Energy Modelling Initiative — Initiative de modélisation énergétique

Bringing the Tools to Support Canada's Energy Transition — Outiller le Canada pour réussir la transition

An Overview of Energy Models

Panel Session:

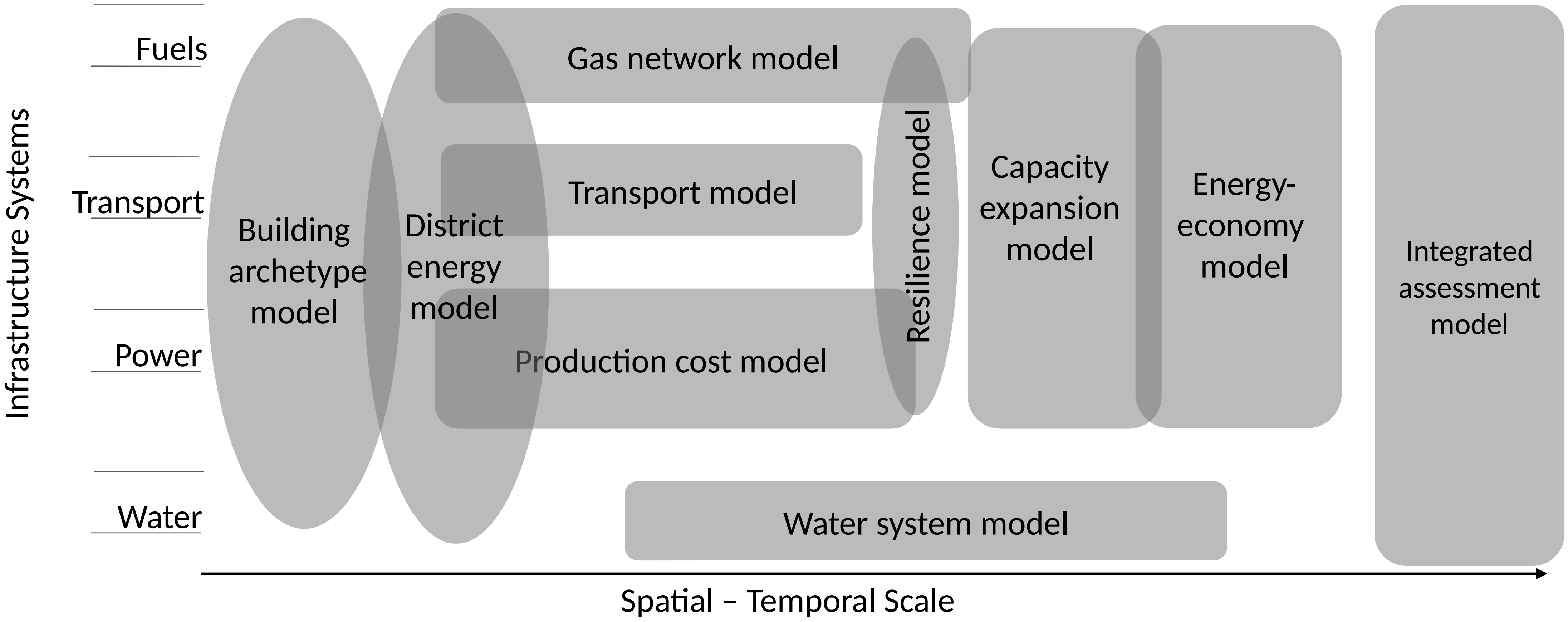
Hadi Dowlatabadi, Professor, UBC
Sean Broadbent, BC Ministry of Environment
Cameron Wade, PhD Student, IESVic
Madeleine McPherson, Assistant Professor, IESVic
Curran Crawford, Professor, IESVic
Ralph Evins, Assistant Professor, IESVic

EMI — Western Workshop

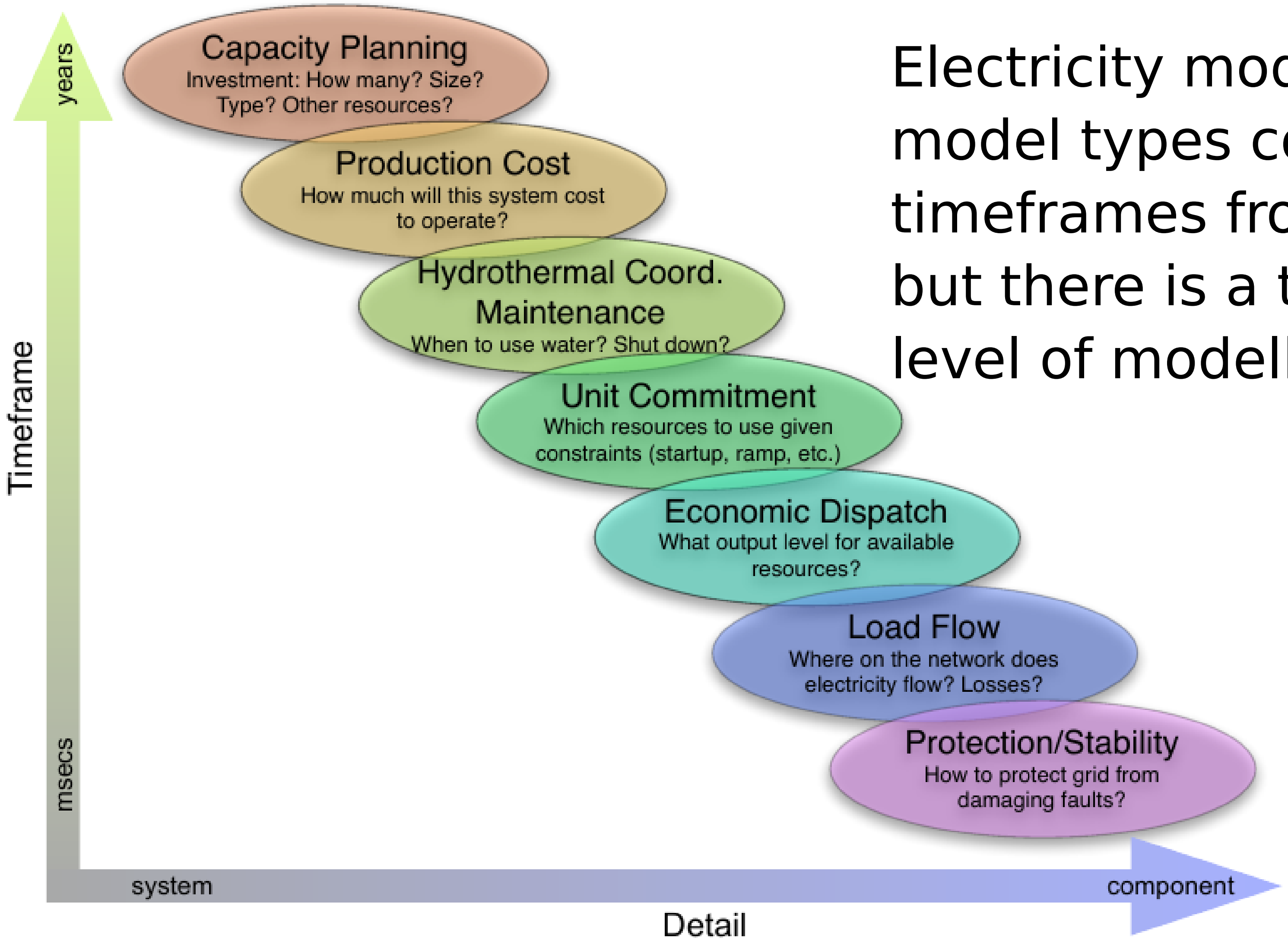
Friday, September 27, 2019

University of Victoria

Model Landscape: sector vs spatial-temporal resolution



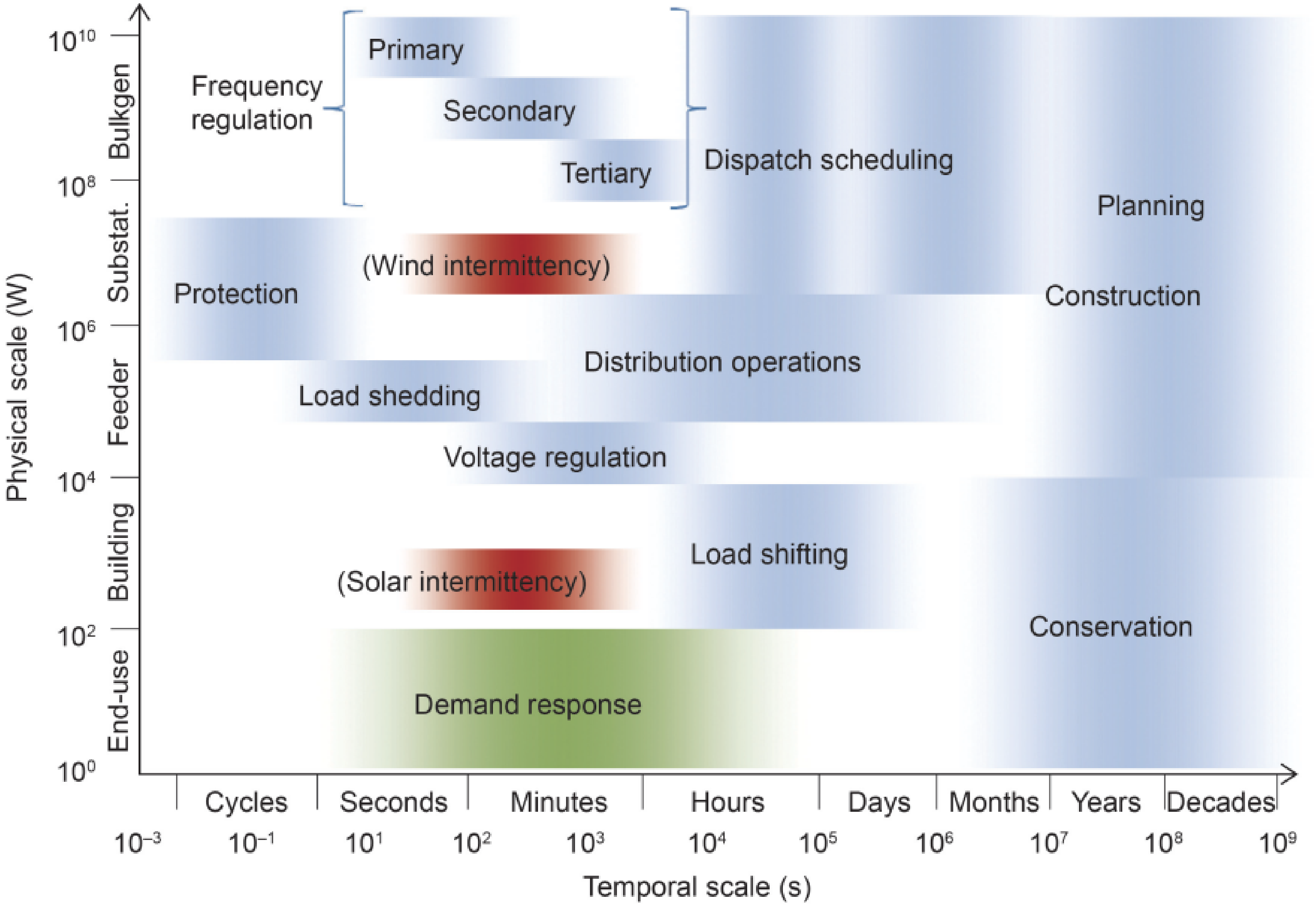
Model Landscape: temporal resolution vs detail



