



# 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

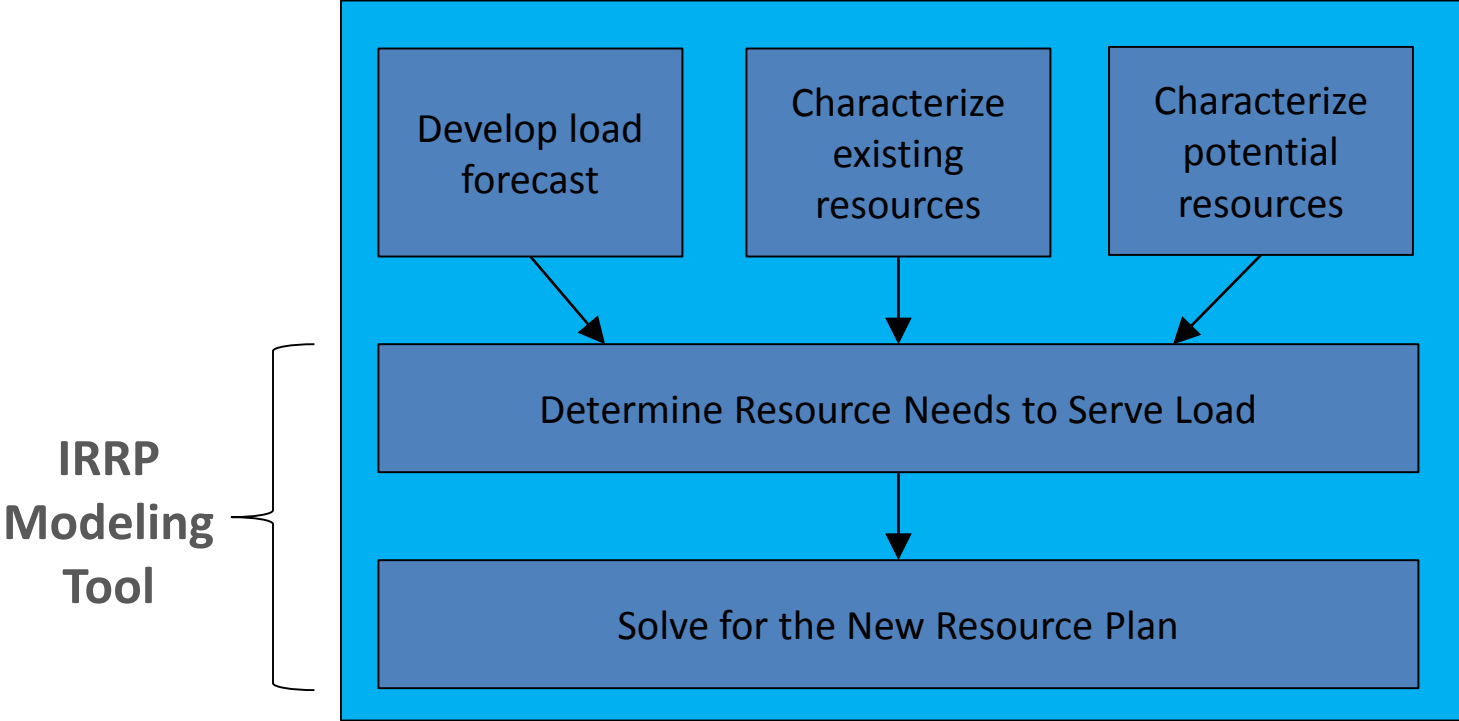
*Presenters: Maria Scheller, Molly Hellmuth*

