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

USAID Training – March 6, 2017

Session 2: What Planning Looks Like

Part One – Components & Process

Presenters: Maria Scheller, Sanjay Chandra, Ken Collison,
Bill Prindle, Molly Hellmuth

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What Components and Factors are Considered within an IRRP?

Presenter: Maria Scheller

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Key Elements of Integrated Resource Planning

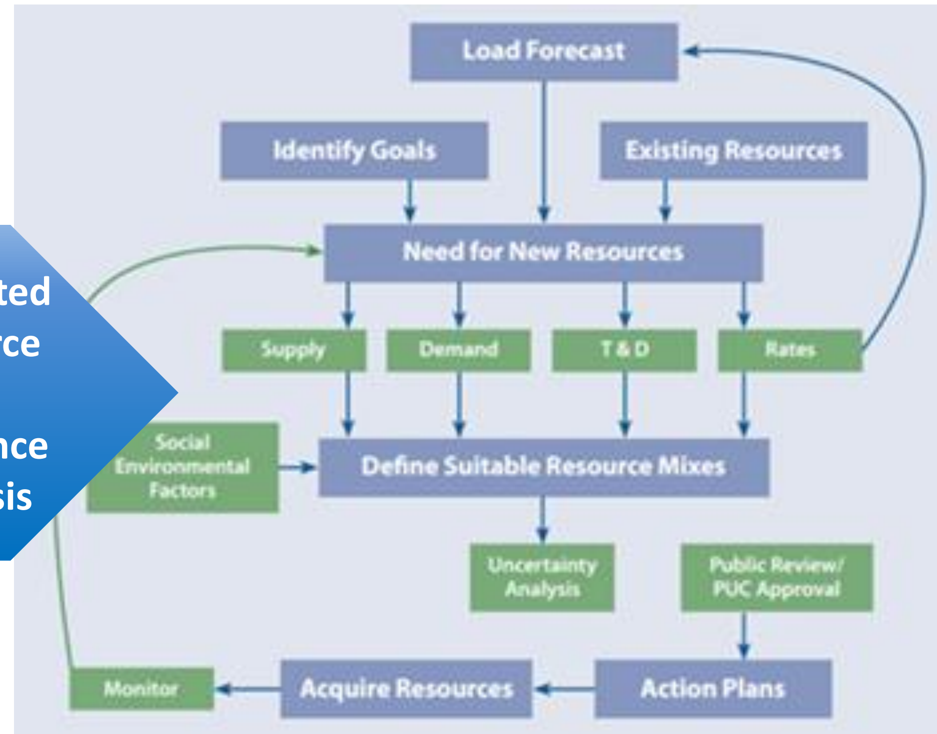
- Integrate resources and people across departments
  - Supply, demand, transmission, distribution, and pricing
  - Cooperation, coordination, and communication
- Treat uncertainty explicitly
  - Alternative resource portfolios
  - Factors external to the utility
  - Collect and analyze additional data
- Continue planning process
  - Feedback from implementation to planning
  - Develop new plans
- Involve the public in the planning process
  - Customers, nonutility experts, Independent power producers, and regulator
- Consider environmental factors
- Implement plan
  - Acquire demand and supply resources

Source: Adopted from "Technical competence of integrated resource plans prepared by electric utilities", Eric Hirst and Martin Schweitzer, March 1990.

