Integrated Resource & Resilience Planning (IRRP) for the Power Sector

USAID Training – March 6, 2017

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Session 4: What Planning Looks Like

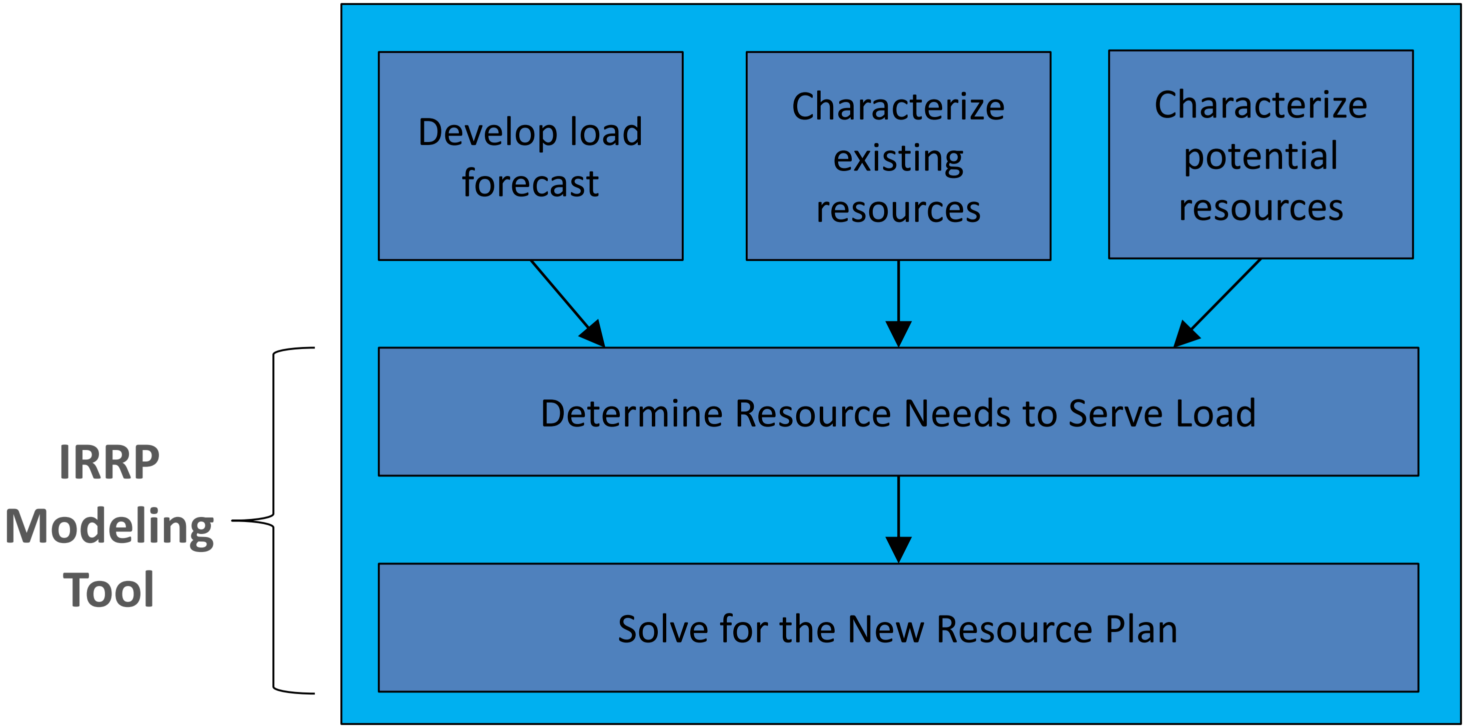
Part Two - Modeling

Presenters: Maria Scheller, Molly Hellmuth

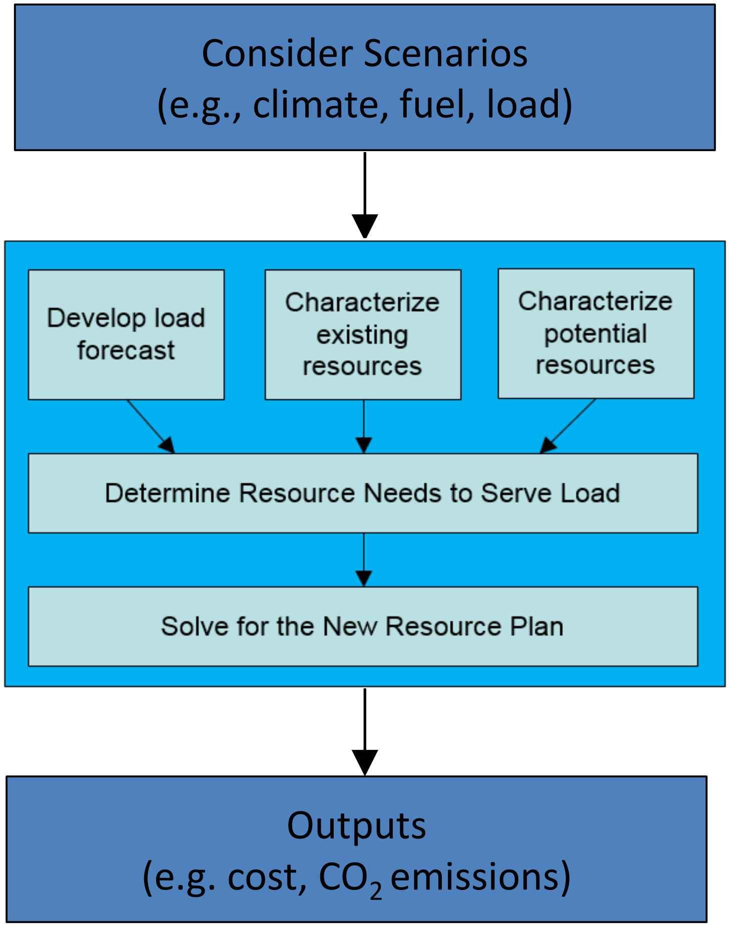
IRRP Optimization - Considering Scenarios, Risks, and Alternatives

