Co-optimization of Transmission and Supply Resources

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Outline

1. **Project Overview**
2. **Uses of Co-optimization**
3. **Benefits of Co-optimization**
4. **Example Methodology Review**
5. **Institutional & Data Issues**
6. **Recommendations**

1. Overview

Goal: Provide EISPC with a comprehensive overview of co-optimization modeling: applications, benefits, state-of-the-art, and institutional issues.

Co-optimization: simultaneous evaluation of two or more classes of investments within one optimization problem

- **Such as G&T; G&T & gas pipelines; G&T & DR.**

Why of interest? Traditional planning: generation-first, then design transmission to facilitate generation plan

- **But transmission affects economics of plant siting, and vice versa**
- **Better solutions (economically, environmentally) may be identified by searching (optimizing) generation and transmission simultaneously.**

Deliverable: White paper covering 15 tasks

Task	Project Tasks
1	Review strengths/limits of current resource planning models
2	Identify benefits of co-optimization models
3	State of the art of co-optimization models
4	Detail the incremental data requirements
5	Identify benefits of incremental data
6	Information from planning coordinators required to run co-optimization models
7	Advantages/disadvantages of approaches to co-optimization
8	Establish validation protocols
9	Computing requirements
10	Time requirements for model development/initial validation
11	Confidentiality concerns
12	Uncertainty modeling
13	States' role in developing databases & utilization of co-optimization models
14	Co-optimization models in the public domain
15	Recommendations for next steps

Methods:

- Literature reviews
- Discussions with Planning Coordinators, vendors
- Small & large co-optimization applications

2. Uses of Co-optimization: *Vertically Integrated Utilities*

- **Planning generation, transmission & other resources together to minimize total cost of power delivered**
  - **Within subarea of service territory:**
    - ***alternatives at circuit level for serving load pocket***
  - **Over entire service territories:**
    - ***planning for renewables interconnection***
  - **Interconnection of different service territories:**
    - ***alternatives at interface level for economic power exchange***
- **IRP for all resources (storage, demand, gen, transmission)**


http://www.energy.ca.gov/maps/infrastructure/3part_enlargements.html

Uses of Co-optimization: *Unbundled Markets*

- ***"Anticipatory Transmission Planning":*** **Grid planning anticipating how generation investment & dispatch may react:**
  - **Within subarea of service territory:**
    - ***how load pocket reinforcement affects incentives to site plants inside pocket***
  - **Over entire service territory:**
    - ***how grid affects incentives for remote vs. nearby renewable development***
  - **Over entire market or between markets:**
    - ***how interconnections affect trade, competition, & incentives for plant mix & siting***

- **Guide capacity market design to evaluate mixes of resources (gen, storage, DR, transmission) & fuel needs**


http://www.energy.ca.gov/maps/infrastructure/3part_enlargements.html

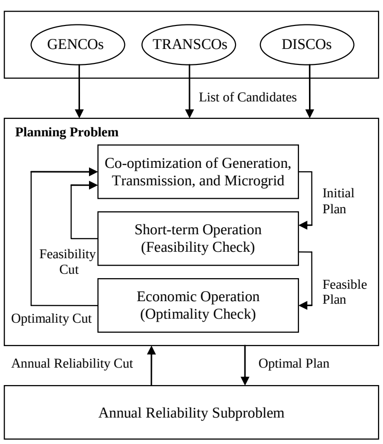
3. Benefits of Co-optimization

- **Benefits of co-optimizing T with G (and other resources):**
  1. **Co-optimization detects substitutability between wider array of resources**
     - ***Lowers overall cost of serving load → consumer benefits***
     - ***Offers more flexibility to respond to locational restrictions***
  2. **Disregarding how T affects G siting & dispatch is unrealistic, increases likelihood of inefficiently sited investments**
     - ***So co-optimization can lower the risk of stranded G & T assets***
  3. **Provides insights on G's sensitivity to T investment**
     - ***Contributes to using T to achieve economic & environmental goals***
     - ***Values all of the benefits of T***

- **Cost savings from co-optimization are illustrated with:**
  - **Simple 3-4 bus examples**
  - **13 region models of the US**

A Simple Example (One of Seven)

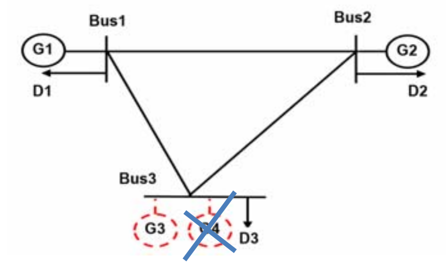
GENTEP Model (IIT)



