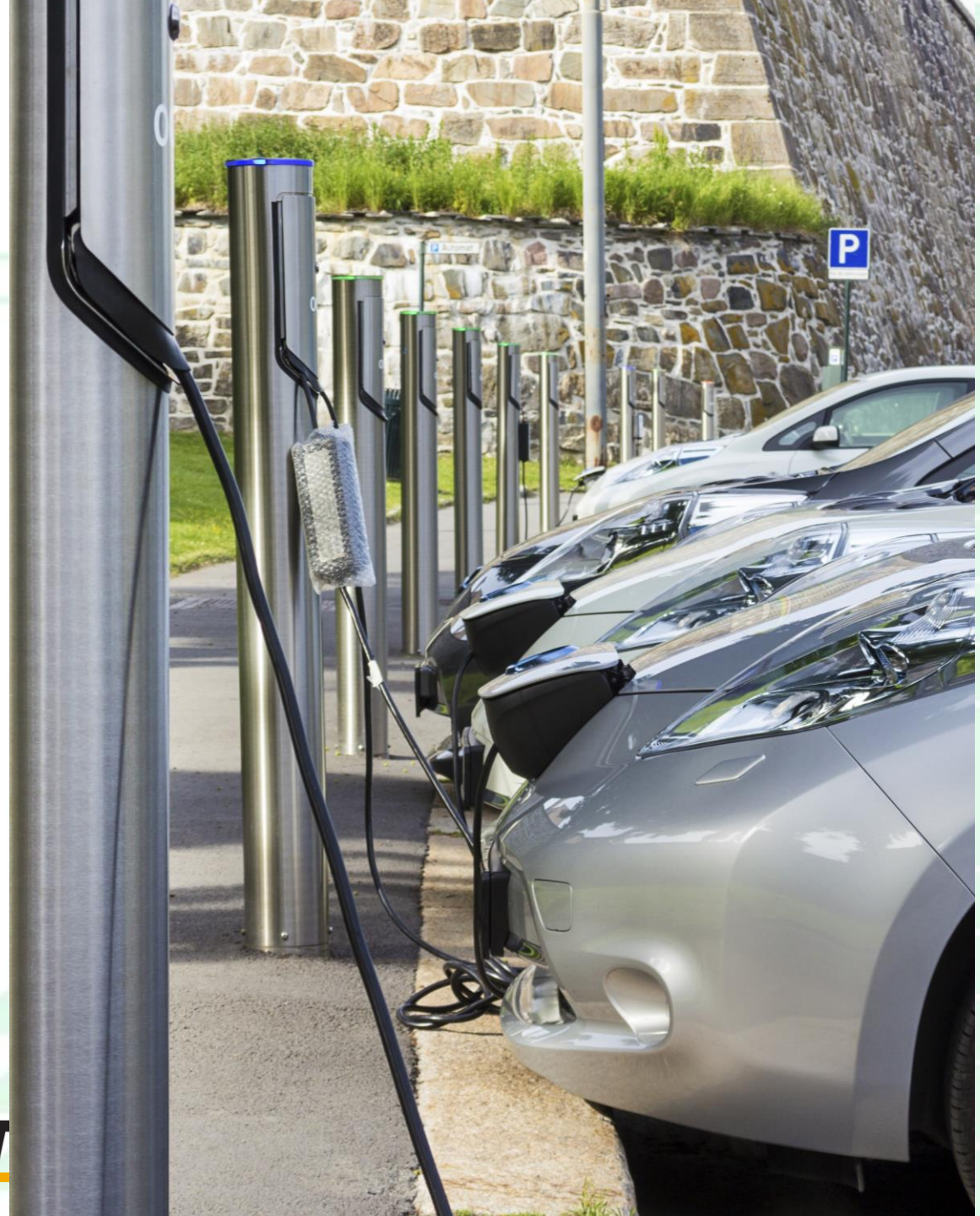


Forecasting Grid Capacity Impacts of Electric Vehicles

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ROLE OF ELECTRIC VEHICLES IN THE ENERGY TRANSITION

30%-50%

Projected North American EV market growth over the next 7 years

2035

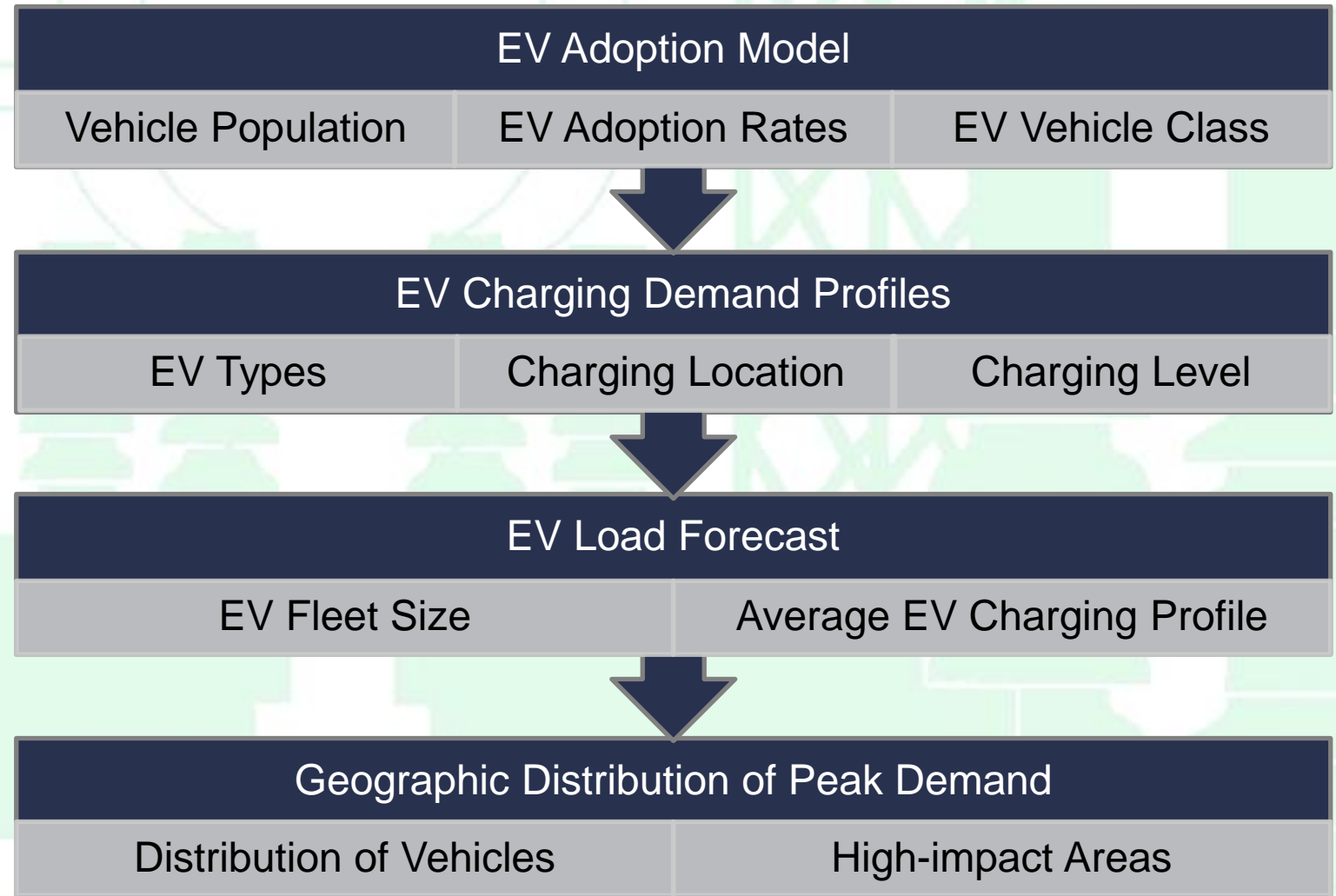
Canadian federal target for all new vehicle sales to be EVs

70%-75%

Expected percentage of new vehicle sales that are EVs by 2030

OVERVIEW OF EV FORECASTING PROCESS

1. Forecast total vehicle count and EV uptake
2. Apply EV demand profiles
3. Combine into probabilistic load forecast
4. Predict geographic distribution (in the City of Toronto)



