Modeling and Simulation in Service of Energy Policy

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Modeling and Simulation in Service of Energy Policy

This presentation

- Provides the general view of energy policy decisions
- Identifies the key challenges of modeling the energy policy decisions
- Presents system dynamics as a viable modeling approach

Energy Policy Decisions

- ***are at the forefront*** of public debates, legislative fora, and public and corporate decision making.

- ***are made in the face of a basic dilemma*** Economic growth and development and environmental emissions

- ***and are complex due to*** the dynamic interaction among actors, resources, and technology, and regulatory regimes

Energy Policy Decisions

- ***Are well served by modeling and simulation community*** of public debates, legislative fora, and public and corporate decision making.

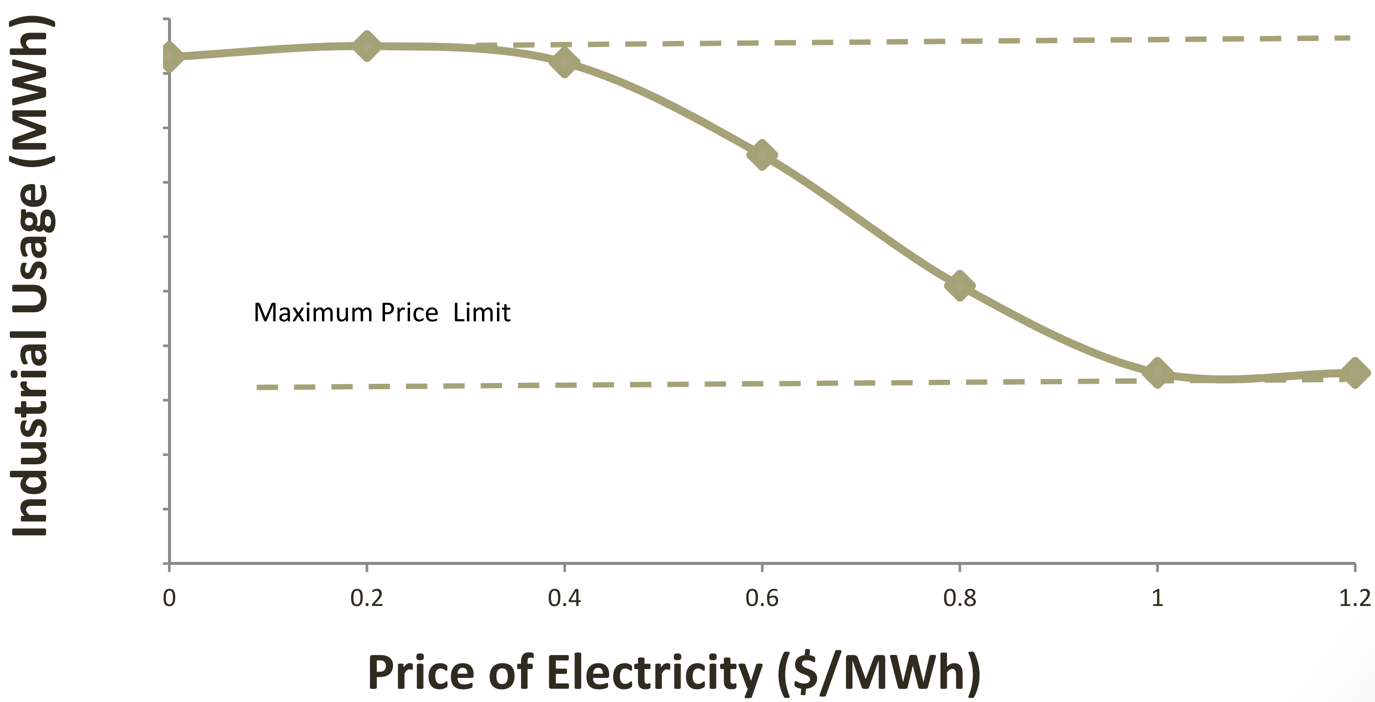
Methodologies	Example Models
Linear programming and dynamic programing	WASP model (Foel, 1985), MARKAL model (Fishbone & Abilock, 1981), & RES model
Mixed-integer linear program	MILP model (Omu et al., 2013
Econometric methods	NEMS model (Kydes & Shah, 1997) & SGM model (Praetorius & Schumacher, 2009)),
Partial equilibrium model	DEAS model (Wood & Geinzer, 1997)
Scenario analysis	Munasinghe and Meier's model (1993)
Agent-based modeling	ENGAGE model (Wang et al., 2013) 201

Major Challenges

- **Uncertainties abound**
  - ***The nature and life of incentives and rules keep changing***
  - ***Technological disruptions can severely impact the investments***
  - ***The availability and prices of fuels are rarely in smooth order***
  - ***Deregulation has expanded the nature and dimensions of stakeholders***
  - ***Perceptions of people change and sometimes in a relatively short order***