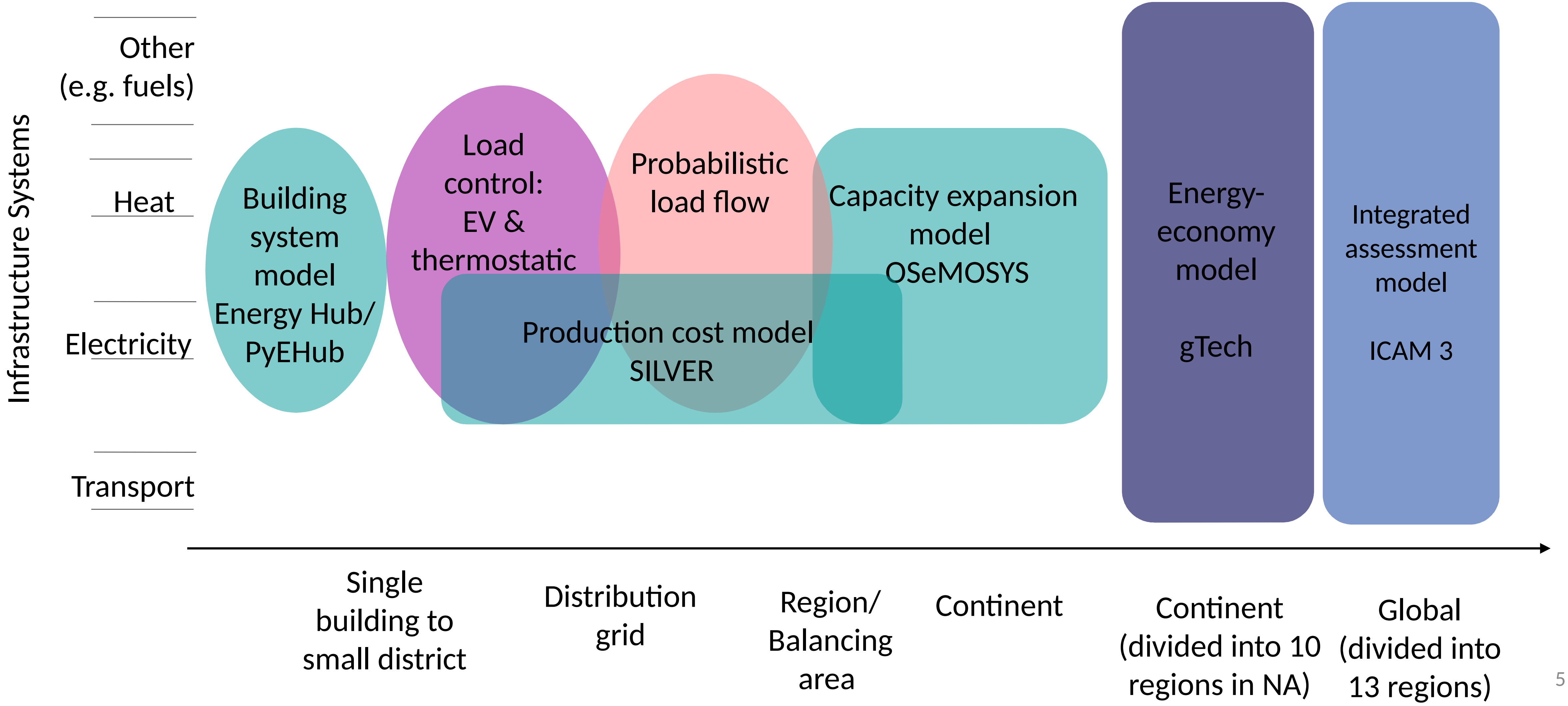
Electricity modelling types: different model types cover overlapping timeframes from milli-seconds to years, but there is a trade-off with the feasible level of modelling detail

Reference: Palmintier, B. (2013). “Incorporating operational flexibility into electric generation planning: impacts and methods for system design and policy analysis” PhD dissertation, Massachusetts Institute of Technology

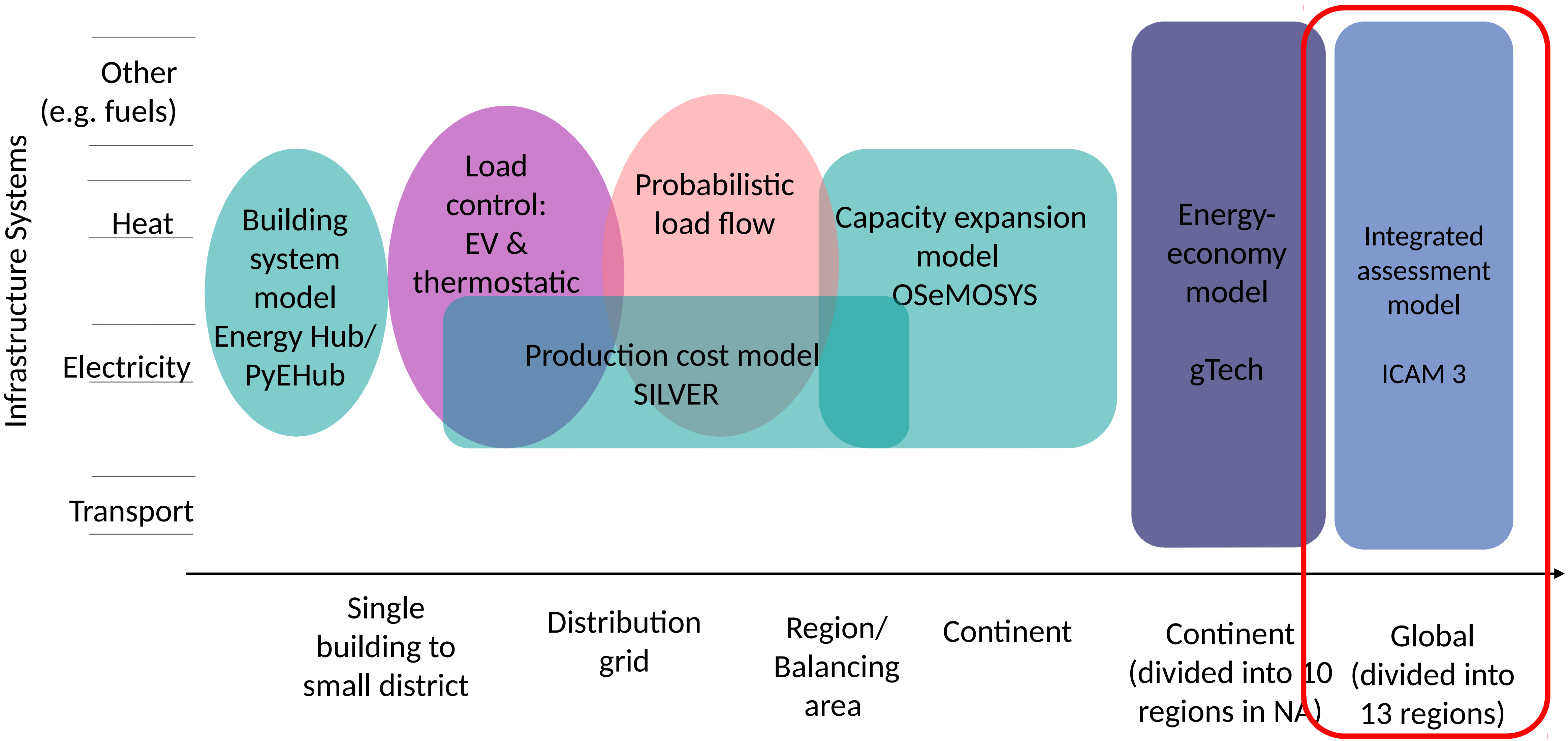
Modeling landscape - approach must be question & technology appropriate



Model Landscape: sector vs spatial coverage



Model Landscape: sector vs spatial coverage



Modelling
Non-marginal change

Hadi Dowlatabadi

Institute for Resources Environment & Sustainability

UBC

Introduction

- A policy aiming for change exceeding 10% is seeking non-marginal change.

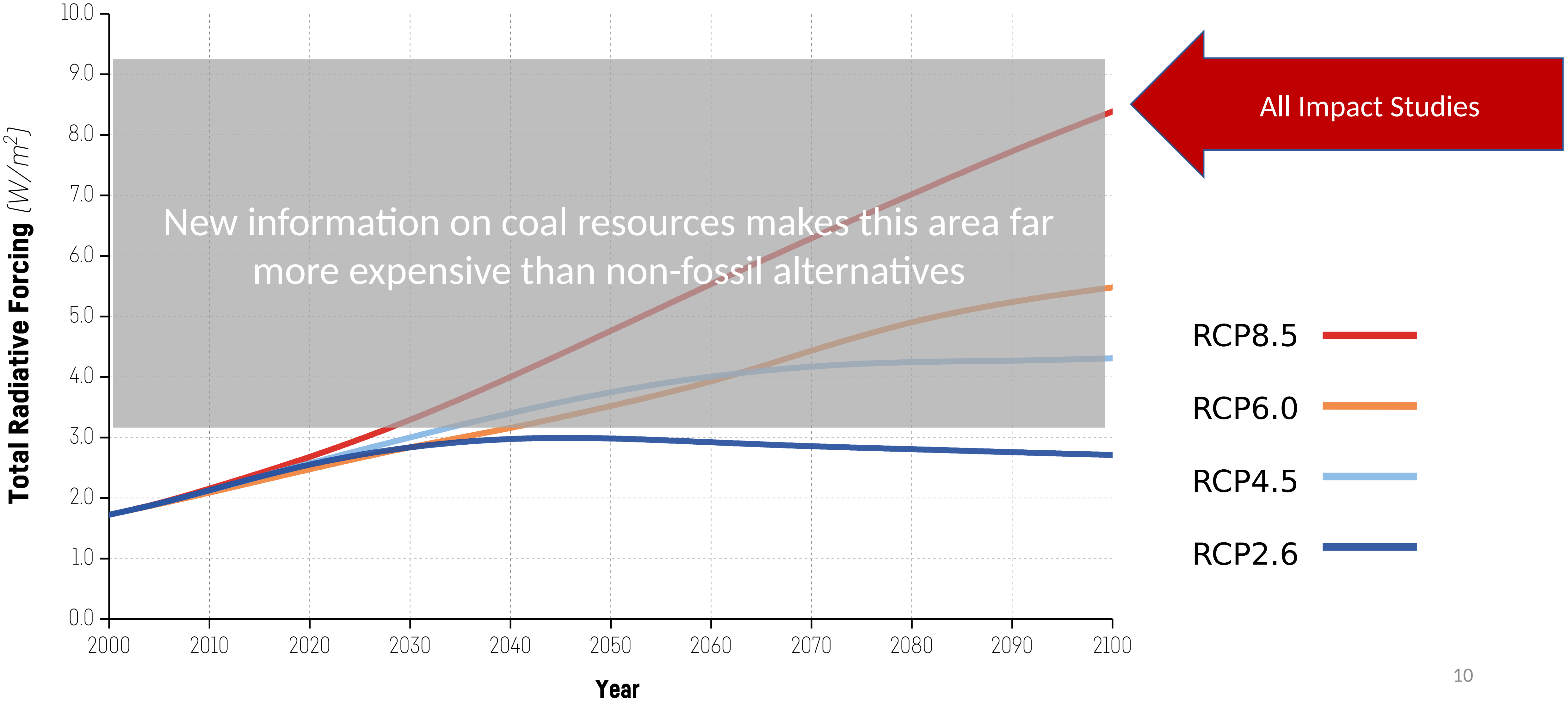
- Such modelling cannot:
  - Rely on historic elasticities in demand and income.
  - Assume “all else held constant”; because hardly anything will be as it is at present.

