Integrated electricity supply and demand modelling to investigate renewable pathways at the city scale

By Madeleine Seatle, Lauren Stanislaw, Robert Xu & Madeleine McPherson

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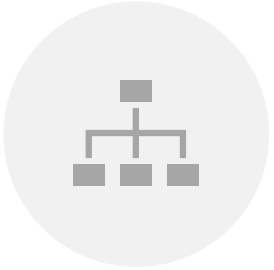
Outline

Motivation



Model architecture

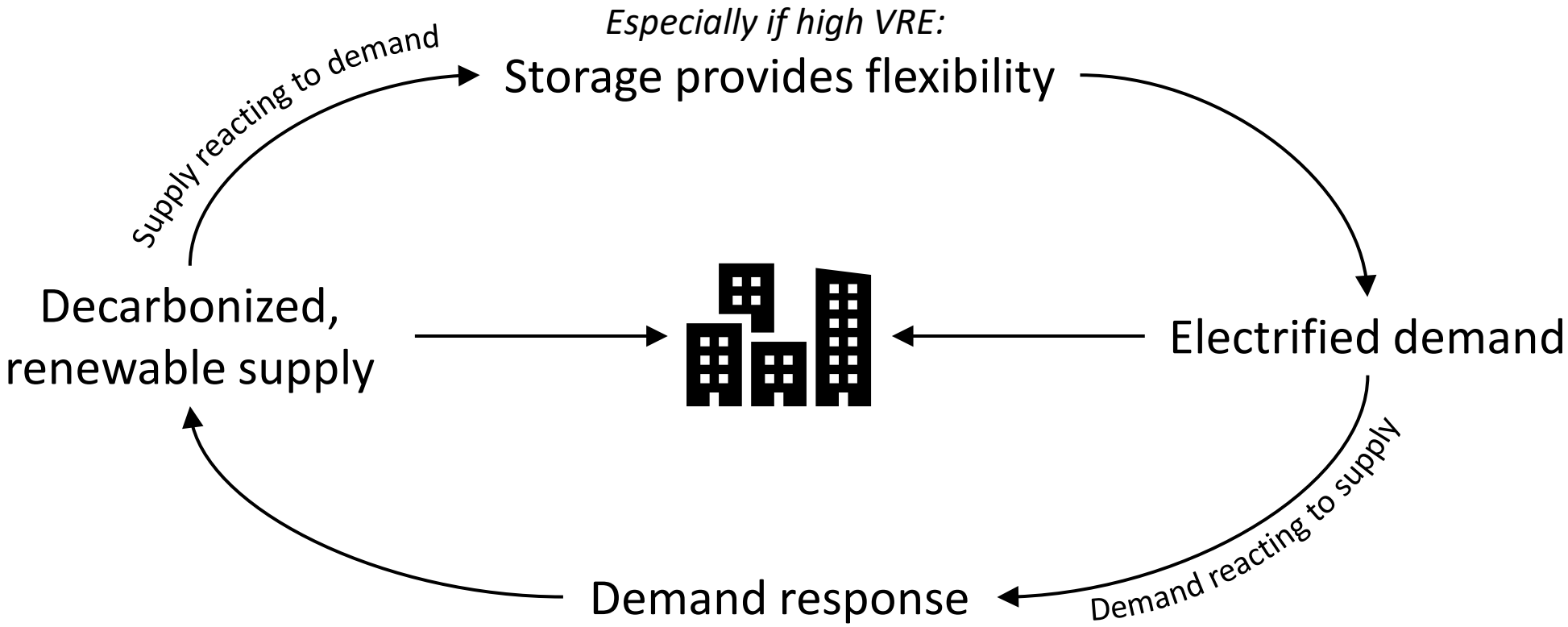
Model workflow

Future applications

Motivation

- 458 Canadian municipalities have committed to reducing GHG emissions
  - Most GHG emissions in cities from transportation and buildings sectors
- Effective GHG strategies vary between cities
  - Electrification necessary on demand side
  - Electricity supply different across Canada
    - Vancouver vs. Calgary

Motivation


Especially if high VRE:
Storage provides flexibility
Supply reacting to demand
Decarbonized, renewable supply
Electrified demand
Demand response
Demand reacting to supply

