INEEL
Instituto Nacional de Electricidad y Energías Limpias

“INEEL Vision for Development of Applications for the Electrical Systems Planning”

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Open Modelling Platform for Deep Decarbonisation Studies Workshop

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Outline

1. Background
2. The PEGYT model
3. Model enhacements
4. INEEL vision for new developments

Background

Recently, INEEL has launched a R&D&I program to cope with the future challenges and respond to the needs of INEEL Administration.

The R&D&I program, among others will include the following topic:

- The development of Applications for the co-optimization of the long-term expansion of generation and transmission capabilities.

The PEGYT Model

The PEGYT Model

On the Applications for the co-optimization of the long-term expansion of generation and transmission capabilities, INEEL has developed a Model for Long Term Generation and Transmission Planning (PEGYT).

- ✓ PEGYT is used by CFE, CENACE, SENER and for doctoral research, as well.
- ✓ CFE used PEGYT to obtain the Investment Program of the Electrical Infrastructure (POISE)
- ✓ CENACE and SENER have used the model to support the studies related with the National Electric System Development Program (PRODESEN).

The PEGYT Model

- ✓ PEGyT allows to determine regional expansion plans in terms of generating capacity and the inter-regional transmission network, in order to satisfy the future electricity demand; providing reliability at minimum total cost in the long term.
- ✓ The generation plants proposed as candidate in each region, to be selected in the optimum expansion plan, are defined exogenously based on Generation projects reference catalog.
- ✓ The bulk power system is represented up to 75 regions interconnected by up to 150 branches. The solution method is based on mixed-integer linear programming with Benders decomposition.

PEGyT Model

Data base

Load forecasting

Load duration curve for each area of the system

Existing power plants (thermal and hydro capacity, transmission limits, retirement program, firm aditions)

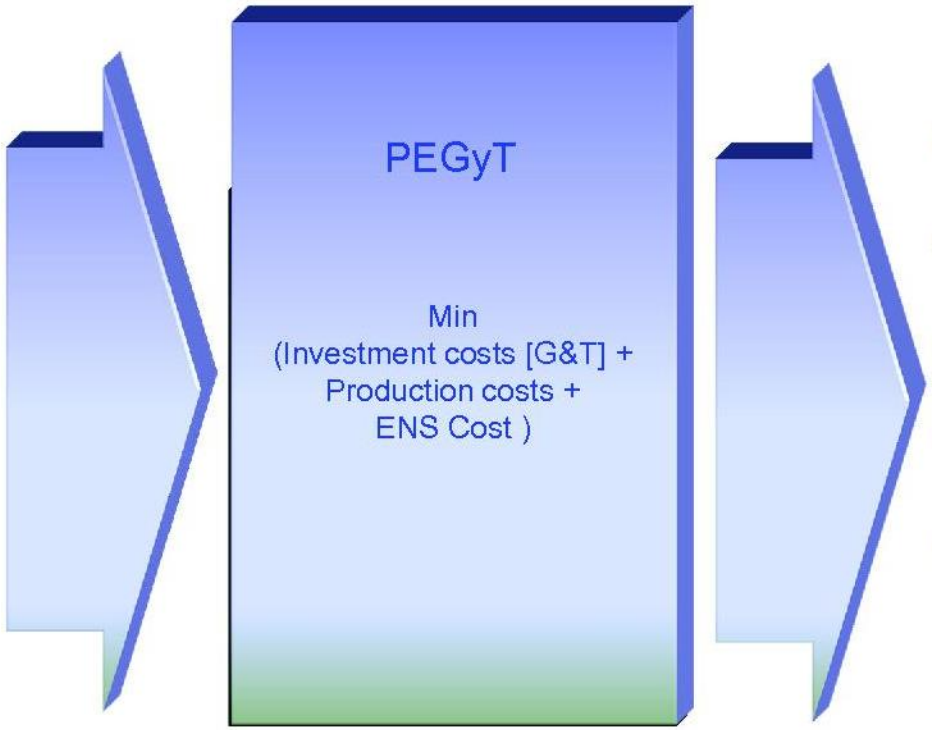
Generation Technologies proposed in each region (candidate projects)

Transmission reinforcement (candidates)

Investment costs for new generation and transmission

Generating cost, current and evolution (based on fuel cost scenario)

Evaluation parameters (Discount rate, ENS cost)



Linear Programming
(Benders partition method)

Main results

- Generation projects selected by region
- Transmission reinforcement
- Commissioning date [G&T]
- Reserve margin of the system
- Total Expansion costs (PV): investment [G&T], Production [fuel+O&M], and ENS

Regional System Expansion Planning

Regional expansion of the generation system

Definition of the location plants based on the regionalization of the national electric system, considering the costs of investment and operation in each region and the costs of the necessary interconnections

Model enhancements

Renewable capacity modelling

PEGYT models renewable capacity as follow:

- ✓ The intermittency of renewable energy throughout the hours of the day is considering by limiting the Capacity Factor for every group of hours of the demand curve.
- ✓ Considers the limits of the renewable regional potential.
- ✓ Considers the annual clean energy production goals established by the legislation.

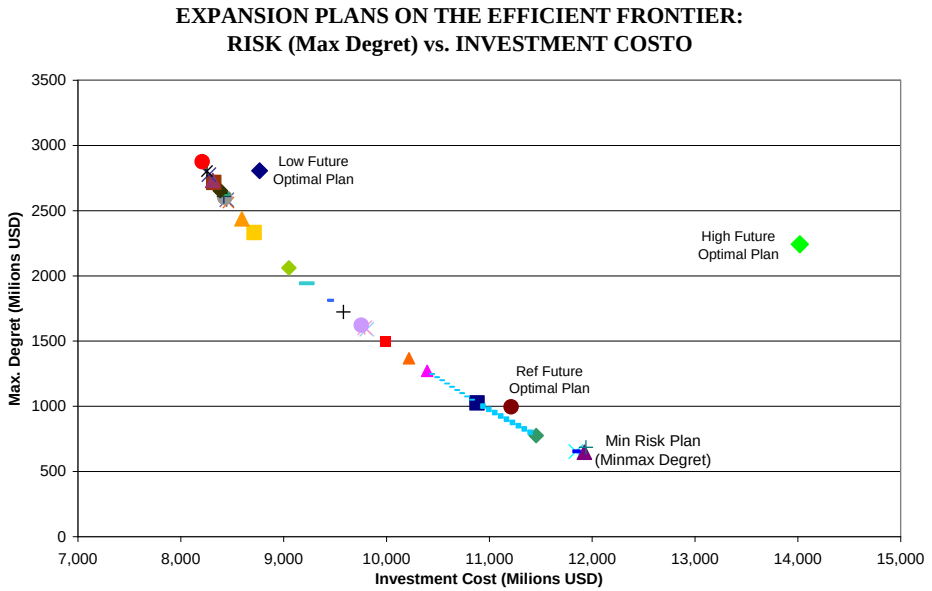
A model to consider the fuel prices uncertainty

The Planning Framework includes a Set of Futures that captures the planner's view of Fuel Price Uncertainty.