Challenges in non-marginal change

- Unexpected technological change
- Unpredictable public choices
- Other unknowns

IPCC (2014) AR5 Synthesis Report:

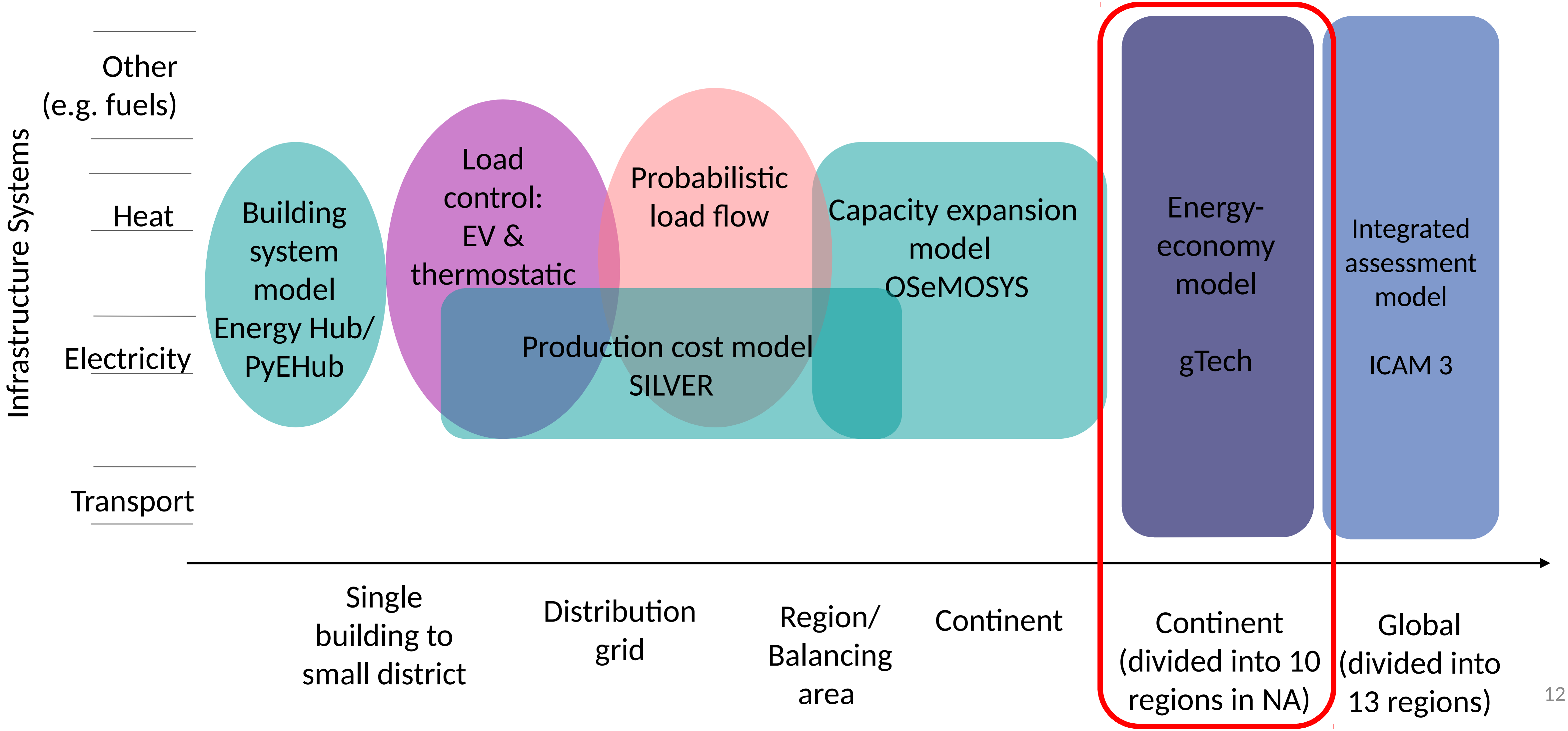
"Scenarios without additional efforts to constrain emissions ('baseline scenarios') lead to pathways ranging between RCP6.0 and RCP8.5"



Summary

- Modelling allows policymakers to explore strategies and their susceptibilities to various uncertainties.
- Robust policy-making is only possible when various contingencies addressing the uncertainties and their impacts have been considered and baked in.

Model Landscape: sector vs spatial coverage



cleanBC Modeling with Navius' gTech Model

Energy Modeling Initiative Western Workshop
September 27, 2019

Sean Broadbent, PhD
Climate Action Secretariat

BRITISH COLUMBIA | Ministry of Environment and Climate Change Strategy

Context

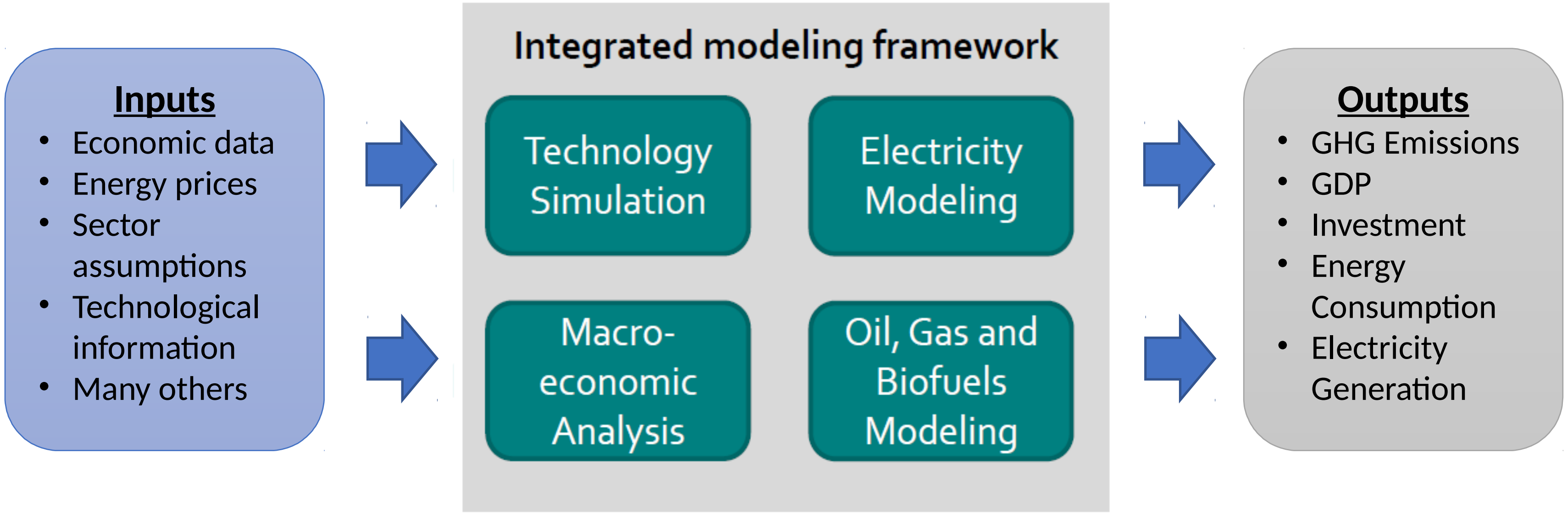
- BC has legislated targets to reduce provincial GHG emissions by 40% below 2007 levels in 2030, 60% in 2040 and 80% in 2050.
- The Climate Action Secretariat (CAS), in consultation with Ministry partners and stakeholders, led modeling of CleanBC policies
- CAS used Navius' gTech model to forecast the effect of CleanBC on BC's economy and GHGs.

The DNA of gTech

Specifics of gTech

- 200 technologies including biofuels
  - Each technology has capital, operating, and non-financial behavioral costs
- Full equilibrium macroeconomic feedbacks:
  - balanced supply and demand every 5 years
- 10 regions
  - British Columbia, 8 other Canadian regions and the United States
- Over 70 sectors of the economy in each region

gTech Inputs and Outputs



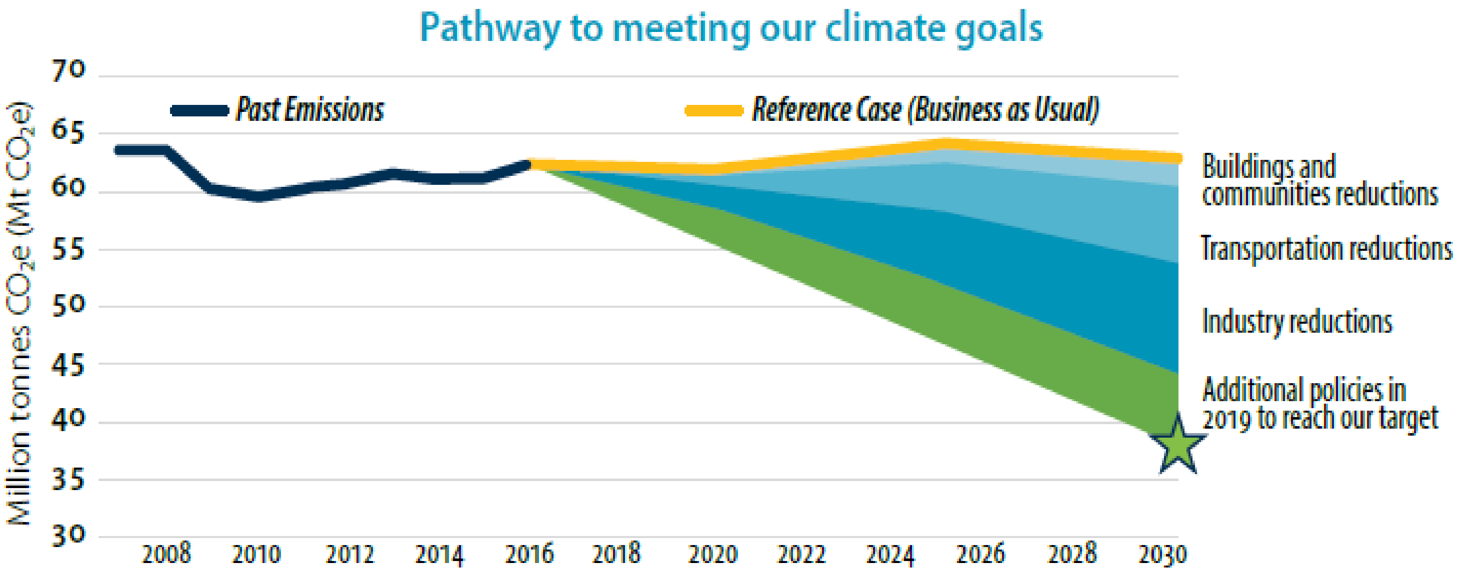
gTech can Model Various Policies

- Carbon pricing
- Incentive programs
- Regulations
- Flexible regulations
- Variations in other tax policy
- Policy packages

gTech Limitations

- Three types of limitations:
  - Uncertainty about the future energy economy
  - Boundaries of the model
  - Calibration challenges
- Some sectors are outside of scope of the model
  - e.g. deforestation