Presenter: Maria Scheller

Integrated Resource Planning Process



Risk Analysis and Scenarios



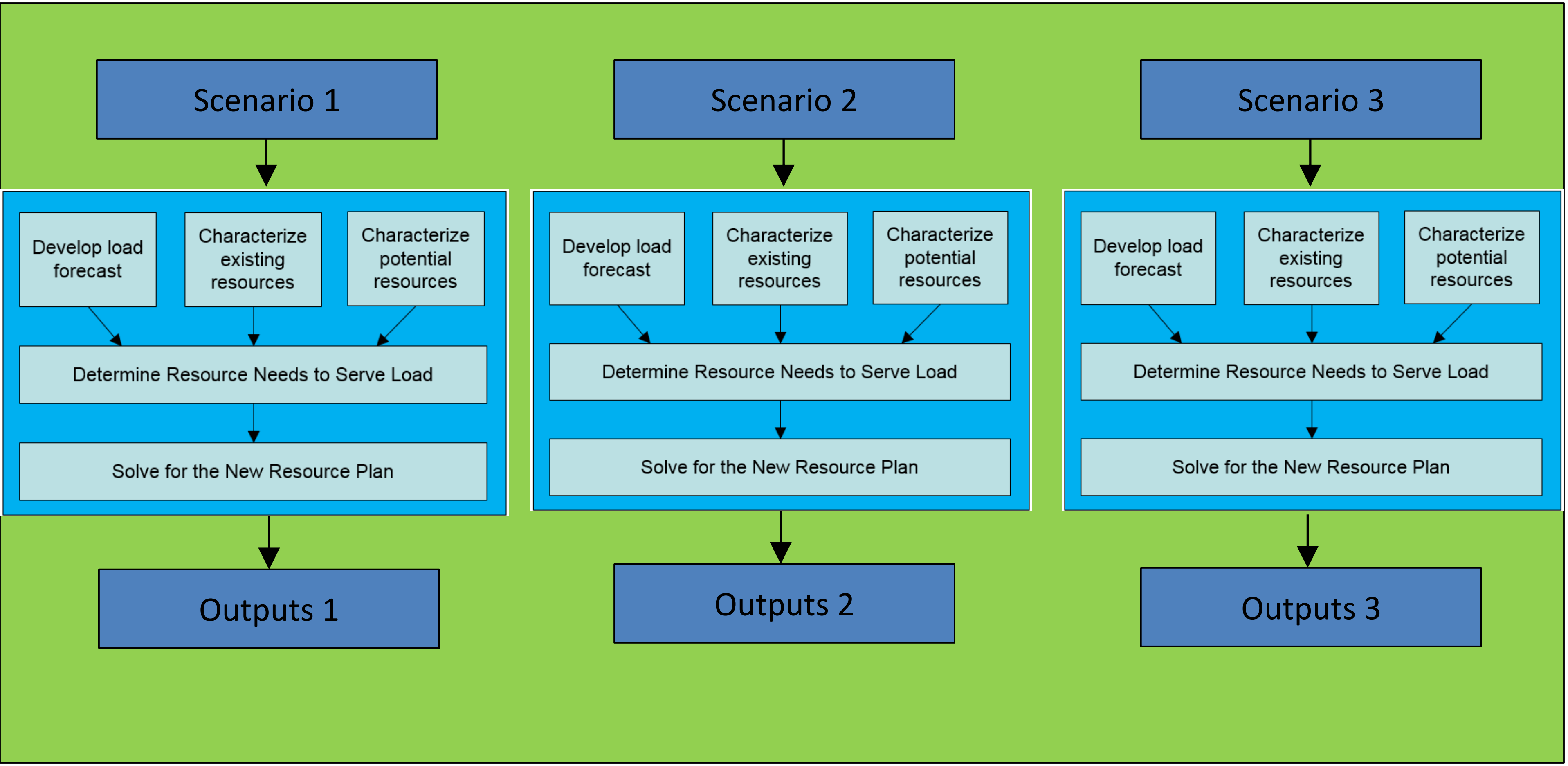
Defining Scenarios

- Set of model inputs
  - e.g., load forecasts, fuel prices and availability, technology costs and availability, resource availability, etc.
- Reference scenario
  - reflects generally expected or likely forward conditions
- Alternative Scenario
  - alternative inputs that reflect uncertainties/risks

Illustrative Scenarios

Scenario 1	Scenario 2	Scenario 3
Reference load	**High load**	**Low load**
Expected gas price	**Expected gas price**	**High gas price**
Mild drought	**Severe drought**	**No drought**

Multiple Risk Scenarios



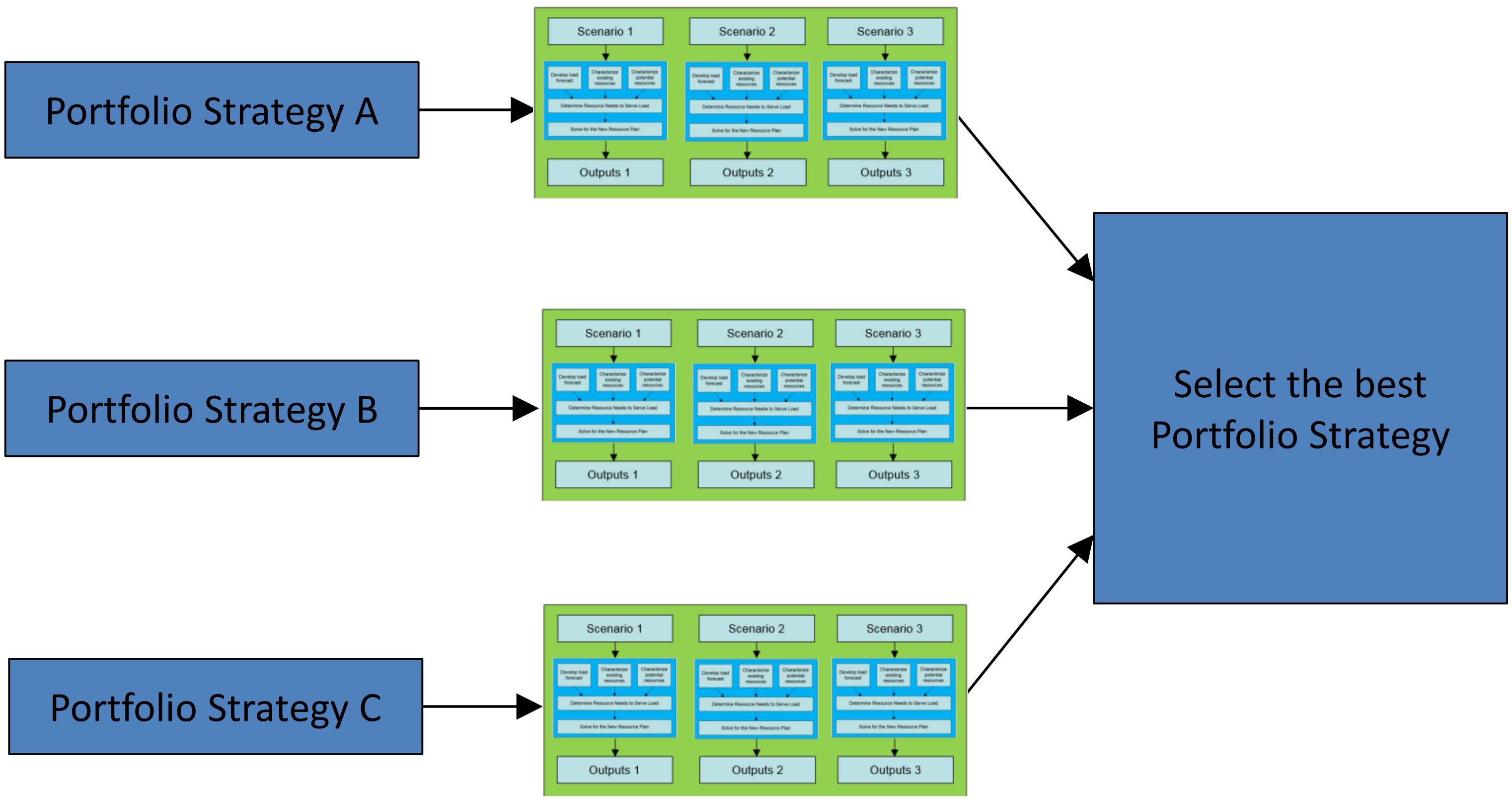
Defining Alternate Investment Portfolio Strategies to Meet Requirements

- Business as usual strategy
  - e.g., least-cost investment strategy
- Alternative strategies, e.g.,
  - require 50% renewables in the resource mix by 2030
  - require 20% hydro
  - carbon emission limits
  - electricity import/export goals

Illustrative Strategies

Strategy A	Strategy B	Strategy C
Business as usual	**High renewable generation investment**	**Foreign trade expansion**

Assess Multiple Investment Portfolio Strategies



Metrics & Scoring

- For each portfolio strategy, metrics are evaluated, e.g.,
  - Were the strategy goals met in each scenario
  - Net present value of revenue requirements
  - Wholesale power prices
  - Residential load served
  - Unserved energy
  - Build plan volatility
  - GHG emissions
- Metrics are appropriately weighted, statistically analyzed, and combined to determine a score for each strategy
  - Strategies are ranked based on their scores
  - **The resource plan of a highly-ranked strategy is more resilient under different scenarios**

Least-Regrets Resource Plan

- The least-regrets resource plan is one which provides the highest performance under the selected metrics
- We are working to derive such a resource plan for Ghana and Tanzania based on jointly developed scenarios and metrics
  - Collaborative process
  - Collective input from Ghana and Tanzania stakeholders
  - Inputs, feedback, discussions from/with stakeholders is crucial
- The modeling tool is the foundation for getting to this stage (middle of next year)
- **Learning the IPM tool is the first step…**