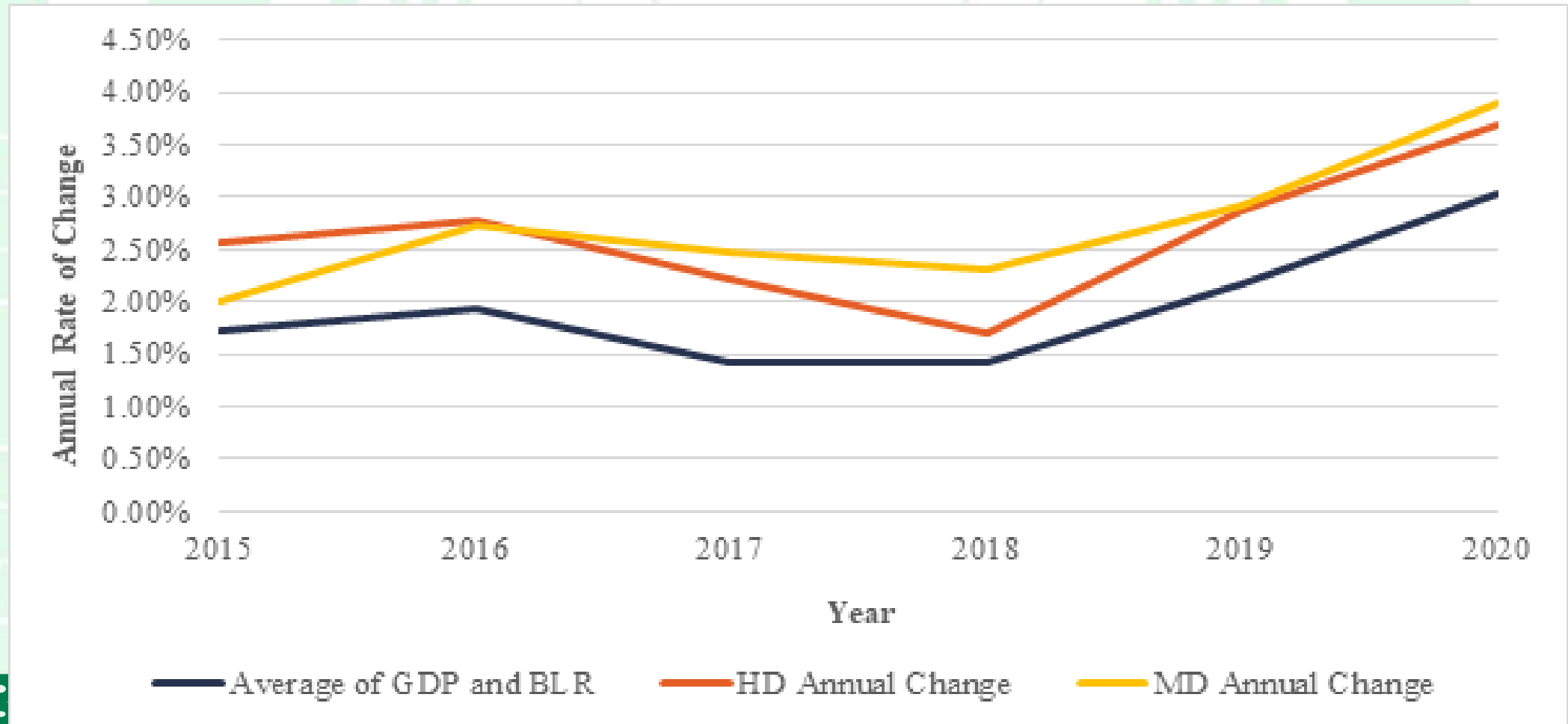
COLLECTING VEHICLE DATA FOR EV ADOPTION MODEL

- Collected total vehicle count from StatsCan for 5 years (pre-COVID)
- Average growth rate of light-duty vehicles is 162,000 per year
- Extrapolated growth rates for medium-duty and heavy-duty vehicles seems unrealistically high