# IRRP Optimization - Considering Scenarios, Risks, and Alternatives

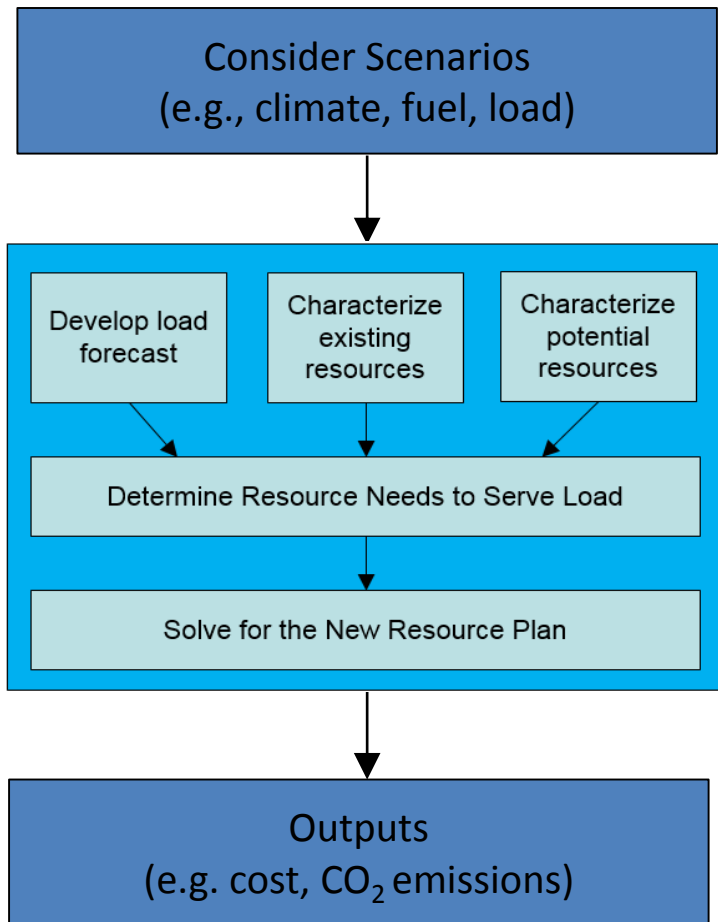
*Presenter: Maria Scheller*



# 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

Reference load

Expected gas  
price

Mild drought

## Scenario 2

High load

Expected gas  
price

Severe drought

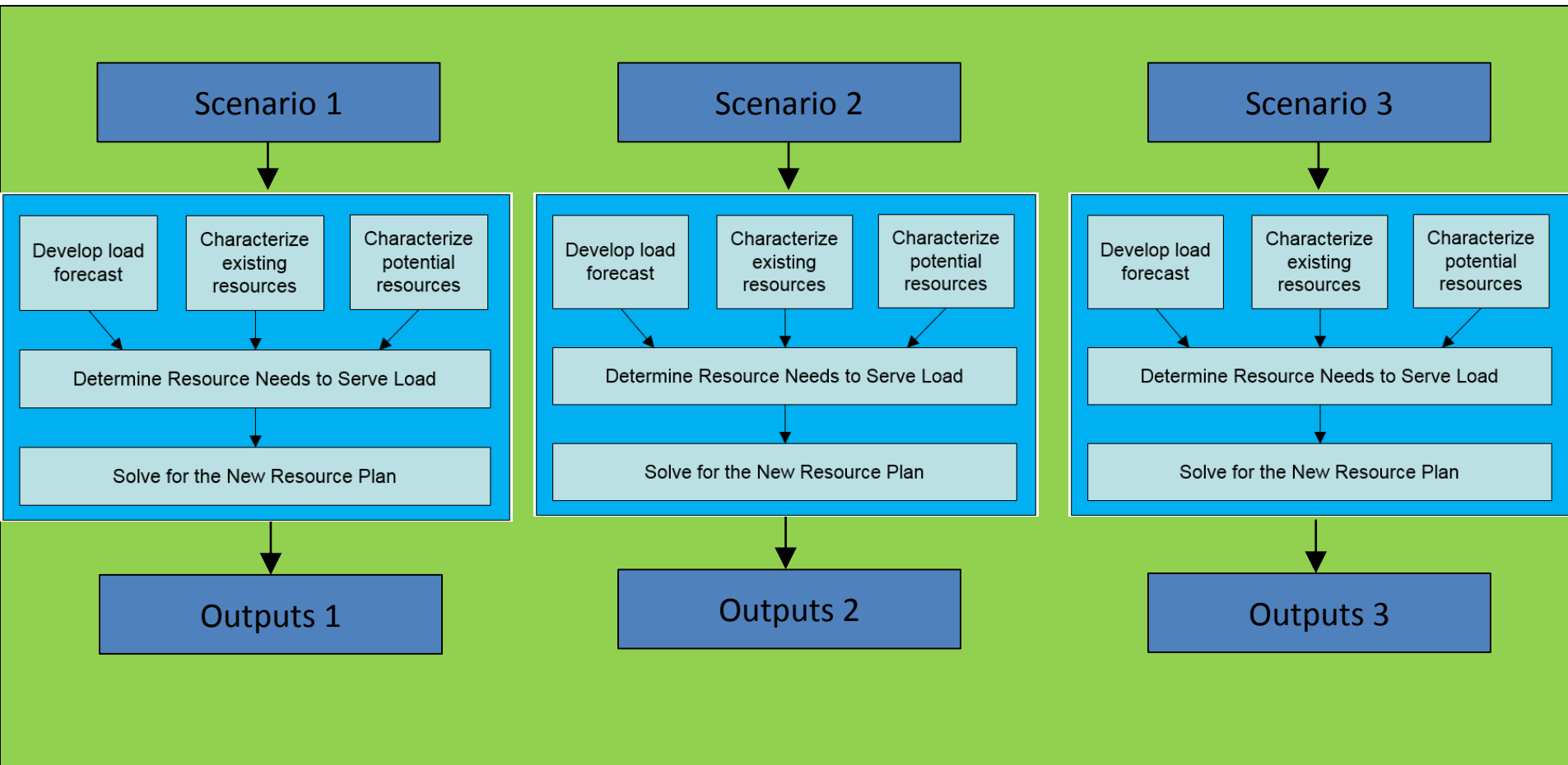
## Scenario 3

Low load

High gas  
price

No drought

# Multiple Risk Scenarios



# Defining Alternate Investment Portfolio Strategies to Meet Requirements

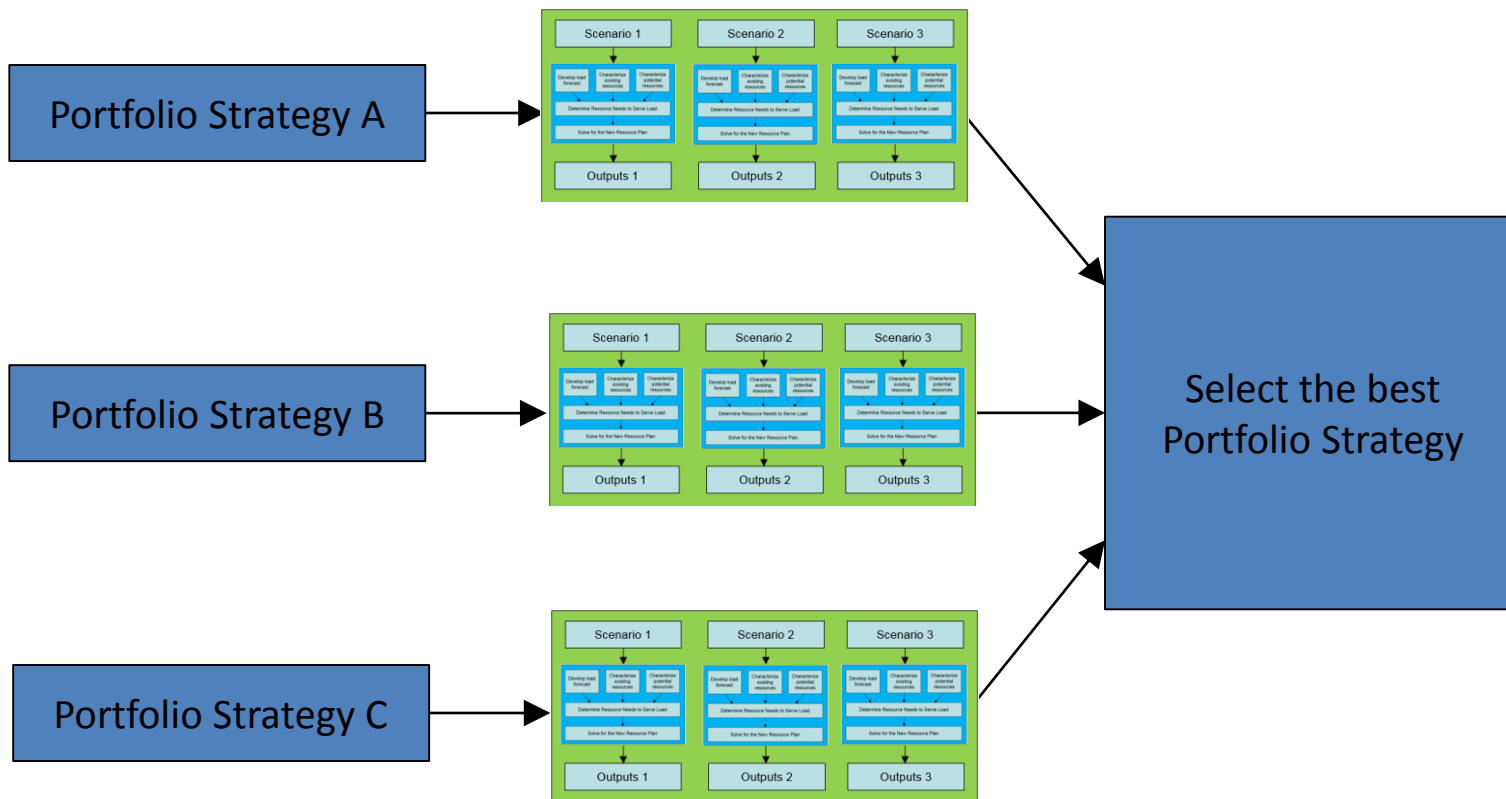
- Business as usual strategy
  - e.g., least-cost investment strategy
- Alternative strategies, e.g.,
  - require 50% renewables in the resource mix by 2030
  - require 20% hydro
  - carbon emission limits
  - electricity import/export goals