Major Challenges

- ***Existence of non-linear relationships is a reality***



Major Challenges

- ***Time lags can't be ignored***

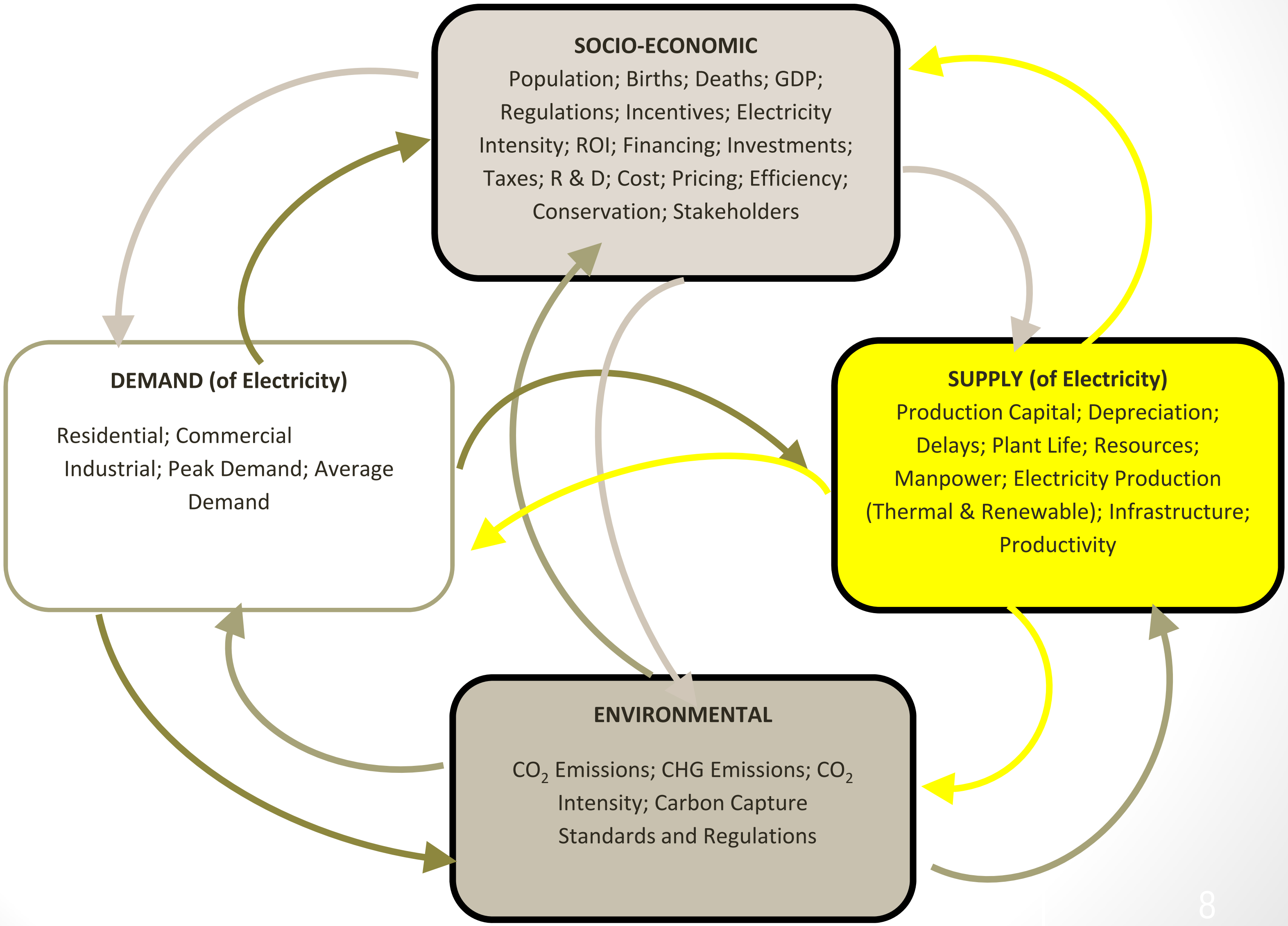
    - ***Material delays (e.g., construction)***
    - ***Information delays (e.g., approval(***