Contribution to model space

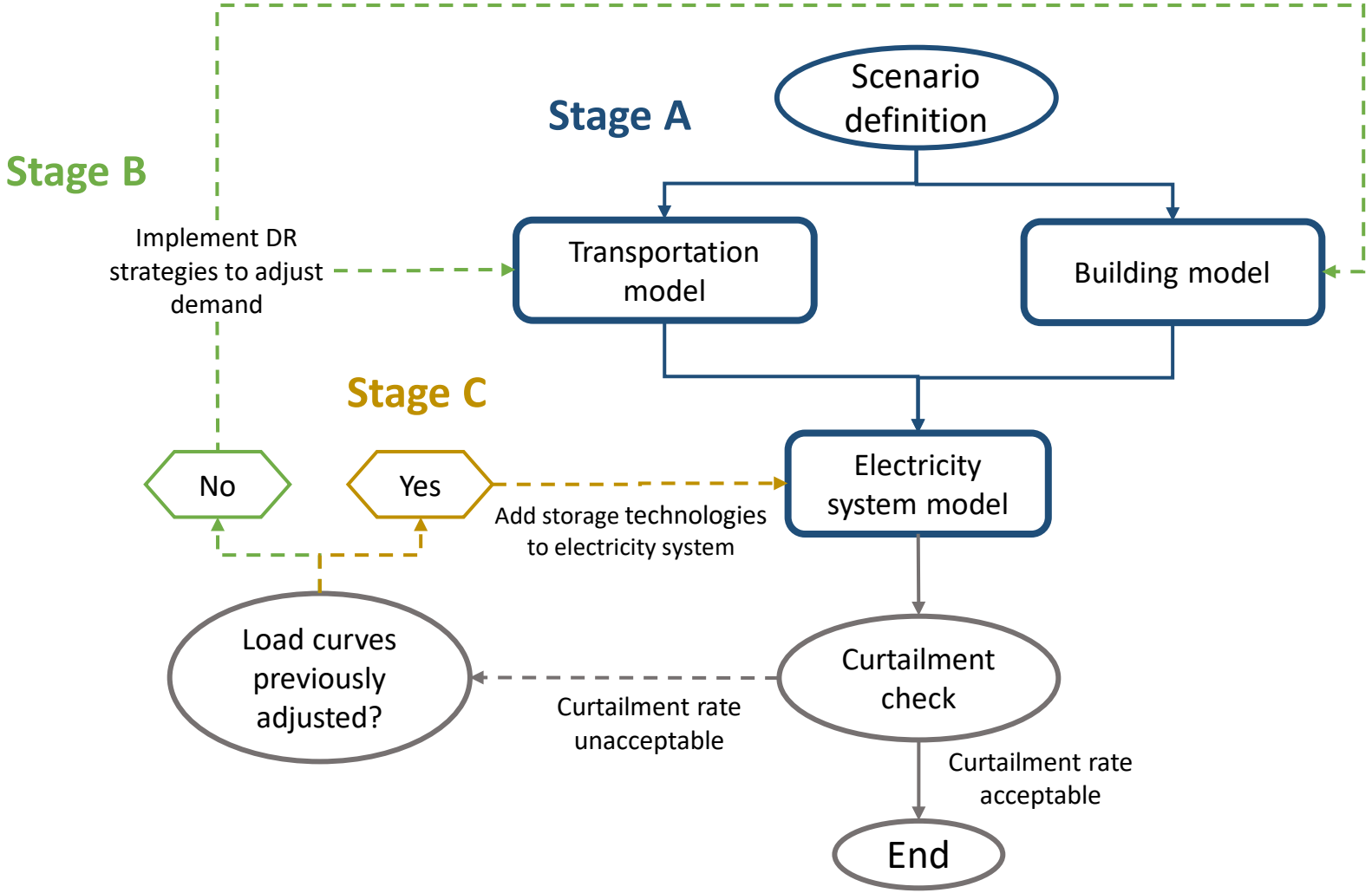
Modelling gap

- Spatial and/or temporal resolution too low for some modelling needs
- DR strategies lacked details and accuracy
- Communication gap between decision makers and modelers