	2015	2016	2017	2018	2019
Light-duty	7,866,332	8,037,343	8,199,865	8,357,600	8,514,952
Medium-duty	122,686	125,157	128,564	131,755	134,789
Heavy-duty	122,462	125,594	129,084	131,952	134,202
Total	8,358,366	8,538,070	8,707,286	8,870,625	9,031,832

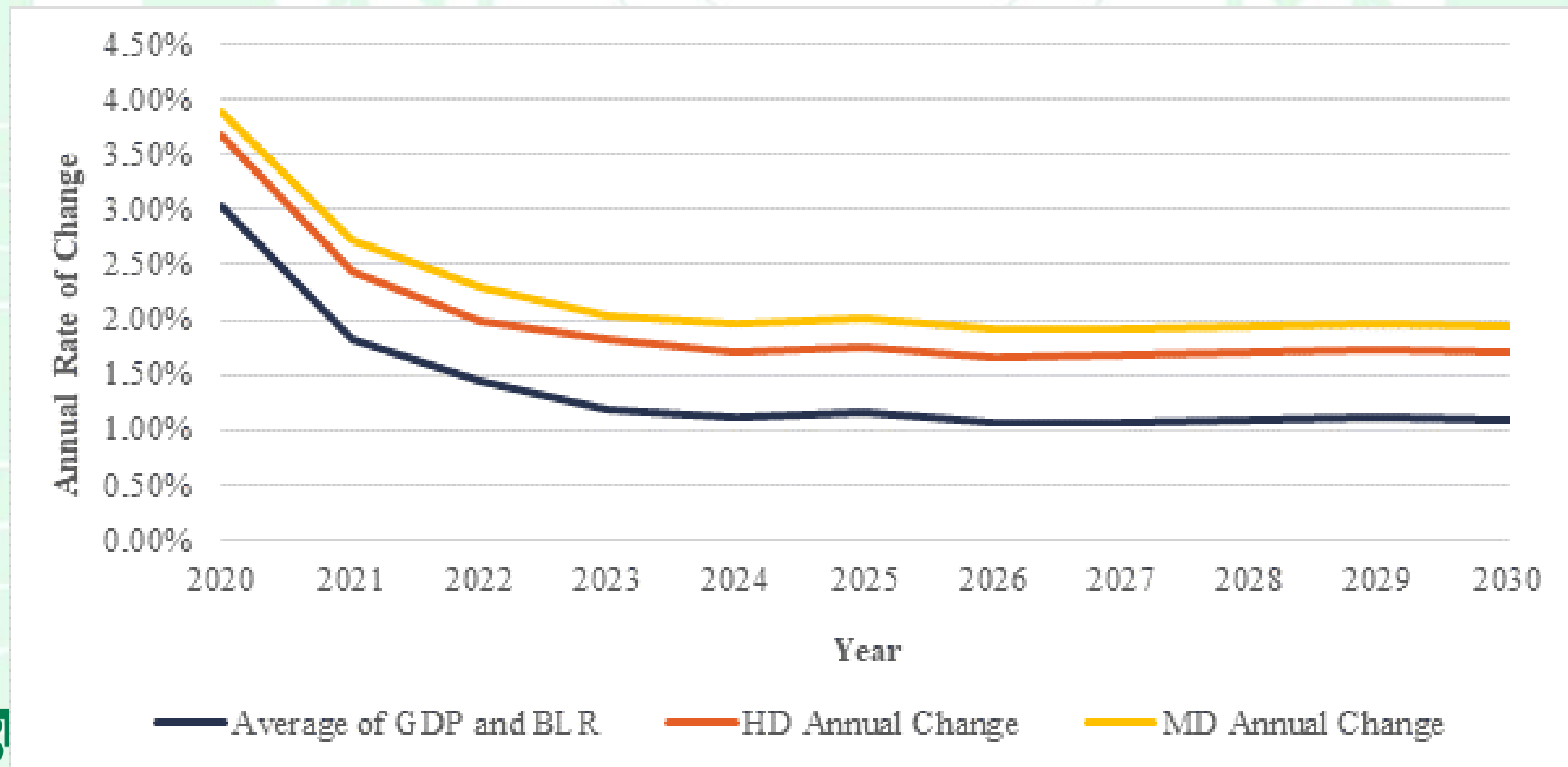
CORRELATING MD AND HD VEHICLE GROWTH RATES