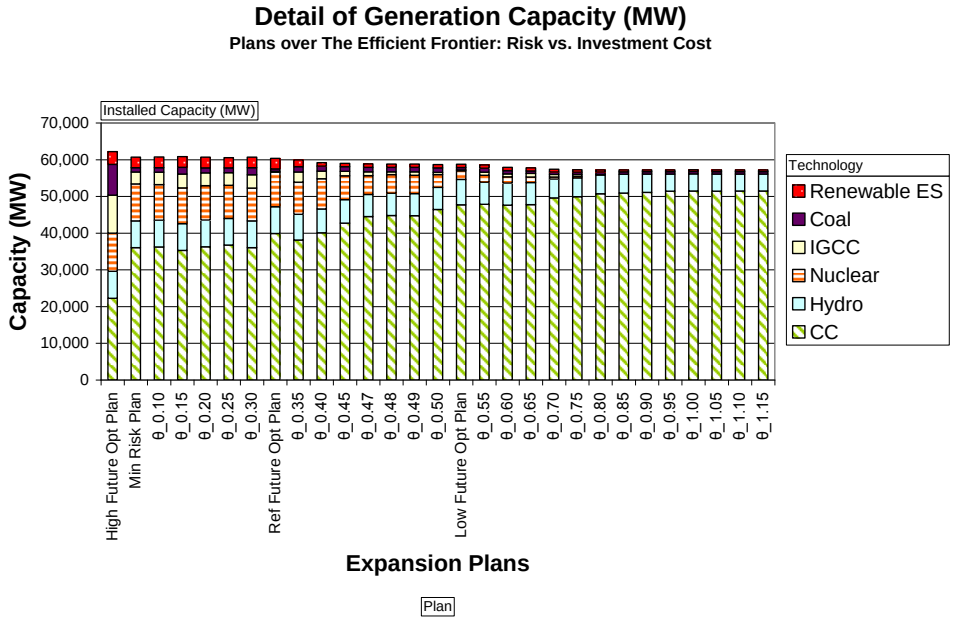
The model is designed to create a set of expansion plans that include:

- ✓ An Optimal Expansion Plan for each future, where optimality is defined in the context of the minimization of the present value sum of investment and production costs.
- ✓ An Expansion Plan which Minimize the Economic Risk of the Fuel Price Uncertainty, where risk is measured as the maximum regret in the set of futures.
- ✓ A Subset of Plans on the two efficient trade off frontiers in the two dimensional space defined by Investment Cost vs. Risk, and Total Cost (investment & operation costs) vs. Risk

A model to consider the fuel prices uncertainty



Note: This study considered three evolution futures of the fuel prices, cited in the DOE Annual Energy Outlook 2007.

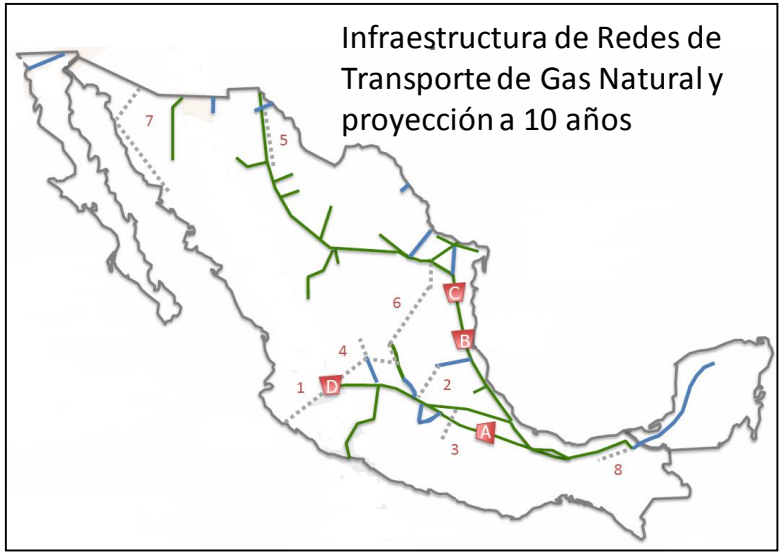


A model for the integrated planning of the bulk power and natural gas systems

To determine a multiperiod expansion plan that includes:

Electric System
- The technological mixture and its capacity levels
- Regional location of the new capacity
- Additions of interegional transmission lines

Natural gas transportation network
- Increment of capacity in supply sites (sources) of natural gas.
- Increment of capacity to install in pipelines
- Location for capacity of technologies (electric system)



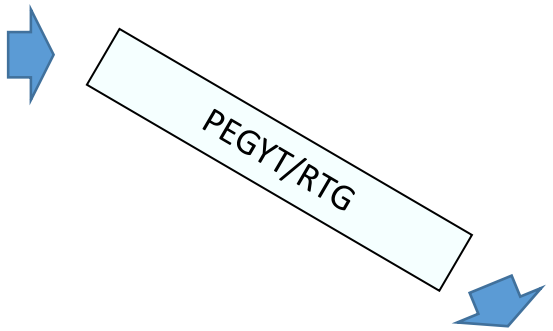
Optimization Model

The objective is to minimize:
- Investment costs of new generation capacity .
- Investment costs of new transmission capacity.
- Production costs of new and existing capacity.
- Investment cost in sources and in the new gas transportation capacity.

Solved by decomposing the problem in two subproblems, and using the conditional gradient method.

A model for the integrated planning of the bulk power and natural gas systems

- Input
  - Horizon planning.
  - Regional Electric Power Network Configuration.
  - Natural Gas Network Configuration.
  - Demand of gas for other uses in addition to the electric one.
  - Length in miles of pipelines.
  - Capacity on pipelines.
  - Maximum capacity in gas sources.
  - Consumption of gas for generation technologies that use gas.
  - Maximum demand permitted in sites.
  - Piecewise linear cost function of capacity gas transportation.
  - Discount rate.



- Output
  - Location for capacity of new generation technologies that use gas.
  - Increment of capacity in pipelines.
  - Gas demand in sites.
  - Flow of gas in pipelines.
  - Increment of capacity in gas production sources.