## Illustrative Strategies





# 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

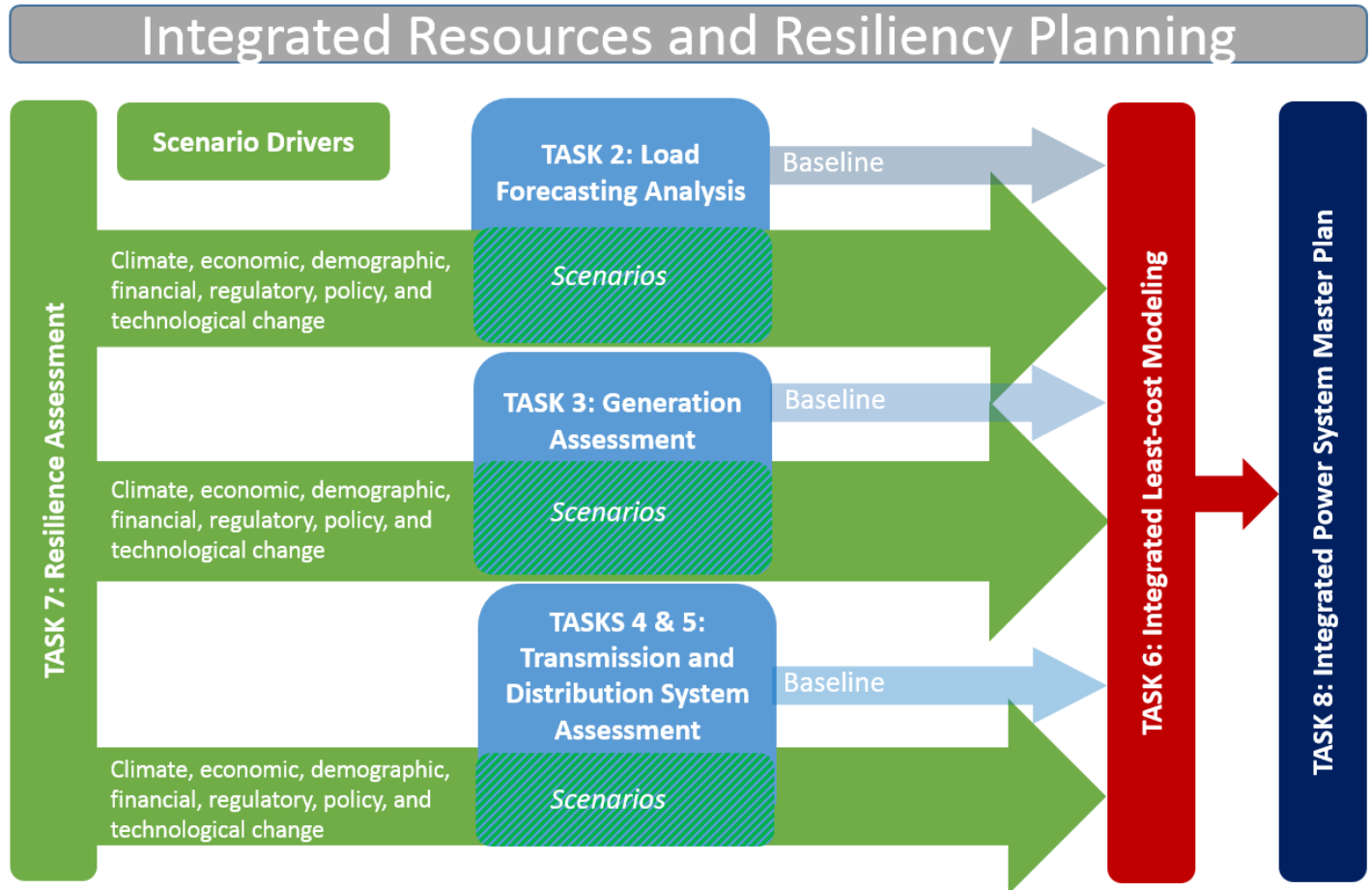
- The least-regrets resource plan is one which provides the highest performance under the selected metrics
- We are working to derive such a resource plan for Ghana and Tanzania based on jointly developed scenarios and metrics
  - Collaborative process
  - Collective input from Ghana and Tanzania stakeholders
  - 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*



# Methodology



- Crosscutting Power System
- Quantitative Modeling
- Qualitative Assessment

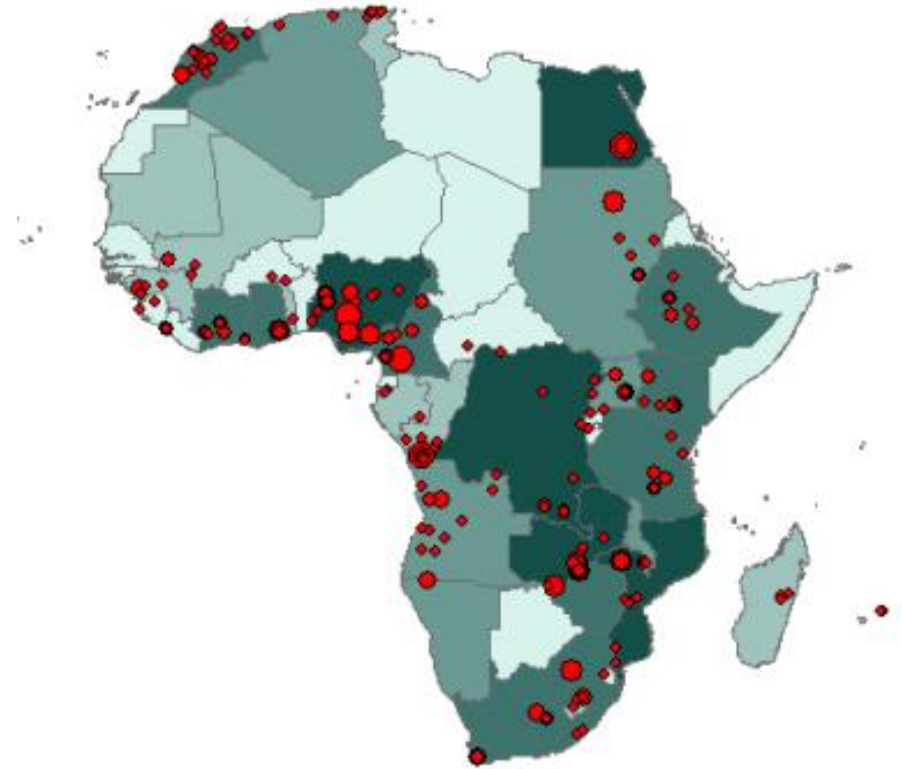
# Risk and Resiliency: Climate Scenarios

- **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°C	Monthly rainfall, maximum, and minimum temperature projections	Increasing frequency of El Nino events