- For Toronto, business license renewals (“BLR”) and gross domestic product (“GDP”) show good correlation with vehicle population growth



FORECASTING MD AND HD VEHICLE GROWTH RATES

- MD and HD vehicle growth rate expected to normalize at 1.5%-2% per year based on GDP and business license renewal forecasts



PROJECTED EV PERCENTAGES BASED ON CITY STRATEGY

- City of Toronto EV Strategy:
 - 15% of new sales and 5% of total vehicles by 2025
 - 40% of new sales and 20% total vehicles by 2030
- Forecasted new vehicle registrations and total vehicle counts to achieve target of 220,000 LDEVs in Toronto by 2030
- % of vehicle retirements is modelled for each year

Year	New EV Registrations	Total EVs	EV % of New Registrations	EV % of LD Vehicles in Toronto
2017	1,032	2,577	1.0%	0.25%
2018	3,656	6,215	3.6%	0.59%
2019	1,289	7,442	1.3%	0.70%
2020	2,570	9,915	3.4%	0.96%
2021	3,406	13,143	4.2%	1.28%
2022	5,000	17,854	5.4%	1.7%
2023	9,000	26,408	8.9%	2.6%
2024	13,000	38,615	12.7%	3.7%
2025	15,500	52,764	15.0%	5.0%
2026	25,000	75,653	23.9%	7.2%
2027	33,000	105,249	31.3%	9.9%
2028	43,000	142,460	40.3%	13.2%
2029	46,000	179,770	42.7%	16.5%
2030	52,000	220,085	47.8%	20.1%
2031	60,000	265,339	54.6%	24.0%

EV CHARGING DEMAND PROFILES

- electrical demand impact of EVs depends on rated charger output, rated EV charging power, current state of charge, battery capacity, charging duration, temperature etc.
- Diversity of load drives the overall impact when modeling EV chargers in aggregate
- U.S. DRIVE report identifies peak of 1.50 kW per LDEV
- Scaled to Toronto average commuting distance below

Hour of Day	0	2	4	6	8	10	12	14	16	18	20	22	kWh/ Day	Km/ Day
USDRIVE	0.42	0.20	0.05	0.01	0.10	0.15	0.20	0.30	0.80	1.50	1.30	1.00	12.1	83.9
Scaled USDRIVE	0.20	0.10	0.02	0.00	0.05	0.07	0.10	0.14	0.38	0.72	0.62	0.48	5.8	40.3

CHARGING DEMAND FOR MDEV AND HDEV

- Reference data for MDEV and HDEV charging profiles collected by the Lawrence Berkeley National Laboratory
- Demand profiles for food and beverage trucks aggregated by the National Renewable Energy Laboratory
- These demand profiles were transformed to fit the City of Toronto