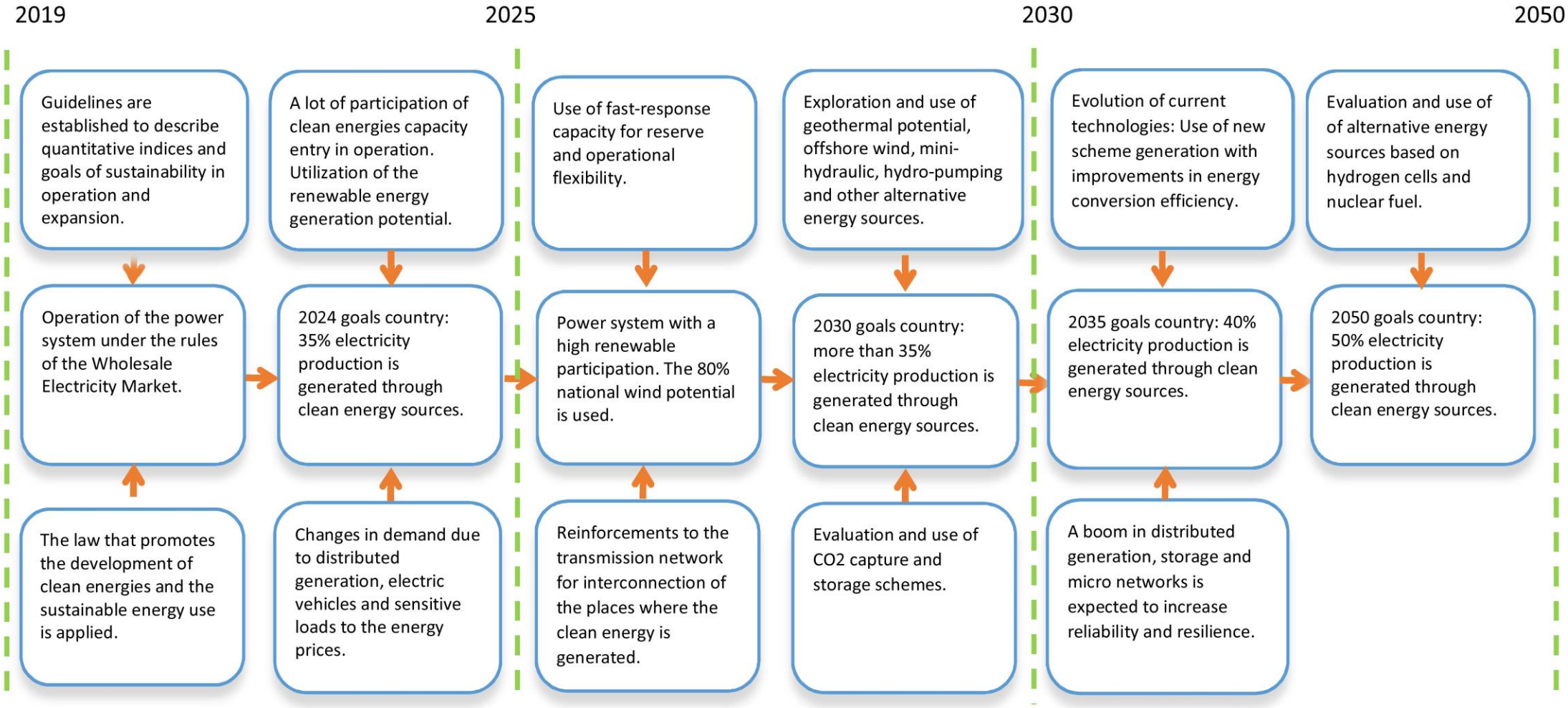
INEEL vision for new developments

INEEL Vision

INEEL Vision regarding the R&D&I program in large-scale electrical systems:

Through projects with the electricity industry, to promote:

- ✓ The medium and long-term compliance with all the goals established in the generation area,
- ✓ The utilization of renewable energy and the sustainable utilization of energy,
- ✓ All of these in conditions of economic viability, without impairing the efficiency, quality, reliability, continuity and security of the National Electric System.



Evolution scenarios of the Mexican Power System according to the vision of the Energy Transition Law.

Short-term goals

Applications should be reinforced to:

- ✓ Model in more detail the variability of the renewable sources generation capacity on the demand curve (more segments).
- ✓ Evaluate the real state and utilization of the national renewable potential. It will require more flexible generation to respond with reserve and fast ramping, to the inherent volatility in renewable sources.
- ✓ Contemplate strategies to deal with uncertainty in planning scenarios, for example, demand growth, technology options and costs.
- ✓ Contemplate the growth of the electrification scenarios and another demand changes such as distributed generation, energy prices sensitive loads, etc.
- ✓ Consider the sustainability goals on decisions.
- ✓ Exploit multiprocessor platforms and parallel programming.

Medium-term goals

- ✓ Reach an exact representation of mixed transmission networks, including the HVDC lines.
- ✓ Model the temporal segmentation of the demand for a better representation of the operational flexibility of the proposed units.
- ✓ Consider the operational entry of large blocks of energy storage resources and distributed generation in the electrical system.
- ✓ Consider in detail the technological options with CO2 capture and sequestration schemes and its efficient management.