# Focus on Hydropower Modeling in Tanzania

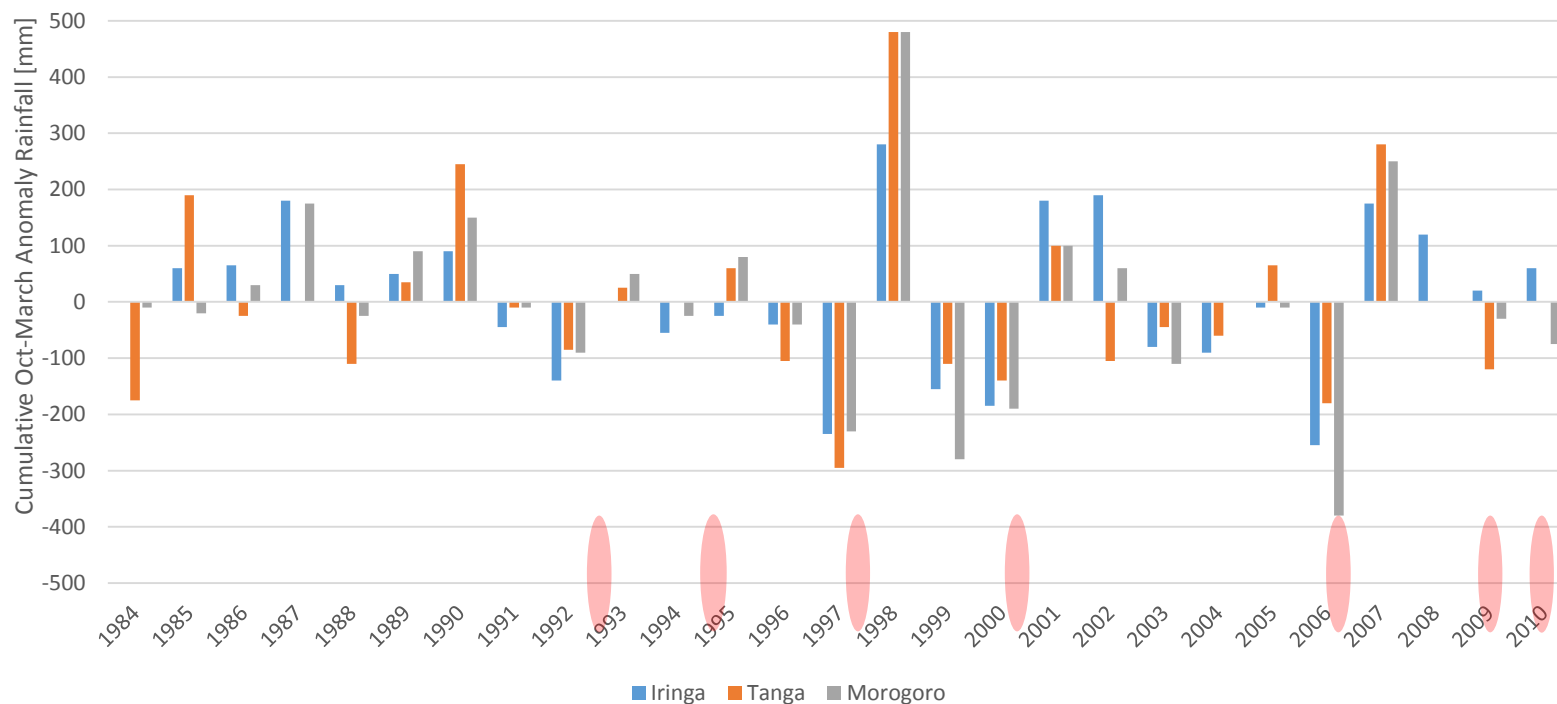
- One of more hydro-dependent countries in Africa
- Shift towards diversification  
90% dependence (2002) →  
35% (2016)



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

# Generation tracks rainfall

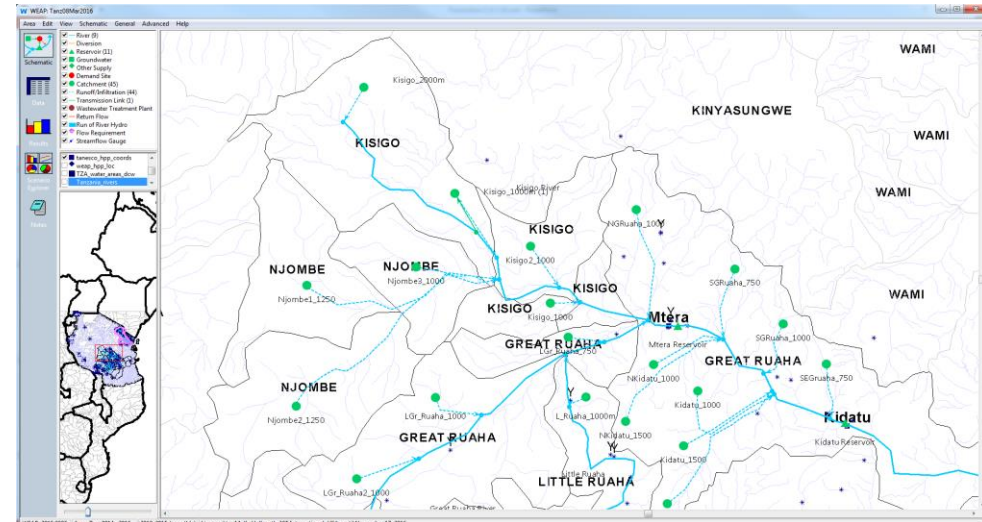
- Historical power rationing/black outs due to below normal rainfall





# Risk and Resiliency: Hydropower modeling

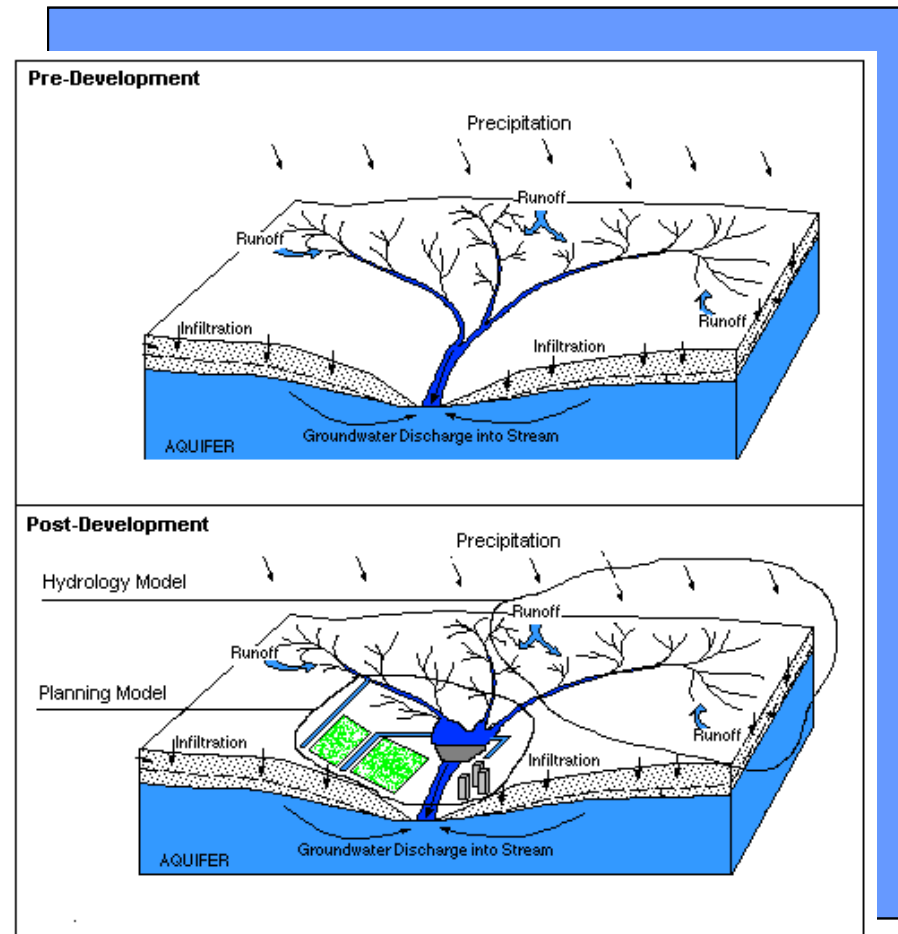
- Water Evaluation and Planning (WEAP) model
  - Partnership with the Stockholm Environment Institute (SEI)
  - ICF and SEI will deliver the model and provide training
- The outputs of WEAP feed into IPM
- IPM's optimization will be used to project future hydropower builds