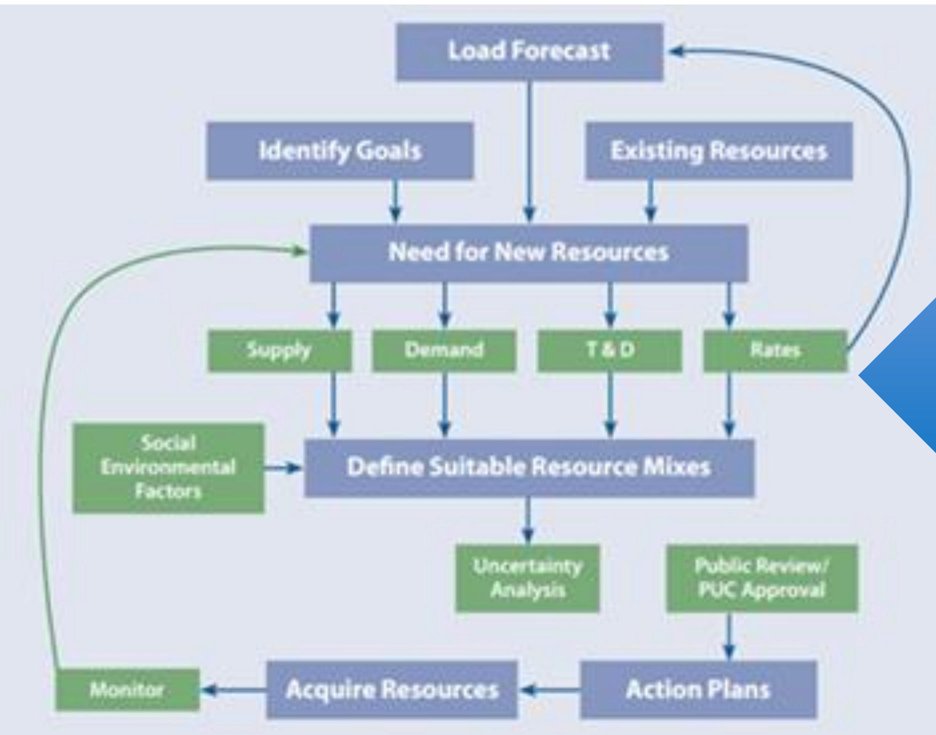
Components of IRRP Analysis

- Demand Analysis & Forecast
- Distribution System Analysis
- Supply-side Resource Analysis
- Transmission Network Analysis
- Demand-side Resource Analysis

Integrated Resource and Resilience Analysis



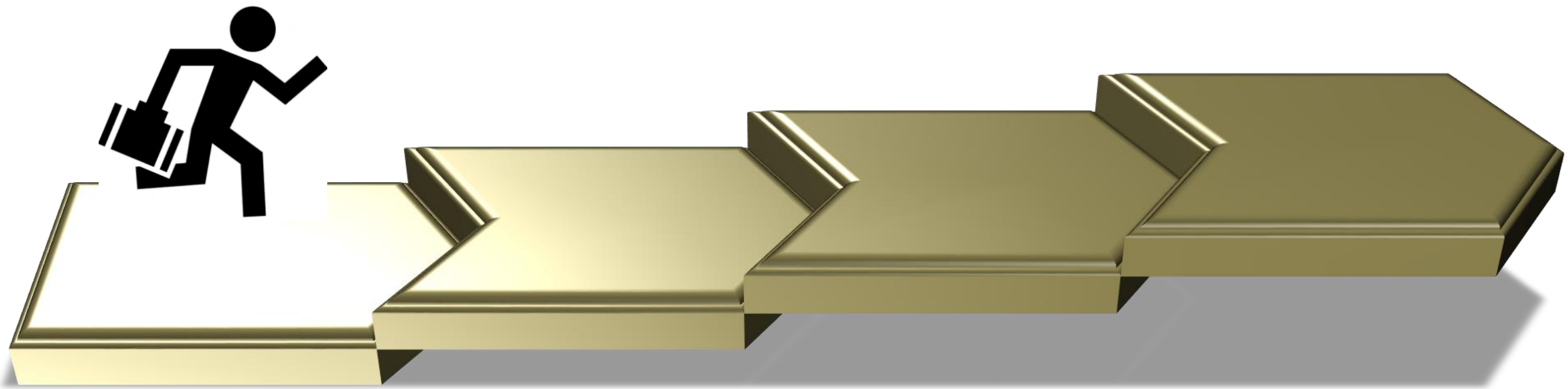
Factors Influencing an IRRP Analysis



Integrated Resource and Resilience Analysis

- Economy
- Environment / Climate Goals
- Political Motivations
- Consumer Willingness to Pay
- Regulatory Structure
- Technological Progress

Sample IRRP Analytical Phasing Structure



- Determine Input Data
  - Supply resources
  - Demand levels
  - Demand resources
  - Fuels
  - Transmission
  - Capital limits
  - Environmental limits
- Design Decision Criteria