- ***Causation not correlation informs strategic decisions***

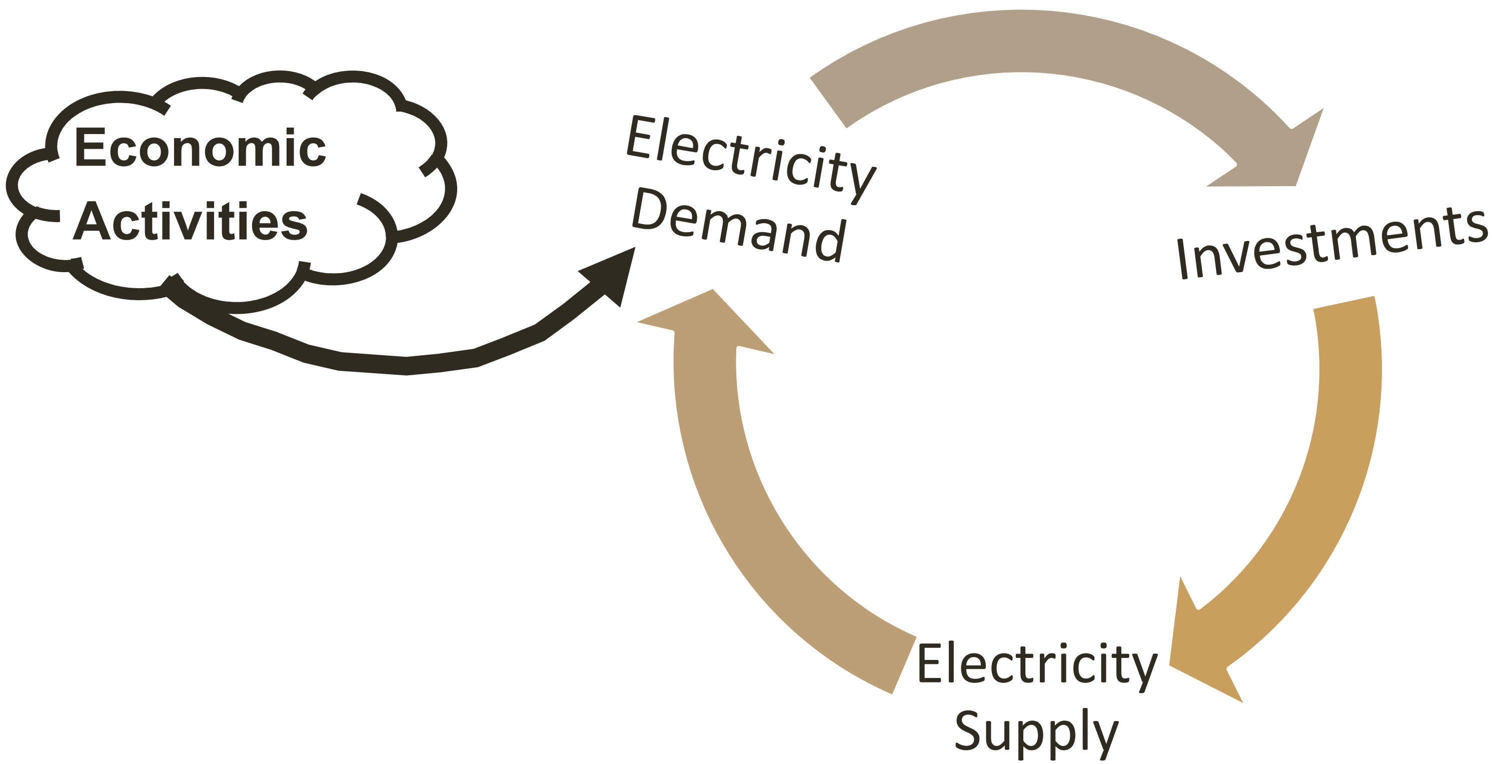
    - ***How does the stock of "electricity capital" impact electricity prices, over time?***
    - ***Which electricity supply-mix can provide affordable and cleaner electricity?***

Major Challenges

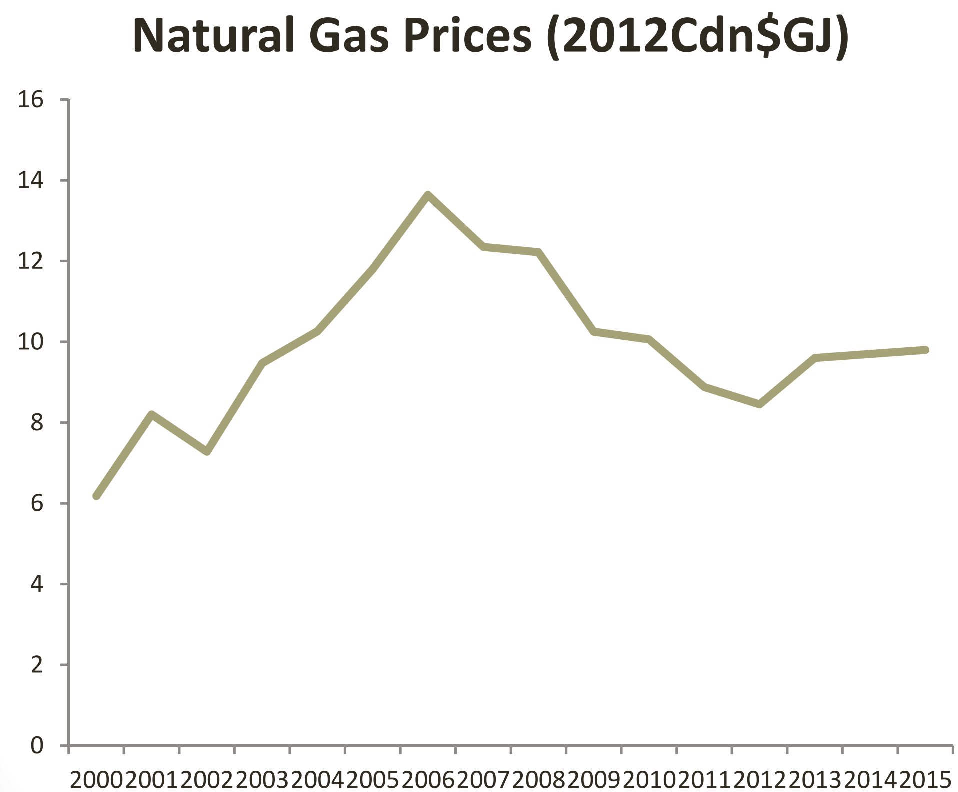
- *Energy systems are essentially feedback systems*