# 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

The screenshot displays the WEAP21 software interface for the Weeping River Basin. The main window is titled "WEAP21: Weeping River Basin" and has a menu bar with "Area", "Edit", "View", "General", "Tree", and "Help".

On the left side, there is a vertical toolbar with icons for "Schematic", "Data", "Results", "Overviews", and "Notes". Below these is a project tree showing the hierarchy: "to Industry East", "to South City", "to Agriculture West", "to West City", "Local", "River", "Weeping River", "Reservoirs" (with "North Reservoir" and "Central Reservoir" selected), "Flow Requirements", and "Reaches" (with "Below Weeping River", "Below North Reservoir", and "Below Return Flow from" listed).

The main area is divided into several sections:

- Data for:** "Supply Measures (1999-20)" with buttons for "Manage Scenarios..." and "Data Report..."
- Configuration Tabs:** "Physical", "Operation", and "Hydropower" (selected).
- Hydropower Settings:** "Min. Turbine Flow", "Max. Turbine Flow", "Tailwater Elevation", "Plant Factor", and "Generating Efficiency".
- Table:** A table with the following data:

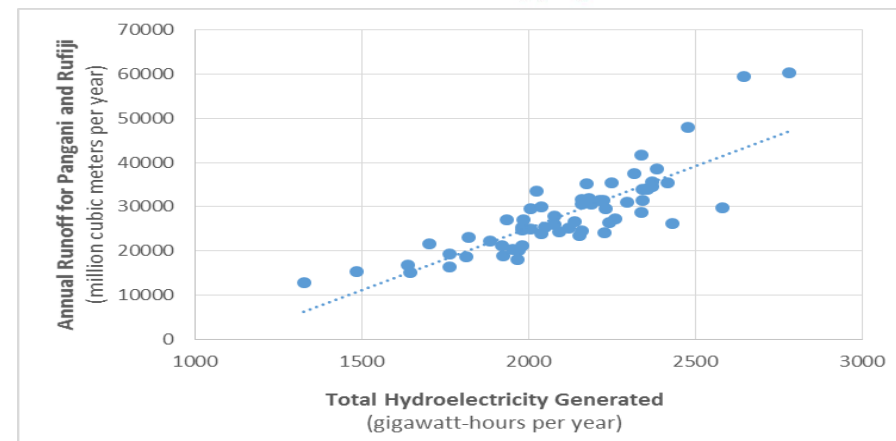
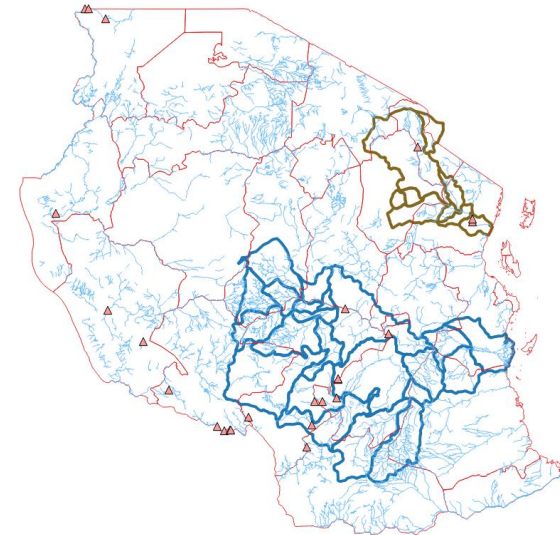
Reservoir	Scale	Unit	1998	1999-2008
Central Reservoir		CMS	11.33	11.33
- Chart:** A line chart titled "Min. Turbine Flow" showing a constant value of 11.33 CMS from 1998 to 2008. The y-axis is labeled "CMS" and ranges from 0 to 10. The x-axis shows years from 1998 to 2008.

A black text box with white text is overlaid on the chart area, stating: "Specify capacities, efficiencies, and other properties of power generation".

At the bottom of the window, it says "Area: Weeping River Basin", "Data View", and "Registered to: Tellus Institute".

# 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

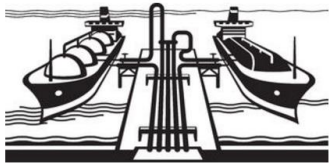


# Integrated Planning Models

*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<sub>x</sub> control options
- Wet and Dry FGD
- ACI and Fabric Filter
- Co-benefits for Hg



## Transmission

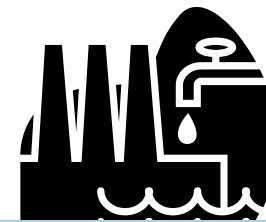
- New FERC Policies
- Long-term tradeoffs with Generation
- Grid operation

## Electric Demand

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

## Power Plant Dispatch and Grid Operation

- Economic dispatch



## Air Policy Specifications

- NO<sub>x</sub>, SO<sub>2</sub>, Hg and CO<sub>2</sub>
- MACT vs. Cap and Trade
- Banking and Progressive Flow Control
- National, Regional and State Programs
- Renewable Portfolio Standards

## Operation

- Maintenance
- Outages
- Must Run



## 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<sup>®</sup> Front-end Main Screen

← North America Integrated Planning Model

About Edit Model Data Run IPM View History Security

Supply & Demand Pollutants Retrofit/Refurbish/Repower/Retire Transmission Other

**Fuel**

Fuels Fuel Related Links Fuel Rules Fuel Use Case Fuel Mix Case Unified Fuel Steps

**Units**

Existing Plants Potential Build Potential Unit Bounds Unit Properties Capacity Related Links

Unit Schedules Pump Storage Cutoff Pump Storage Particulate Controls Post Combustion Controls

**Operation**

Availability Capacity Factors Area Protection Turndown Renewable Gen. Profiles Retirement Schedules