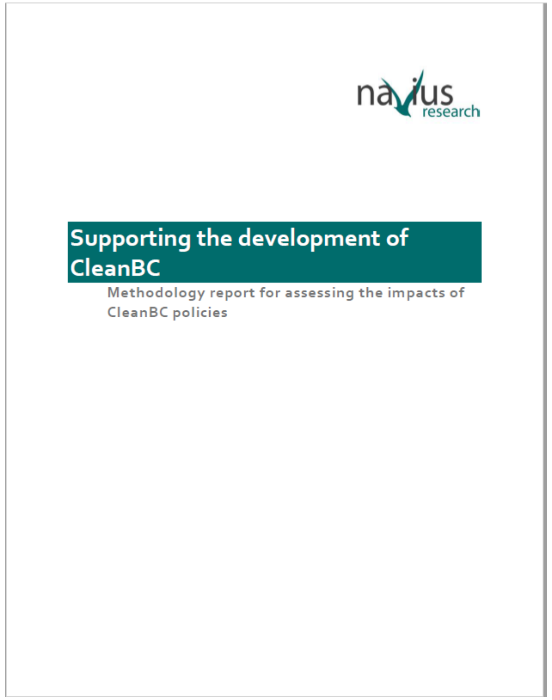
CleanBC Results



18.9 Mt of GHG reductions:

- ZEV mandate at 100% ZEV sales by 2040
- Low carbon fuel standard at 20% by 2030
- Carbon tax at $50 in 2021
- Renewable natural gas requirement at 15% in 2030
- Building code strengthening after 2030
- Incentives for ZEVs and heat pumps
- Methane regulations
- Stringent organic waste diversion; landfill gas capture and other policies

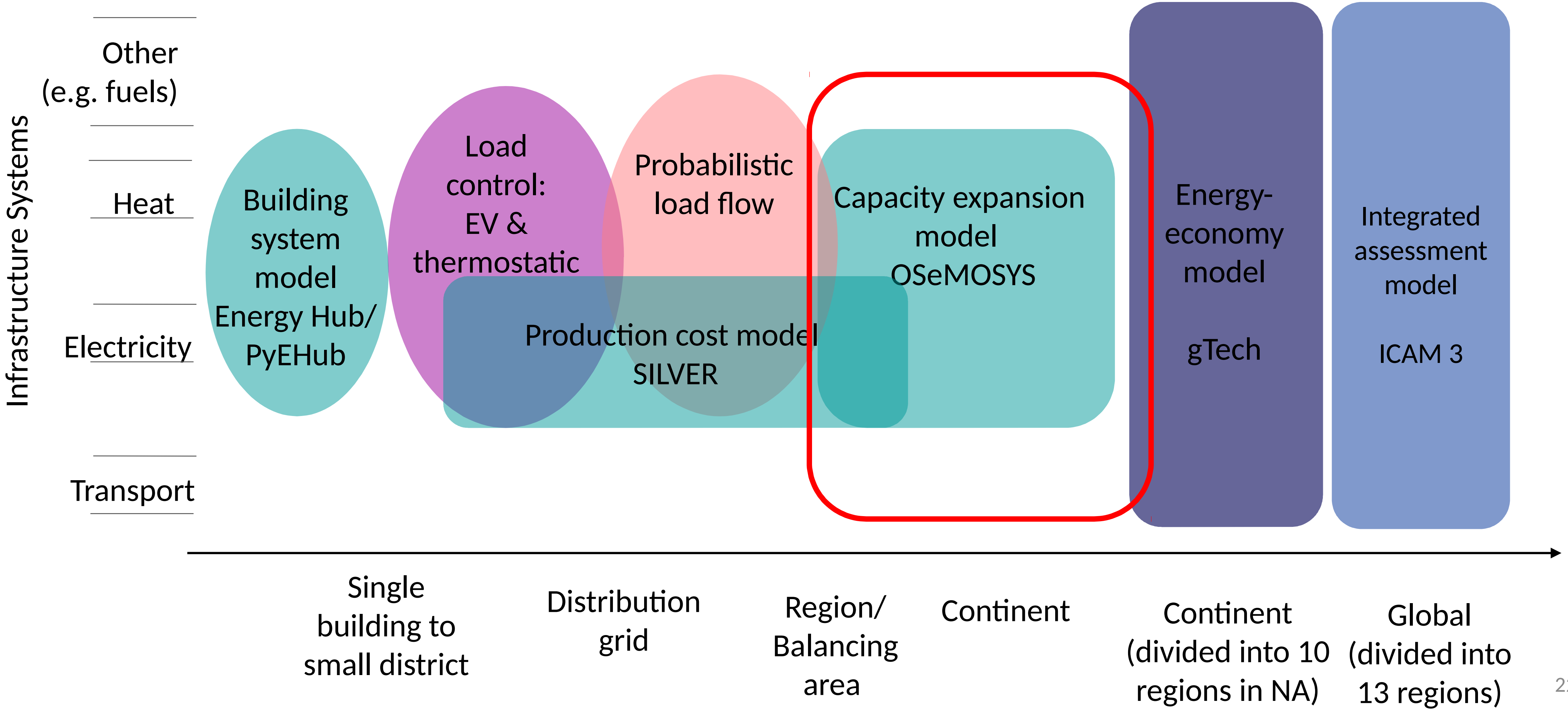
Want More Information?


Supporting the development of CleanBC

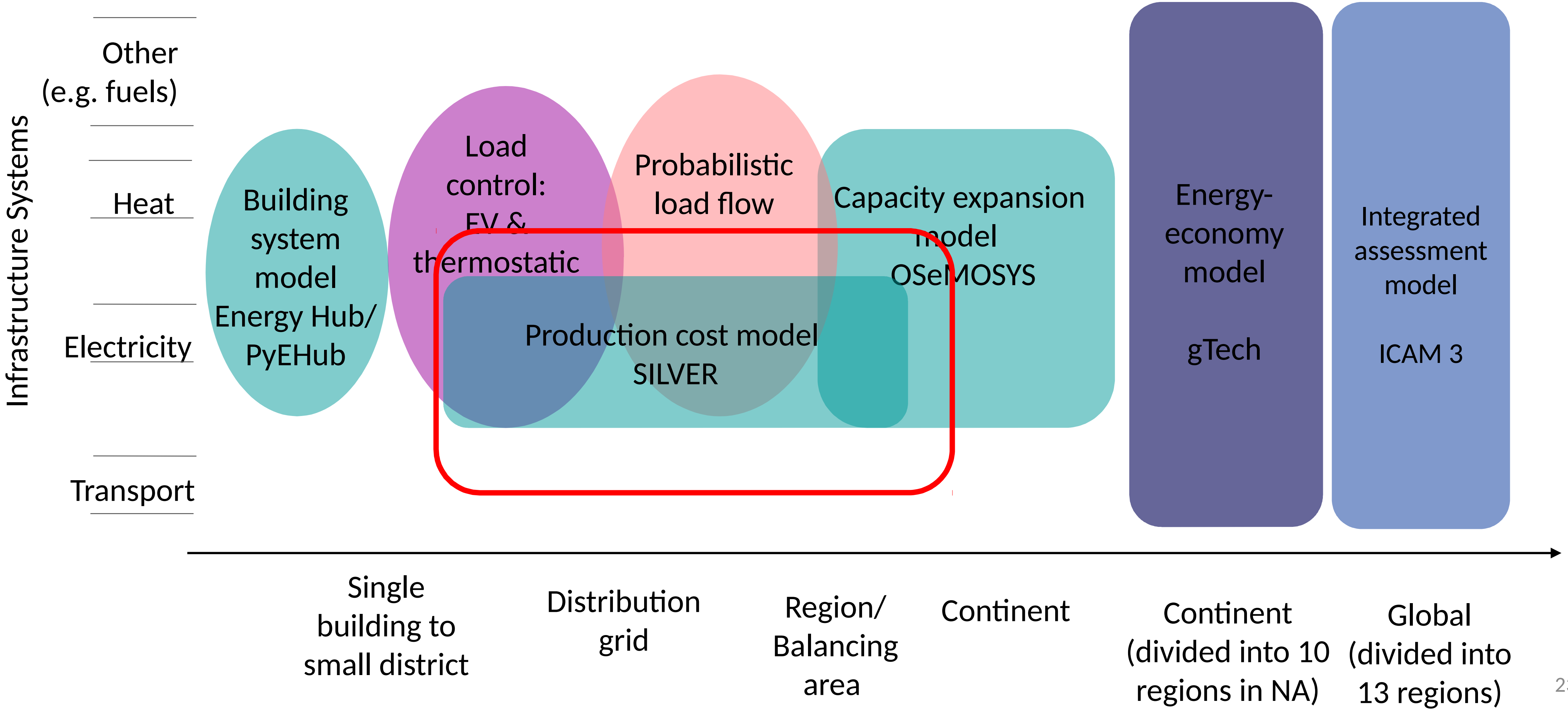
Methodology report for assessing the impacts of CleanBC policies

- Description of the “modeling toolkit” used to analyze the impact of CleanBC
- Key assumptions and limitations of the approach
- Description of how existing and proposed CleanBC policies are modeled
- Raw modeling results