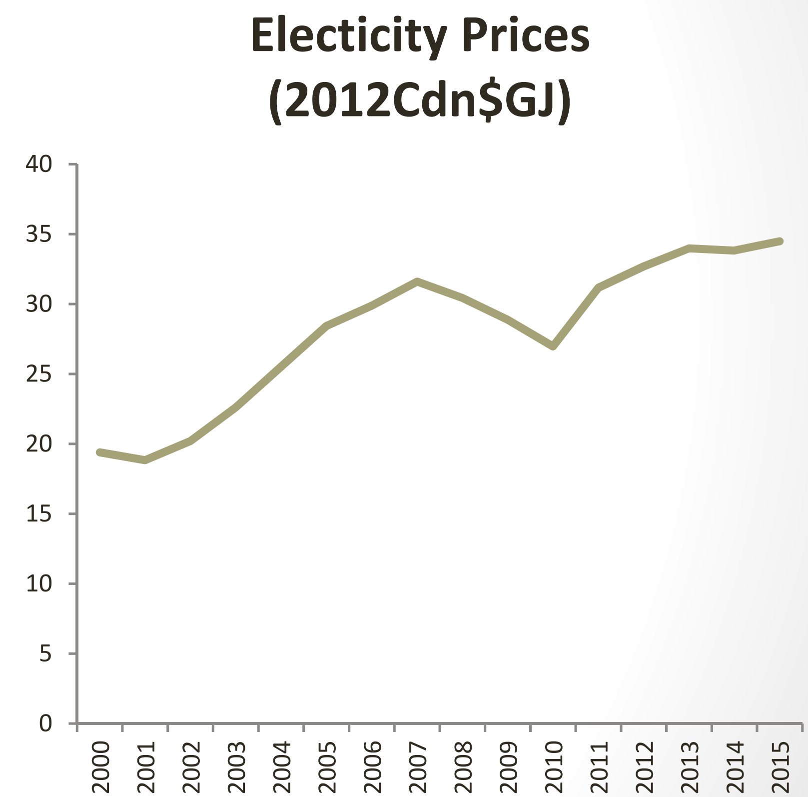


Major Challenges



Feedback structures create dynamic behavior





- Traditional modeling approaches are hardly adequate here….?

A Systematic Solution: System Dynamics Modeling Approach

- Structure of a system drives its dynamic behavior – endogenous view

- A utility company's loss of market share, according to System Dynamics (SD) perspective, is due to internal factors (e.g., low level of investments and low innovation rate---

System Dynamics Models

Some examples	References
Regional and national energy policies	Nail, 1973; Qudrat-Ullah & Davidsen, 2001; Dyner et al., 2009; Bassi et al., 2013; Amlin, 2013
Privatization of electricity	Bunn & Larsen, 1992; Bunn & Larsen, 1999; Dimitrovski et al., 2007
Efficiency analysis	Dyner et al., 1995; Qudrat-Ullah,2013
Electricity market design and responses	Vlahos, 1998; ; Dyner et al., 2009; Arango & Larsen, 2011
Renewables and environmental emissions	Fiddaman, 2002; Ford et al., 2007; Han & Hayashi, 2008; Trappey et al., 2012; Qudrat-Ullah, 2005, 2014