Integrating Climate Risk and Resilience into Modeling

Presenter: Molly Hellmuth

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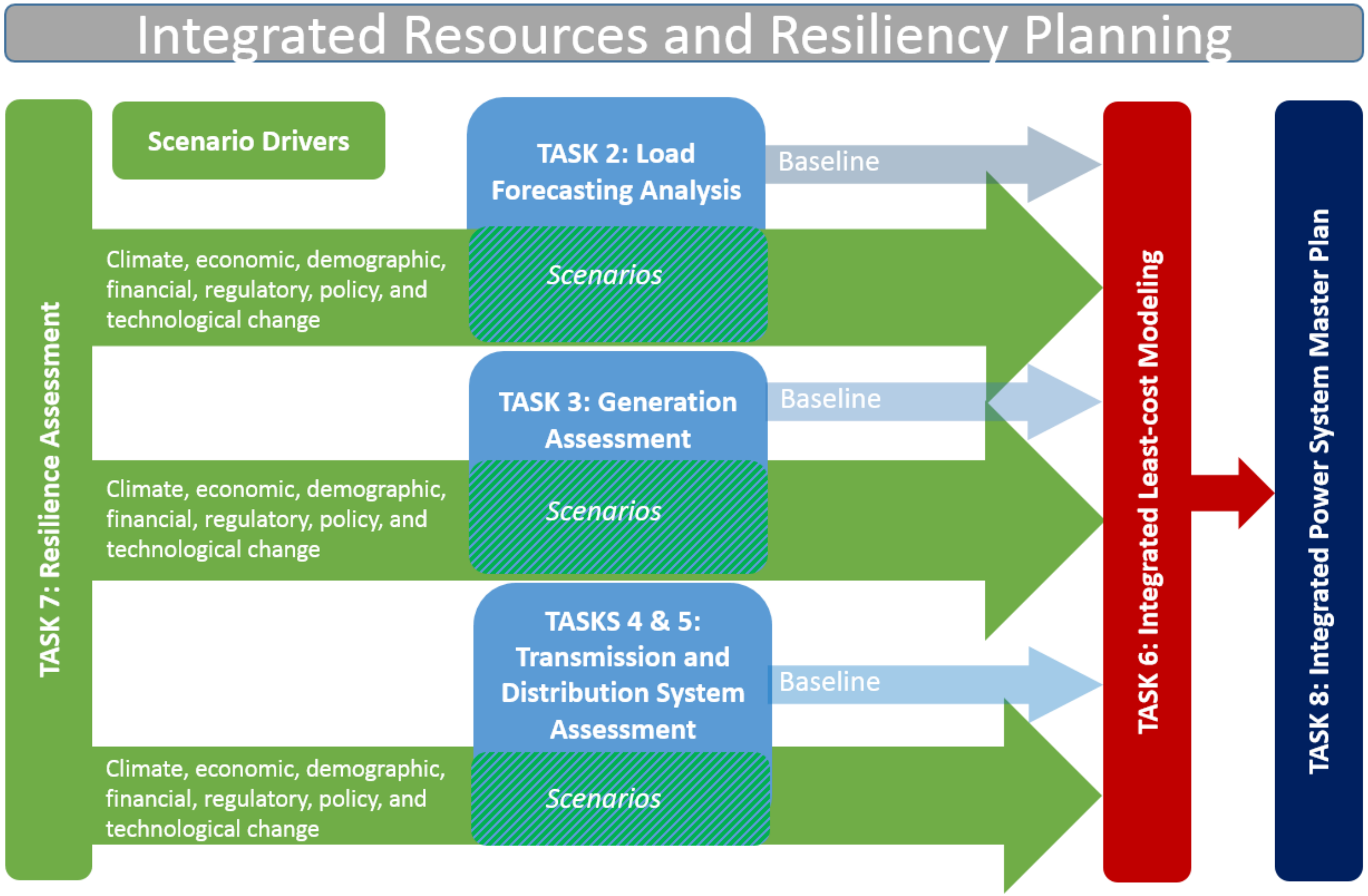
Methodology

- Crosscutting Power System
- Quantitative Modeling
- Qualitative Assessment



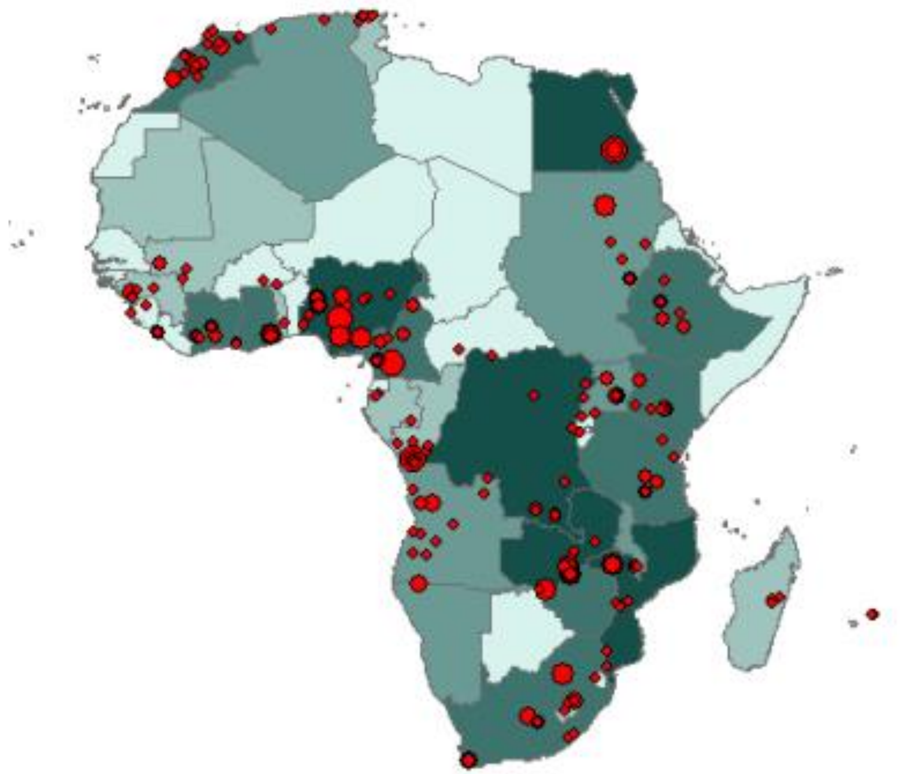
Risk and Resiliency: Climate Scenarios

- What are climate scenarios?
  - A *plausible* future climate, or the difference between some plausible future climate and the present-day climate
  - Can be outputs of GCMs, analogues of past events, incremental changes
  - Climate scenarios are used in impact models. For example:
    - Hydropower, supply and demand, load forecasting, transmission and distribution
- Scenario Choice
  - Recommendations based on preliminary analysis
  - Participatory exploration and discussion
- Potential scenarios
  - Increase in frequency and intensity of extremes: temperature, drought, flood
  - High or low emissions scenarios – projections of key climate variables

Time period	Scenario #1	Scenario #2	Scenario #3
2040-2060	Monthly temperature increase from 1- 3^{o}C	Monthly rainfall, maximum, and minimum temperature projections	Increasing frequency of El Nino events

Focus on Hydropower Modeling in Tanzania

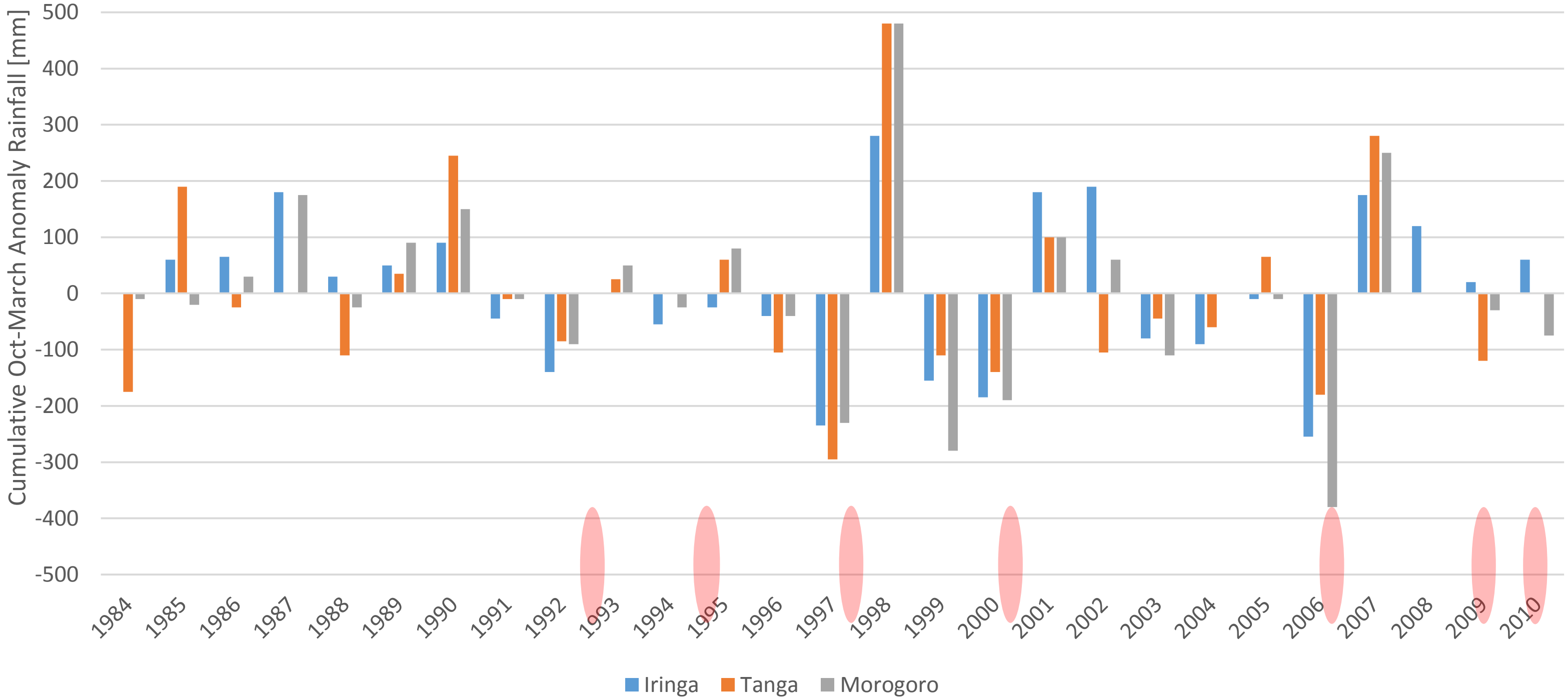
- One of more hydro-dependent countries in Africa
- Shift towards diversification 90% dependence (2002) → 35% (2016)



