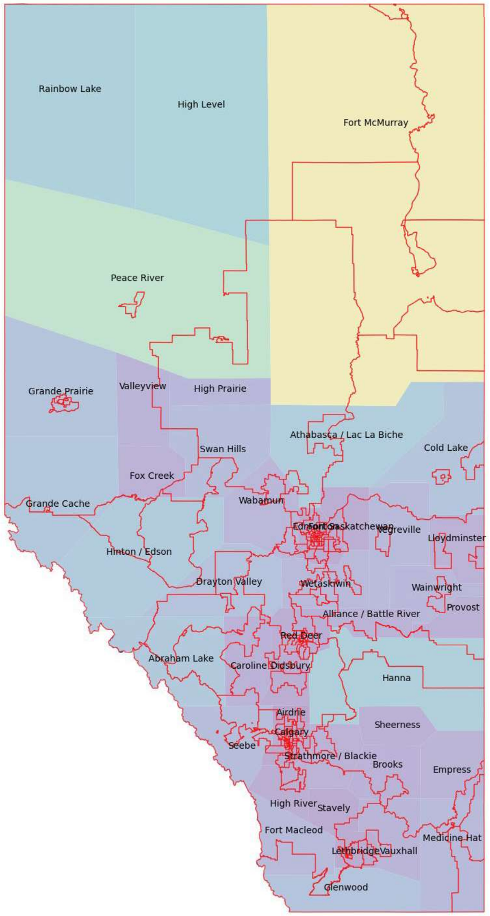
Electric Vehicle Modeling and Projections

January 2023

EVs Forecast



Geographical Allocation : Area

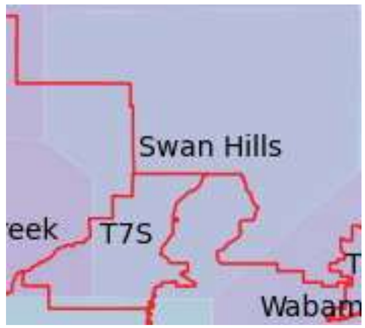


Inputs:

- Total # and load of EVs* for current and forecasting years in Alberta.
- Current # of EVs in different Forward Sortation Areas (FSAs).

Steps:

- Map Forward Sortation Area (FSA) to the AESO planning area.
- Allocate the # of EVs for each FSA to the AESO planning area.
- Obtain the total # of EVs in each area based on aggregating the # of EVs contained therein.
- Forecast EV number and load related to each area for different assumptions and various types of registered vehicles for the next 20 years.

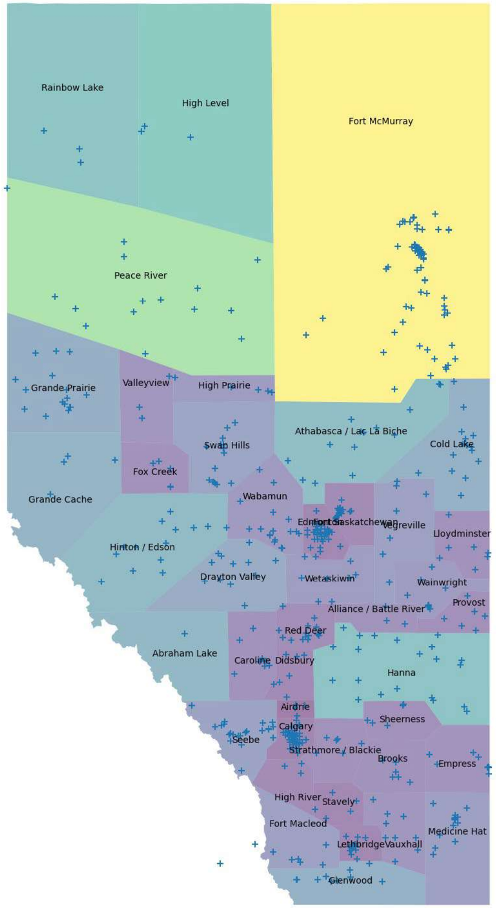


Notes:

- Original data (BEVs) was provided by the Alberta Ministry of Transportation.
- *EVs in this work is battery electric vehicles+ plug in hybrid.
- Total number of the battery electric vehicle until March 2021 is 3,527.
- A few FSA data are missing.

THE FUTURE OF ELECTRICITY

Geographical Allocation : Substations



Scenario 1: Allocate EV charging stations to substations.

- Considerations:
  - The residential charging loads are not considered.
  - There are no information about future EV charging stations' locations.

Scenario 2: Allocate center of FSA to substations.

- Considerations:
  - Assumes car registration addresses are where EVs will be charged going forward
  - EV owners charge their vehicles at home or the closest EV stations.

Scenario 3: Blended scenarios 1 and 2 (preferred).

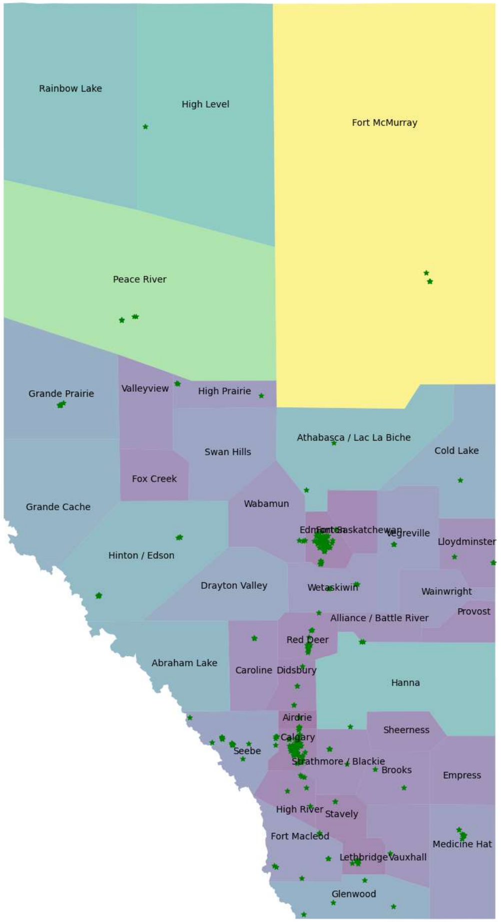
Notes:

- Total number of substations in October 2022 is 716.
- Substations number supplying load less than 3 MW is 92 and excluded from the substations. list; these are mostly service stations (i.e., substations serving generation assets load).
- Substations with no MPIDs connection are excluded from the list of substations.