GRACIAS

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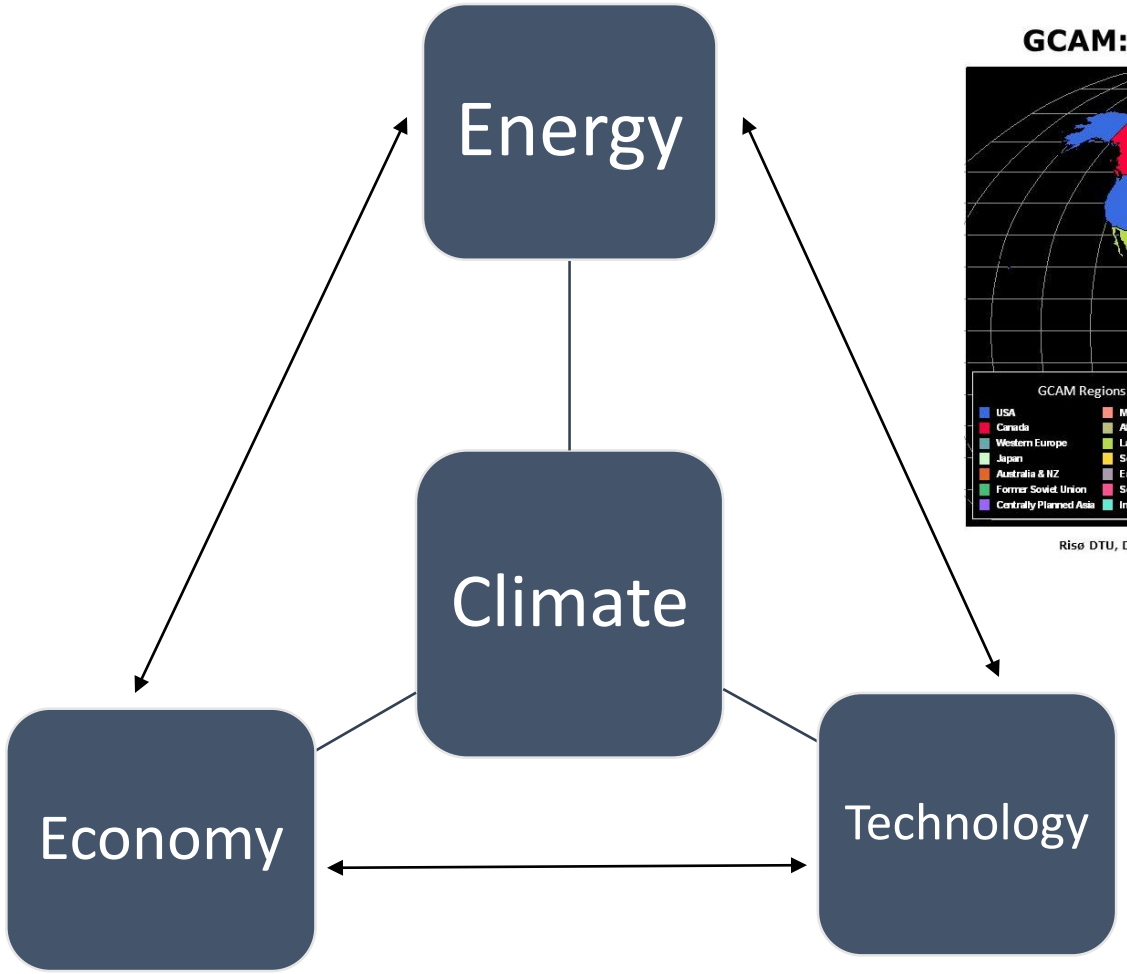
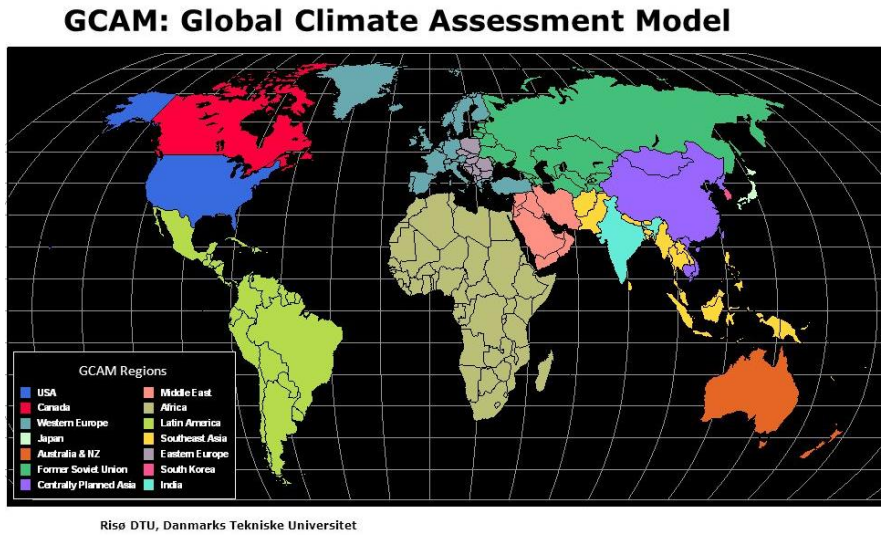
Summary of Mexico's Climate Change Policy Goals

Year	Policy	Goal
2030	INDC	Unconditional – Reduce emissions of GHG by 22% and Black Carbon by 51%. Total reduction of 25% compared to BAU.
		Conditional - Reduce emissions of GHG by 36% and Black Carbon by 70%. Total reduction of 40% compared to BAU.
2050	LGCC	Reduce emissions by 50% compared to 2000
	ENCC	At least 50% of generation comes from clean energies

LGCC - General Law on Climate Change
ENCC - National Climate Changes Strategy
INDC - Intended Nationally Determined Contributions

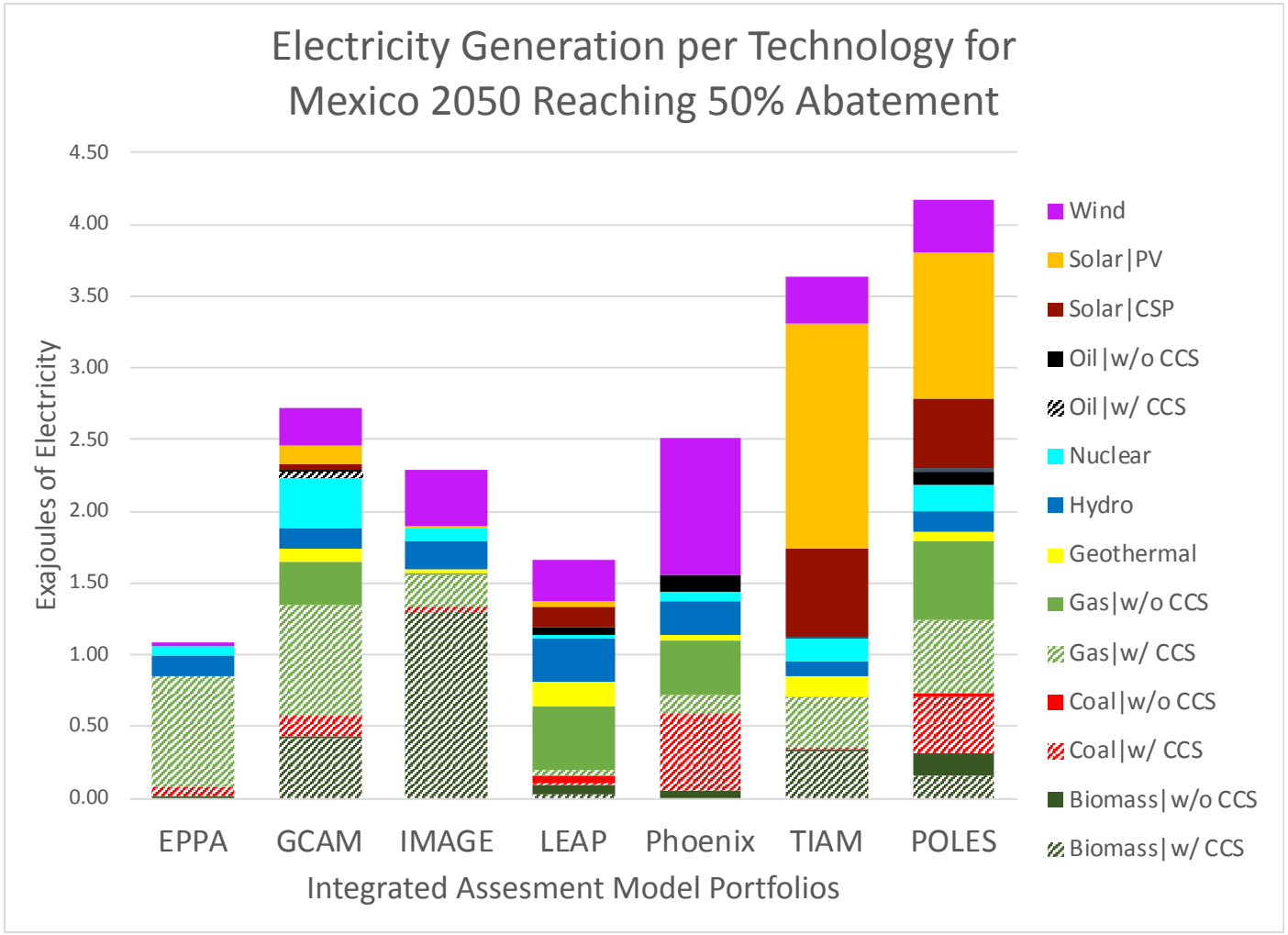
Top Down - Integrated Assessment Models





Source: GCAM http://www.globalchange.umd.edu/

CLIMACAP-LAMP Generation Portfolios



Source: J. Veysey "Pathways to Mexico's climate change mitigation targets: A multi-model analysis," Energy Econ., vol. 56, pp. 587–599, 2014