Source: Cole et al., 2012. Climate Change, Hydro Dependency and the African Dam Boom

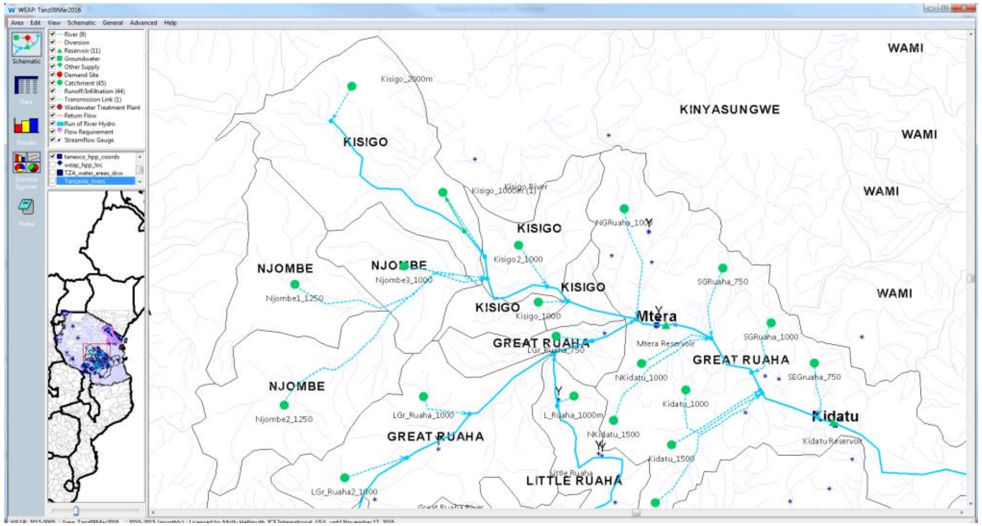
Generation tracks rainfall

- Historical power rationing/black outs due to below normal rainfall



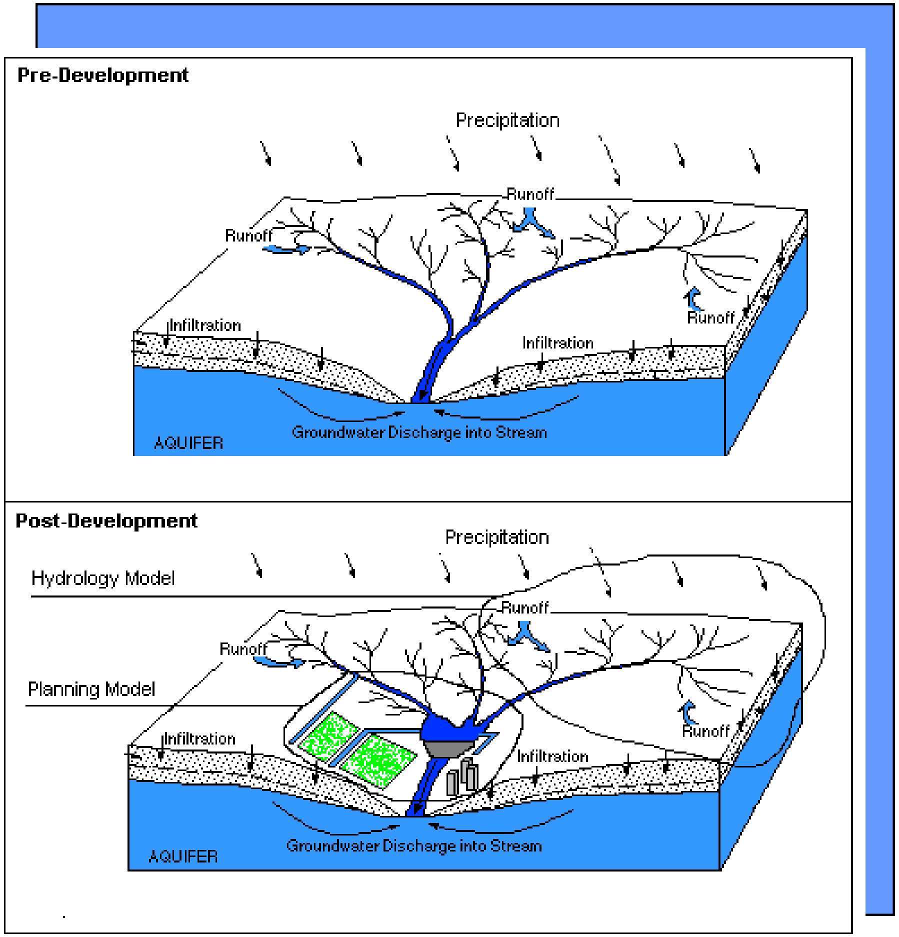
Risk and Resiliency: Hydropower modeling

- Water Evaluation and Planning (WEAP) model
  - Partnership with the Stockholm Environment Institute (SEI)
  - ICF and SEI will deliver the model and provide training
- The outputs of WEAP feed into IPM
- IPM's optimization will be used to project future hydropower builds

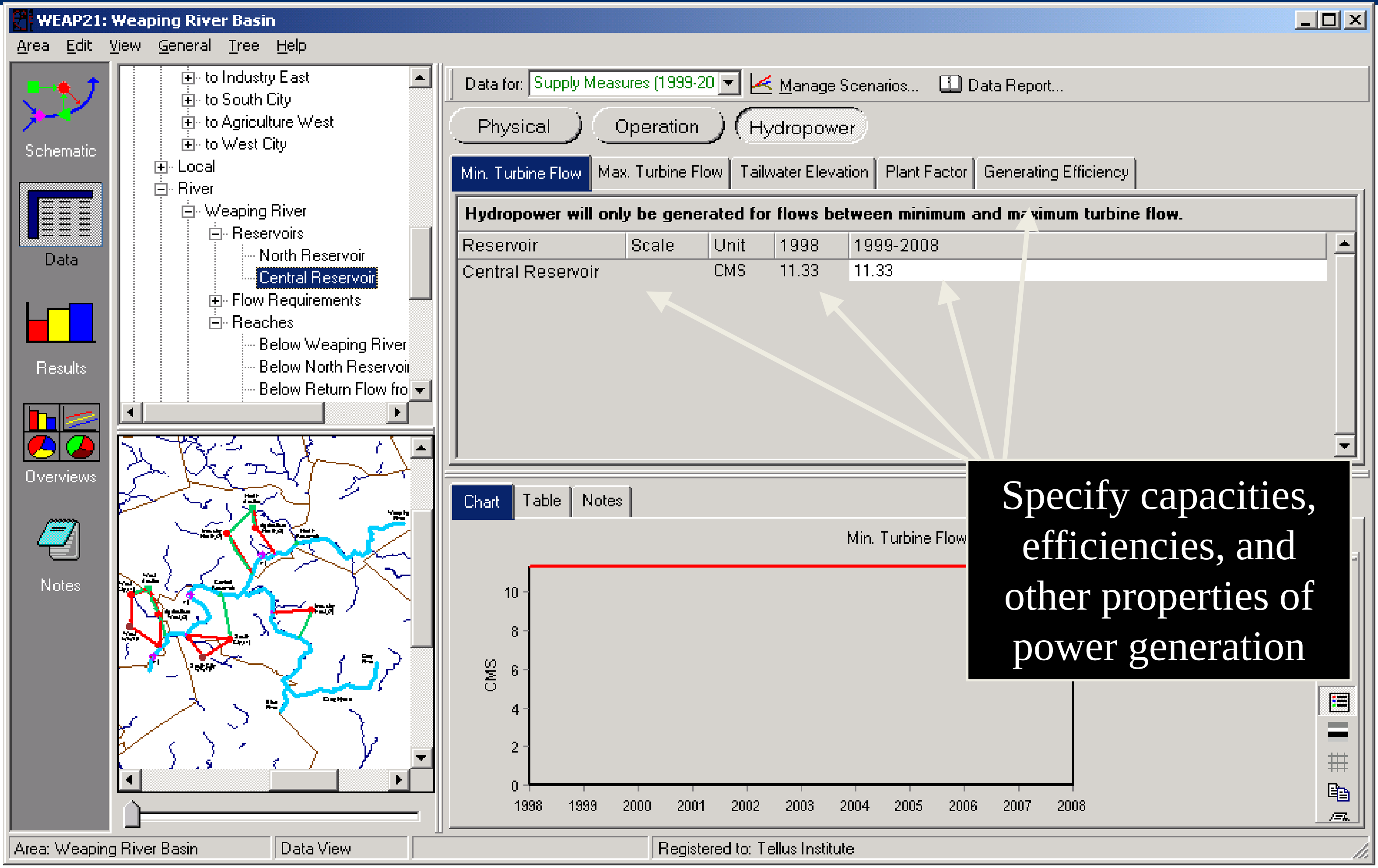


Hydrology and Management

- WEAP21 advantage: seamlessly integrates watershed hydrologic processes with water resources management
  - Can be climatically driven
  - Time Steps as short as 1-day, or longer
  - (Pcp, Tmp, RH, Wind)