THE FUTURE OF ELECTRICITY

Geographical Allocation : Substations (Scenario 1- EV stations allocation)

aeso

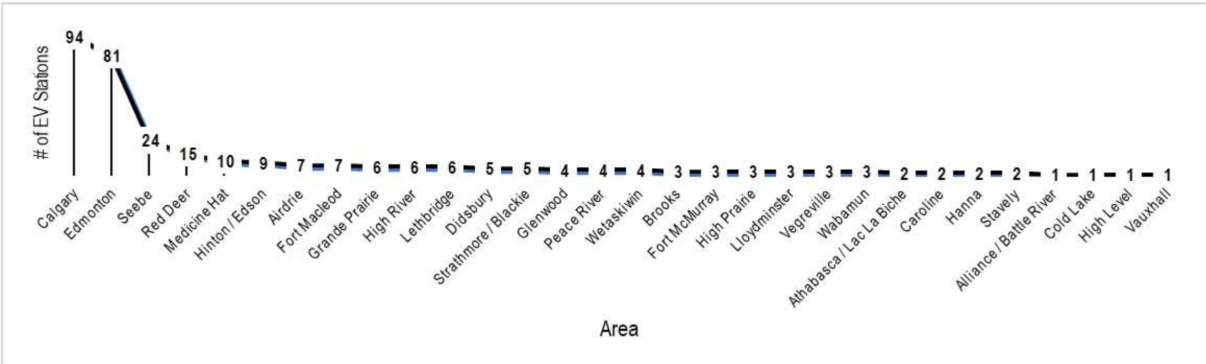


Step(s):

- Calculate the Haversine distance of each EV station with each substation in each area and assign each EV station to the closet substation.

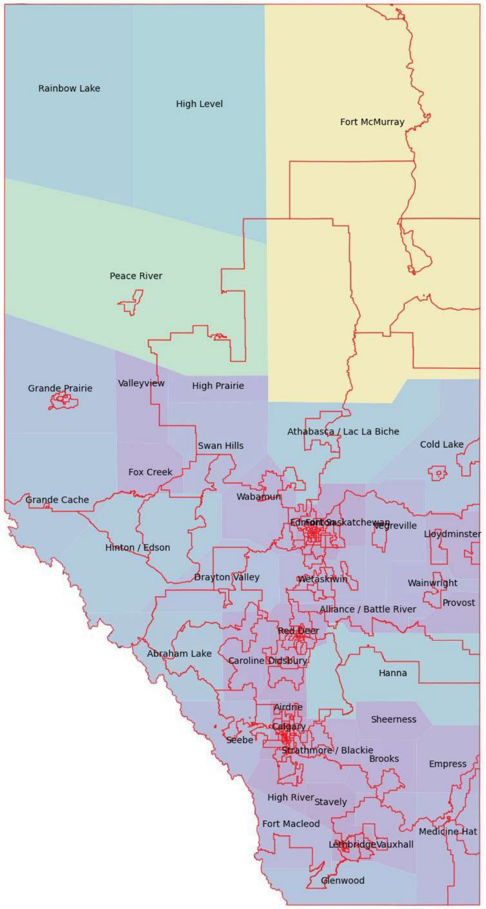
Notes:

- Total number of EV charging stations is 322 in Alberta.
- Assumption: The number of EV stations stays same for the future.



THE FUTURE OF ELECTRICITY

Geographical Allocation : Scenario 2- FSA Allocation



Step(s):

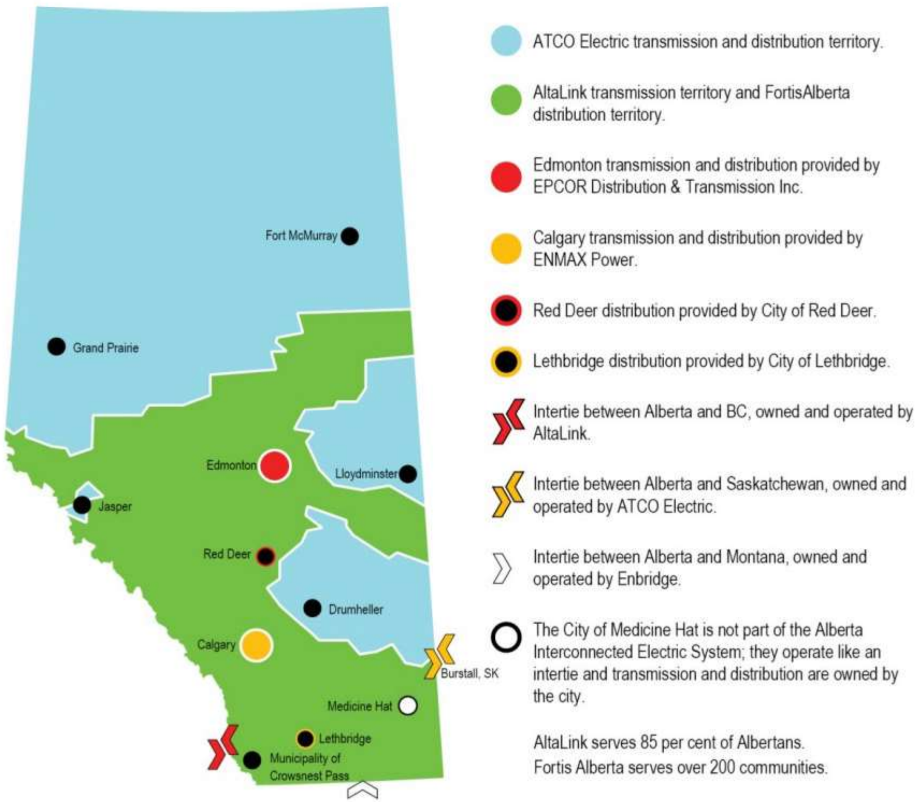
- Calculate the Haversine distance between center of each Polygon/multi-polygon and substations and assign each forward sortation area (FSA) to a substation.

Notes:

- Total number of FSA is 154.

THE FUTURE OF ELECTRICITY

DFO Segmentation



Source: Electricity Distribution [Fact Sheet], Government of Alberta

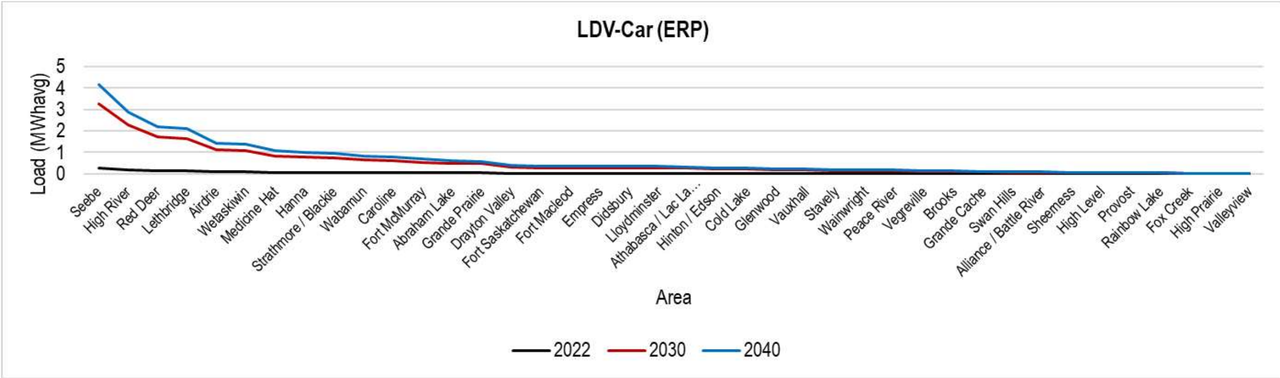
THE FUTURE OF ELECTRICITY

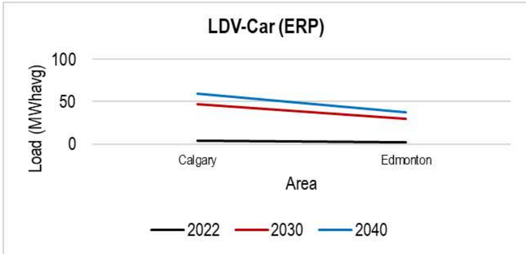
LDV-Car Forecast by Area

Summary stats

- Load (MWhavg) results from area forecast:

Area	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary	3.5	47	60
Edmonton	2	30	38
Seebe	0.3	3	4





Geographical Allocation : Scenario 1- EV Stations Allocation

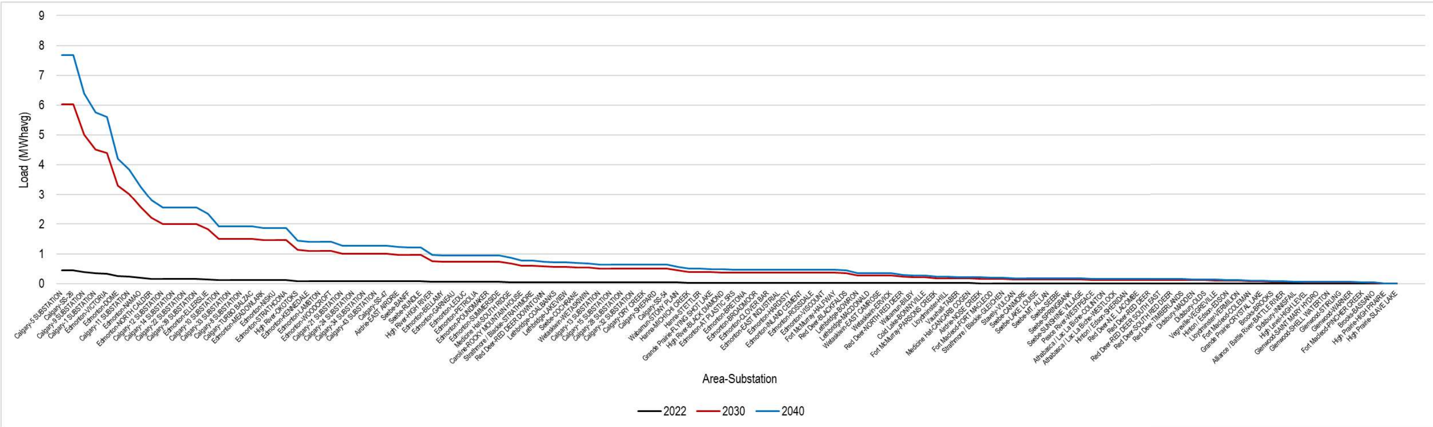
aeso

Summary stats

- Load results from EV stations in 2040 is ~17 times higher than 2022.

- First 3 highest load (MWhavg) results from Scenario 1:

Area-Substation	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary-5 SUBSTATION	0.45	6.02	7.67
Calgary-SS-26	0.45	6.02	7.67
Calgary-9 SUBSTATION	0.38	5.02	6.39

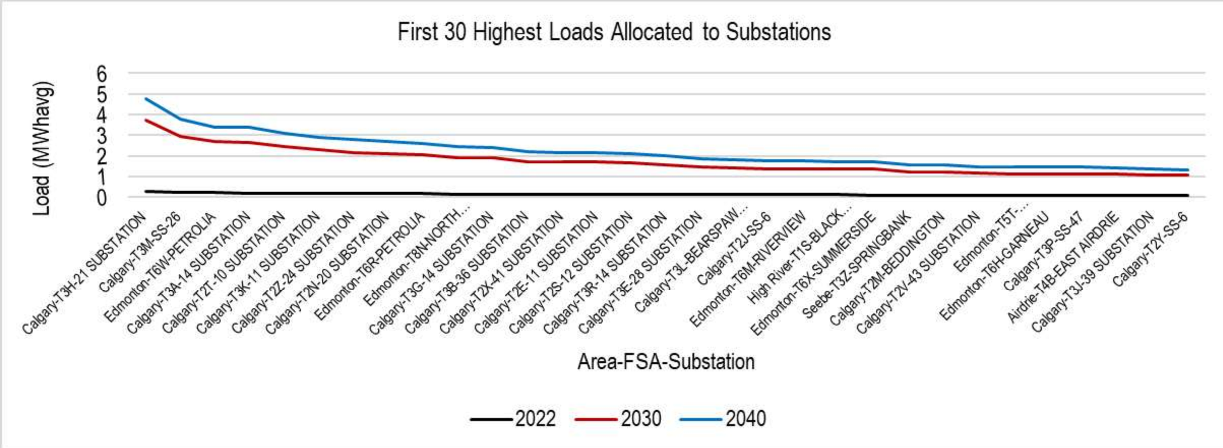


Geographical Allocation : Scenario 2- FSA Allocation

Summary stats

- First 5 highest loads (MWhavg) results from vehicles:

Area-FSA-Substation	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary-T3H-21 SUBSTATION	0.28	3.75	4.78
Calgary-T3M-SS-26	0.22	2.96	3.77
Edmonton-T6W-PETROLIA	0.20	2.67	3.41
Calgary-T3A-14 SUBSTATION	0.20	2.65	3.38
Calgary-T2T-10 SUBSTATION	0.18	2.42	3.09

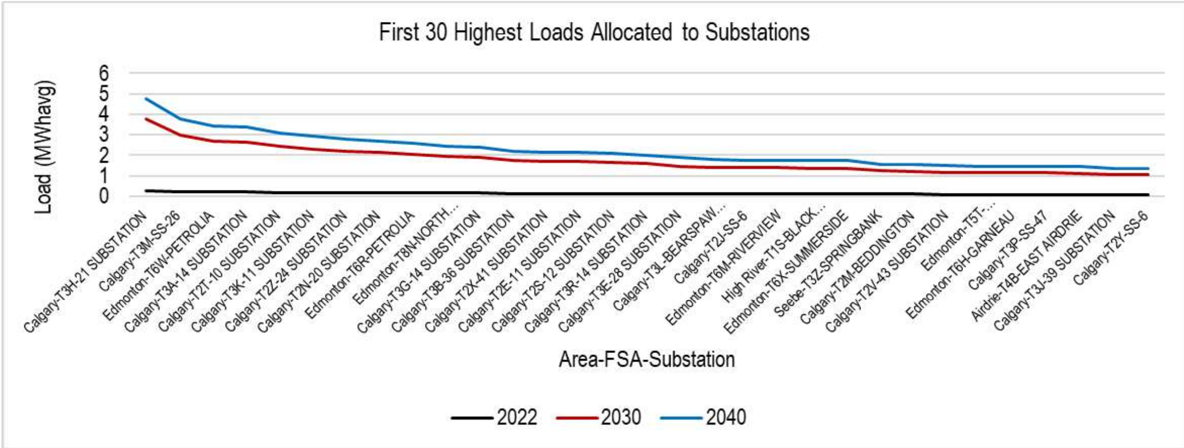


Geographical Allocation : Blended Scenario

Summary stats

- First 5 highest loads (MWhavg) results from FSA allocation to substations:

Area-FSA-Substation	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary-T3H-21 SUBSTATION	0.28	3.75	4.78
Calgary-T3M-SS-26	0.22	2.96	3.77
Edmonton-T6W-PETROLIA	0.20	2.67	3.41
Calgary-T3A-14 SUBSTATION	0.20	2.65	3.38
Calgary-T2T-10 SUBSTATION	0.18	2.42	3.09



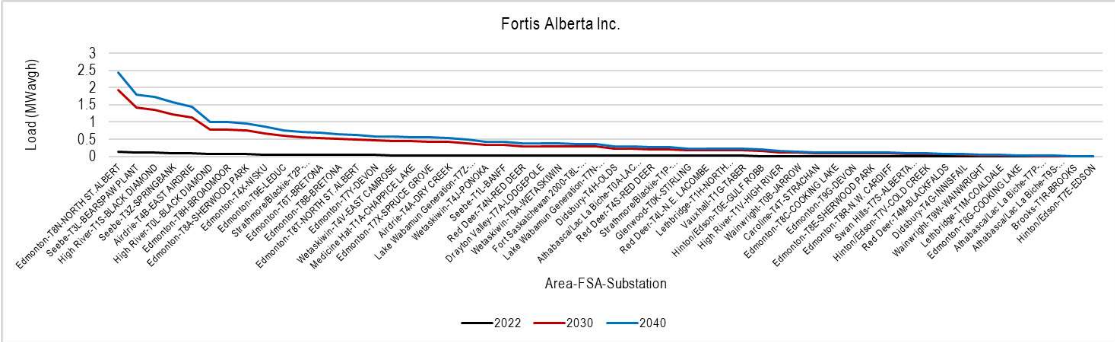
THE FUTURE OF ELECTRICITY

DFO : Preferred Scenario (example)

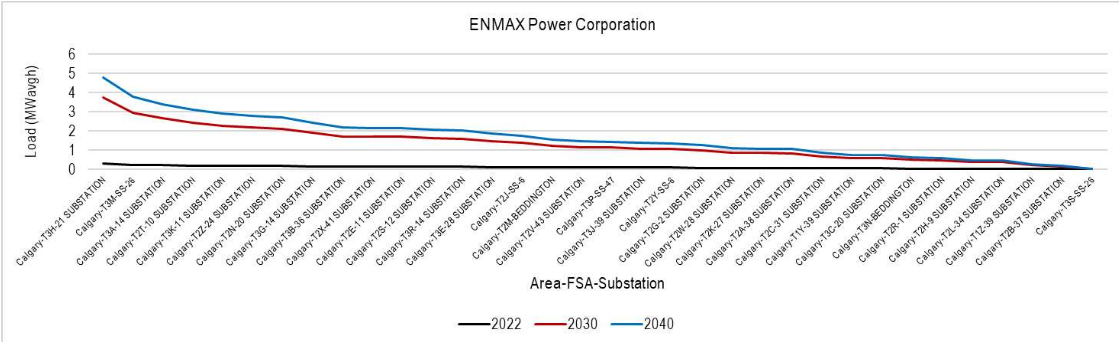
Summary stats

- First 3 highest load (MWhavg) results from Scenario 2:

Fortis Alberta Inc. (Area- FSA-Substation)	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Edmonton-T8N-NORTH ST.ALBERT	0.14	1.92	2.44
Seebe-T3L-BEARSPAW PLANT	0.11	1.41	1.80
High River-T1S-BLACK DIAMOND	0.10	1.36	1.73



ENMAX Power Corporation (Area-FSA-Substation)	2022 (MWhavg)	2030 (MWhavg)	2040 (MWhavg)
Calgary-T3H-21 SUBSTATION	0.28	3.75	4.78
Calgary-T3M-SS-26	0.22	2.96	3.77
Calgary-T3A-14 SUBSTATION	0.20	2.65	3.38



Summary

- Forecast is based on average of flat growth (5 years) and economic growth.
- ~3,500 EVs and ~27,200 Hybrid are registered in 2021, according to the data provided by the Alberta Ministry of Transportation.
- The highest number of EV allocations belongs to Calgary and Edmonton with 48.70% and 30.69%, respectively.
- Number of EVs in 2040 is ~17 times higher than in 2022.
- From 2022 to 2040, loads resulting from EVs, will increase from 3.5 MWhavg to 60 MWhavg and 2 MWhavg to 38 MWhavg in Calgary and Edmonton, respectively.
- Three scenarios are considered for the allocation to substations: 1) EV charging stations allocation, 2) FSA allocations, and 3) blended scenario.
- The highest number of charging EV stations (#12) is allocated to Calgary-5-SUBSTATION and increased from 0.47 MWhavg to 7.67 MWhavg.
- The highest numbers of EV+1/2 Hybrid in scenario 2 (FSA allocation) is allocated to Calgary-T3H-21 SUBSTATION (# 651).
- Highest load in scenario 2 (FSA allocation) is allocated to Calgary-T3H-21 SUBSTATION, and from 2022 to 2040 it will increase from 0.28 MWhavg to 4.78 MWhavg.
- The highest number of charging EV stations and loads allocation is related to ENMAX Power Corporation.

Thank you

Electric Vehicle Economic Modeling and Projections

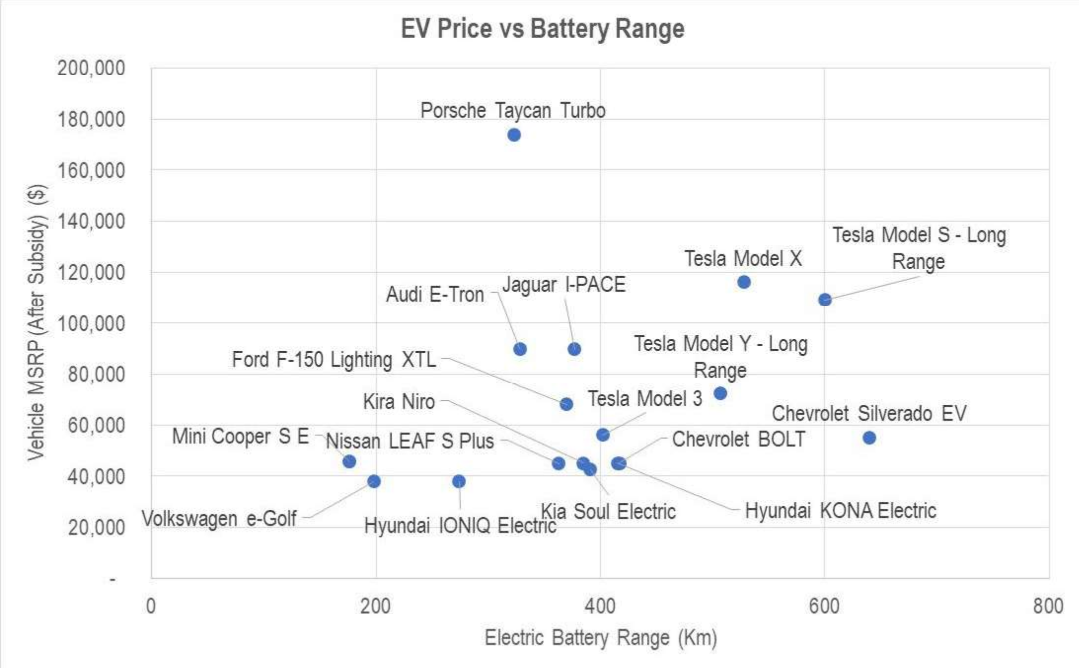
January 2023

AESO Internal

Comparative analysis approach

- EV classification is based on range and paired up with a most-likely substitute internal combustion vehicle