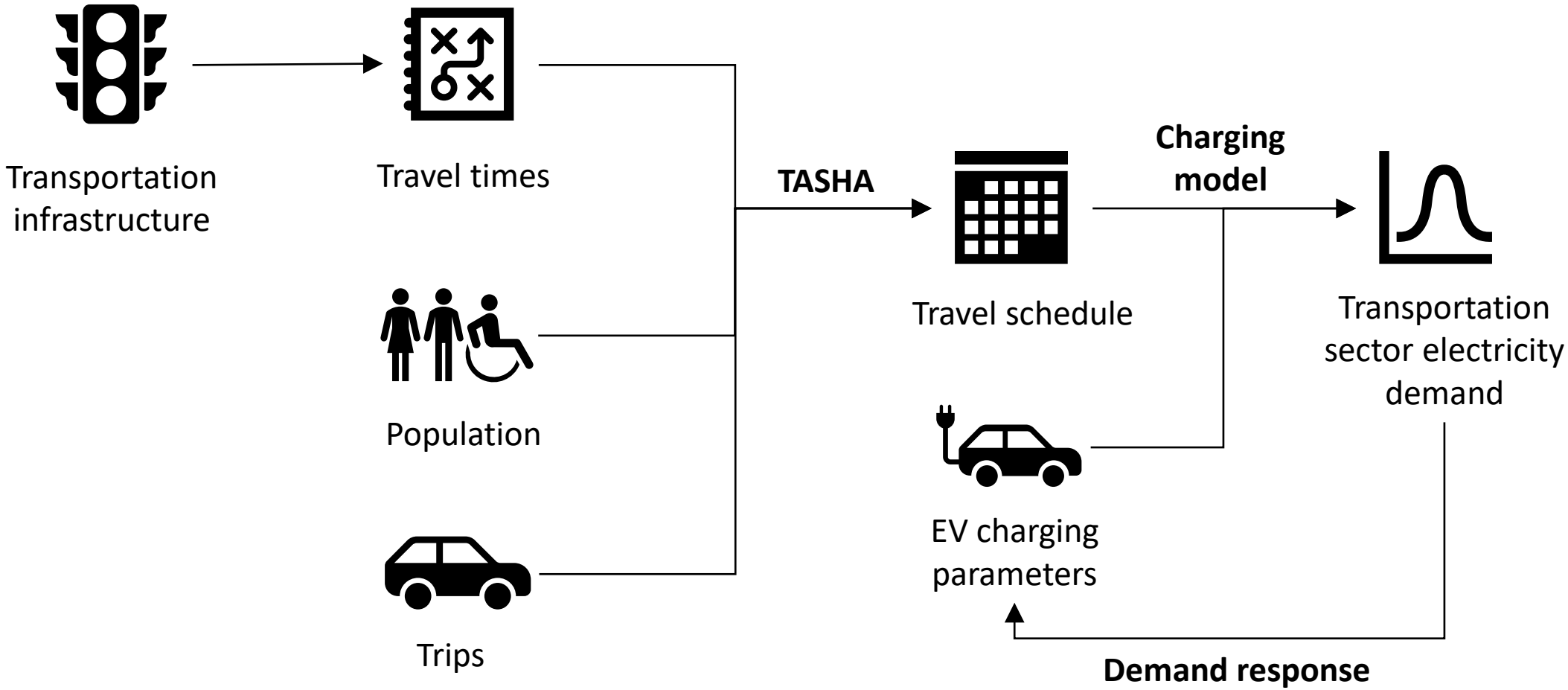
Solution

- Electricity system model linked with operational transportation and building models
- Operational models allow for greater control of DR implementation
- Proposed workflow helps to "translate" policy to modelling scenarios