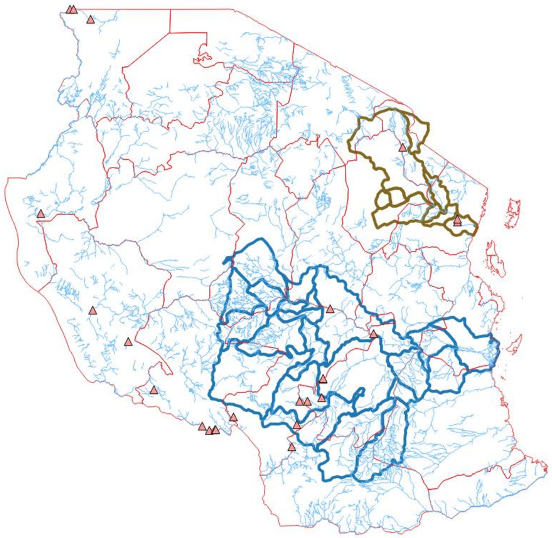
Hydropower

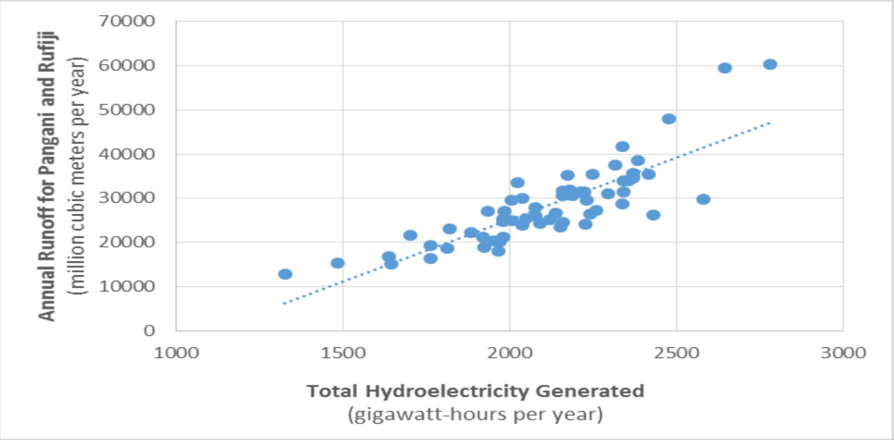


Specify capacities, efficiencies, and other properties of power generation

Risk and Resiliency: WEAP Hydropower modeling

- Hydropower Plants
  - Existing/potential hydro plants
- Climate Scenarios
  - [As identified by stakeholders]
- River Basin Hydrology
  - Land-use, land cover changes
  - Watershed conservation/ water quality
- Water Supply and Demand
  - Agriculture, domestic, industrial, energy, environmental
  - Increase competing water demands
- Integrated Water Resources Management
  - Operational changes
  - Capital investments - storage capacity



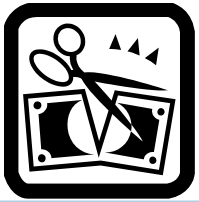


Integrated Planning Models

Presenter: Maria Scheller

Integrated Planning Model (IPM®)

Resource Supply
- Gas Supply
- Coal Supply
- Hydro Supply
- Biomass Supply
- Renewable Potential



Existing Power Plant Variable Cost
- Fuel Transportation
- Fuel Costs
- Heat Rates
- O&M Costs

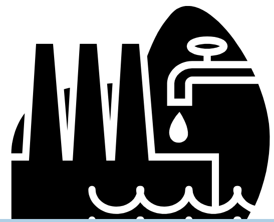
New and Existing Power Plants
- Coal
- Oil & Gas Steam
- Combustion Turbine
- Combined Cycle
- Geothermal
- Nuclear
- Hydro
- Renewables
- Cogeneration

Retrofit Technology
- SCR, SNCR, and new NO_X control options
- Wet and Dry FGD
- ACI and Fabric Filter
- Co-benefits for Hg

Transmission
- New FERC Policies
- Long-term tradeoffs with Generation
- Grid operation

Electric Demand
- Hourly Demand
- Peak & Energy Growth
- Reserve Margin
- Steam Demand

Power Plant Dispatch and Grid Operation
- Economic dispatch



Air Policy Specifications
- NO_X, SO_2, Hg and CO_2
- MACT vs. Cap and Trade
- Banking and Progressive Flow Control
- National, Regional and State Programs
- Renewable Portfolio Standards

Operation
- Maintenance
- Outages
- Must Run

O P T I M I Z A T I O N

Projections

Power Prices
Fuel Prices
Allowance Prices
Asset Values
Dispatch Decisions
Capacity Build Decisions
Emissions
Compliance Costs
Compliance Decisions
Plant Retirement Decisions