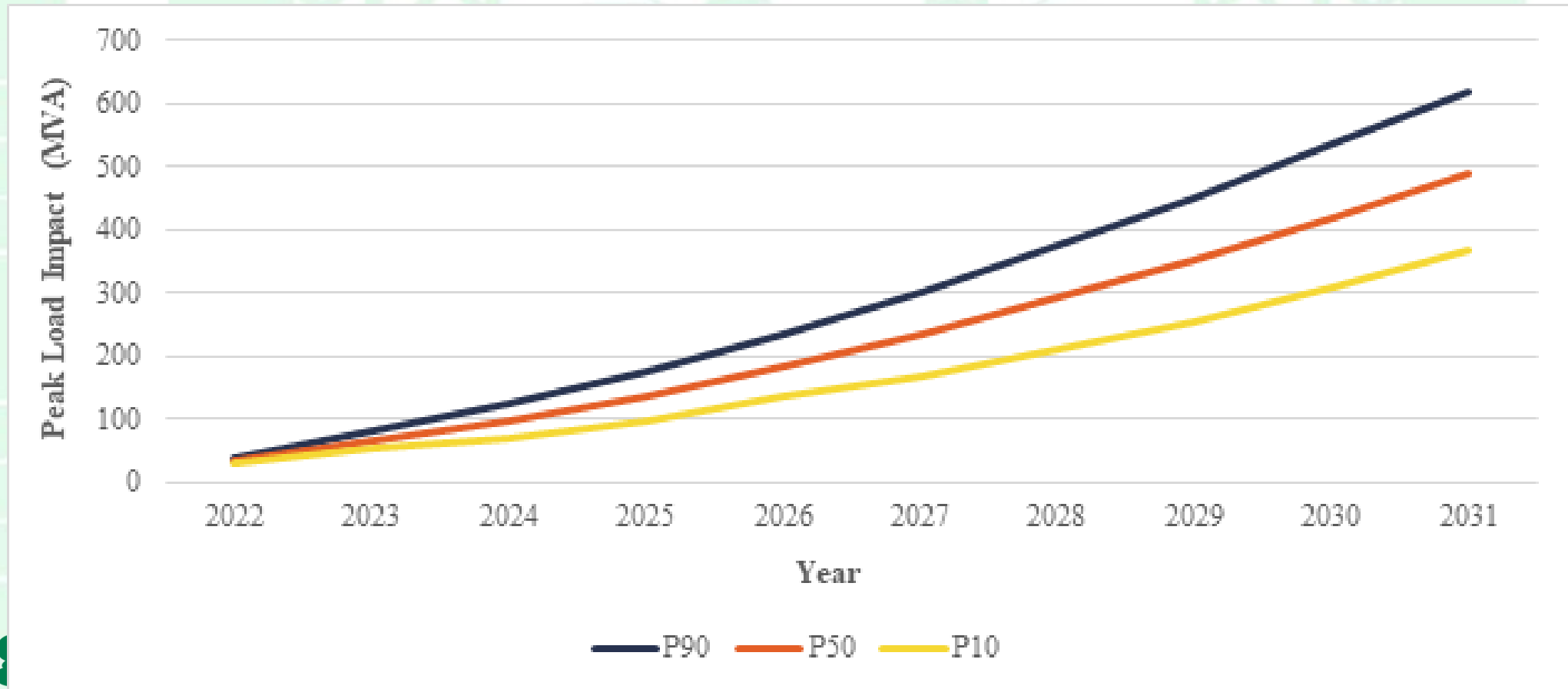
Hour	MDEV	HDEV	Hour	MDEV	HDEV
0	4.47	32.20	12	4.54	12.97
1	4.57	28.04	13	4.07	11.48
2	4.07	21.50	14	3.96	12.16
3	4.84	16.40	15	5.29	10.51
4	4.56	15.74	16	6.33	10.19
5	4.00	13.49	17	5.74	9.76
6	3.53	14.22	18	5.48	7.13
7	3.18	13.23	19	5.57	6.47
8	0.95	2.69	20	6.42	4.91
9	1.12	9.66	21	6.45	4.48
10	2.00	11.63	22	5.70	3.65
11	2.28	15.17	23	4.47	32.20
Daily Per EV Charge Load (kWh)				103.56	319.87
Daily Per EV Peak Demand (kW)				6.45	32.20

MONTE-CARLO SIMULATION PROCESS

- The EV load forecasts for LDEVs, MDEVs, and HDEVs were modelled individually
- For each vehicle type, the annual vehicle adoption rate and peak kW demand were treated as random variables to be selected from a normal distribution via a Monte-Carlo simulation of 1,000 trials per year of the 10-year forecast
- The results are displayed as the 90th percentile or “P90”, 50th percentile (“P50”), and 10th percentile (“P10”)

EV LOAD FORECAST RESULTS

- It is predicted that much of the load growth will be driven by HDEVs due to their high impact per vehicle
- The impact of LDEVs is also predicted to be substantial



CONCLUSIONS & NEXT STEPS

- Monitor EV adoption and usage/charging patterns
- Investigate EV charging policies to manage peak demand and peak shifting:
 1. Timers and load sensors for passive control
 2. Active control from the utility control room
 3. Smart controls using automated schemes
 4. Bidirectional V2G control schemes
- Consider last-mile impacts along distribution lines including voltage drop
- Account for other impacts such as building electrification, DERs, CDM, etc.
- More forecasting and planning now will help prepare all stakeholders for the energy transition and avoid costly pitfalls along the way