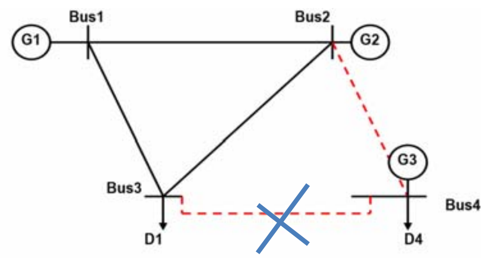
- **Generation-Only Planning**
  - ***Min investment + operations costs of generation***
  - ***Subject to fixed grid***
- **Transmission-Only Planning**
  - ***Min transmission investment + generation operations costs***
  - ***Subject to fixed generation siting pattern***
- **Co-optimization**
  - ***Min investment + operations costs of generation & transmission***

Simple Example

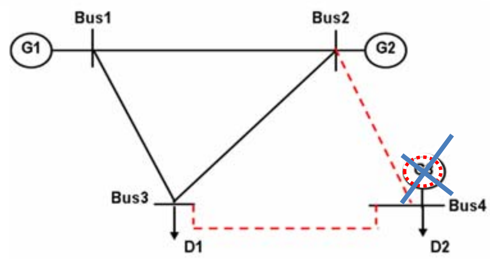
- **Generation-Only**
  $44.42M/yr



- **Transmission-Only**
  $37.5M/yr



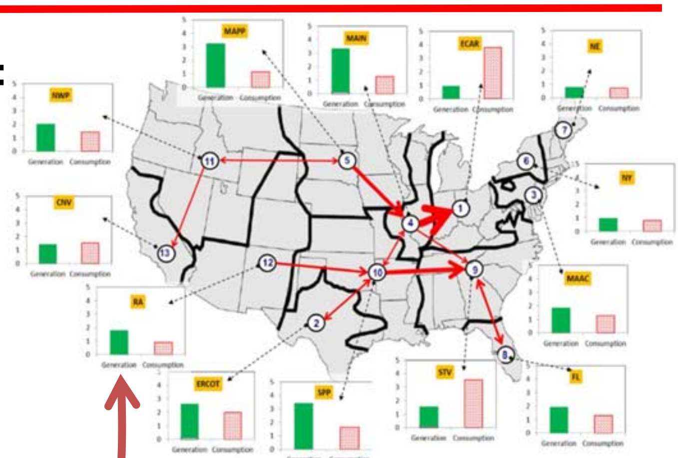
- **Co-optimization**
  $33.0M/yr



US Hypothetical Example (1): Gen-Only *vs* Co-optimization

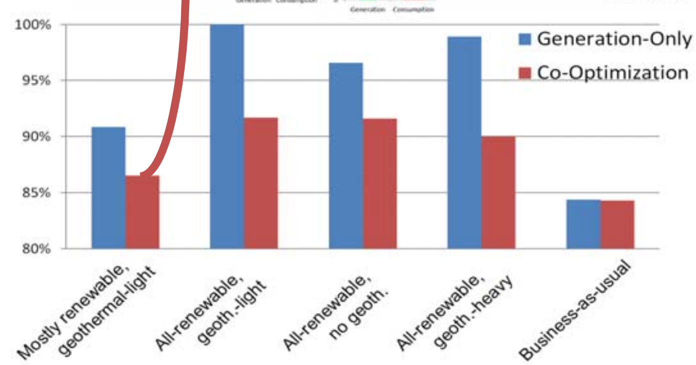
ISU Co-optimization Model:

- *13 US regions*
- *Build, dispatch thermal & renewable resources by region*
- *Select inter-regional transmission capacity*
- *Subject to natural gas pipeline capacities, gas costs*



Illustrative Results

- *Normalized (Maximum cost = 100%)*
- *Gen-only: Considers existing grid*
- *Largest savings from co-optimization: $46B/yr*



US Hypothetical Example (2): Gen-Only *vs* Trans-Only *vs* Two Types of Co-optimization

JHU Model:

- *13 US regions*
- *Build & dispatch gen; build transmission*
- *Two co-optimization approaches:*
  1. *Iterate (gen-only, then trans-only, etc.)*
  2. *Simultaneous*

Illustrative results:

- **Gen-Only (with existing grid): $1846B PW**

Co-op Iterate: $1716B

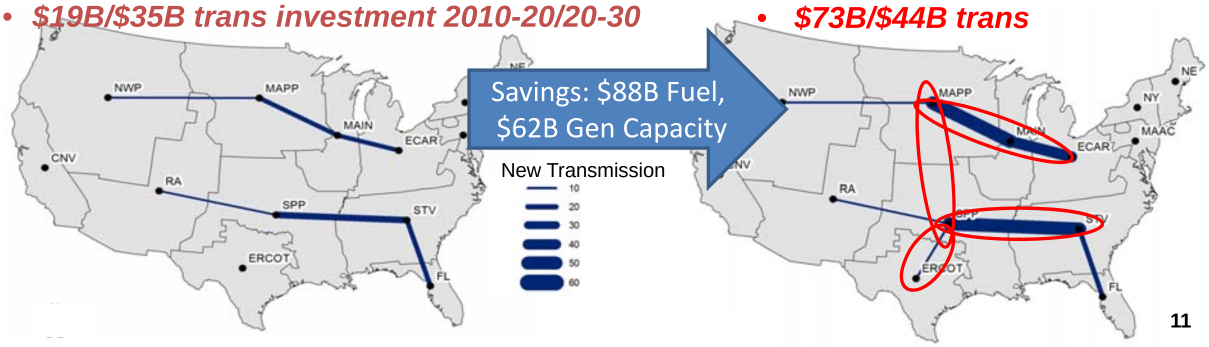
- ***$26B/$45B trans***

Trans-Only (with Gen-Only generation): $1766B

- ***$19B/$35B trans investment 2010-20/20-30***

Co-op Simultaneous: $1679B

- ***$73B/$44B trans***



4. Example Review: Some Tools for Co-optimizing T&G

Model Name	Developer	Trans Investments	Optimizer	Sectors
COMPETES	Energy Research Centre of the Netherlands	AC/DC Continuous	LP (iteratively solve linearized DC model)	Electric
Stochastic Transmission Planning Model	JHU	AC Binary	MILP (non-iterative) / Bender's decomposition for large problems	Electric
NETPLAN	ISU	Pipes Continuous	LP (simultaneous multi-period optimization)	Electric, Fuel, Transportation
Iterative gen-trans Co-optimization	ISU	AC/DC Binary/Continuous	Iterative LP (gen.) & MILP (trans.) / Bender's decomp. for large problems	Electric
Meta-Net	LLNL	Pipes Continuous	Market equilibrium model	Electric, Fuel, Transportation
ReEDs	NREL	Pipes Continuous	LP (multi-stage multi-period optimization)	Electric
GENTEP	IIT	AC/DC Binary/Continuous	MILP / Benders decomposition	Electric (including microgrids), Gas
Prism 2.0	EPRI	Pipes Continuous	General equilibrium economy model	Electric, Fuel, Transportation
PLEXOS	Energy Exemplar	DC	LP	Electric (Gas under development)
REMix	German Aerospace Center DLR	AC/DC Continuous	LP (static investments at begining, yearly operations optimized for multi-years)	Electric/Heat

Advantages/Disadvantages of Modeling Choices

Network Representation- Model Fidelity

CHOICES	PROS	CONS
AC model	High P & Q model fidelity	Requires NL solver - excessive computation
DC model	Can use linear solver; good P fidelity	No Q-V information.
Pipes	Highest computational efficiency	No impedance effects, poor model fidelity
Hybrid	Obtain benefits of each choices	More complex modeling involved

Optimizer

CHOICES
Non-iterative
Iterative
Linear continuous
Linear mixed integer

Evaluation Periods

CHOICES
Single evaluation period/ single optimization period
Multiple evaluation periods/ single optimization period
Multiple evaluation periods/ multiple optimization periods

Uncertainty

CHOICES
Deterministic
Component outages
Parametric uncertainty in conditions (e.g. demand, fuel prices, variable gen)
"Large" uncertainties (e.g., $4 N gas vs. $10 N gas, CO_2 tax or not, 0.5% demand growth vs. 3% demand growth)

End Effects

CHOICES
Truncation
Salvage value
Primal equilibrium
Dual equilibrium

Uncertainty

Types of Uncertainties	Examples
Market	• Capital costs • Fuel costs
Weather, climate	• Wind speed • Solar irradiation
Consumption	• Load growth and shape • DR/DGs/Microgrids • PHEV charging
Technologies	• Outage rates • New builds/Retirements • Future cost reductions
Regulatory uncertainties	• New reliability standards • Environmental policies

- **Methods exist for modeling:**
  - Short-run variability
  - Long-run uncertainties
- **Considering these yields:**
  - More geographically dispersed investment to take advantage of diversity
  - Hedging by investing in generation types, corridors that offer more flexibility
- **Issues: Model size, data**
  - New algorithms
  - Improved computers

5. Institutional & Data Issues: Example Conclusions

1. **Incremental data**
   - *E.g., Fine resolution load & generator characteristics/costs*
   - *Build on existing databases*
2. **Incremental effort**
   - *Significant, but data would benefit other planning activities*
   - *Computational effort higher, but continuing improvements in hardware make possible*
3. **Confidentiality / Public domain**
   - *Confidentiality obstacle to data sharing*
   - *Public domain tools encourage transparency/feed-back/wider involvement; might be misused or slow down process*
   - *Proprietary models may encourage innovation*
4. **State Roles**
   - *Regulatory oversight: e.g., ensure important objectives reflected in models*
   - *Cooperate to create data repositories*

6. Recommendations

- **High potential benefits of co-optimization: of same magnitude as transmission investment itself**
- **EISPC should initiate development & application of co-optimization tools for long-term systems planning**
  - Although research-grade co-optimization tools exist, none have all desired features → Investment would be needed to:
    - ✓ *create commercial-grade software*
    - ✓ *build/maintain databases*
  - Planning Coordinators or States should collaborate with research groups to apply existing tools to quantify benefits of co-optimization in realistic settings, providing:
    - ✓ *more precise estimates of co-optimization benefits*
    - ✓ *more information on effort required by co-optimization, and insights obtainable*