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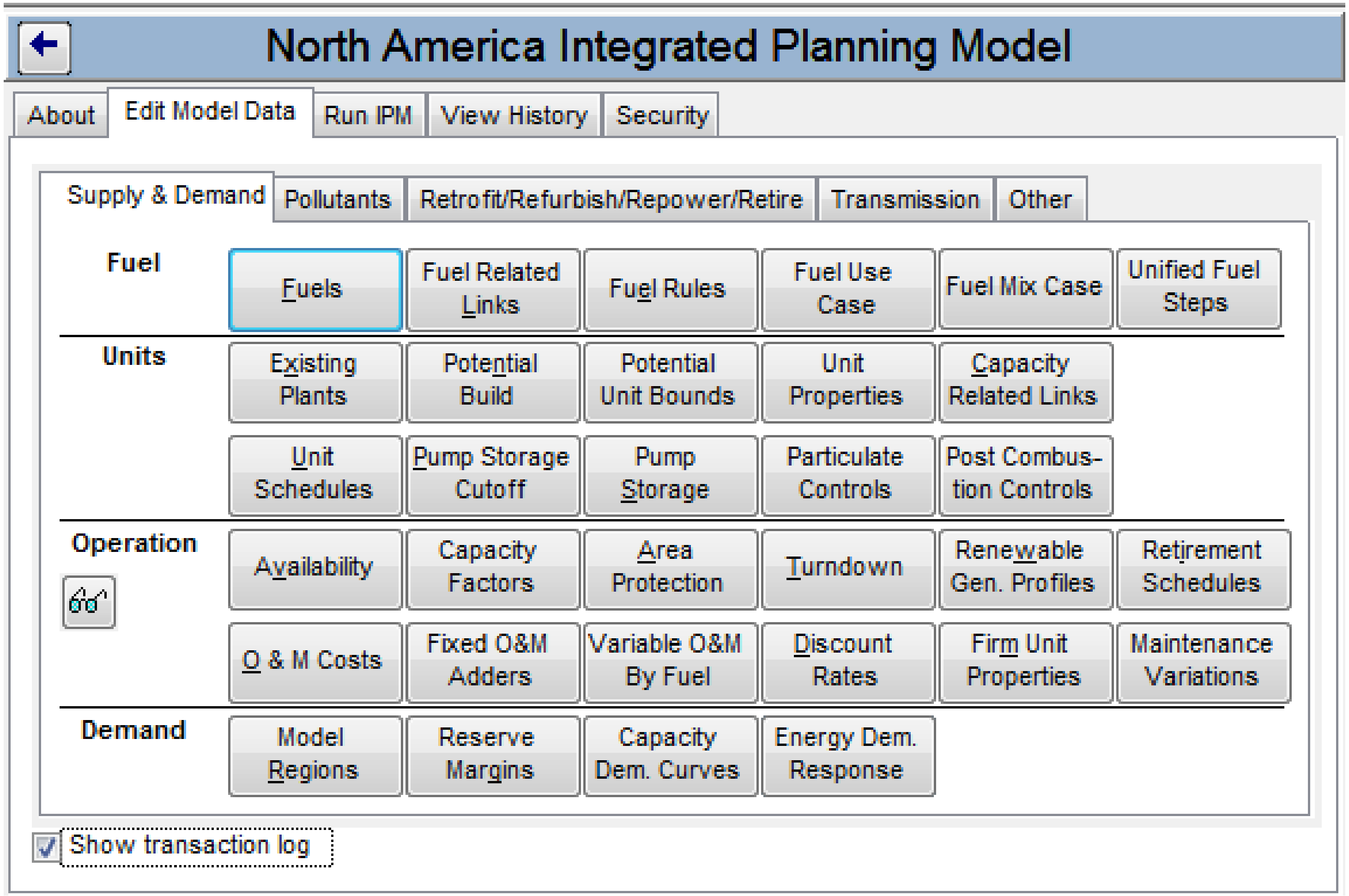
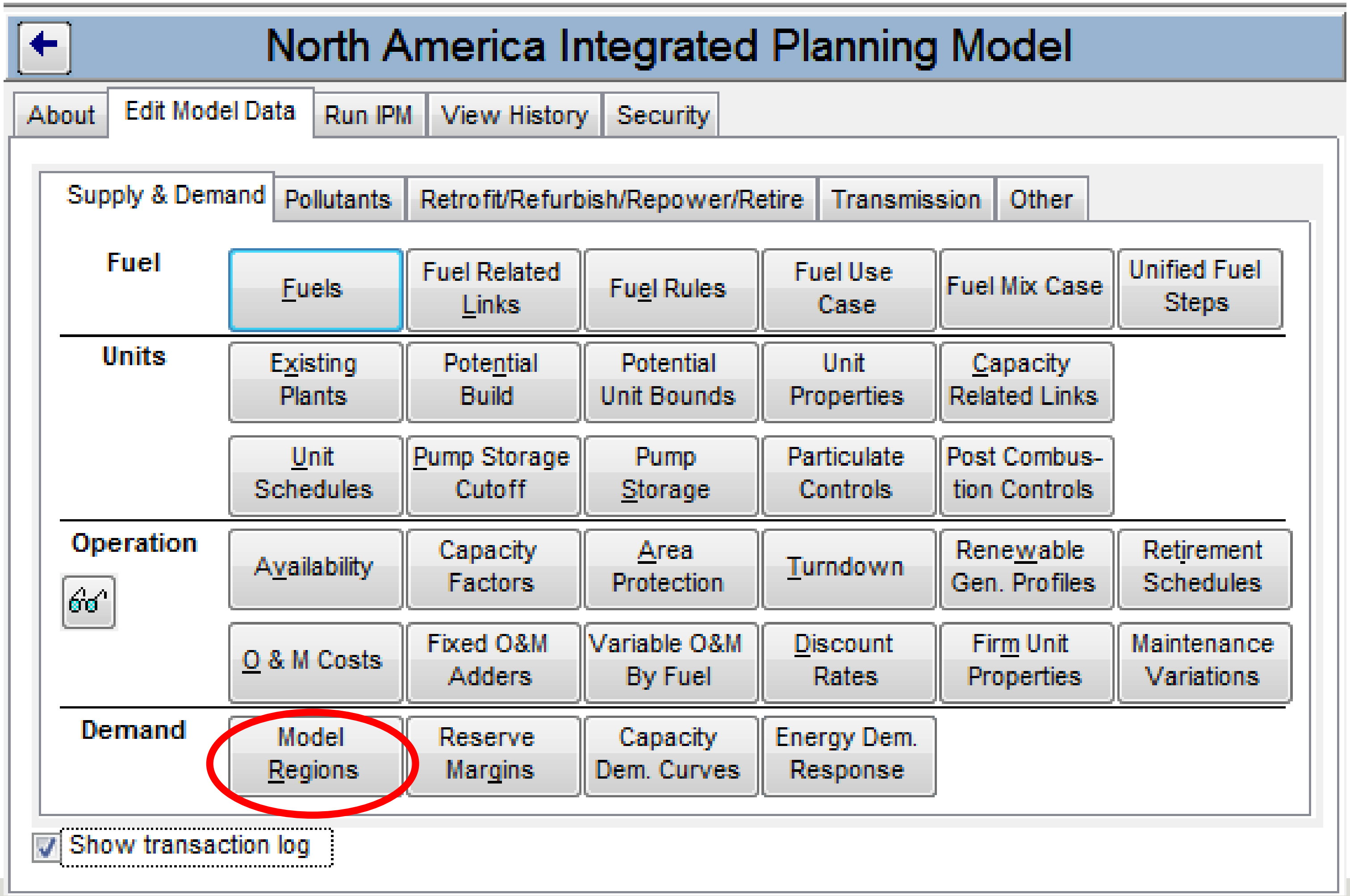
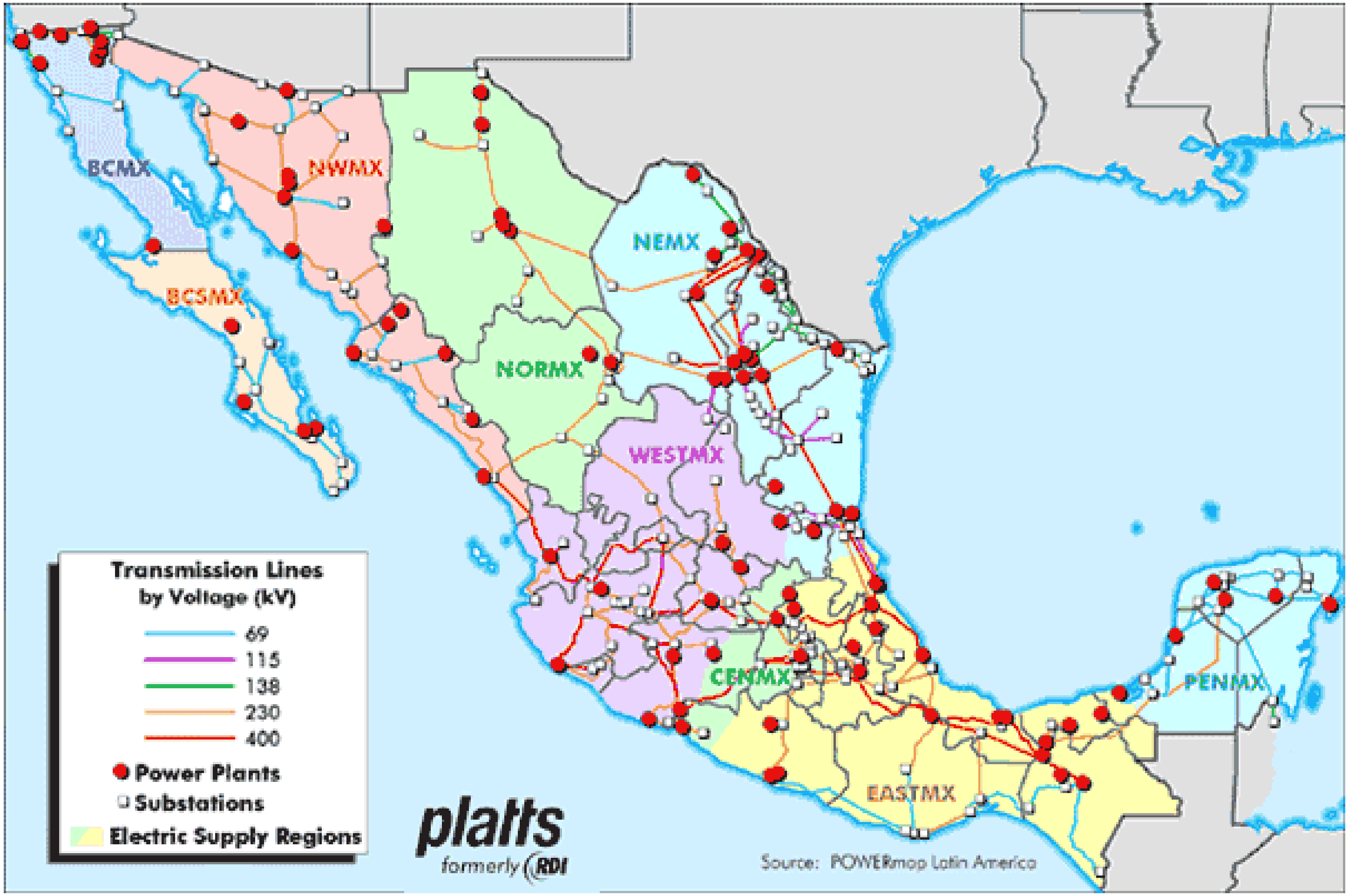
IPM® Front-end Main Screen