Battery Electric Vehicle	Internal Combustion Alternative
Short-range BEV (< 200 km)	
Mini Cooper S E	Mini Cooper 3 door
Volkswagen e-Golf	Volkswagen Golf Comfortline
Mid-range BEV (200-400 km) Under $50,000	
Hyundai IONIQ Electric	Hyundai Elantra Essential
Kira Niro	Kia Seltos
Hyundai KONA Electric	Hyundai KONA Essential
Nissan LEAF S Plus	Nissan Sentra S
Kia Soul Electric	Kia Soul
Chevrolet BOLT	Chevrolet Trax
Mid-range BEV (200-400 km) Over $50,000	
Ford F-150 Lighting XTL	Ford F-150 XTL
Tesla Model 3	Toyota Camry SE
Jaguar I-PACE	Jaguar XE
Audi E-Tron	Audi Q5
Porsche Taycan Turbo	Porsche Panamera Turbo
Long-range BEV (400+ km)	
Tesla Model Y - Long Range	Mazda CX9 GS
Tesla Model X	Toyota Highlander LE AWD
Tesla Model S - Long Range	Toyota Avalon XSE
Chevrolet Silverado EV	Chevrolet Silverado LD



Vehicle specifications

- Total cost of ownership depends on initial purchase price (minus applicable subsidies), fuel charges and maintenance costs
  - Initial purchase expense is a barrier to adoption
  - Fuel cost differential is a key advantage to EV ownership

Category	BEV Purchase Cost ($)	ICV Purchase Cost ($)	Purchase Cost Differential ($)	BEV Efficiency (kWh/100km)	ICV Efficiency (Liters/100km)
Short-range (< 200 km)	38,000-46,000	24,000-28,000	11,000	18.1-18.4	7.5
Mid-range (200-400 km) < $50k	33,000-40,000	17,000-23,000	18,000	14.0-17.1	6.8-9.1
Mid-range (200-400 km) > $50k	51,000-174,000	26,000-180,000	25,000	18.7-29.0	7.4-11.8
Long-range (400+ km)	55,000-117,000	40,000-46,000	45,000	14.8-31.3	9.4-18.5

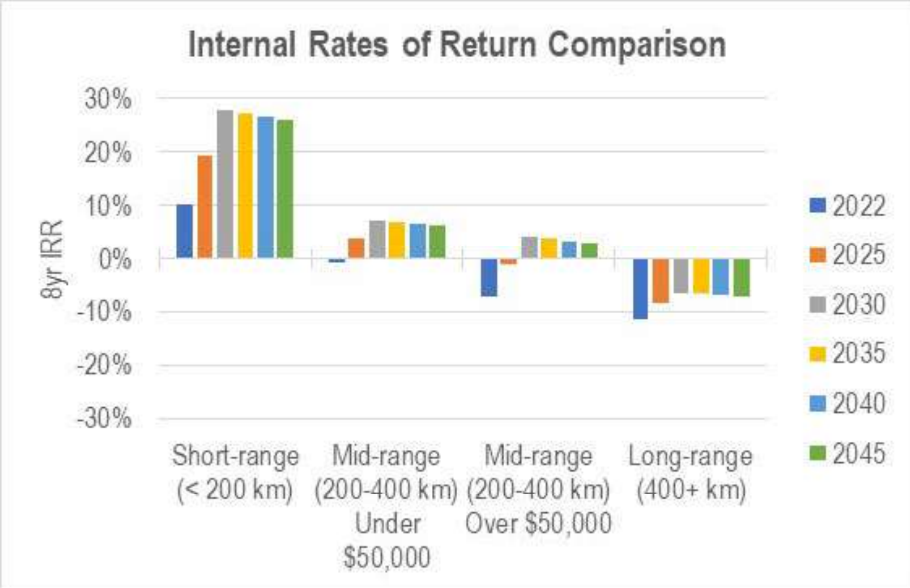
Notes: BEV purchase cost do not include home charger devices and installation costs. BEV purchase estimates are net of federal incentives for zero-emission vehicles where applicable (in this case, those in the short- and some of the mid-range vehicles). Fuel efficiency estimates are manufacturer's specifications and may not be adjusted for Alberta-specific weather conditions. Some estimates are based on pre-production rollout announcements which could change pricing and battery specifications.

Cost differential analysis

- The differential in vehicle cost is assessed by different purchase years to assess economic viability of opting for EVs over IC vehicle at different periods
  - Positive returns (IRR) supports EV ownership over an ICV substitute

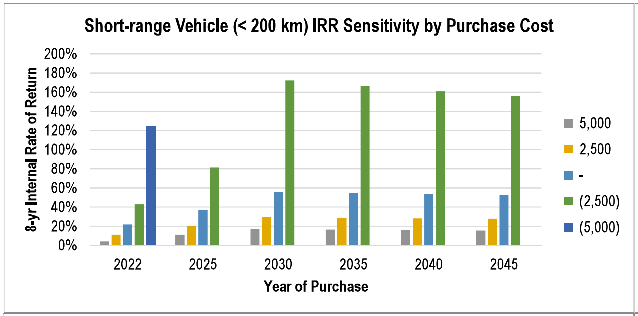
- Analysis focuses on “typical” driver behaviour
  - Assume a daily driving profile of 50km (20,000 km/yr) and an 8-year financial life

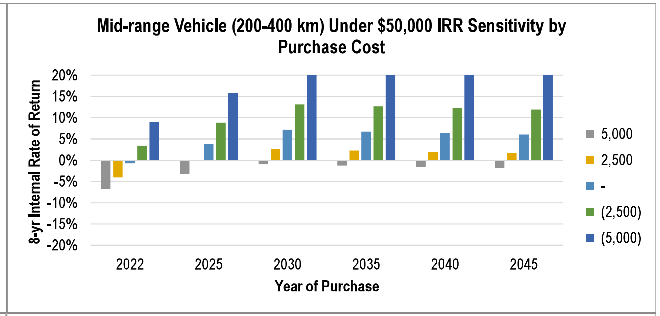
- **Results suggests short- to mid-range BEV are most economic-attractive options**