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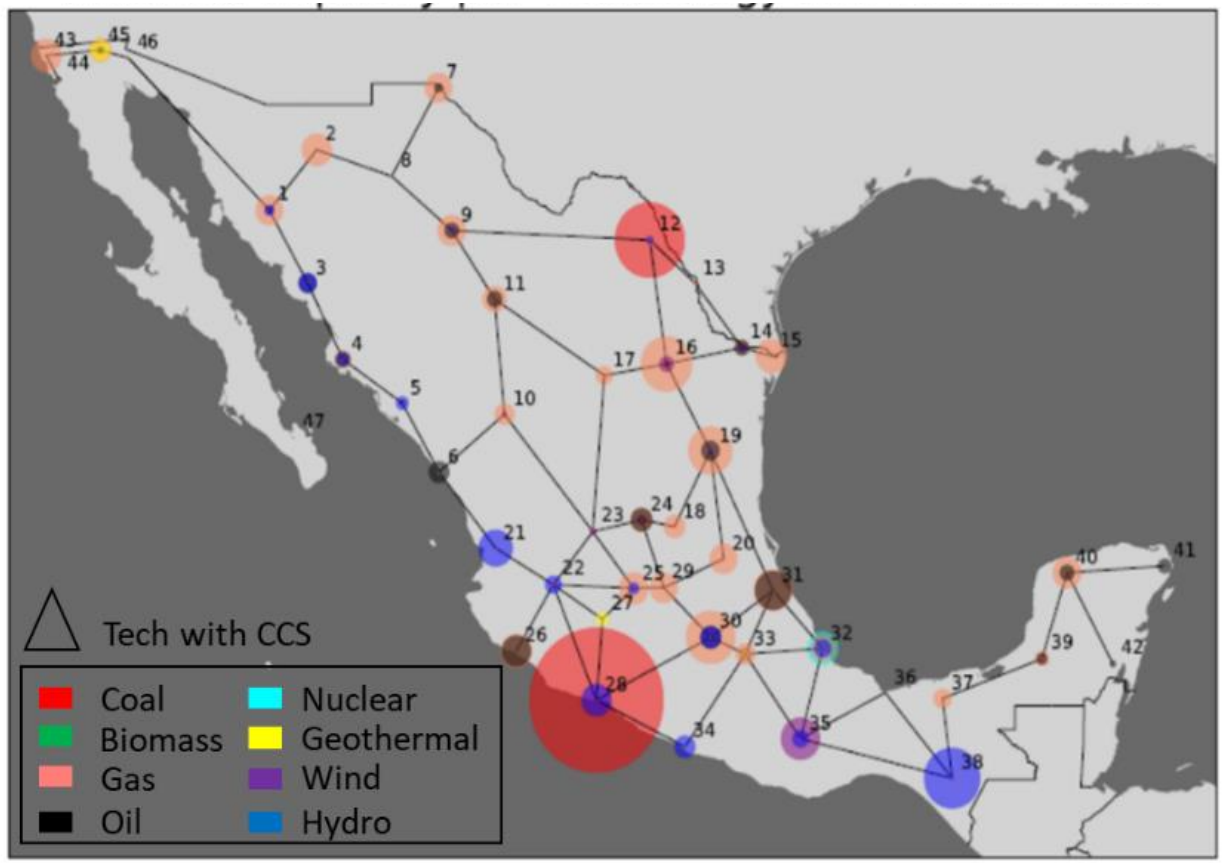
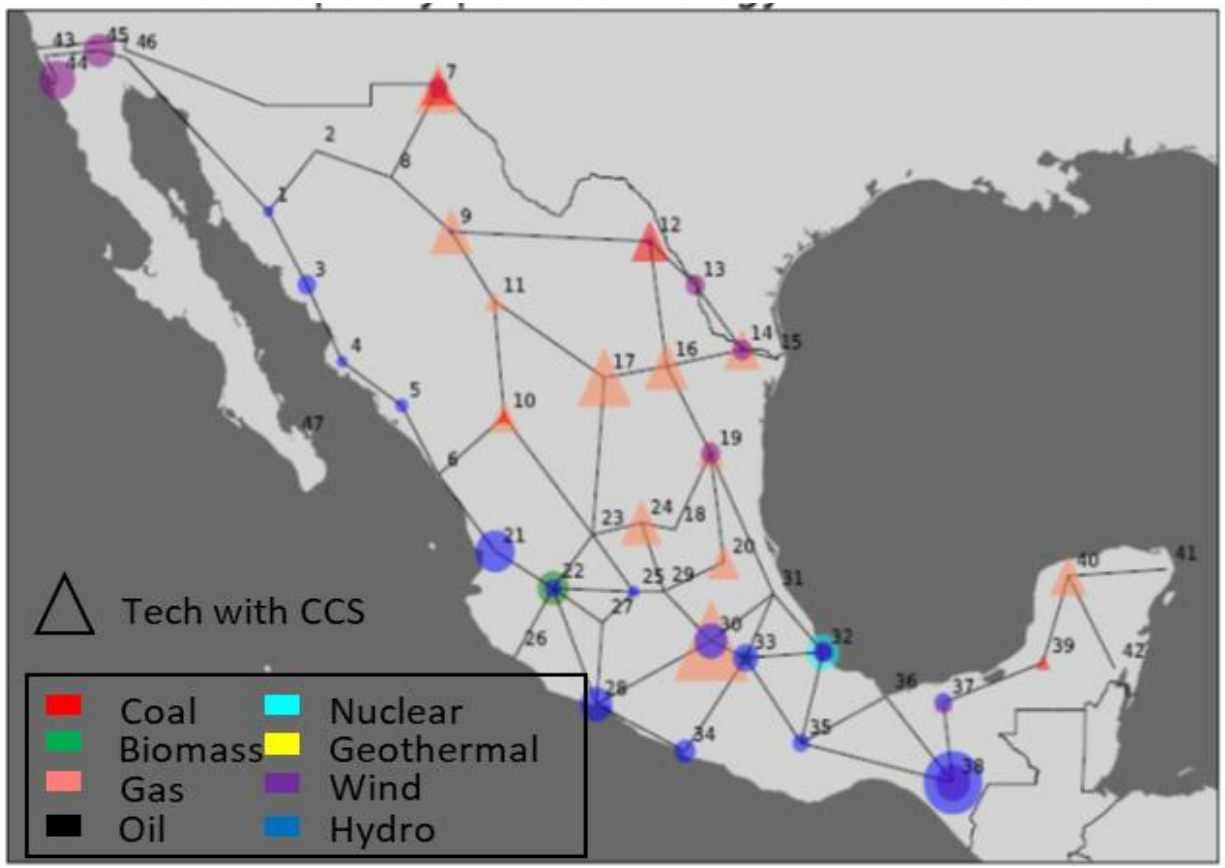
GCAM Portfolio Expansion Plan Sample Results