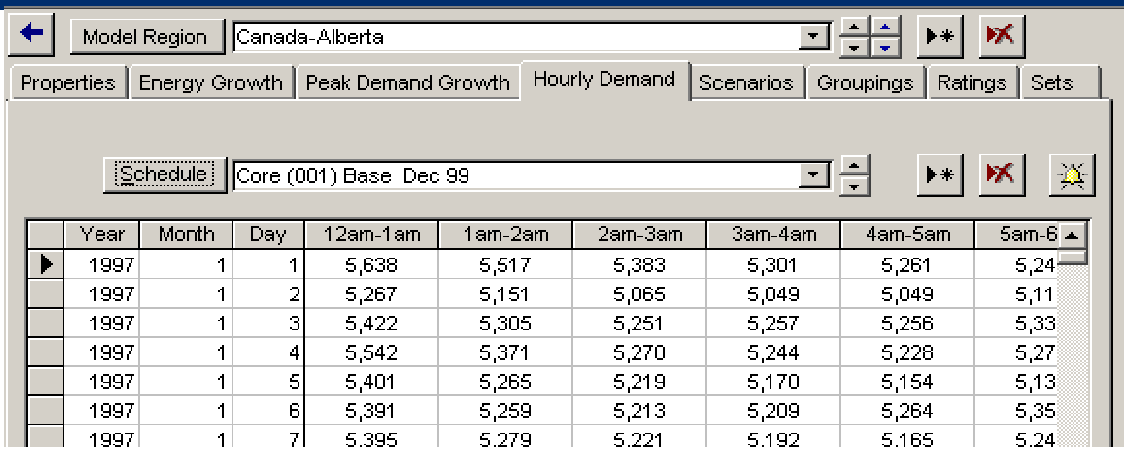
IPM® Model Region Specifications

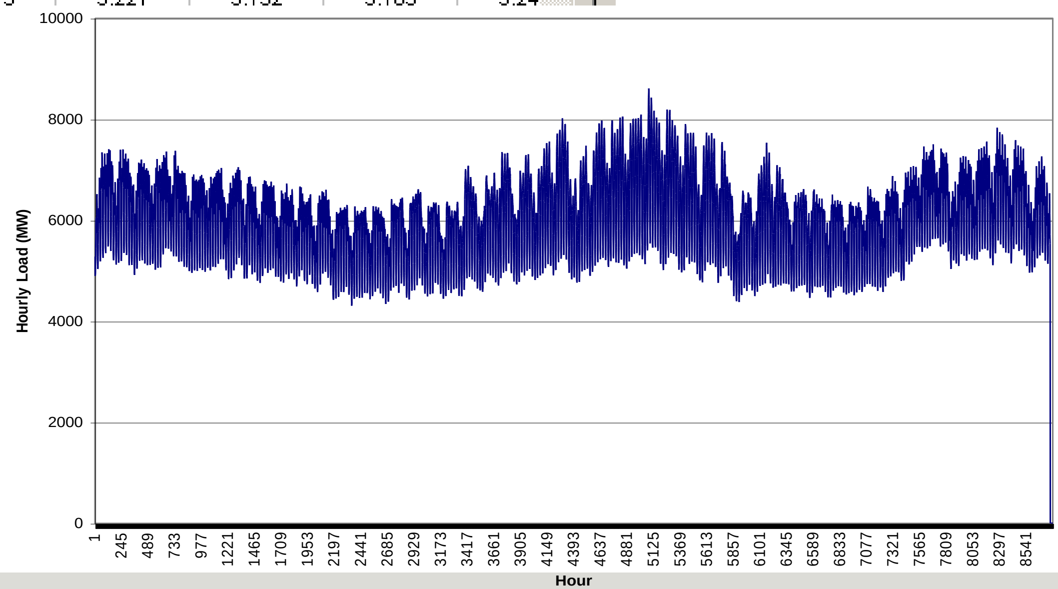


IPM® Sample Mexico Representation
9 Model Regions



Hourly Load Shape - Regional





Peak Demand Growth Over Time

Model Region: Canada-Alberta

Properties | Energy Growth | **Peak Demand Growth** | Hourly Demand | Scenarios | Groupings | Ratings | Sets

Schedule: Yada Core10 (003) Peak Demand 04-22-10

Demand Choice: Highest Net Internal Summer/Winter (default)

Peak Winter-Summer Rating Map:

Apply Growth Rate

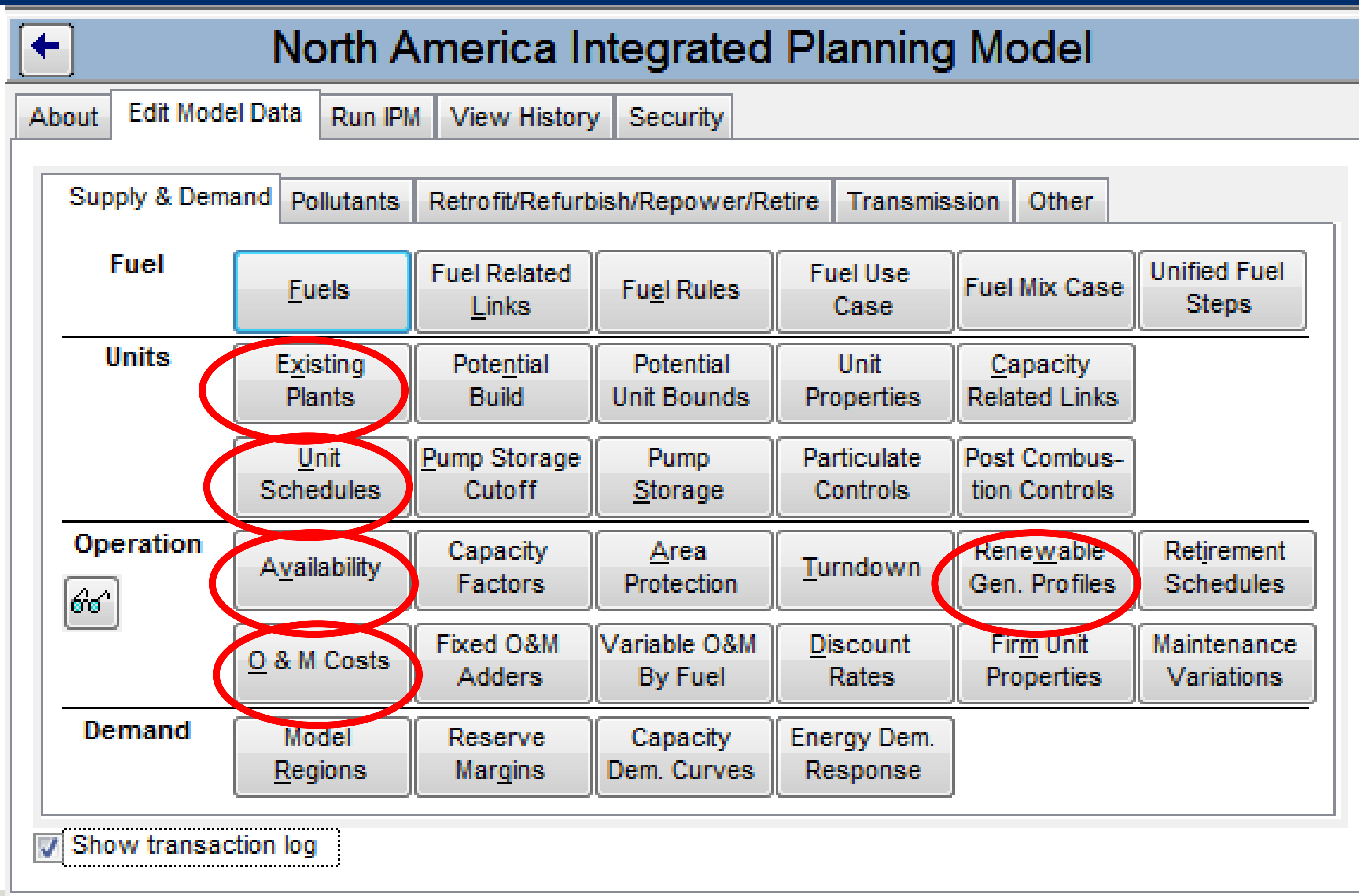
Show Growth Rate

Year	Summer Peak (MW)	Winter Peak (MW)	Summer Net Internal Demand (MW)	Winter Net Internal Demand (MW)	Summer Growth Floor (%)	Winter Growth Floor (%)
2009	10,281	12,259	10,281	12,259		
2010	10,526	12,513	10,526	12,513		
2011	10,777	12,772	10,777	12,772		
2012	10,979	12,980	10,979	12,980		
2013	11,185	13,191	11,185	13,191		
2014	11,438	13,450	11,438	13,450		
2015	11,739	13,758	11,739	13,758		
2016	12,049	14,074	12,049	14,074		
2017	12,320	14,348	12,320	14,348		