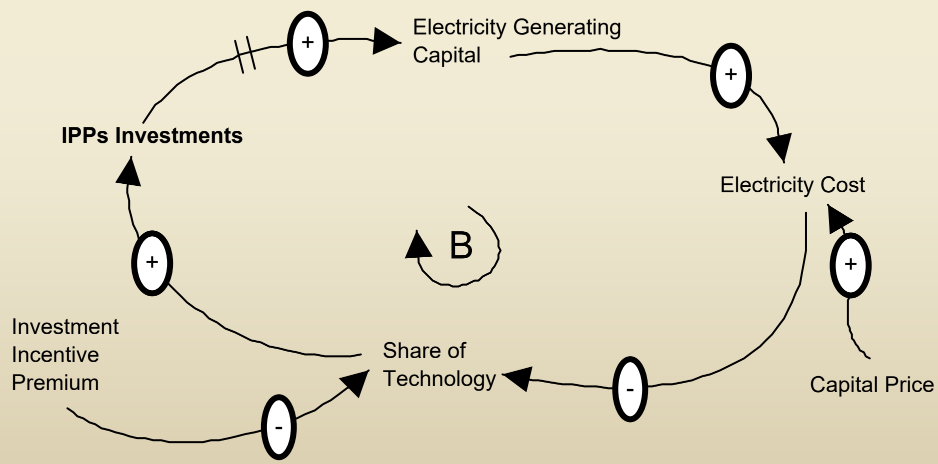
Modeling of inter-fuel substitution process and policy incentives

$$TC_i = CCi + OC_i + FC_i + IIP_i + IDPi + ENP_i,$$

$$ST_i = exp\ (-\ \alpha\ x\ TC_i)\ /\ \Sigma_i\ exp\ (-\ \alpha\ x\ TC_i),$$

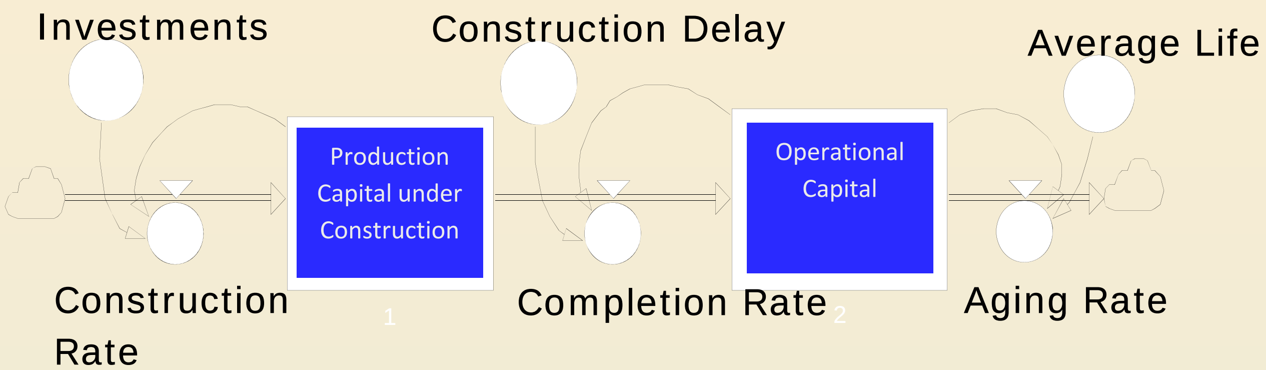
where i = technology 1, technology 2, technology 3,….technology n.

TC: Total Cost; CC: Capital Cost; OC; Operating Cost; Fuel Cost; IIP: Investment Incentive Premium; IDP: Indigenous Resource Use Premium; ENP: Environmental Premium (Carbon tax)