Installed Capacity per Technology (MW) Mexico 2016



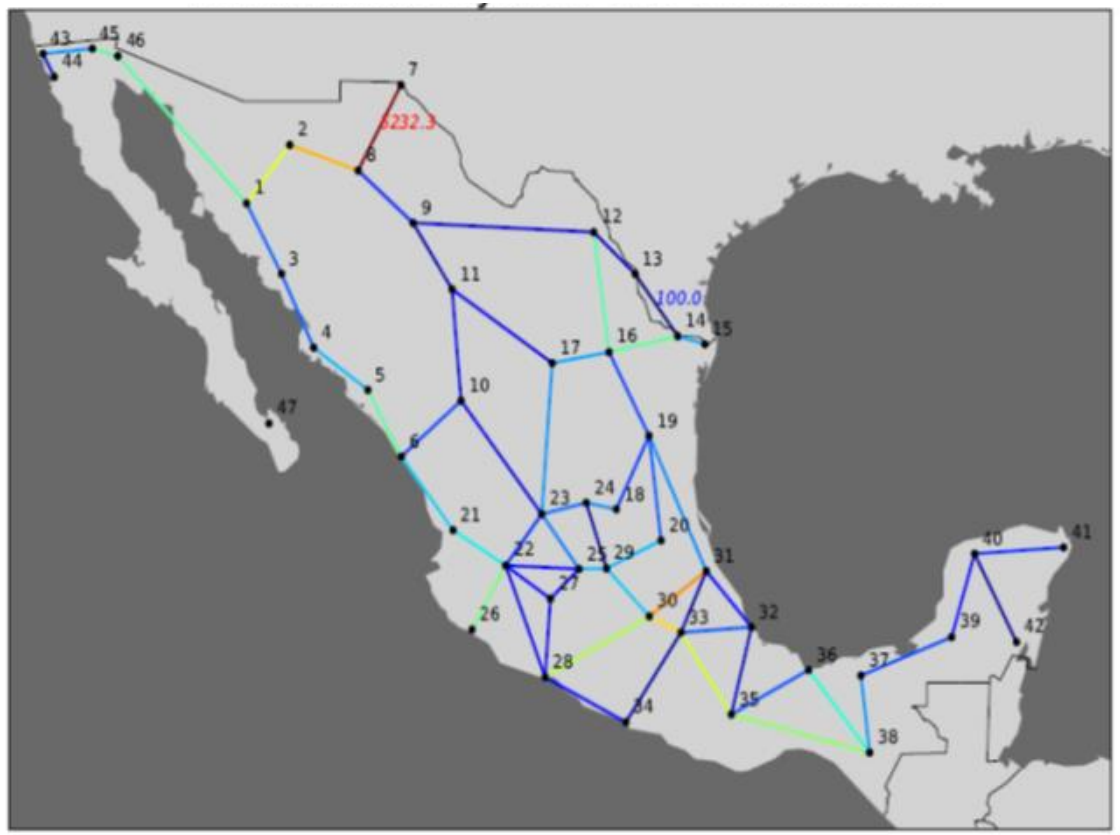
Installed Capacity per Technology (MW) Mexico 2050



GCAM Portfolio Expansion Plan Sample Results

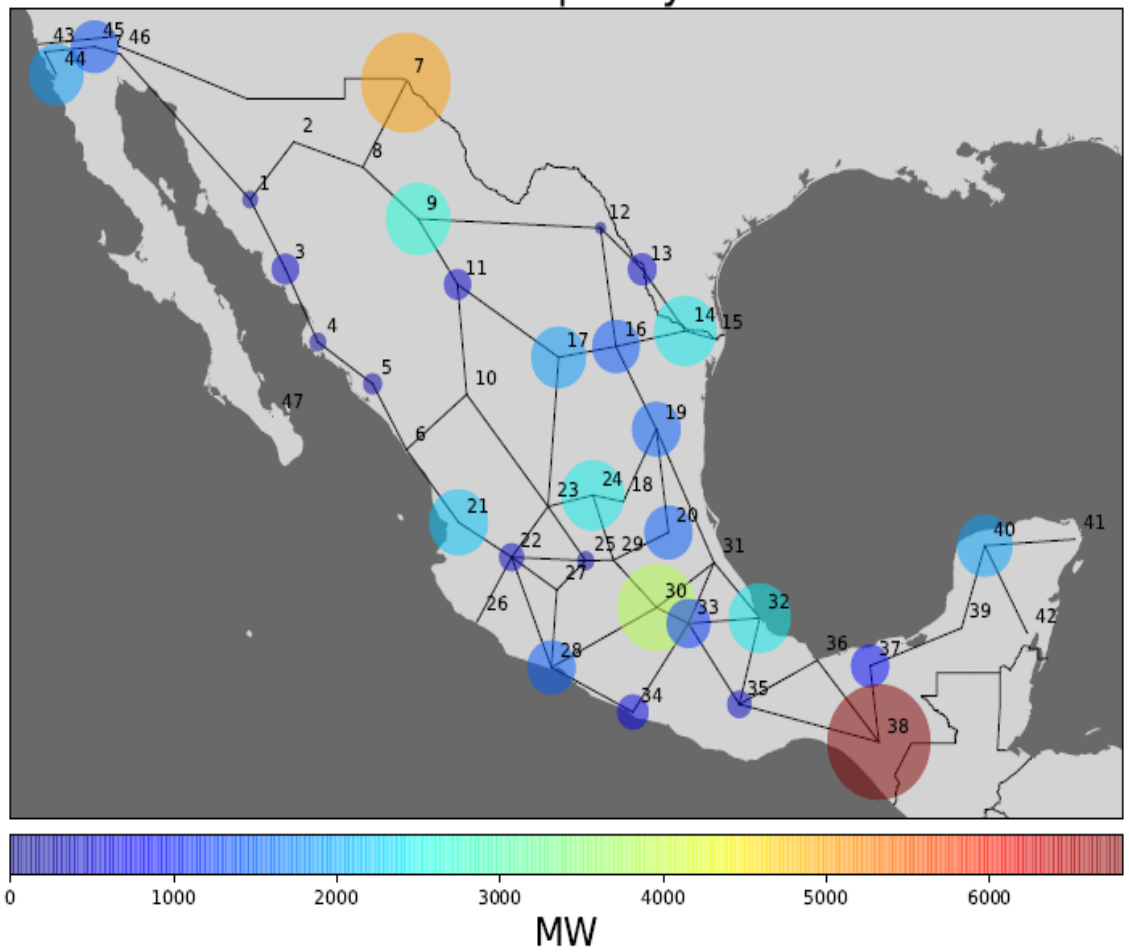
Transmission System Capacity (MW) Mexico 2016