Peak Demand (Summer) in MW

NUM

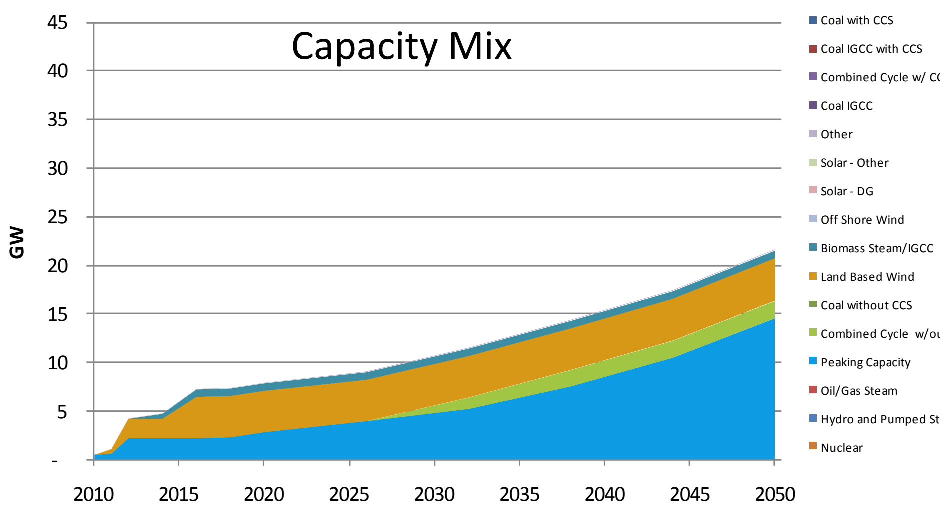
IPM® Unit and Operation Specification

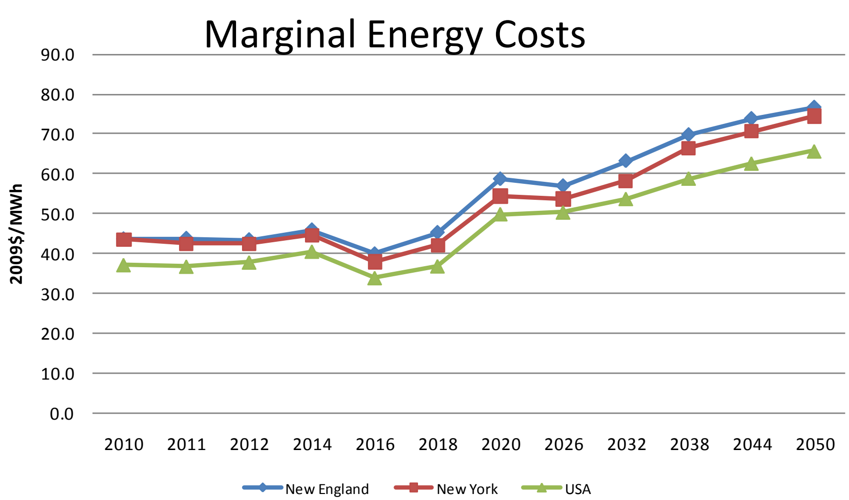


Sample Solution Results

Annual Investment Expense

UnitType	2010	2011	2012	2014	2016	2018	2020	2026	2032	2038	2044	2050
Potential Build Biomass Conventional	-	-	-	5,232	10,522	-	11,252	32,637	14,177	2,336	918	547
Potential Build Biomass IGCC	-	-	-	-	-	-	-	-	-	2,467	1,229	-
Potential Build Coal IGCC_CCS	-	-	-	-	-	-	-	-	-	-	-	-
Potential Build Coal_Scrubbed	-	-	-	-	56,506	-	-	-	172,950	622,856	951,365	502,543
Potential Build Combined Cycle - Cycling	-	-	-	31,552	-	-	-	-	-	934	-	4,858
Potential Build Combined Cycle - Turndown	-	-	-	17,265	5,009	9,948	50,736	114,342	105,908	86,663	72,746	11,059
Potential Build Combustion Turbine	-	2,521	10,778	472	-	11,135	53,797	8,478	32,915	31,118	27,804	22,474
Potential Build Geothermal	-	-	-	-	8,138	3,794	-	1,946	-	-	-	3,376
Potential Build Jet Engine (LMS 100)	2,740	-	1,027	-	-	-	-	-	-	-	-	-
Potential Build Landfill	560	452	934	3,081	2,842	3,666	3,679	7,299	-	-	-	-
Potential Build Nuclear	-	-	-	-	-	-	-	-	-	-	-	28,873
Potential Build Solar PV	-	8,301	4,155	11,506	41,573	-	498	53,650	18,595	-	2,413	-
Potential Build Solar TH	-	-	-	-	27,264	-	-	121	95	-	1,552	6,056
Potential Build Wind	1,659	13,974	27,272	2,446	56,020	2,384	14,263	26,315	-	-	32,324	26,457
Potential Combined Cycle with CCS	-	-	-	-	-	-	-	-	-	-	-	-
Total	4,960	25,248	44,166	71,553	207,873	30,926	134,225	244,788	344,641	746,374	1,090,349	606,243

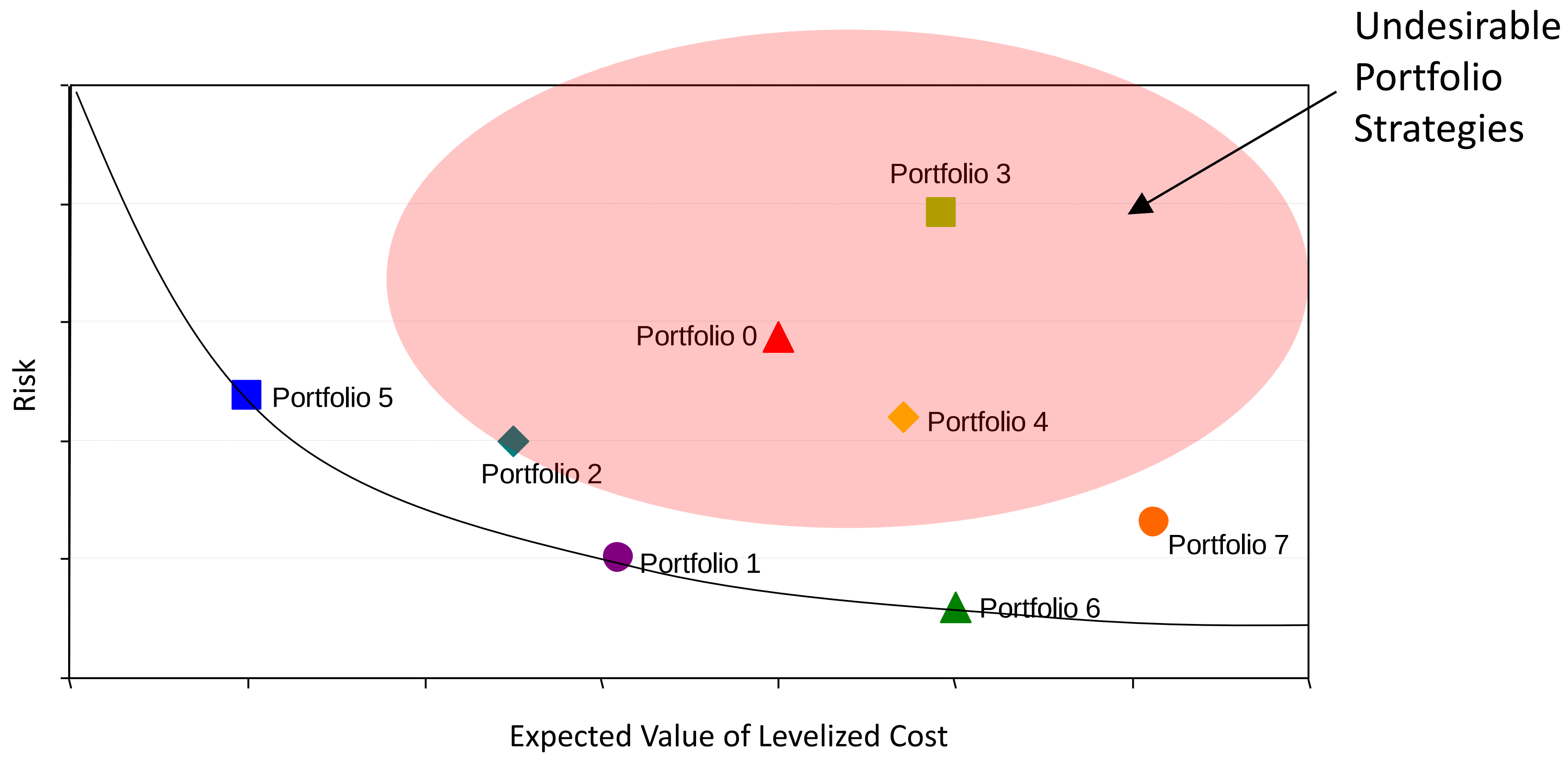




Utilizing Evaluation Criteria

Presenter: Maria Scheller

Portfolios With High Risk and Cost Are Less Desirable



Scorecard Approach

Criteria		Cost			Risk				Environmental		
Portfolio		2012-2030 Cost NPV ($Mil)	2012-2030 Levelized Cost (2011 $/MWh)	Cost Rating Score	95th Percentile Costs ($Mil)	Reserve Margins 2025 (%)	Quantum Risk	Risk Rating Score	CO_2 Changes from 2012 to 2025 (%)	Renewable Generation As % of Load (%)	Environmental Stewardship Score
Status Quo											
Portfolio 1											
Portfolio 2											
Portfolio 3											
Portfolio 4											
Portfolio 5											
Portfolio 6											
Portfolio 7											
Portfolio 8											
Portfolio 9											

Score Rating: Favorable Neutral Unfavorable