Model Landscape: sector vs spatial coverage



Model Landscape: sector vs spatial coverage



Production cost models - overview

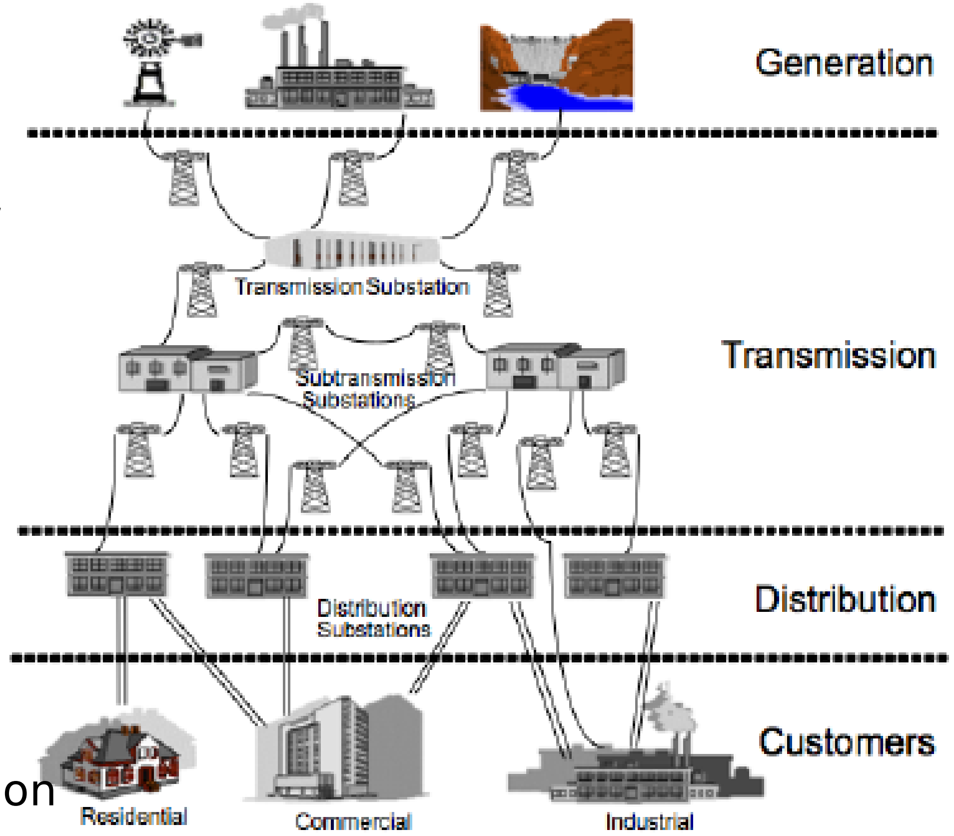
Objective: determine the least-cost dispatch of generation assets on the electricity system that meet load at every timestep and node

Production cost model

- Unit commitment, economic dispatch, optimal power flow
- Mixed-integer linear formulation

Several model platforms:

- PLEXOS – commercial
- SILVER – python based



Common applications

- Grid decarbonization
- Renewable energy, storage, and electric vehicle integration
- Electrification

Production cost models – Key attributes

Detailed grid-scale technology representations

- Generators (conventional, renewables)
- Transmission (distribution) lines

- Demand response
- Electric vehicles
- Storage technologies

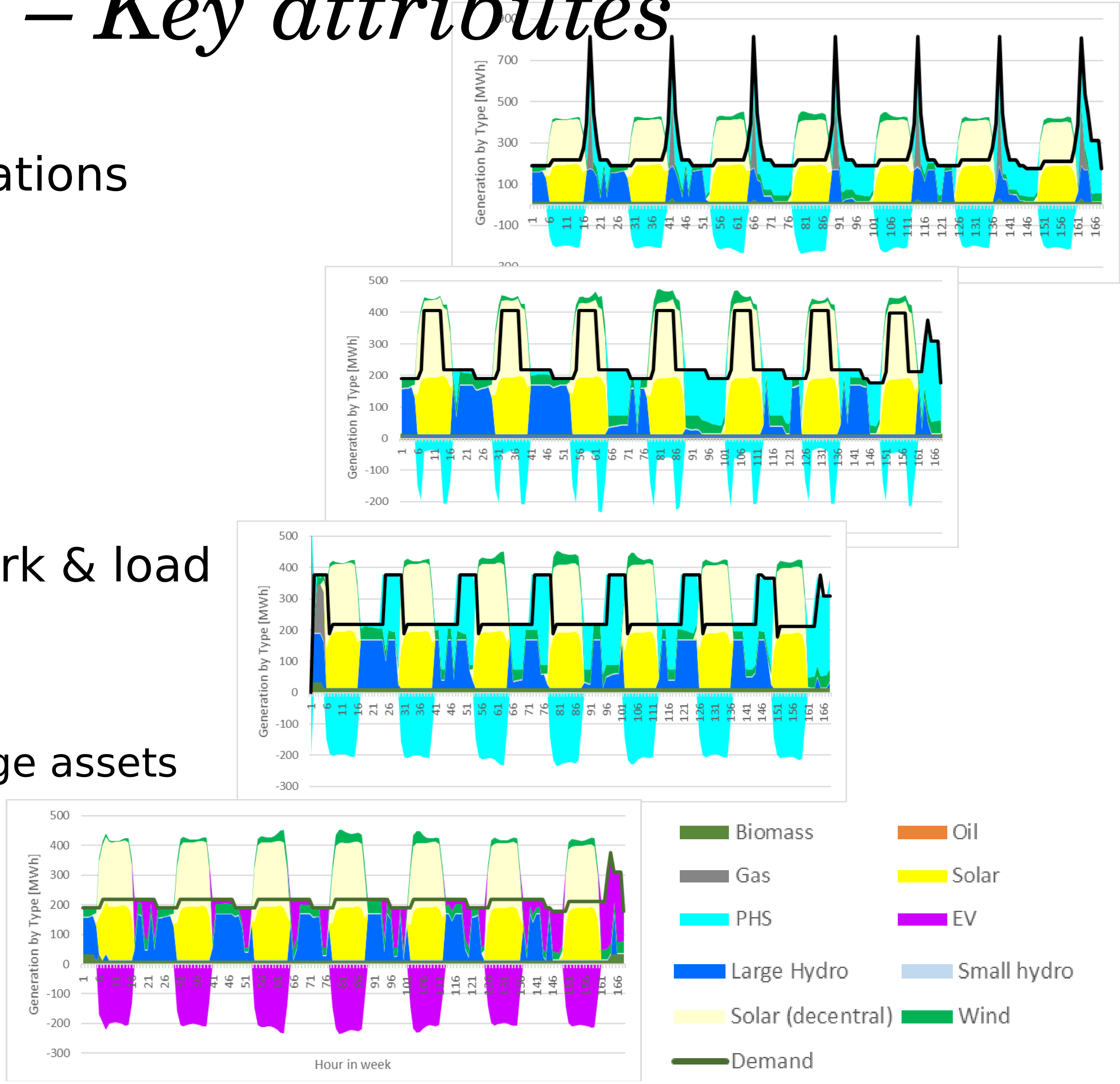
Spatial accounting of transmission network & load centers

Alternative market structures

- Dispatch horizon > forecasting errors; storage assets
- Remuneration policies

Scenario design approach

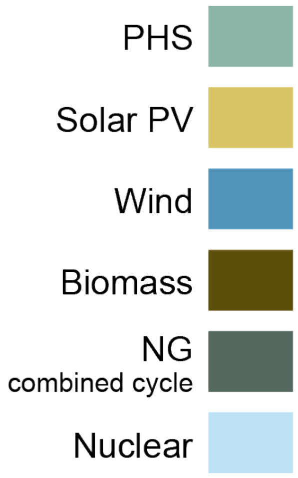
- Long term energy plan proposals
- Output from capacity expansion model

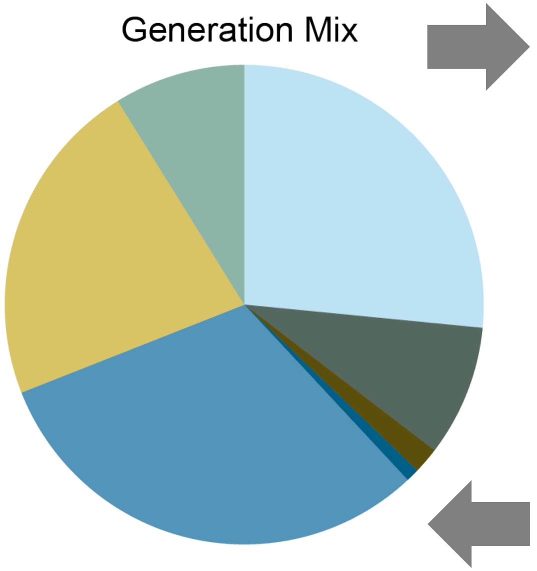


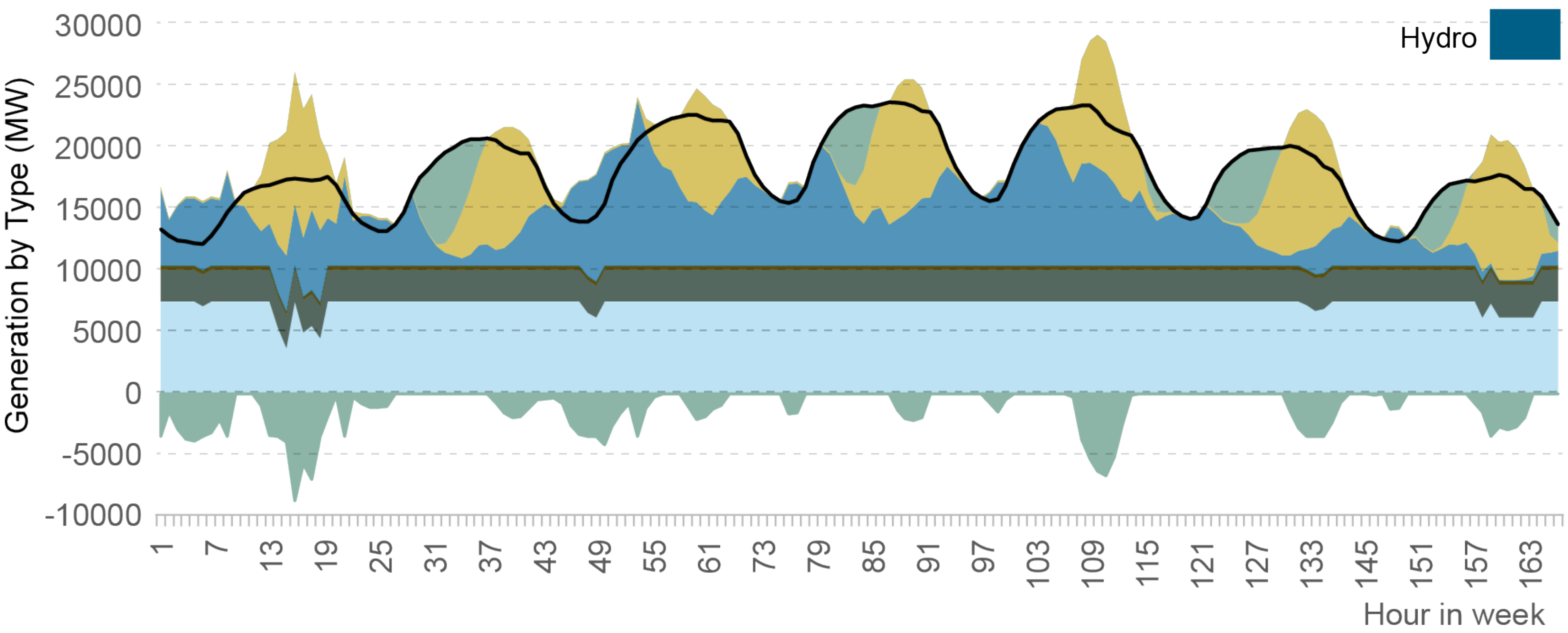
Capacity expansion +
Production cost model synergy