Transmission System Capacity (MW) Mexico 2050

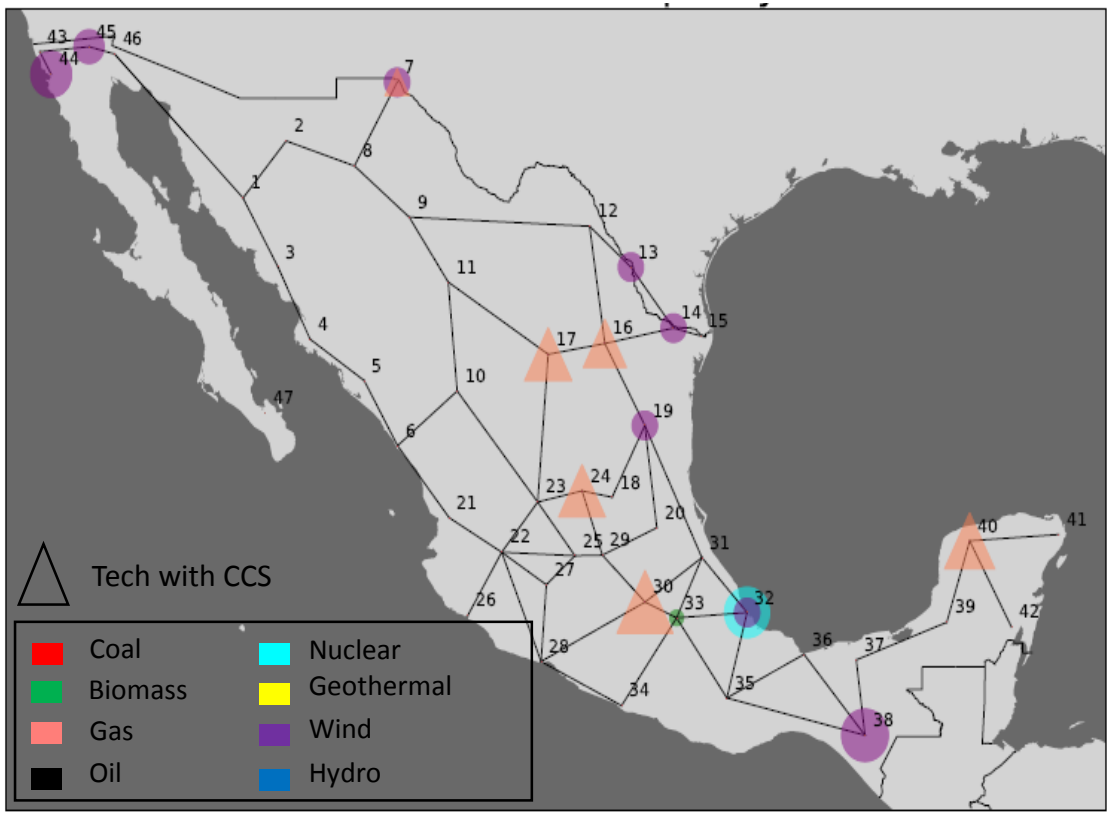


Critical Areas of Development

Min Added Installed Capacity MW Mexico 2050

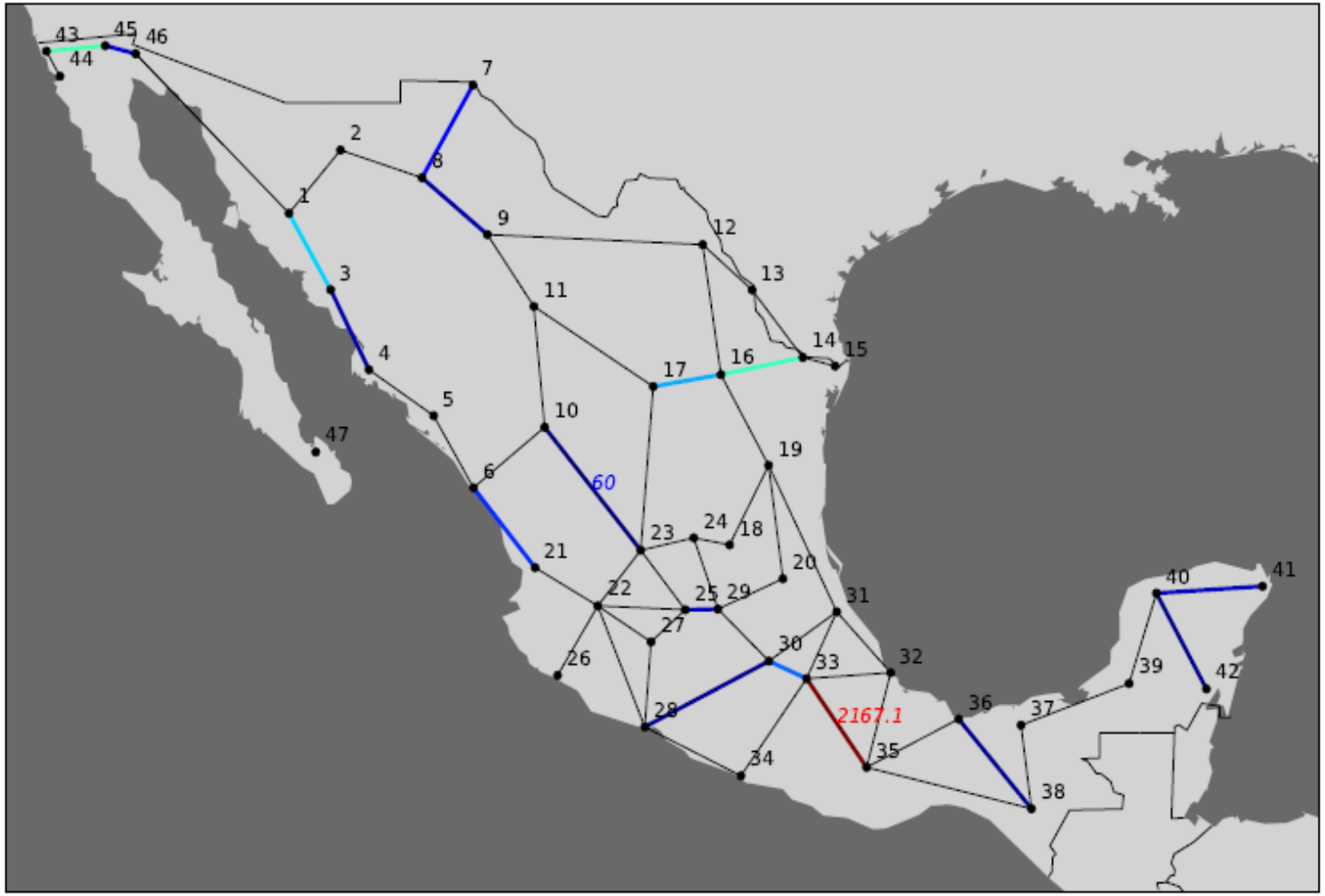


Min Added Capacity per Tech MW Mexico 2050



Critical Areas of Development

Minimum Transmission Capacity Added (MW) Mexico 2050



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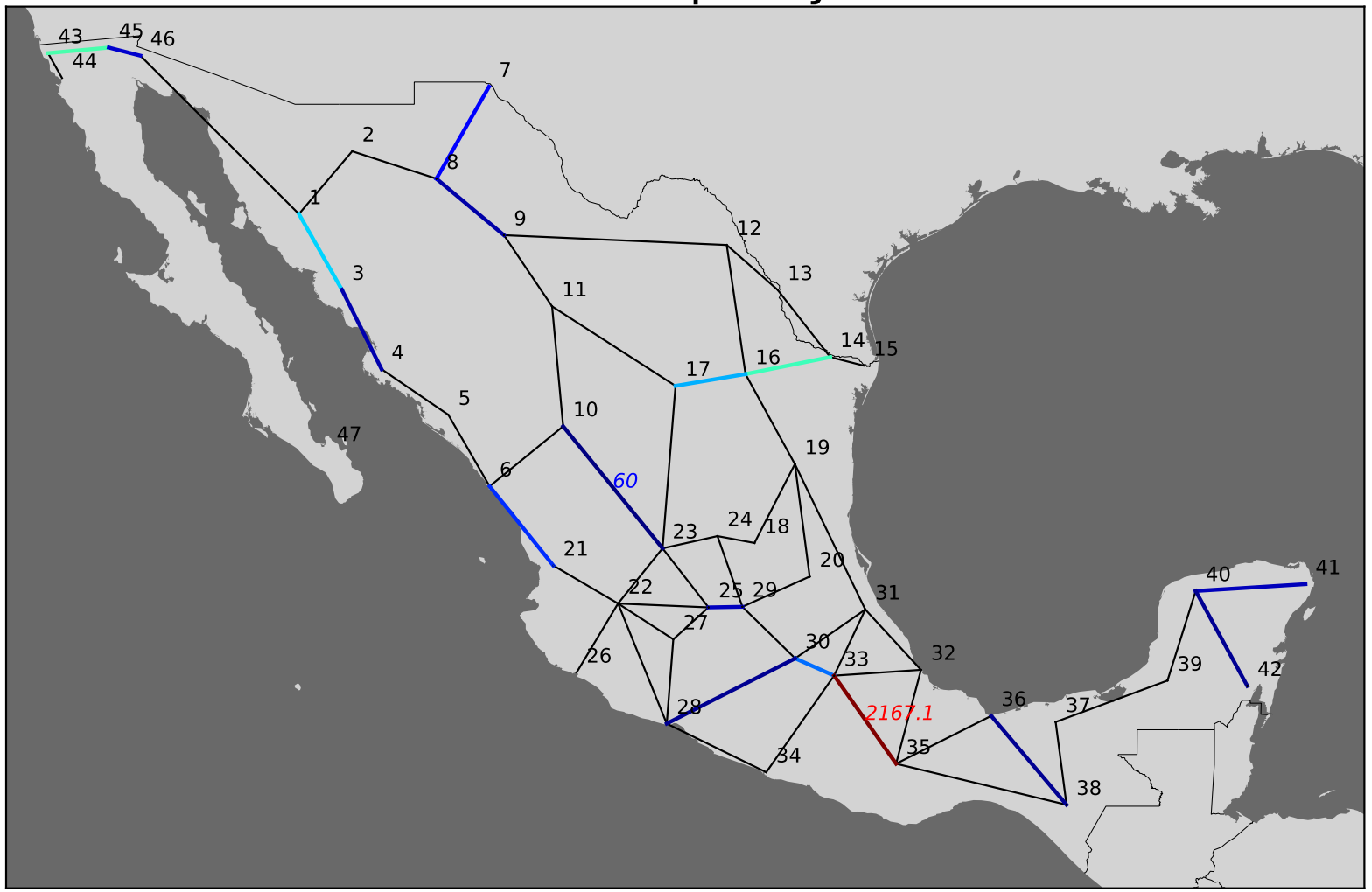