O & M Costs Fixed O&M Adders Variable O&M By Fuel Discount Rates Firm Unit Properties Maintenance Variations

**Demand**

Model Regions Reserve Margins Capacity Dem. Curves Energy Dem. Response

Show transaction log



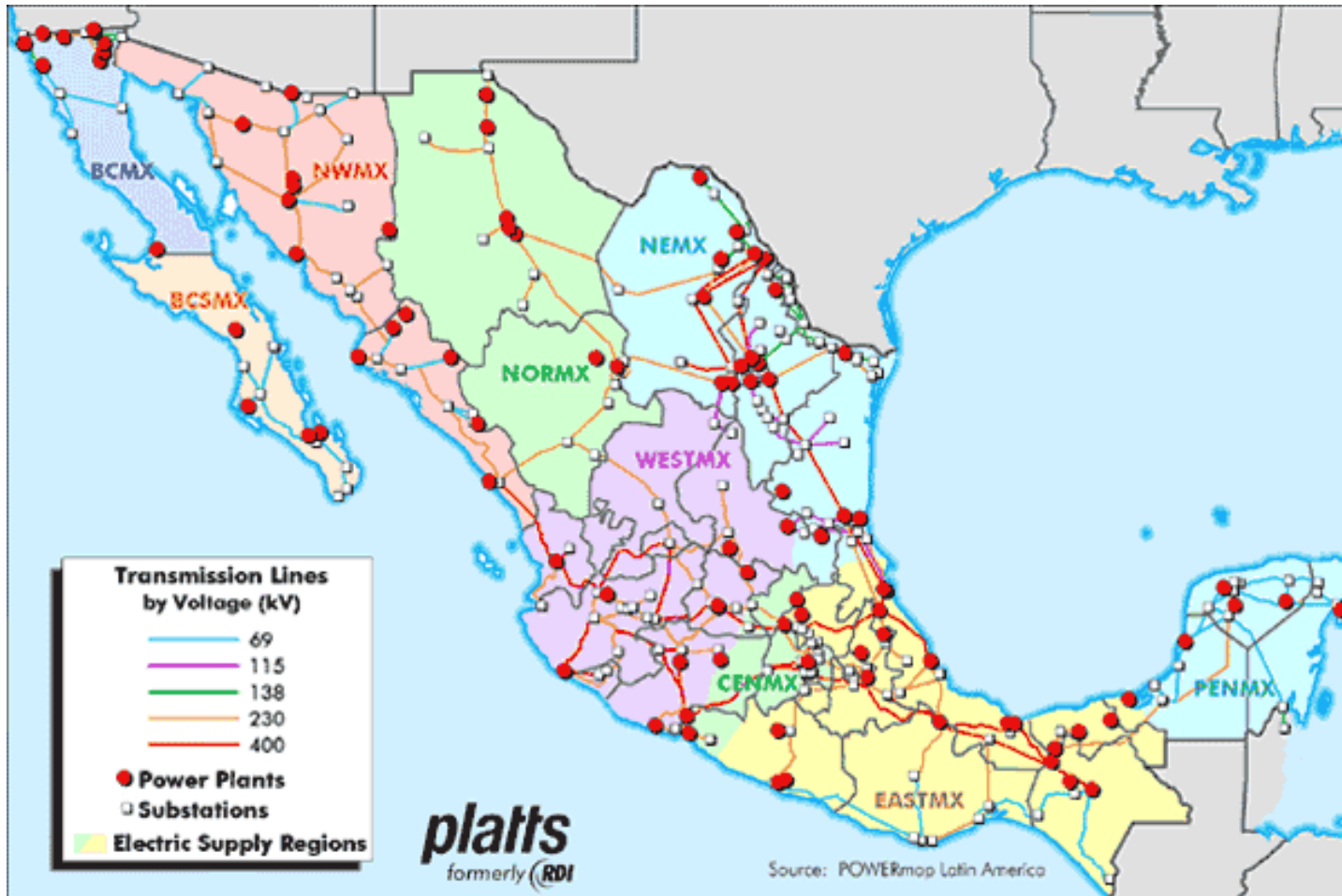
# IPM® Model Region Specifications

The screenshot displays the 'North America Integrated Planning Model' interface. At the top, there is a navigation bar with a back arrow and the title 'North America Integrated Planning Model'. Below this is a menu bar with options: 'About', 'Edit Model Data', 'Run IPM', 'View History', and 'Security'. The main content area is organized into several sections: 'Supply & Demand', 'Pollutants', 'Retrofit/Refurbish/Repower/Retire', 'Transmission', and 'Other'. The 'Fuel' section includes buttons for 'Fuels', 'Fuel Related Links', 'Fuel Rules', 'Fuel Use Case', 'Fuel Mix Case', and 'Unified Fuel Steps'. The 'Units' section is divided into two rows of buttons: 'Existing Plants', 'Potential Build', 'Potential Unit Bounds', 'Unit Properties', 'Capacity Related Links' in the first row; and 'Unit Schedules', 'Pump Storage Cutoff', 'Pump Storage', 'Particulate Controls', 'Post Combustion Controls' in the second row. The 'Operation' section includes a small icon and buttons for 'Availability', 'Capacity Factors', 'Area Protection', 'Turndown', 'Renewable Gen. Profiles', and 'Retirement Schedules'. A second row of buttons includes 'O & M Costs', 'Fixed O&M Adders', 'Variable O&M By Fuel', 'Discount Rates', 'Firm Unit Properties', and 'Maintenance Variations'. The 'Demand' section includes buttons for 'Model Regions' (circled in red), 'Reserve Margins', 'Capacity Dem. Curves', and 'Energy Dem. Response'. At the bottom left, there is a checkbox labeled 'Show transaction log' which is checked.