- Optimize Resource Mix
  - Economic criteria
- Consider alternate resource portfolios

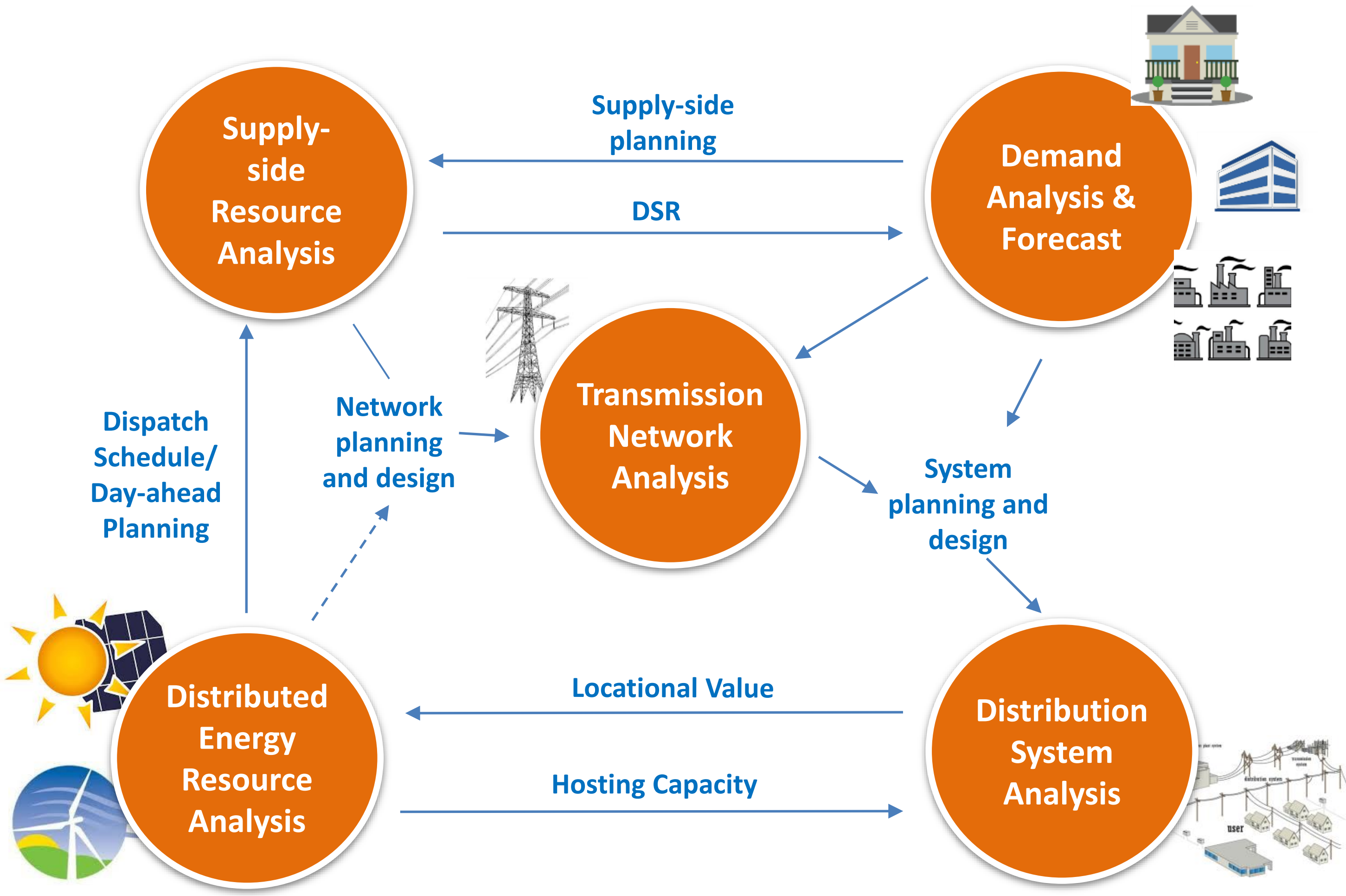
- Consider Risks through Scenario Review
  - Fuel
  - Load Unit Performance
  - Transmission
  - Environmental
  - Build Exuberance
  - Demand Response
  - Climate