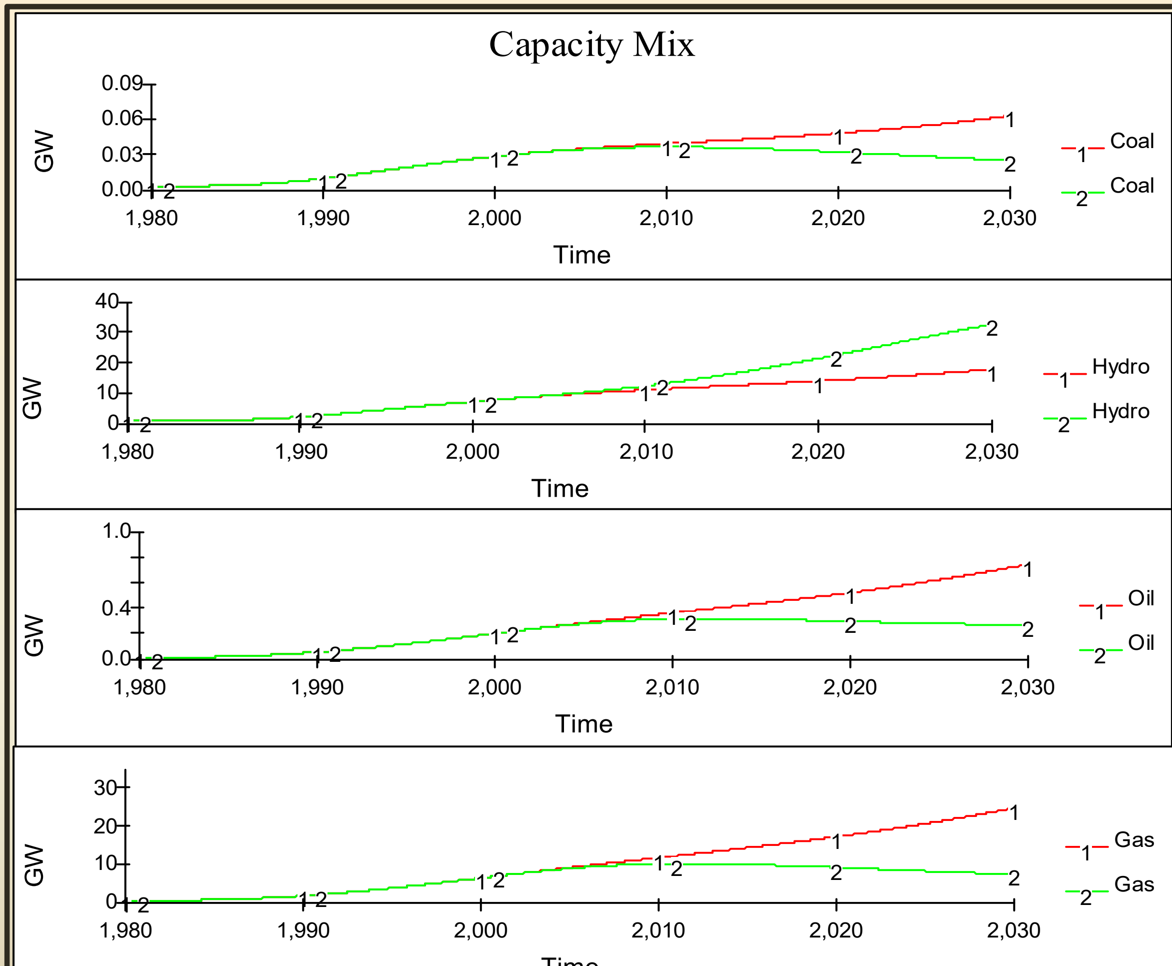
Share of Investments for each Technology due to Policy Incentives

Stock and Flow Structure of Generation Capital



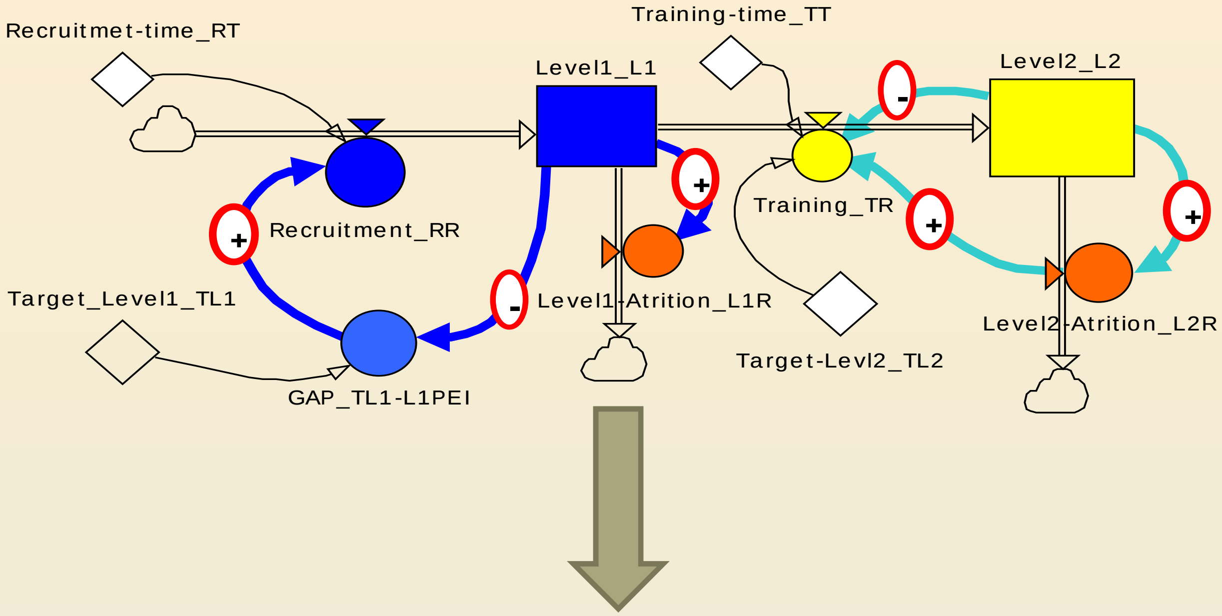
A two-vintage structure of production capital (Source: Qudrat-Ullah, 2013)