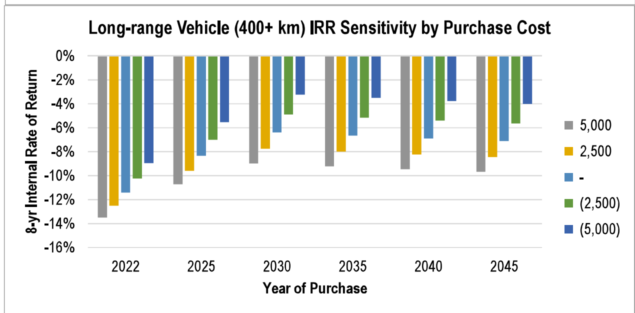


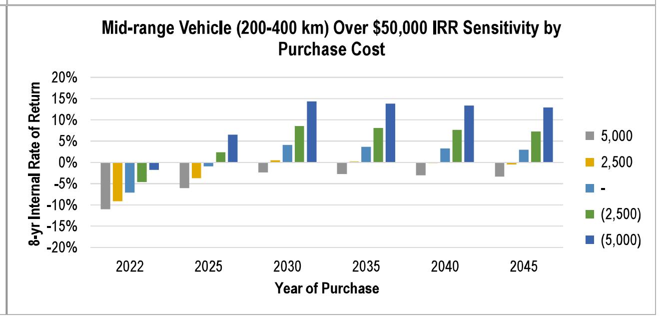
Sensitivity: initial costs

- Multiple factors can affect initial purchases costs: supply costs, inflation and labour wages, government incentives
  - Purchase costs increases impact economic case for mid-range vehicles the most, especially from 2025 onwards
- Mid-range under $50k
  - Largely depends on federal incentives to yield IRRs ~5% or better
- Mid-range over $50k
  - Would benefit from being included in the federal incentive program



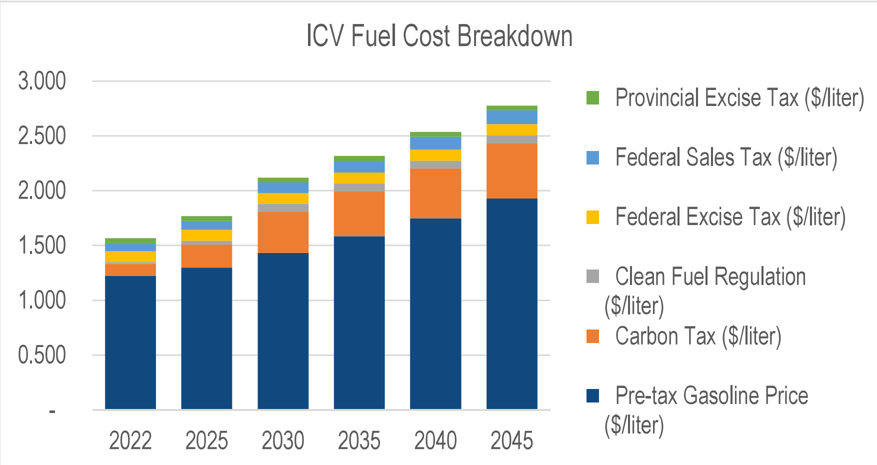


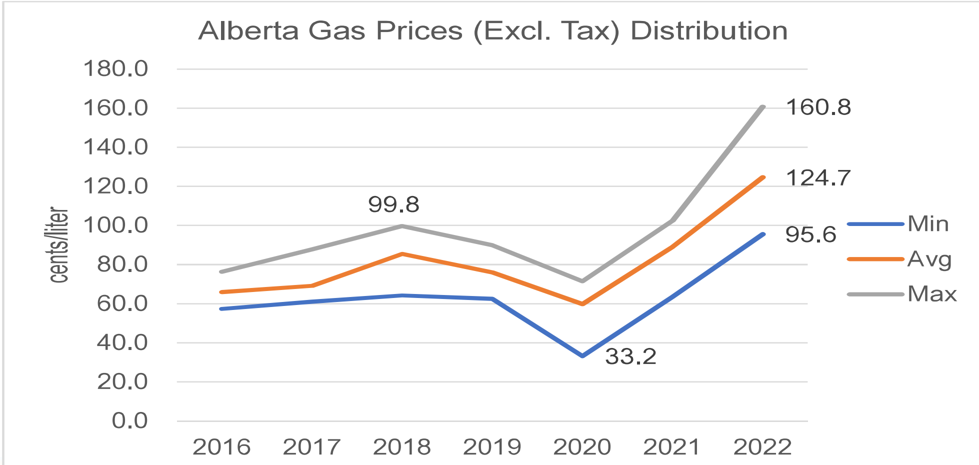




Sensitivity: gas price background

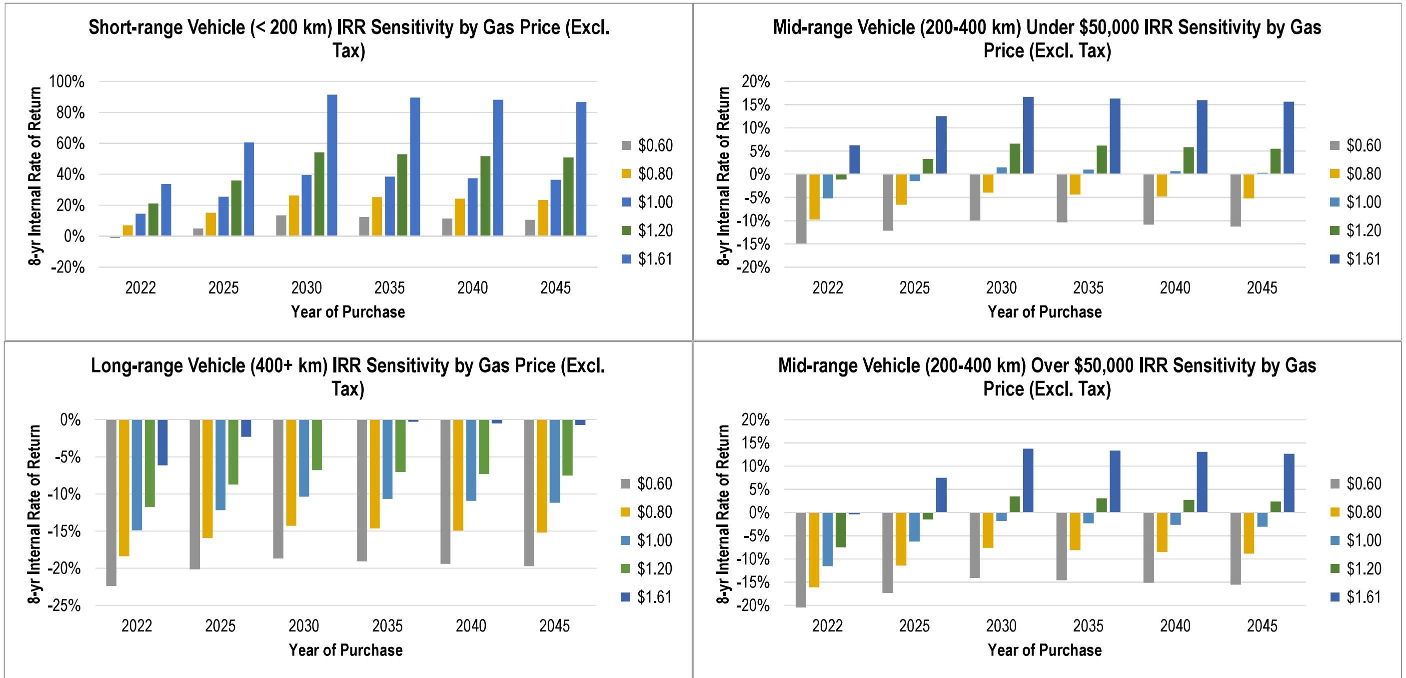
- Current gas commodity price to tax ratio is ~80:20, but expected to shift to ~70:30 by 2030
  - This is due to factors such as the carbon levy at $170/tCO2e, clean fuel carbon intensity at 12 gCO2e/MJ, in addition to excise and sales taxes at the federal and provincial level
- Pre-tax gas price volatility remains a wildcard especially given retail market fundamentals
  - Volatility became exacerbated post 2019 due to the pandemic and geopolitical factors (OPEC+ supply decisions, Russian invasion of Ukraine)