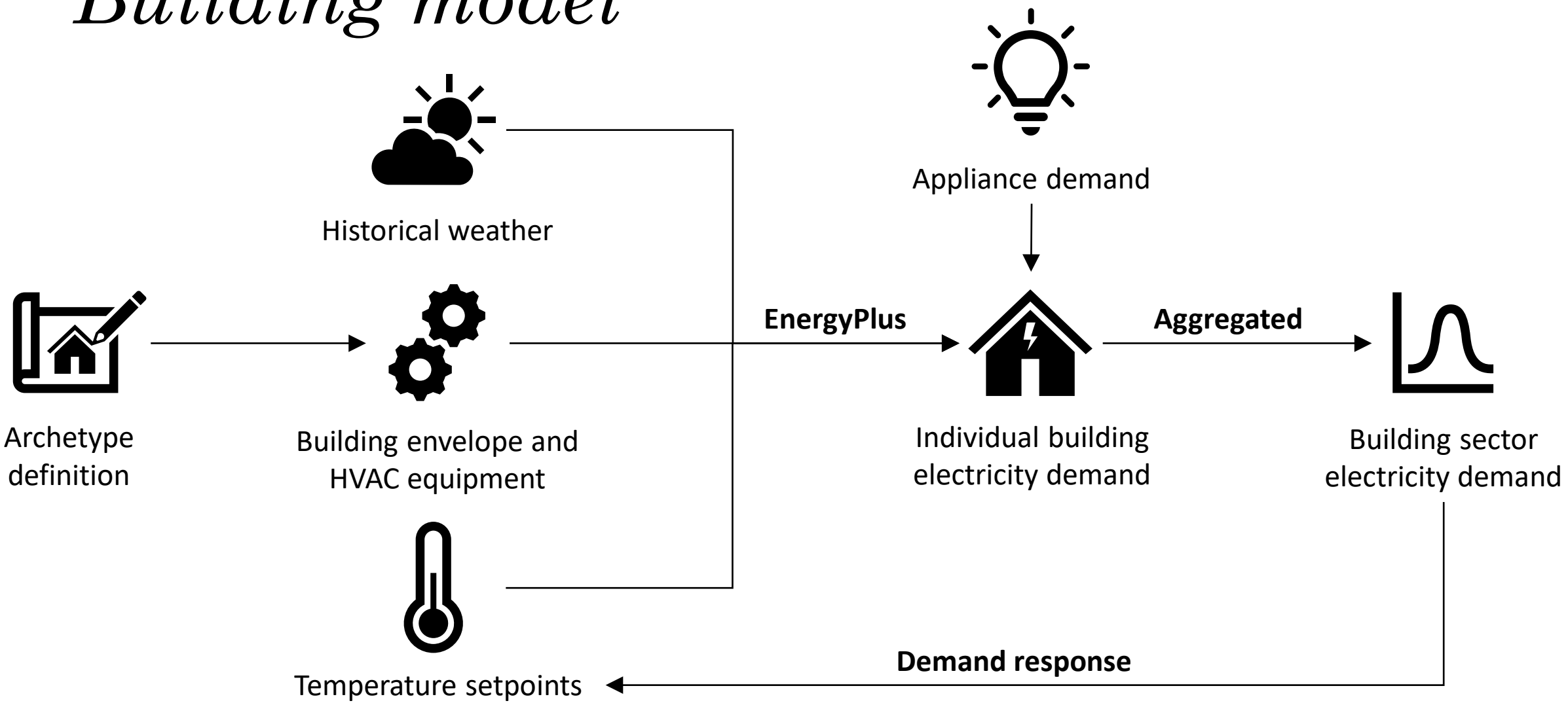
Model linkage



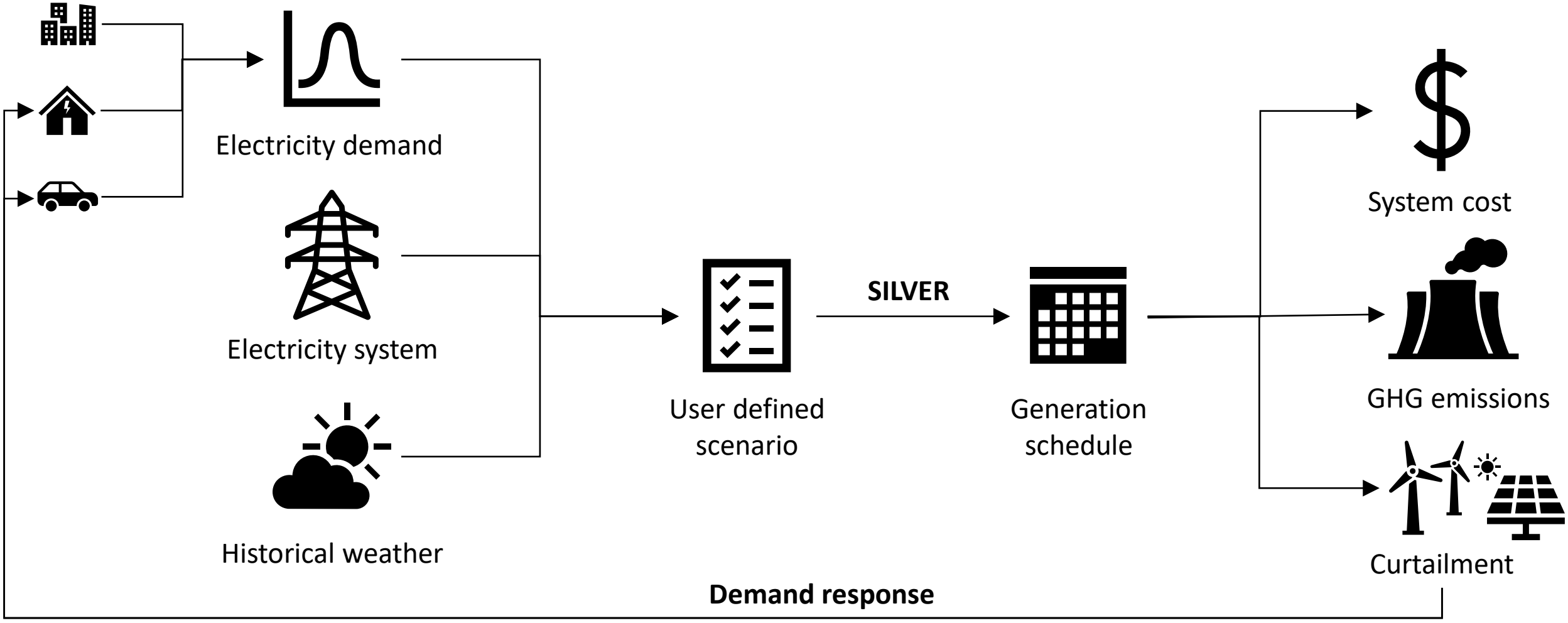
Transportation model



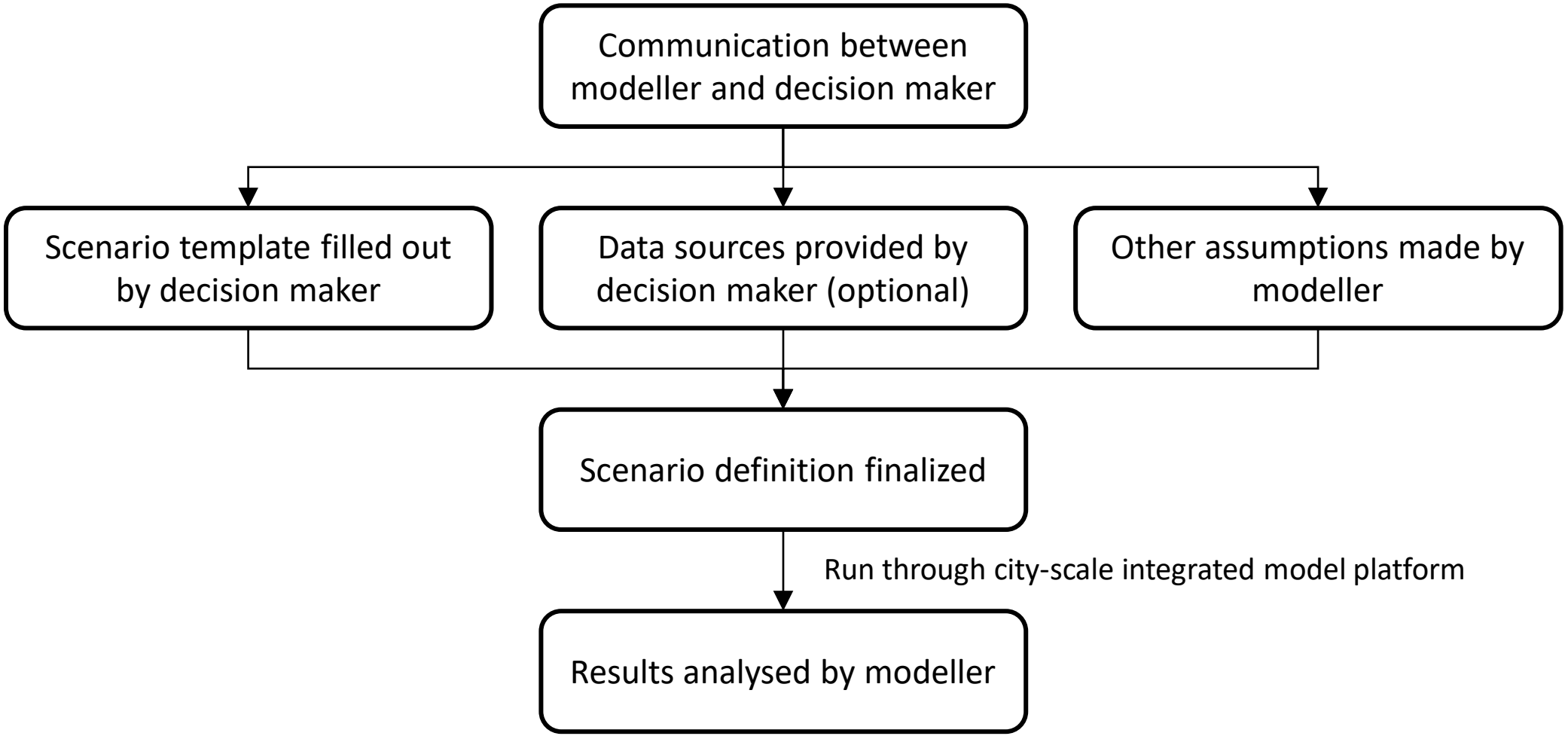
Building model



Electricity system model



Proposed workflow



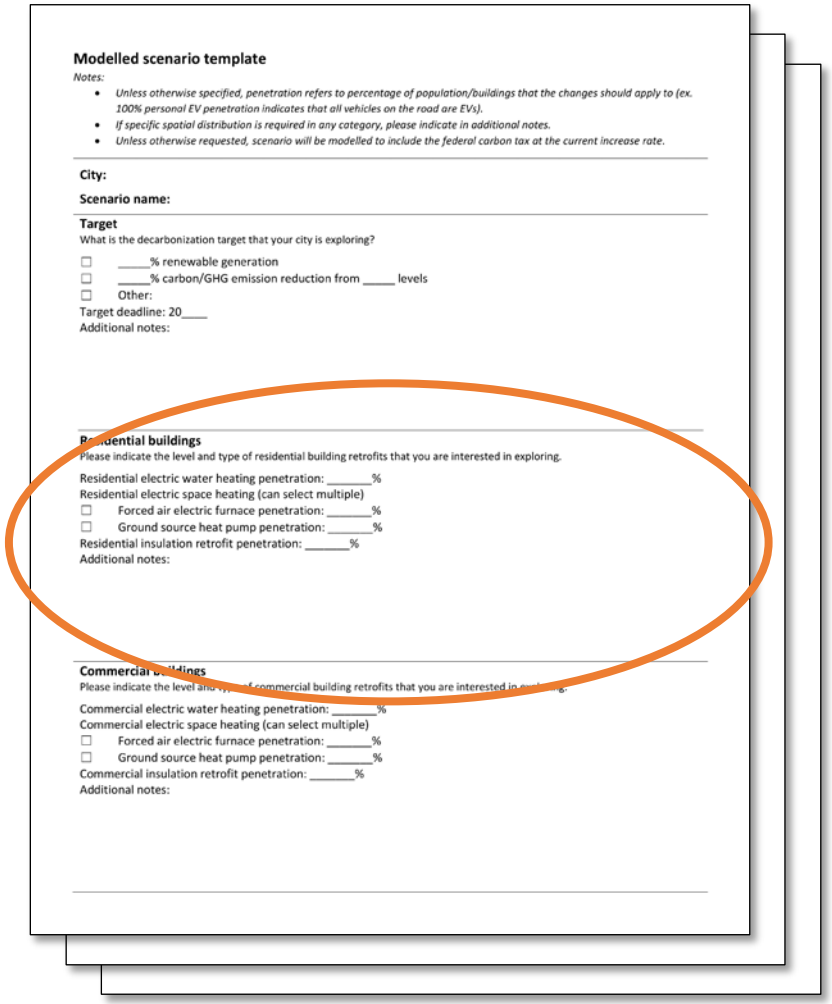
Example

- Decision makers select policy to be explored:
  - Tax incentive introduce for residential building retrofit and electrification for those built **before 1990**
  - Decision makers assume that insulation retrofits will be more popular than electric water and space heating
- Decision makers indicate why they are exploring this:
  - Impact on city-wide GHG emissions
  - Impact on cost of electricity

Next step:

Decision makers fill out scenario template and pass along relevant data

Scenario template



Modelled scenario template

Notes:

- *Unless otherwise specified, penetration refers to percentage of population/buildings that the changes should apply to (ex. 100% personal EV penetration indicates that all vehicles on the road are EVs).*
- *If specific spatial distribution is required in any category, please indicate in additional notes.*
- *Unless otherwise requested, scenario will be modelled to include the federal carbon tax at the current increase rate.*

City:

Scenario name:

Target

What is the decarbonization target that your city is exploring?