Develop insights across spatial-temporal scales

Capacity expansion: National scale – Sustainable design from a planning perspective
Production cost: Provincial and local scale – Sustainable design from an operations perspective







Production cost model - limitations

Accessing good input data

- Generator characteristics (ramp rates, heat rates, ...)
- Nodal, time-series load data
- Transmission/distribution capacity

Historical versus future data

- meteorological (climate change) and
- load data (electrification)

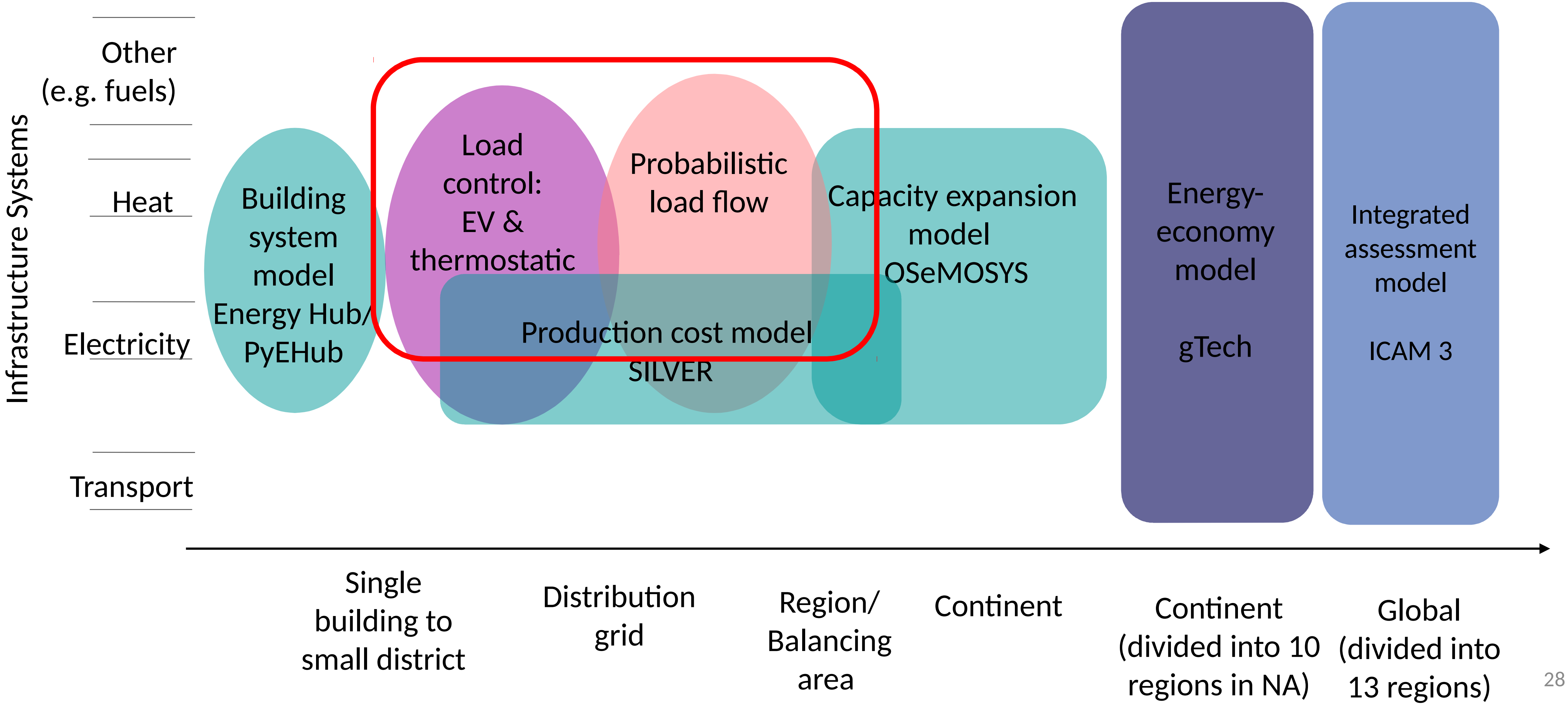
Future policy uncertainty

- Rate structures (time of use pricing, storage remuneration, EV charging)

Computational tractability

- Balancing model accuracy with breadth

Model Landscape: sector vs spatial coverage



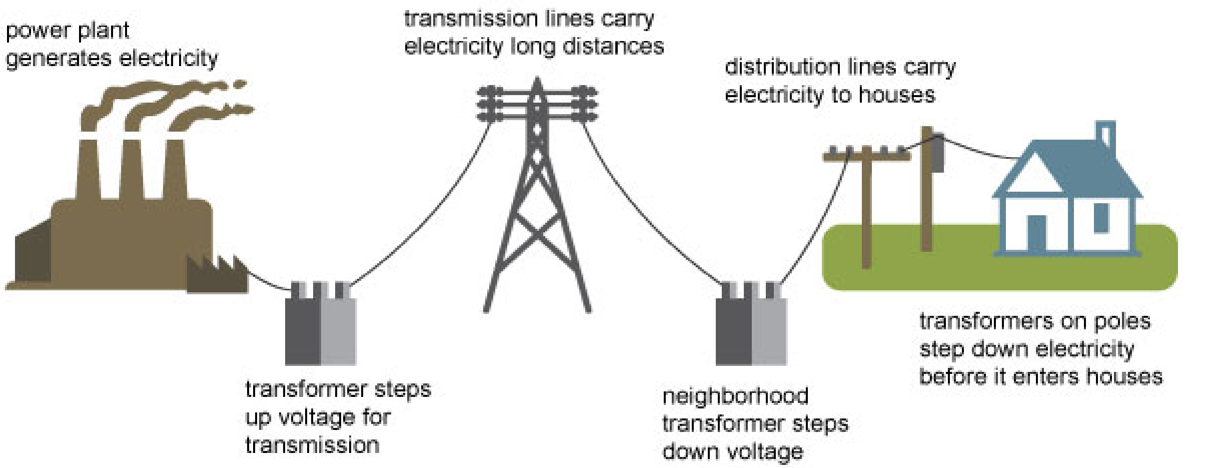
Agent/Market-Based & Stochastic Models

Generating Insights for Renewables, EV and DR Integration

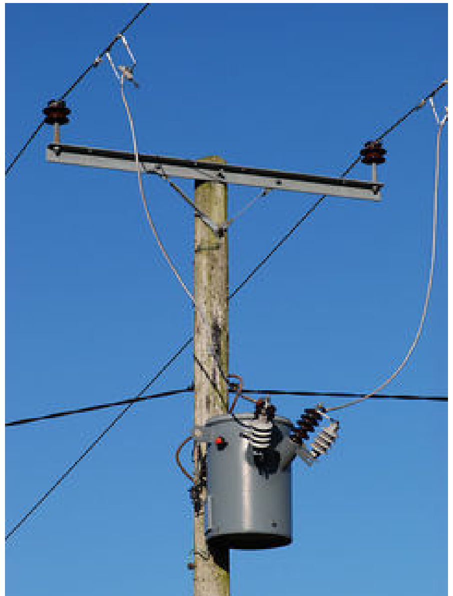
Dr. Curran Crawford (& Dr. Djilali, students)

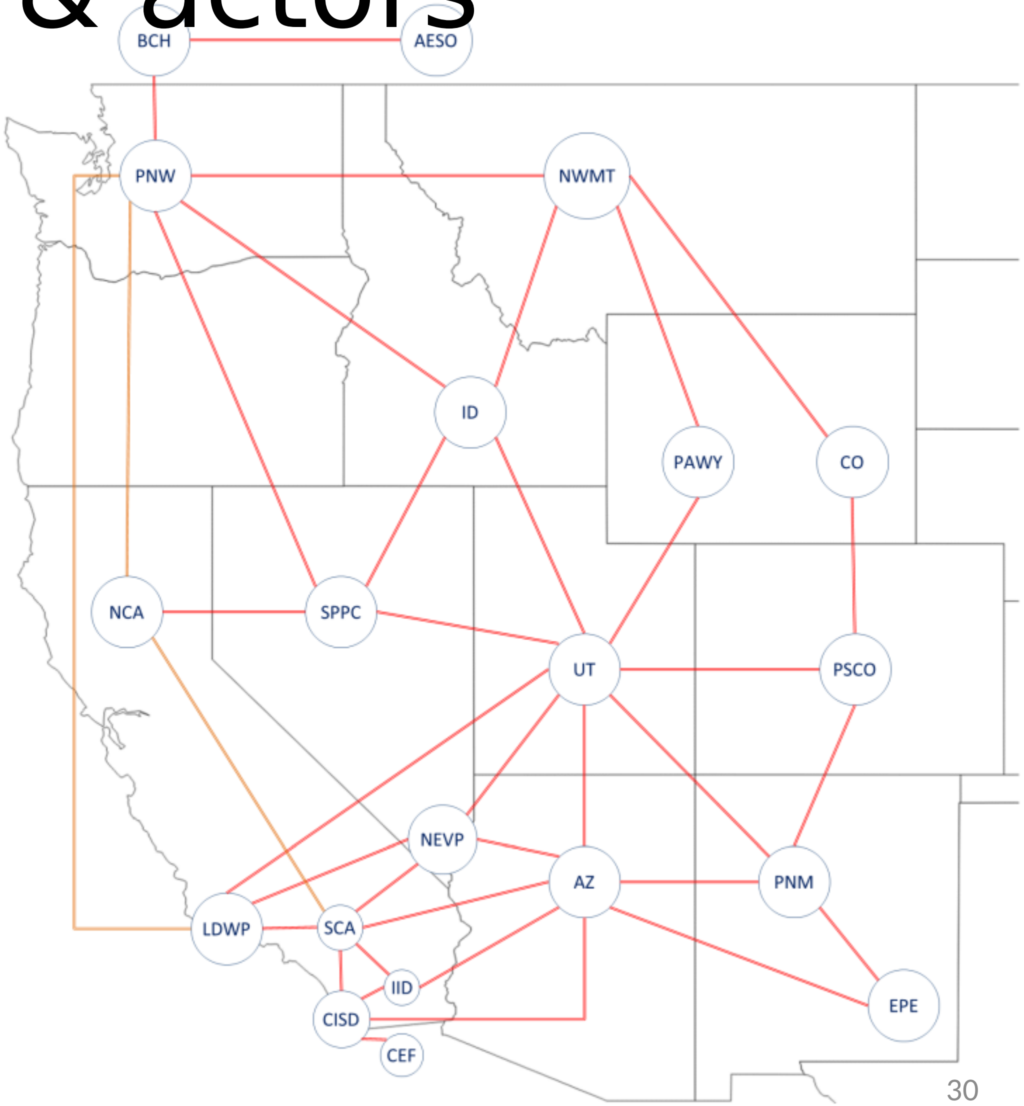
Energy Modeling Initiative Western Workshop
September 27, 2019
Victoria BC