Sensitivity: gas prices

- Mid-range vehicle comparatives improve if gas prices (pre-tax) remain at 2022 levels
  - A return to pre-pandemic low gas prices diminish IRRs even for mid-range under $50k at least until 2030-2035



Impact to 2023 LTO EV adoption outlook

- EV comparative economics largely depend on initial purchase costs and gas prices
  - Lower range, lower priced EVs demonstrate strong returns in different sensitivities favouring strong uptake in Alberta
  - Higher range, higher priced EVs still remain uneconomic across sensitivities and, therefore adoption is based on niche preferences
  - Mid-range vehicle economics widely depend on initial cost and gas price outlooks which have wide uncertainties
    - Adoption of this category will be higher for vehicles under $50,000 and specially under favourable scenarios of lower purchase costs and higher gas prices… and particularly from 2030 onwards

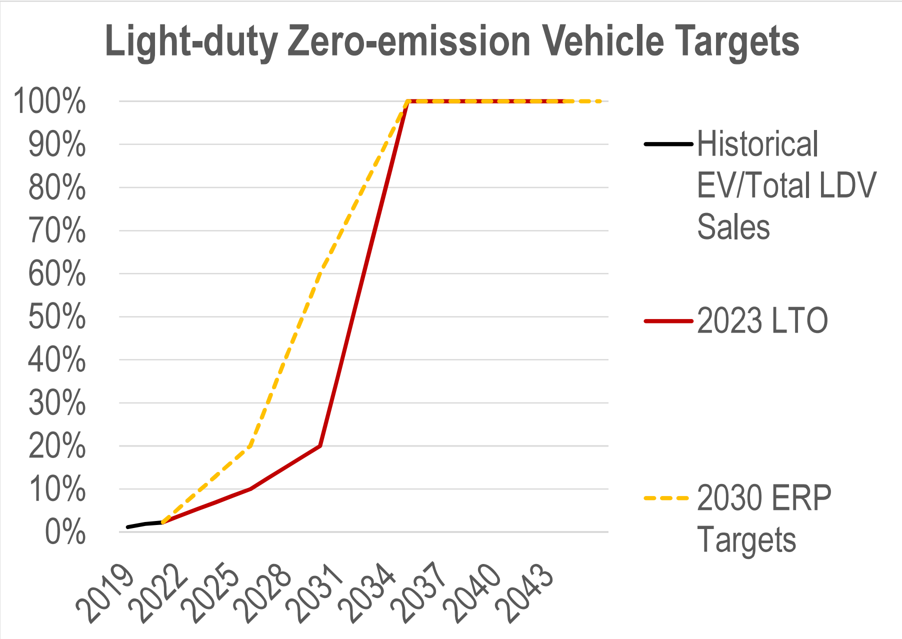
- Under current economic conditions, reaching higher sales of EVs to meet zero-emission vehicle targets as per the federal government seems unlikely
  - The EV adoptions for the 2023 LTO Reference Case will need to be lowered from the Net Zero model to reflect this economic reality; however, Net Zero assumptions can be used for high electrification scenarios

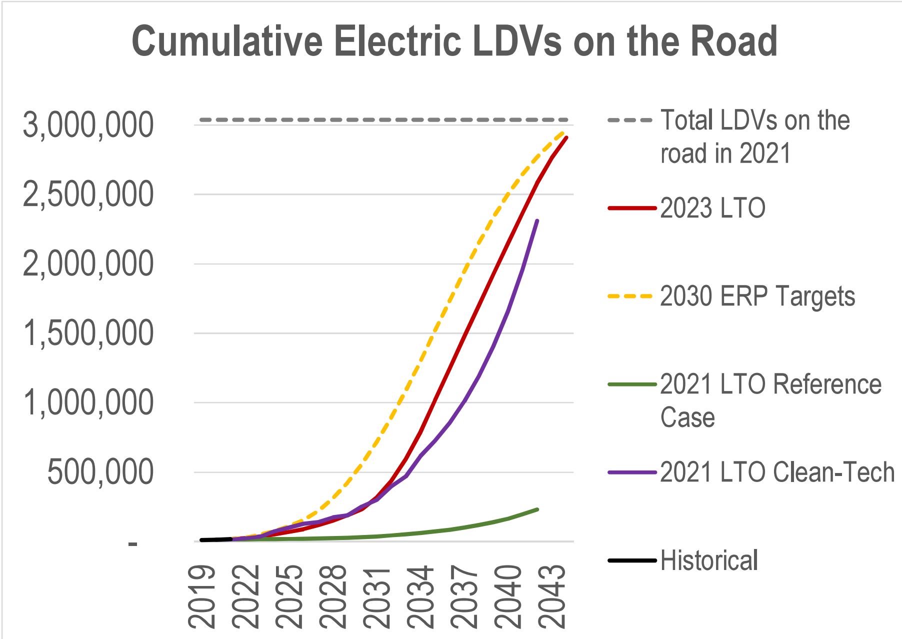
Other factors to consider

- Federal ZEV target regulations
  - Sales would be impacted by the specifics of compliance penalties, credit pooling, and credit banking in the yet-to-be-release regulations (expected Q1 2023)
- Provincial budget and election
  - The extent to which there are provincial incentives and/or other EV-oriented policies
- Longer-term supply challenges
  - Critical minerals production shortages and availability, battery cell price reductions
- EV charging infrastructure
  - Acute challenges not only for on-road charging, but also multi-unit residential buildings
- Cost increases during net zero transition
  - Decarbonization of electricity supply and Tx/Dx grid expansion are expected to increase delivered cost of electricity

2023 LTO Reference Case EV adoption outlook

- Assuming a slower initial pace of adoption, yet maintaining the federal goal of reaching 100% of new sales, could amount to 0.5 million fewer EVs by 2035
  - Energy would be lower by 1,400 GWh (162 MW on average) in 2035