# IPM® Sample Mexico Representation

## 9 Model Regions



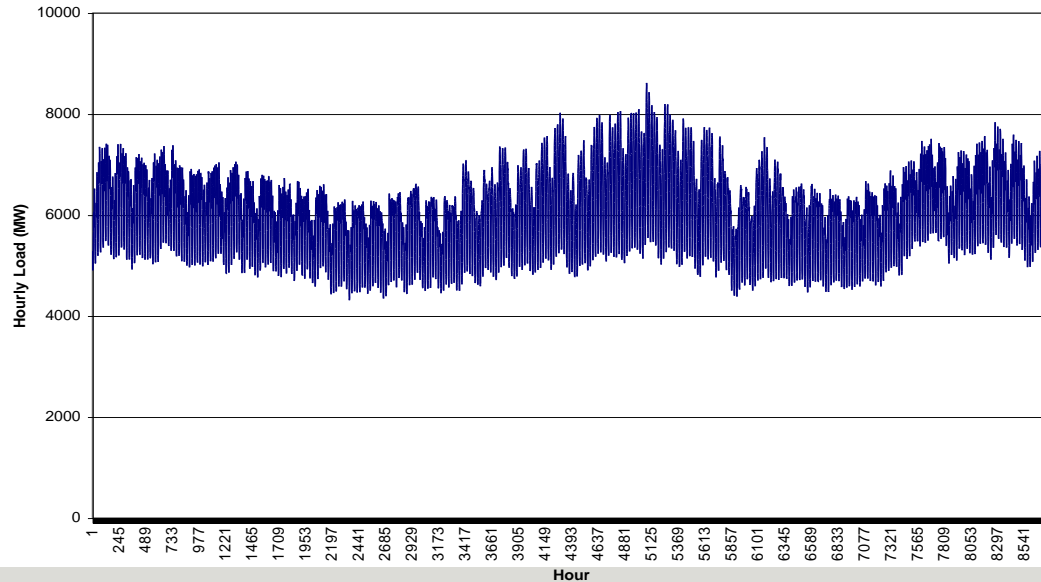
# Hourly Load Shape - Regional

Model Region: Canada-Alberta

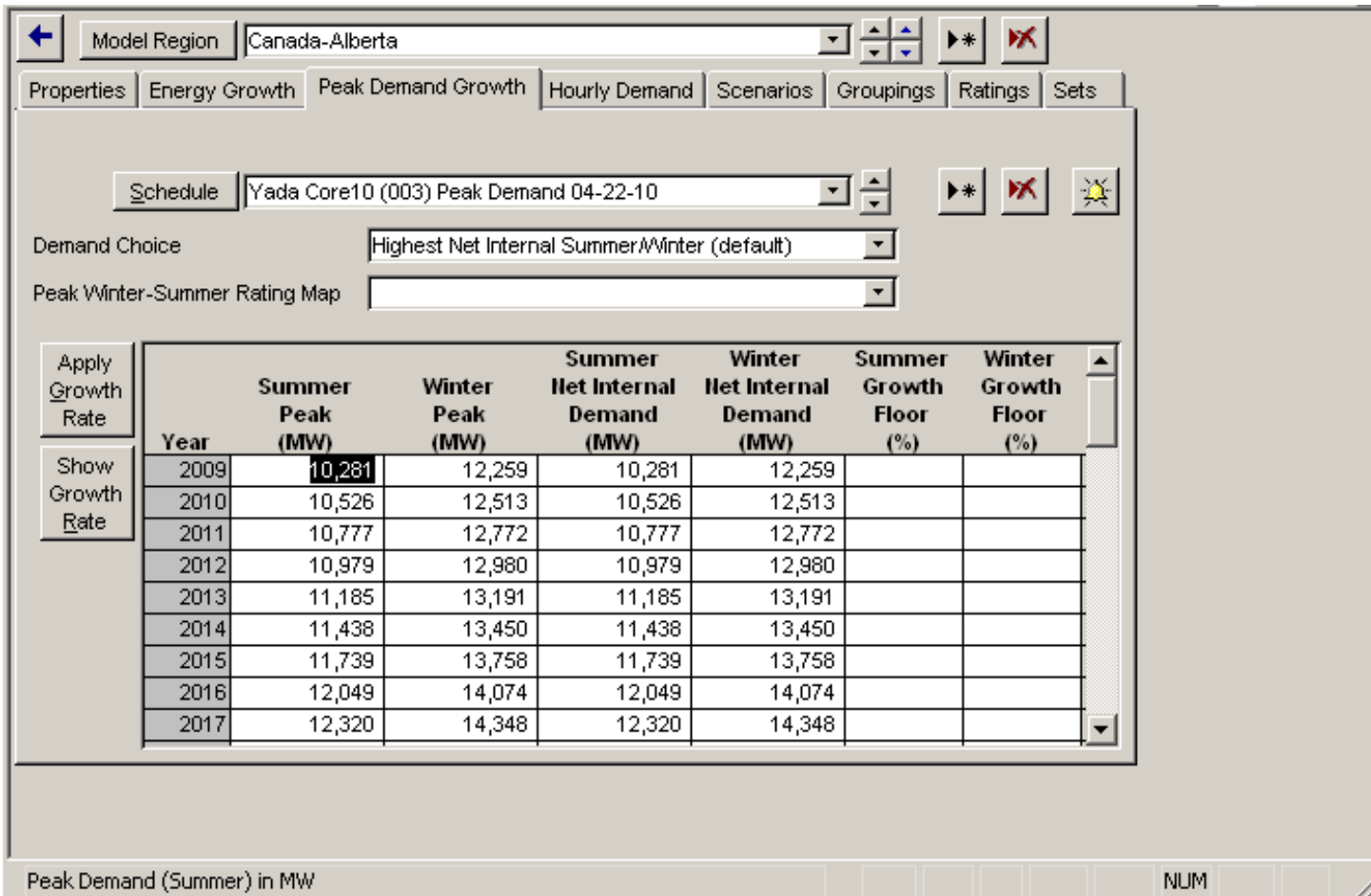
Properties | Energy Growth | Peak Demand Growth | **Hourly Demand** | Scenarios | Groupings | Ratings | Sets

Schedule: Core (001) Base Dec 99

	Year	Month	Day	12am-1am	1am-2am	2am-3am	3am-4am	4am-5am	5am-6am
▶	1997	1	1	5,638	5,517	5,383	5,301	5,261	5,24
	1997	1	2	5,267	5,151	5,065	5,049	5,049	5,11
	1997	1	3	5,422	5,305	5,251	5,257	5,256	5,33
	1997	1	4	5,542	5,371	5,270	5,244	5,228	5,27
	1997	1	5	5,401	5,265	5,219	5,170	5,154	5,13
	1997	1	6	5,391	5,259	5,213	5,209	5,264	5,35
	1997	1	7	5,395	5,279	5,221	5,192	5,165	5,24