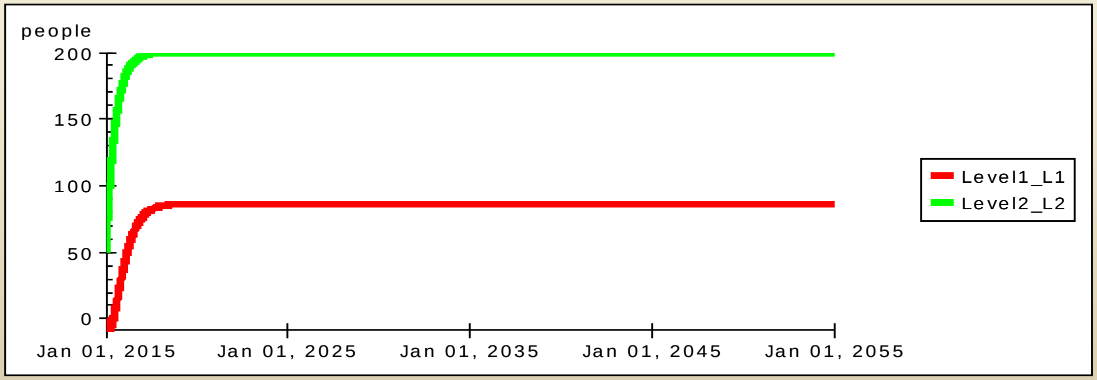
Structure drives behavior



Dynamics of the Substitution Process: Reference (1) versus Environment (2) Scenario