Critical Areas of Development

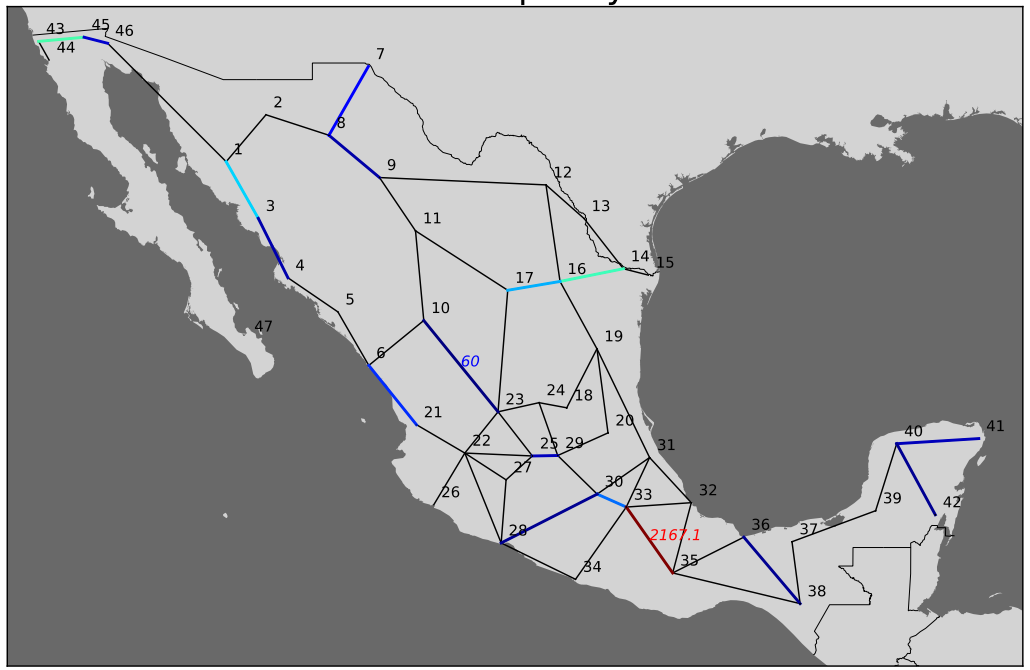
Min Installed Generation per Technology and
Added Transmission Capacity MW Mexico 2050



Future Work

- Identify Critical Decisions for each Portfolio by looking at:
  - Required Investments
  - Critical Areas of Development

Min Installed Generation per Technology and Added Transmission Capacity MW Mexico 2050



- Provide Better Insight and Identify Robust Strategies of Development