☐ _____% renewable generation
☐ _____% carbon/GHG emission reduction from _____ levels
☐ Other:

Target deadline: 20___

Additional notes:

Residential buildings

Please indicate the level and type of residential building retrofits that you are interested in exploring.

Residential electric water heating penetration: _____%

Residential electric space heating (can select multiple)

☐ Forced air electric furnace penetration: _____%
☐ Ground source heat pump penetration: _____%

Residential insulation retrofit penetration: _____%

Additional notes:

Commercial buildings

Please indicate the level and type of commercial building retrofits that you are interested in exploring.

Commercial electric water heating penetration: _____%

Commercial electric space heating (can select multiple)

☐ Forced air electric furnace penetration: _____%
☐ Ground source heat pump penetration: _____%

Commercial insulation retrofit penetration: _____%

Additional notes:

Residential buildings

Please indicate the level and type of residential building retrofits that you are interested in exploring.

Residential electric water heating penetration: 75 %

Residential electric space heating (can select multiple)

☒ Forced air electric furnace penetration: 25 %

☒ Ground source heat pump penetration: 25 %

Residential insulation retrofit penetration: 100 %

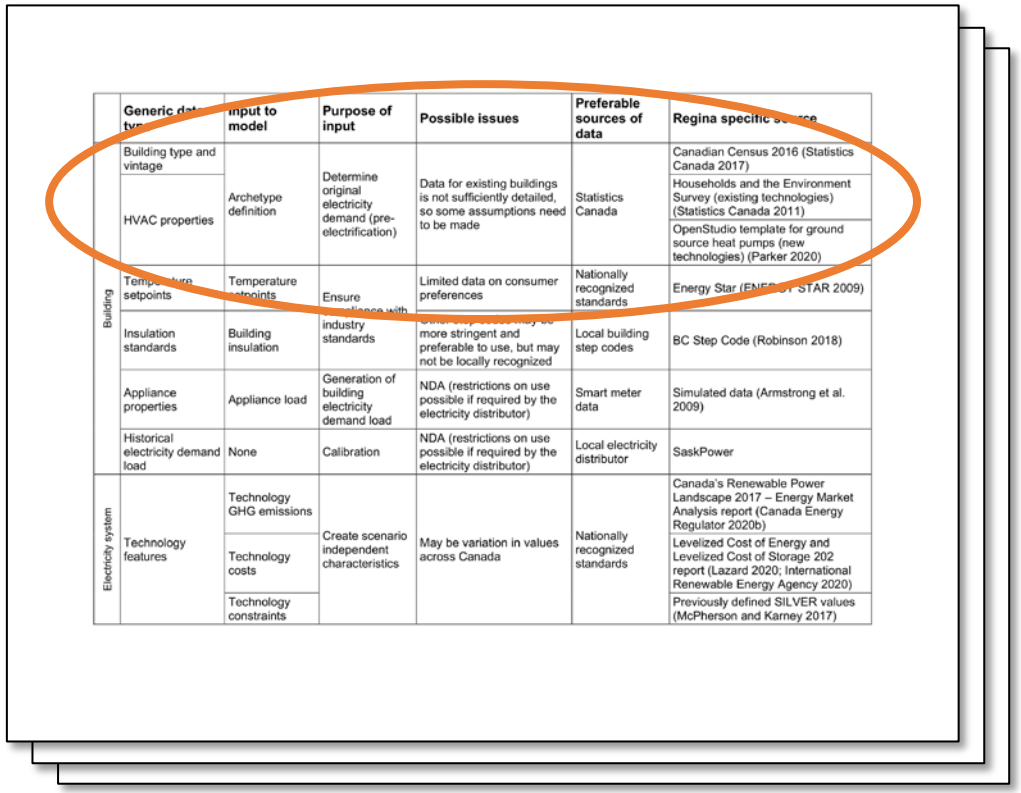
Additional notes:

Penetration values are based off of % of houses built before 1990

Next step:

Modellers collect remaining data and make any other necessary assumptions

Data sources and assumptions



	Generic data type	Input to model	Purpose of input	Possible issues	Preferable sources of data	Regina specific source
Building	Building type and vintage	Archetype definition	Determine original electricity demand (pre-electrification)	Data for existing buildings is not sufficiently detailed, so some assumptions need to be made	Statistics Canada	Canadian Census 2016 (Statistics Canada 2017)
	HVAC properties					Households and the Environment Survey (existing technologies) (Statistics Canada 2011)
						OpenStudio template for ground source heat pumps (new technologies) (Parker 2020)
	Temperature setpoints	Temperature setpoints	Ensure compliance with industry standards	Limited data on consumer preferences	Nationally recognized standards	Energy Star (ENERGY STAR 2009)
	Insulation standards	Building insulation		more stringent and preferable to use, but may not be locally recognized	Local building step codes	BC Step Code (Robinson 2018)
	Appliance properties	Appliance load	Generation of building electricity demand load	NDA (restrictions on use possible if required by the electricity distributor)	Smart meter data	Simulated data (Armstrong et al. 2009)
	Historical electricity demand load	None	Calibration	NDA (restrictions on use possible if required by the electricity distributor)	Local electricity distributor	SaskPower
Electricity system	Technology features	Technology GHG emissions	Create scenario independent characteristics	May be variation in values across Canada	Nationally recognized standards	Canada's Renewable Power Landscape 2017 – Energy Market Analysis report (Canada Energy Regulator 2020b)
		Technology costs				Levelized Cost of Energy and Levelized Cost of Storage 202 report (Lazard 2020; International Renewable Energy Agency 2020)
		Technology constraints				Previously defined SILVER values (McPherson and Karney 2017)

- Building type and vintage data source:
  - Statistics Canada (census data)
- Relevant data:
  - 50% of residential building stock built before 1990
- Other assumptions:
  - New technologies
  - New insulation levels
  - Current insulation levels/technologies (for comparison purposes)

Next step:

Finalize scenario definition, run through city-scale integrated platform and analyse results

Results

Result	Impact group	Purpose
Levelized cost of electricity (LCOE)	Decision makers	LCOE considers capital costs, as well as fixed and variable O&M costs based on the average electricity output over the infrastructure's lifetime. This result can be used to compare scenarios on the basis of cost.
GHG emissions	Decision makers	Calculated using average carbon intensity of non-electric end-use fuel sources or electricity generation type (National Energy Board, 2017). This can be used to assess feasibility of scenarios to meet various GHG reduction goals.
Ability to meet renewable electricity target	Decision makers	Based on the specific target set by the city, quantified by the percent of electric load met by renewable energy
Transportation electricity demand profile	Modellers	Sector specific spatiotemporal distribution of electricity demand that can be used to evaluate the effects of transport or building-sector electrification and/or energy efficiency policies (e.g. improved building insulation).
Building electricity demand profile		
Generation asset dispatch schedule	Modellers	Demonstrates what the required capacity is for a scenario to meet a specific demand schedule. This can be used to assess the feasibility of scenarios that are being considered to meet this demand load.
Electricity system operational cost	Modellers	This can be used to compare feasibility of scenarios if all generation infrastructure already exists, or if capital costs are similar.
Curtailment	Modellers	Used to estimate effectiveness of scenario generation mix in terms of how much potential VRE generation is "wasted". This can be an indication that further system flexibility, in the form of DR or storage may benefit grid operations.
DR impact	Modellers	Measured based on the amount of curtailment reduced through DR programs. Can be used to determine if a DR program is beneficial when comparing savings from reducing curtailment to the compensation required for consumer participation.
Storage impact	Modellers	Measured based on the amount of curtailment reduced by means of adding storage capacity. Can be used to determine if a storage is beneficial when comparing savings from reducing curtailment to the cost of storage.

- For decision makers:
  - GHG emissions
  - LCOE
- For modellers:
  - Building electricity demand profile
  - Generation asset dispatch schedule
  - Curtailment

Future applications

- Canada's goal of 100% EV market share by 2040
- Large-scale adaptation of building codes such as the BC Energy Step Code
- Technology improvements such as EV efficiency and building HVAC properties
- Target levels of renewable generation capacity such as Regina's 100% renewable energy target

Next steps

- Creating additional variables within sector specific models
  - EV charging strategies
  - Building electrification technologies
  - DR strategies
- Apply to additional cities across Canada
  - Personalize recommendations for pathways to meet target

Limitations

- Some required software is not freely available
- Transportation model does not include a traffic assignment step
- Archetype-based approach to constructing the building model under-represents the diversity actually seen in the building stock
- Time-shifting of loads in DR adjustments may create new periods of curtailment within integrated model platform

Questions?

Thanks for your attention