# Peak Demand Growth Over Time



# IPM<sup>®</sup> Unit and Operation Specification

North America Integrated Planning Model

About Edit Model Data Run IPM View History Security

Supply & Demand Pollutants Retrofit/Refurbish/Repower/Retire Transmission Other

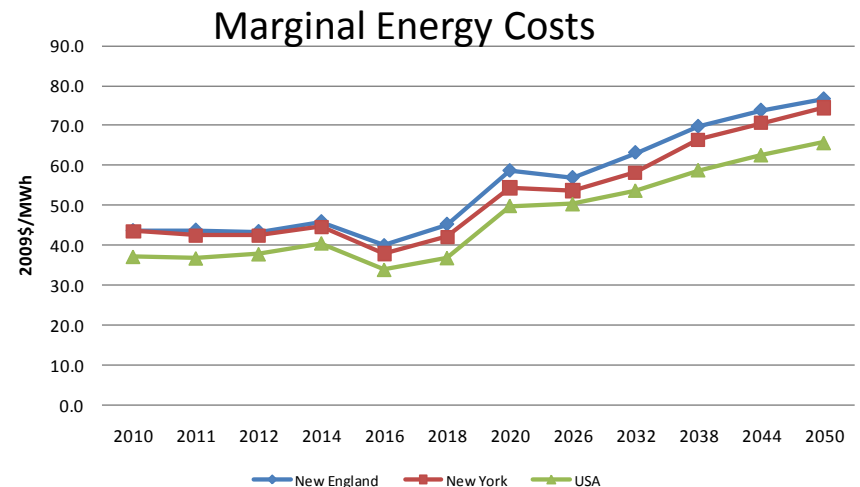
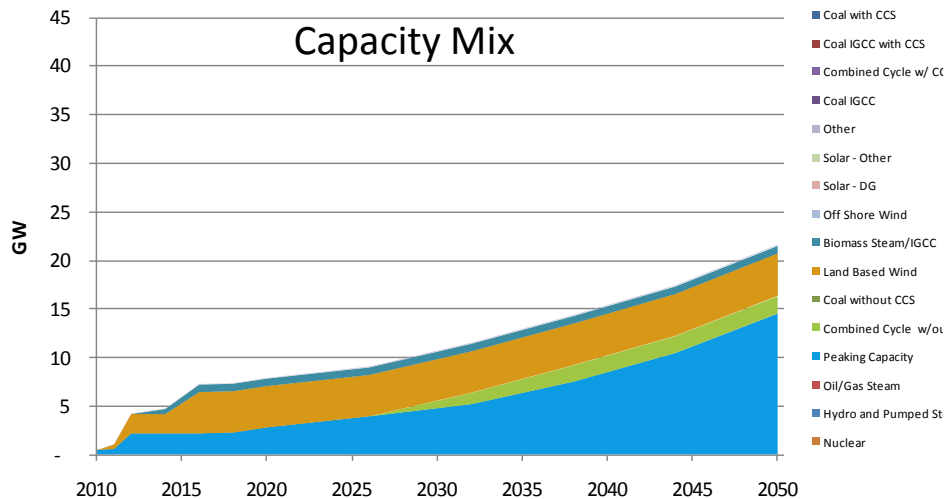
<b>Fuel</b>	<u>F</u> uels	Fuel Related <u>L</u> inks	Fuel <u>R</u> ules	Fuel Use Case	Fuel Mix Case	Unified Fuel Steps
<b>Units</b>	<u>E</u> xisting Plants	Potential Build	Potential Unit Bounds	Unit Properties	<u>C</u> apacity Related Links	
	<u>U</u> nit Schedules	Pump Storage Cutoff	Pump Storage	Particulate Controls	Post Combustion Controls	
<b>Operation</b>	<u>A</u> vailability	Capacity Factors	<u>A</u> rea Protection	<u>T</u> urndown	<u>R</u> enewable Gen. Profiles	Retirement Schedules
	<u>O</u> & M Costs	Fixed O&M Adders	Variable O&M By Fuel	<u>D</u> iscount Rates	<u>F</u> irm Unit Properties	Maintenance Variations
<b>Demand</b>	<u>M</u> odel Regions	Reserve Margins	Capacity Dem. Curves	Energy Dem. Response		

Show transaction log

# 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	-	-	-	-	-	-	-	-	-	-	-	-
<b>Total</b>	<b>4,960</b>	<b>25,248</b>	<b>44,166</b>	<b>71,553</b>	<b>207,873</b>	<b>30,926</b>	<b>134,225</b>	<b>244,788</b>	<b>344,641</b>	<b>746,374</b>	<b>1,090,349</b>	<b>606,243</b>

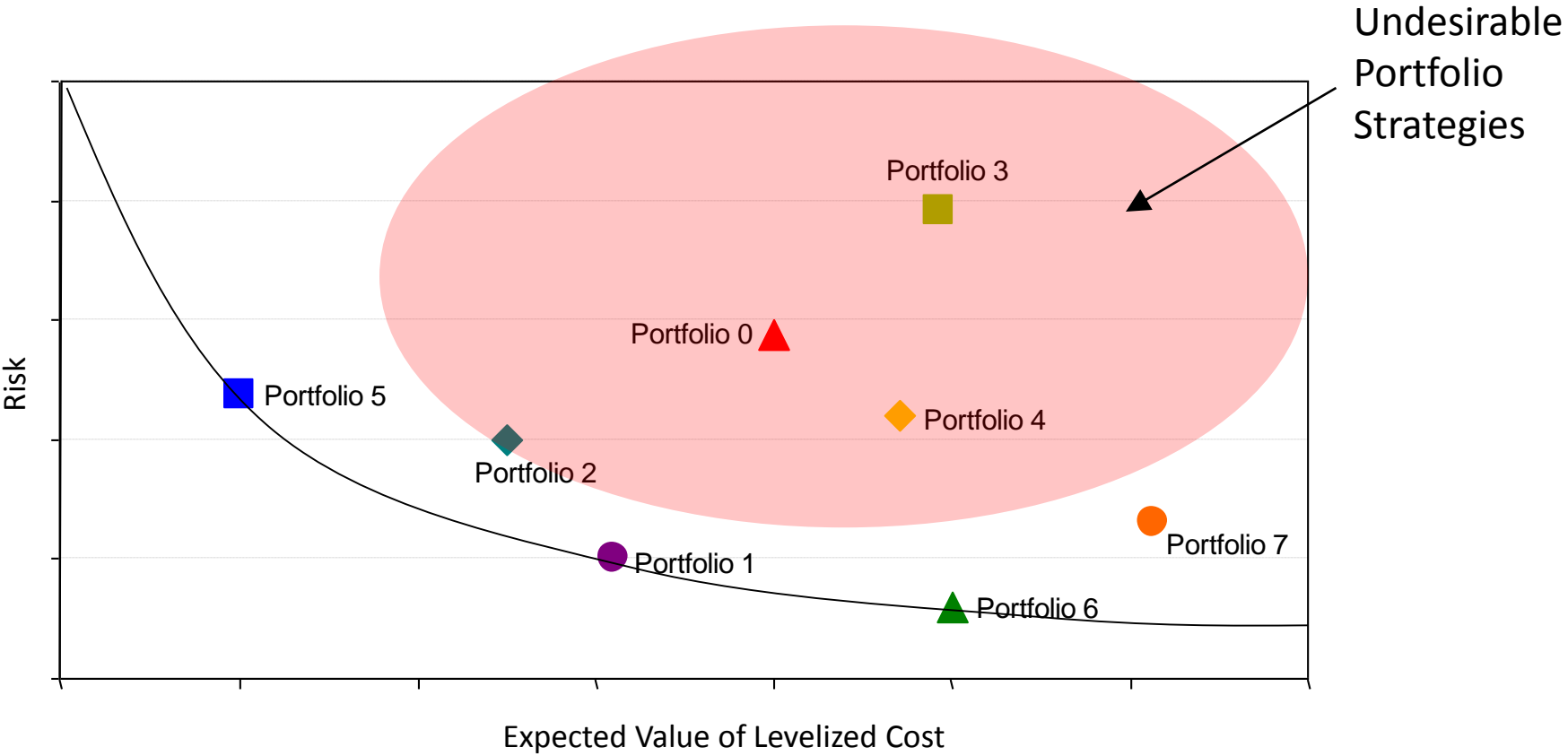


# Utilizing Evaluation Criteria

*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	95 <sup>th</sup> Percentile Costs (\$Mil)	Reserve Margins 2025 (%)	Quantum Risk	Risk Rating Score	CO <sub>2</sub> 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