We want to study real-time operations, across various scales & actors



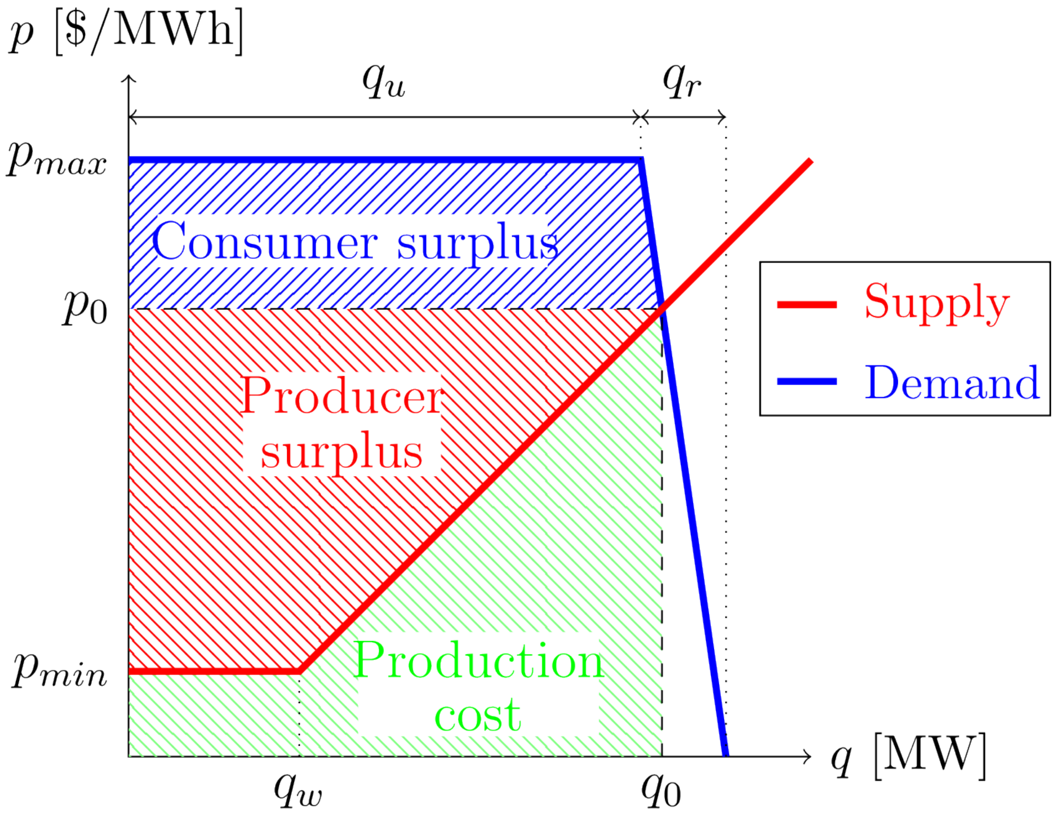
Source: Adapted from National Energy Education Development Project (public domain)





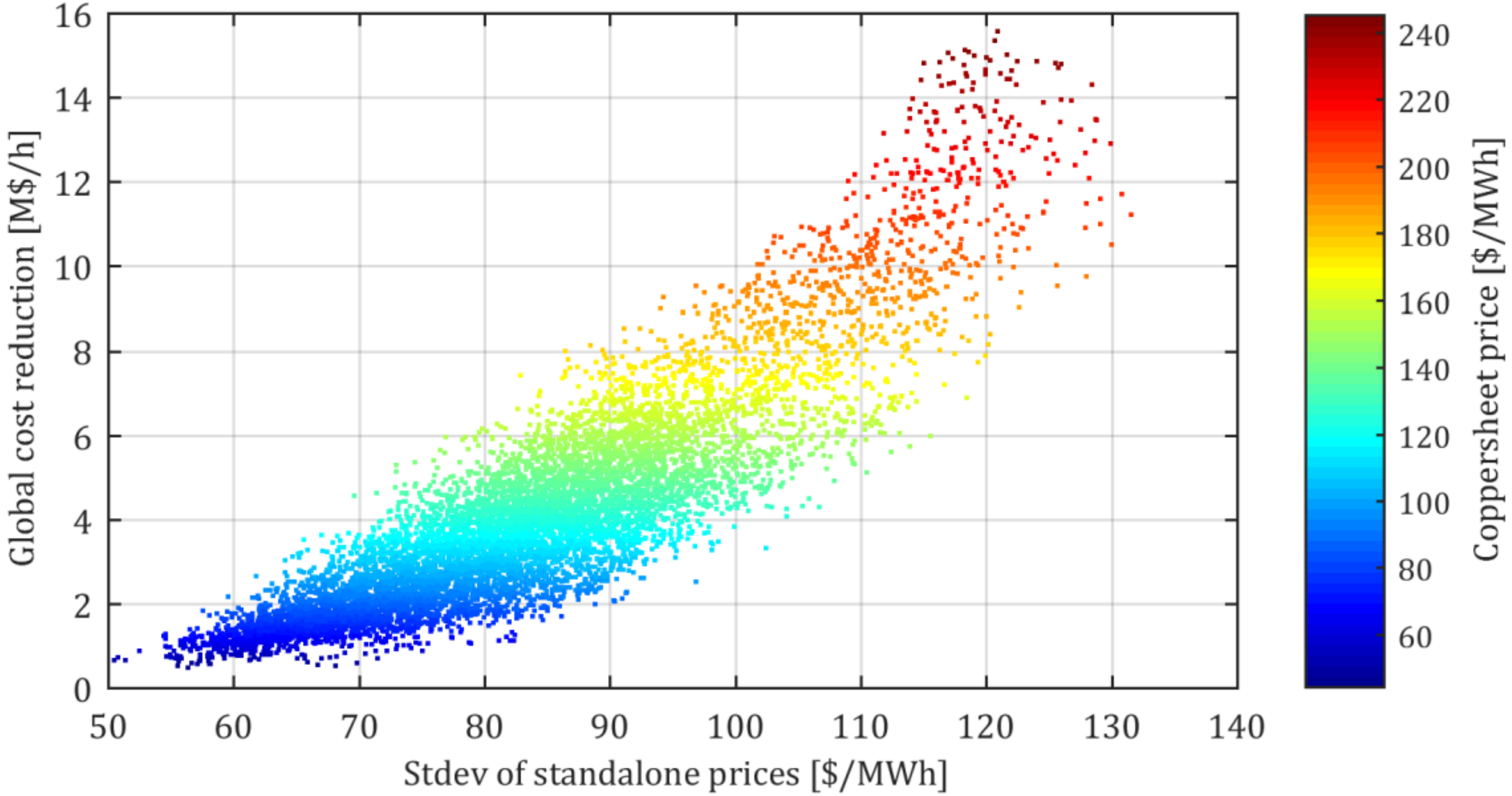
Utilize market dynamics for simulation at distribution or continental scales

- Double auction market
  - Bids from consumers & generation
  - Dispatch @ intersection
  - Slopes represent sensitivities
  - Time-marching solution
- Very scalable simulation framework
  - Extend to multi-area w/ constraints
  - Simplified or detailed cost inputs
  - Cost-optimal solution without ‘optimization’
- DR actors can be represented
  - Price (automatic) consumer preference



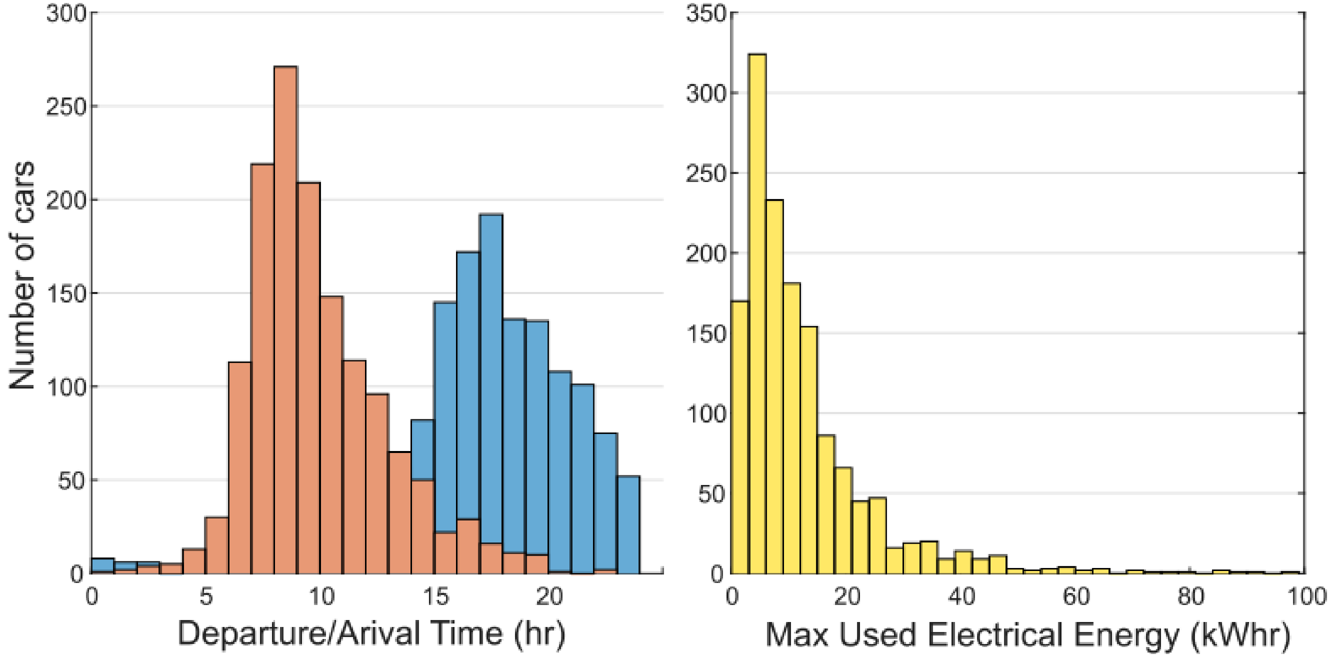
Example result for WECC for interconnection global cost reduction potential