- Evaluate Options based on Criteria
  - Best Portfolio(s) selected on the basis of commercial reality, balance of objectives, and perspective of risk

Possible Objectives and Metrics to Use for Portfolio Evaluation

Objective	Metric
Minimize cost	Levelized NPV ($/MWh) or $/MWh of generation portfolio costs; total Revenue Requirements ($)
Rate stability / Ratepayer risk	Annual volatility of $/MWh associated with portfolio options across scenarios
Resource Adequacy	Level of reserves maintained (%); Frequency (# of events) and level (MWh) of loss of load events associated with portfolios across scenarios
Environmental Stewardship	Tonnage emissions for criteria pollutants; Cost of meeting air quality objectives; External health impact (indirect costs)
Diversity	% concentration on one type of asset or fuel, % of concentration on one generating unit
Land Use	Acres of land required

Interrelationships of Components in the IRRP Process



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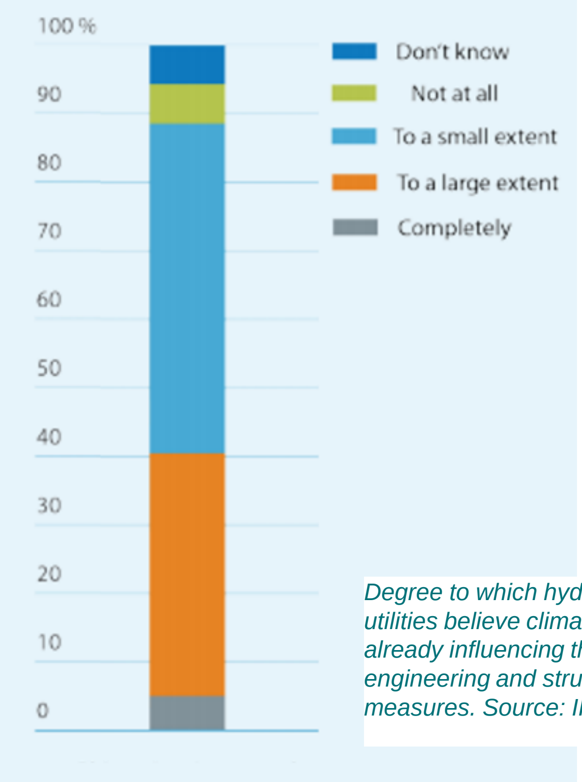
How can IRRP Manage Climate Risk?

Presenters: Molly Hellmuth

Climate Resilient Power Planning

Rationale

- Reliable and cost-efficient energy services are critical;
- Emphasis on renewable energy and investment in infrastructure;
- Climate change is beginning to have significant impacts;
- Due diligence, e.g., USAID ADS 201:
  - ***requires climate risk screening and management in new strategies and plans, including power sector investments***



Degree to which hydropower utilities believe climate change is already influencing their engineering and structural design measures. Source: IHA, 2015.

Climate Resilient Power Planning

Building power planners capacity and understanding of:

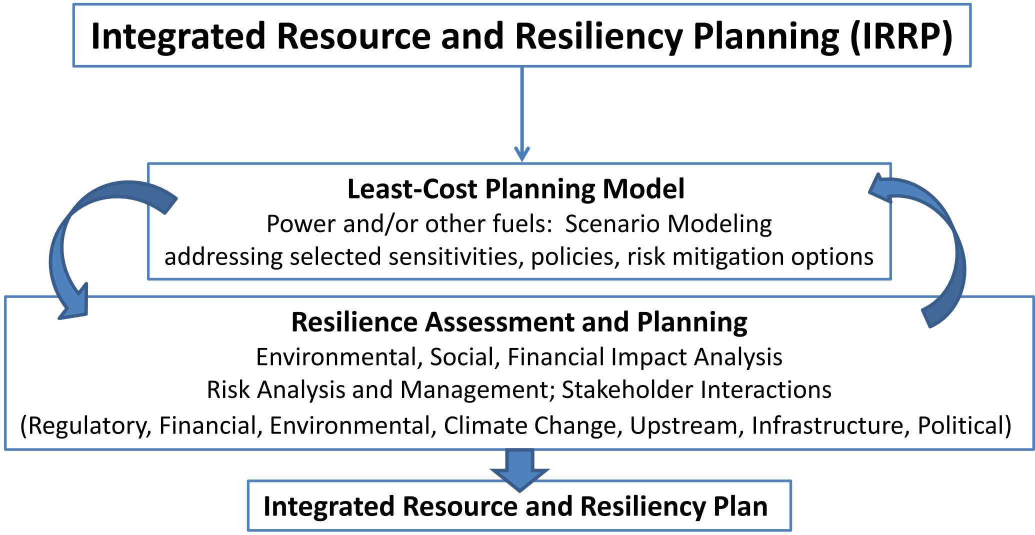
- The types of climate risks and potential impacts to power system resilience
- The types of climate risk management options
- The implications for power systems planning (IRRP)