Will York – Sr Engineer EV portfolio – reg and non-reg business (EV charging assets)

Yenny Wang – Tx/Dx System Planning- evolution of grid to meet customer needs

David Leew – key accounts – C&I customers

Larray Shaben – customer and industry relation (lead)

Transportation Decarbonization

The AESO's model focuses on a sub-set of transportation (i.e., excludes air, marine, and even rail transport) modes based on the most likely to electrify based on policy incentives and technological readiness. These are light-duty (passenger cars and trucks), freight (medium- and heavy-duty transport vehicles), and buses (transit, school, coach).[2]

Modelling EV adoption and charging demand largely depends on a set of key assumptions:

- Adoption drivers – government subsidies, mandated sales targets, comparative cost against internal combustion engine vehicles, stock turnover rate
  - The NZE report assumes federal policy targets drive EV adoption in Alberta

Section 16(1)(c)(i)(ii)

- Driving patterns – driver behaviour, typical mileage, weekend and holiday effects
  - The NZE report does not include holiday effects (i.e., impact of July-August or December holidays on typical driving distances)
- Battery specifications – representative EV type, charging capacity under different seasonal conditions (winter vs summer; for instance, the AESO assumes a 35% deterioration in battery range in the winter compared to summer conditions)

Section 16(1)(c)(i)(ii)

- Charging profile – representative daily driving and charging patterns, impact of incentives/penalties for charging in certain time-blocks (daytime vs evening vs overnight), deployment of managed charging technologies, vehicle-to-grid functionality

[2] Details on the modelling of each sub-sector are explained in PDF pages 19-22 of the NZE report.

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Section 16(1)(c)(i)(ii)

Tables 1 and 2 in the Appendix show the results from the EV model produced for the NZE report.

Discussion questions

- Can you share your most recent EV forecast (# of vehicles, charging load estimates, charging profile assumptions)?
   - Discuss the extent to which the AESO approach is consistent or not with your forecast
- What is the state of modeling of EV adoption and charging profiles in your service territory?
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- Do you see/expect the impact of EV charging to be different depending on location – i.e., residential vs commercial/institutional buildings vs warehouse vs commercial charging stations?
   - Discuss types of analysis conducted on accommodating EV charging for different purposes and at a different locations
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Section 16(1)(c)(i)(ii)

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Section 16(1)(c)(i)(ii)

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Section 16(1)(c)(i)(ii)

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Section 16(1)(c)(i)(ii)

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Section 16(1)(c)(i)(ii)

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- From a collaboration perspective, how can the AESO support your EV load monitoring and modelling?

Context

In October/November 2022, the AESO met with DFOs at the Executive level to increase coordination on the impact of grid transformation resulting from net-zero emission policies and technological trends.

- AESO-DFO collaboration was a recommendation identified by the AESO in its Net-Zero Emissions (NZE) Pathways report (released in June 2022).[1] The report focused on transmission-level impact to market, cost and operations; distribution system impacts were highlighted as a gap to be addressed via further engagement with DFOs.
- Objectives of AESO-DFO engagement agreed at the Executive level include:

Nonresponsive

  - Understand current state of DFO planning for impacts of a net-zero transition including electrification of transportation

Nonresponsive

Dean Stanghetta – Director of system planning and asset gt

Leonard Huynh – manage of Dx assets and planning

Net-Zero Scenario Assumptions

In the NZE report, the AESO produced a single 20-year load forecast that included key sectors that will be impacted by net-zero and carbon policies from 2022 to 2042. Each of these sectors and the modelling assumptions are explained below. Please review and be prepared to comment on degree of alignment

[1] NZE Pathways report can be found here: https://www.aeso.ca/assets/Uploads/net-zero/AESO-Net-Zero-Emissions-Pathways-Report.pdf

between AESO assumptions and your organization's, how your organization is tracking/modeling development in these sectors and how you rely on these types of projections for business decisions.

Transportation Decarbonization

The AESO's model focuses on a sub-set of transportation (i.e., excludes air, marine, and even rail transport) modes based on the most likely to electrify based on policy incentives and technological readiness. These are light-duty (passenger cars and trucks), freight (medium- and heavy-duty transport vehicles), and buses (transit, school, coach).[2]

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    - Dunskey outlook in 2022, main driver was federal policy target; won't be 100%, did a base case and rapid case 45-84% ; no economic analysis ; no attrition for new vehicles
- Driving patterns – driver behaviour, typical mileage, weekend and holiday effects
  - The NZE report does not include holiday effects (i.e., impact of July-August or December holidays on typical driving distances)
    - Charging profiles based on US DOE charging profiles ; hoping to leverage AMI and Pilot data ; pilot was a 2-year, 3 subsets (1 incentive, 1 education, 1 control), n = 200 ;
- Battery specifications – representative EV type, charging capacity under different seasonal conditions (winter vs summer; for instance, the AESO assumes a 35% deterioration in battery range in the winter compared to summer conditions)
    - EV segmentation is hard ; no info on where they are ; would like to join the AESO to lobby AB Govt (address, type,) ; mapping total across communities based on property values (more affluent
- Charging profile – representative daily driving and charging patterns, impact of incentives/penalties for charging in certain time-blocks (daytime vs evening vs overnight), deployment of managed charging technologies, vehicle-to-grid functionality
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Section 16(1)(c)(i)(ii)

    - Enmax is electrification own fleet, so data collection there

[2] Details on the modelling of each sub-sector are explained in PDF pages 19-22 of the NZE report.

- Public charging ; it's not necessarily a separate analysis- they're all service connection ; 1 public charging in SW at 85 St by the COOP

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    - Pilots were mostly for learning ; incentives do help shape behaviour , more than education ; PBR3 application includes early results
- From a collaboration perspective, how can the AESO support your EV load monitoring and modelling?
    - Early stages ; not enough to make significant business decisions yet ; still have time to test and learn and assess bookend cases ;

Nonresponsive

Transportation Decarbonization

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    - Reactionary to EV loads; a 6MW generation; no solar panel penetration; residential ; Dx system has good capacity, so can handle fair amount of influx; keeping an eye on permits, service upgrades; slow chargers are not impactful – small city, low KMs; visibility for public charging

[2] Details on the modelling of each sub-sector are explained in PDF pages 19-22 of the NZE report.

- update standards: 13.8 kV standard, 120/208 V (apartamnet) 347/600 V (commercial); 480 V transformer is more American (not a lot of 480 V transformers) – now they need to stock more transformer (no impact to training); supply chain delays for transformers of all voltage levels; cyber-security challenges
- traditional standard service of 100 amps; newer developments sized to 200 amps;
- council mostly focused on doing at commercial malls

- Do you see/expect the impact of EV charging to be different depending on location – i.e., residential vs commercial/institutional buildings vs warehouse vs commercial charging stations?
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    - ON-based UtilSmart; use analytics to come up with virtual meters; in-house solution is in the works; 15-min intervals
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Nonresponsive