Modeling of Manpower Dynamics



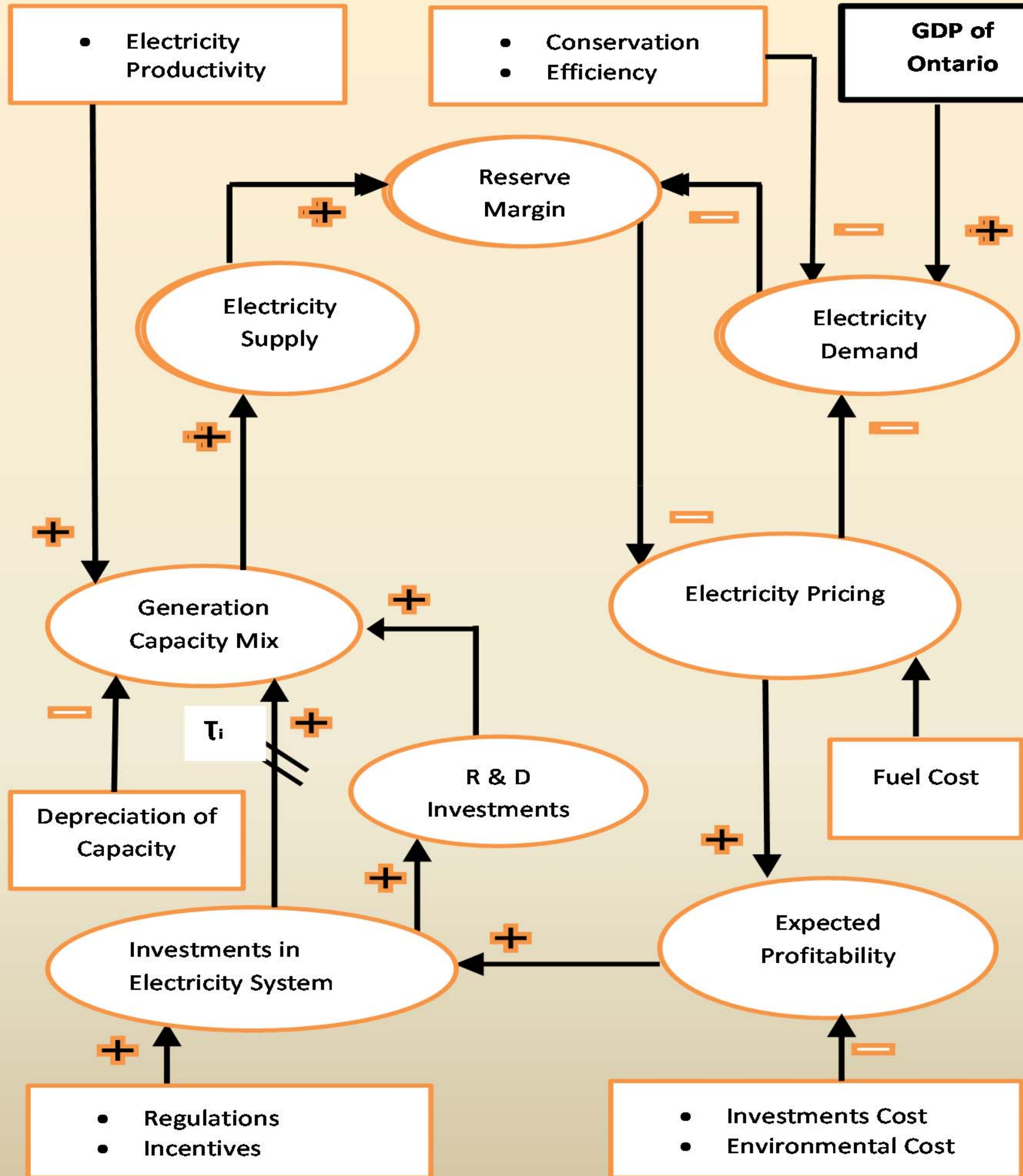


Green Energy in Ontario

(i) Status Quo Scenario: Ontario's economic data and conditions.

(ii) Renewables-Focused Scenario (RFS): If there is a larger support for renewables.

(iii) Low-Carbon Economy Scenario (LES): generation from the technologies with the least CO_2 emissions.



Green Energy in Ontario: Some insights

1. With the “excess capacity” regime at hand, from now to the end of this decade, 2020, Ontario has the opportunity to reconsider OPA's plan. For instance, our results show that the ”Dash for gas” approach will neither help in lowering the electricity rates nor will it reduce the stock of cumulative electricity related CO2 emissions. Instead, the substitution of relative high cost nuclear refurbishments with low cost hydro and nuclear solutions could result in similar CO2 emissions accumulation and intensity but at relatively cheaper “green power

2. *Despite being a significant source of CO_2 emissions, OPA’s plan favors gas-based generation for its status as a “flexible supply” utility. Based on our analysis, however, utilization of hydro reservoir as “energy storage systems” appears to be a cheaper source of “flexible supply” than the gas-based generation..*

3. *In contrast to current OPA’s plan where electricity consumption per capita in Ontario still remain higher than comparable states like New York, a new plan focused on having more low-carbon economy seems to lower the electricity intensity. Lower electricity intensity in Ontario means more “green power” (Qudrat-Ullah, 2014)”*

Some conclusions

- The existence of non-linear and uncertainty intensive variables, several inherent time lags, and intertwined feedback loops in an energy system pose serious modeling challenges

- *System Dynamics methodology* provides viable solutions to complex, dynamic energy policy decisions.

Some of our related work

Qudrat-Ullah, H.,and Kayal, A. (2018). How to improve learners' (mis) understanding of CO2 accumulations through the use of human-facilitated interactive learning environments? Journal of Cleaner Production. 184: 188-197.

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Qudrat-Ullah, H. (2015). Independent power (or pollution) producers? Electricity reforms and IPPs in Pakistan, *Energy*, 83(1): 240-251.

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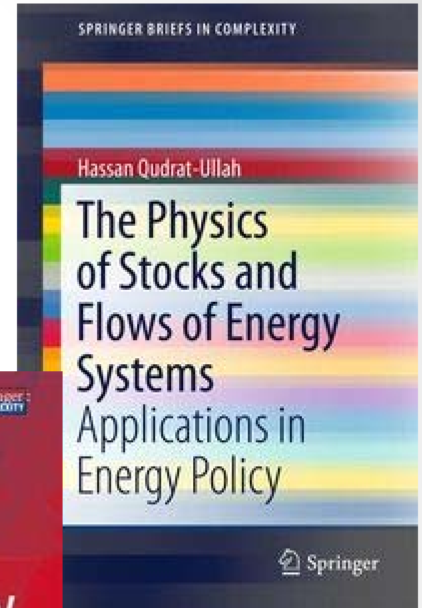
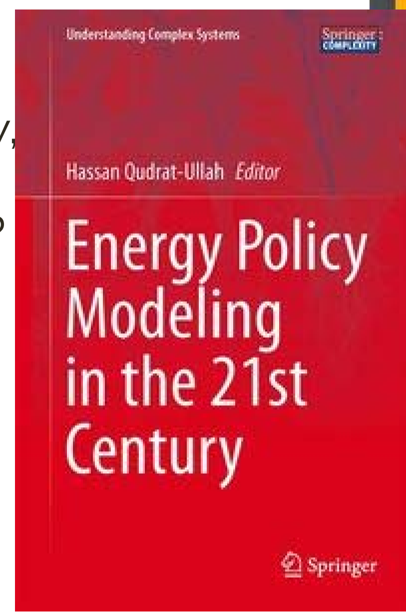
Qudrat-Ullah, H. (2013). Understanding the dynamics of electricity generation capacity in Canada: A system dynamics approach. *Energy*, 59: 285-294.

Qudrat-Ullah, H., and BaekSeo S. (2010). How to do structural validity of a system dynamics type simulation model: The case of an energy policy model. *Energy Policy*, 38(5): 2216-224.





Thank you for listening!