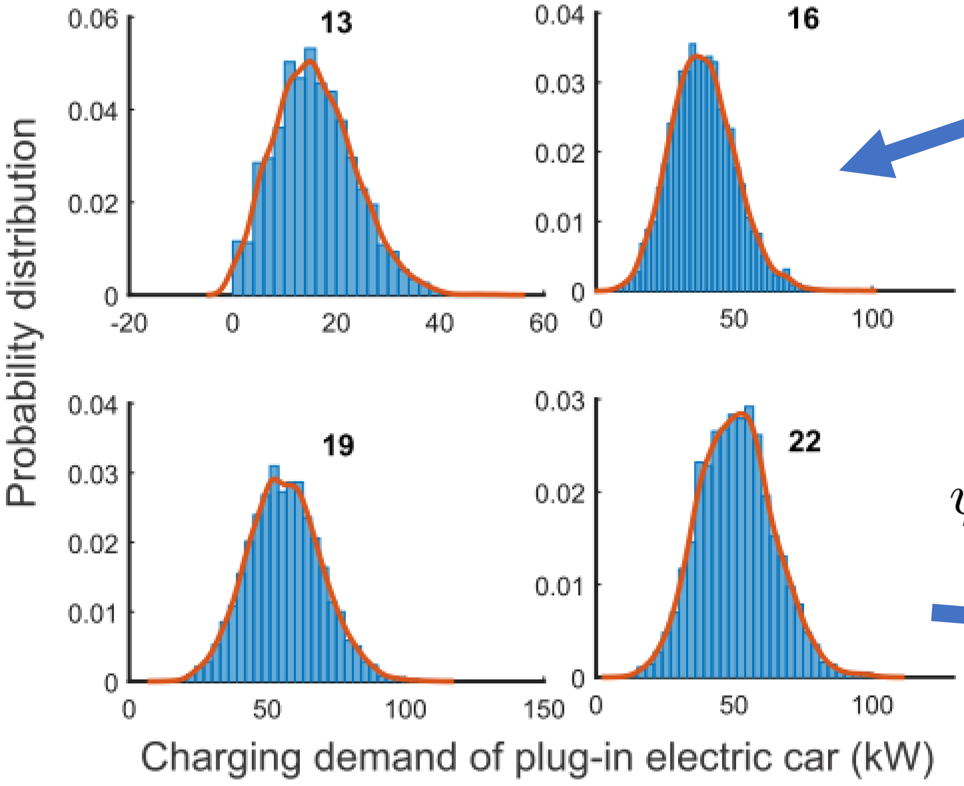
- > std deviation of stand-alone = greater flexibility



Quantifying uncertainty of grid operations is important

- E.g. Statistical EV behavior
  - Translate to PDFs

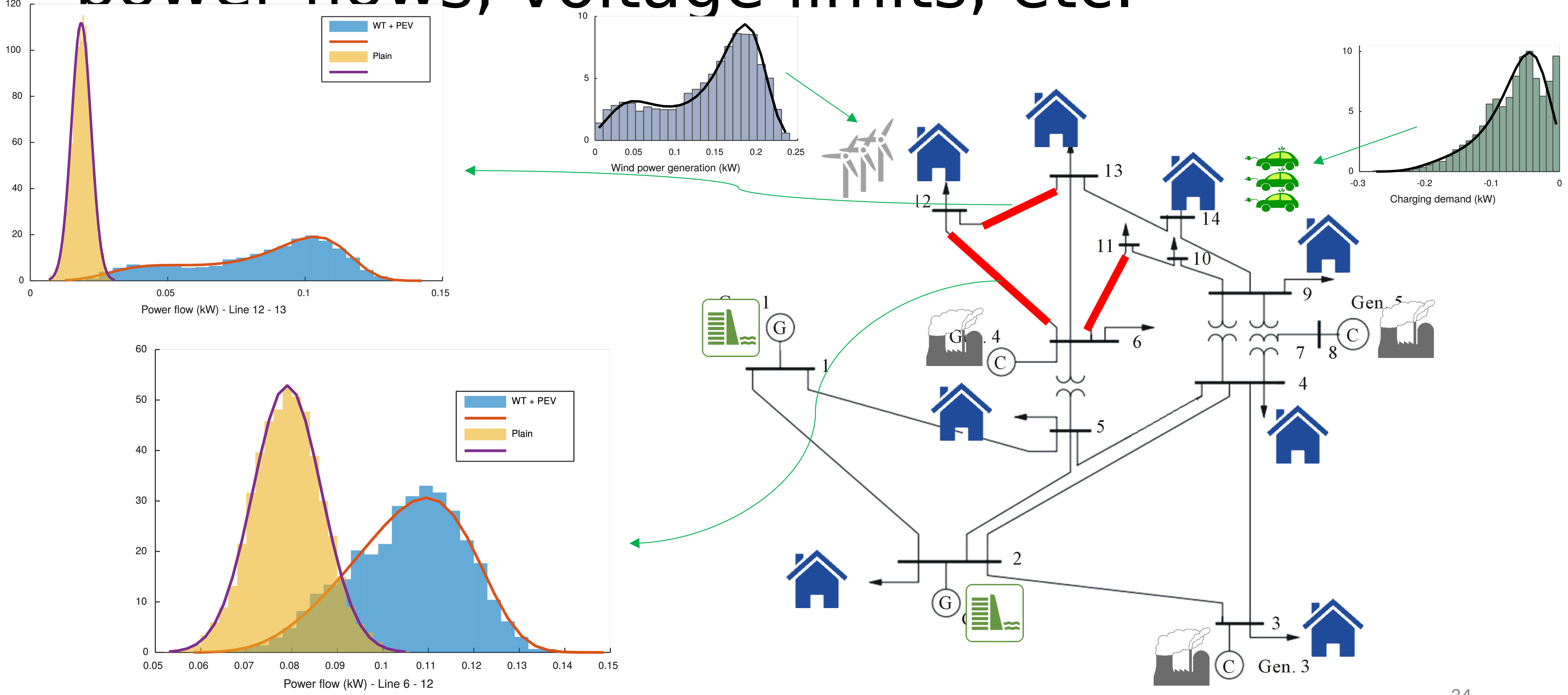




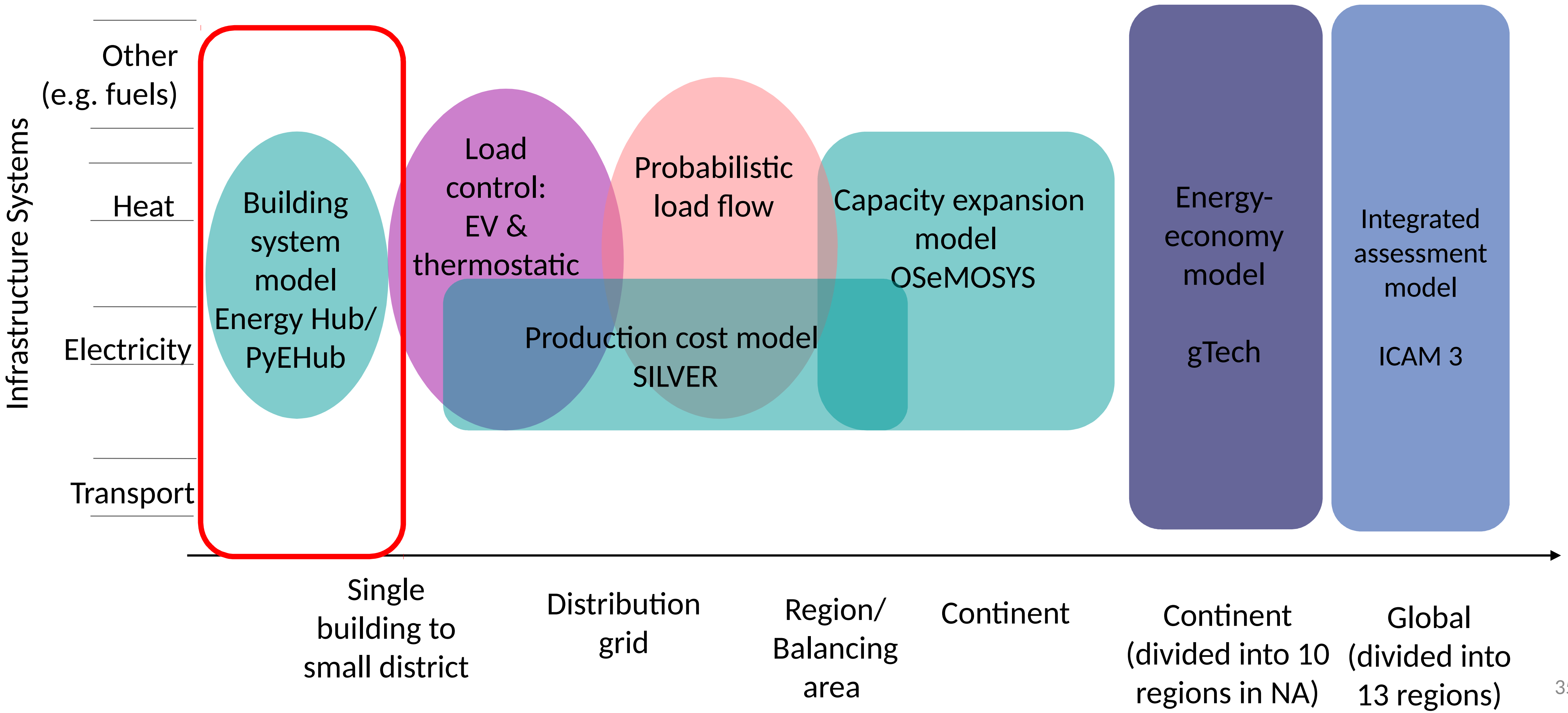
$$\psi^a = \alpha^a + \beta^a_i \chi^i + \gamma^a_{ij} \chi^i \chi^j + \cdots$$

$$\begin{aligned} \kappa^a &= {}_0\{\alpha^a\} + {}_1\{\beta^a_{ij}\kappa^{ij}\} + \mathcal{O}\left(\nu^{-5}\right) \\ \kappa^{ab} &= {}_1\{\beta^a_i \beta^b_j \kappa^{ij}\} \\ &\quad + {}_2\left\{\sum^2 \gamma^a_{ij}\beta^b_k \kappa^{ijk} + \left(2\gamma^a_{ik}\gamma^b_{jl}\right)\kappa^{ij}\kappa^{kl}\right\} \\ &\quad + {}_3\left\{\left(\gamma^a_{ij}\gamma^b_{kl}\right)\kappa^{ijkl}\right\} + \mathcal{O}\left(\nu^{-5}\right) \end{aligned}$$

Gain ability to understand e.g. variability power flows, voltage limits, etc.



Model Landscape: sector vs spatial coverage



Model landscape: objective

ICAM 3: A simulation model with interacting adaptive agents representing different nations and specific interests

gTech: general equilibrium model with technological explicitness, behavioural realism, and macroeconomic feedbacks

OSeMOSYS: Least-cost (capital + O&M + CO2) optimization of generation and transmission capacity expansion

SILVER: Least-cost optimization of electricity system operation

Load control: EV & thermostatic with discrete time marching electricity market simulation

Probabilistic load flow with uncertainty quantification and robust design & control

Energy Hub / PyEHub: minimize cost (investment + operational + CO2) of converters and storages sizes with multi-stream energy balancing