Direct Climate Change Impacts

- Operational and Financial:
  - Resource availability: e.g., changes in quantity or distribution of flow into hydropower reservoirs
  - Efficiency: e.g., increased temperatures reduce transmission and distribution efficiency
  - Structural damage: e.g., exposure of infrastructure to flooding
  - Resource demand: e.g., increased energy for cooling

Indirect Impacts of Climate Change

- **Strategic and Planning Risks:**
  - Risk management in the investment behavior of energy institutions
  - Energy technology R&D investments
  - Energy resource and technology choices
  - Energy Prices



- **Financial:**
  - Adaptation costs (e.g., raising vulnerable assets to higher levels, building future energy projects further inland)

Integration of Risks and Resilience into IRRP

- Step 1: Risk and Resiliency Assessment:
  - Sub-national
  - Climate change
  - Potential impacts by power system component
  - Potential adaptation measures by component
  - Recommended climate scenarios

Integration of Risks and Resilience into IRRP

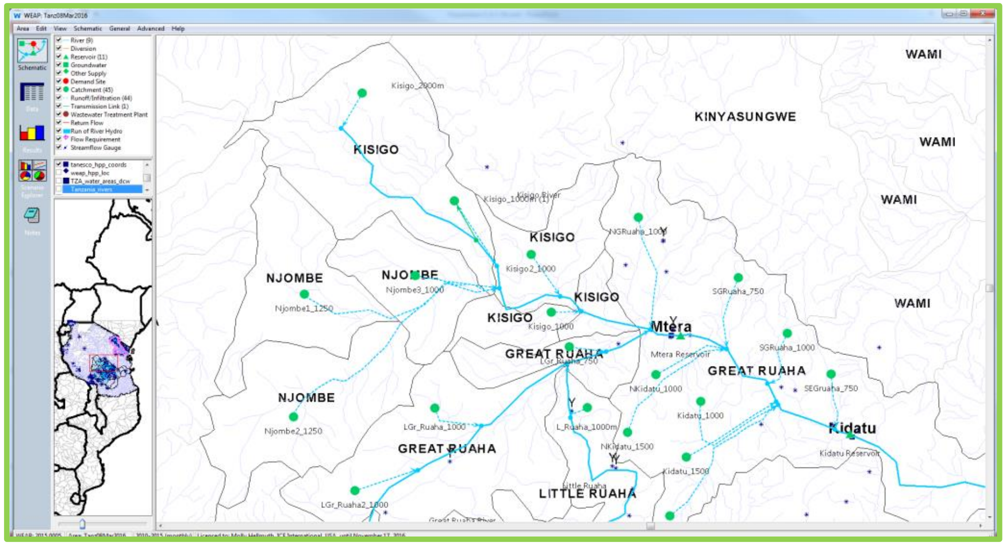
- Step 2: Participatory Risk and Resiliency Workshop:
  - Present the results of the risk and resiliency analysis
  - Identify priority risks and risk management responses
  - Develop climate scenarios

Climate Stressor	Hydro	Thermal	Renewables
Drought	High	Med	High* / Low
Temperature	Med	Med	Med**
Extreme Rainfall & Flooding	High	High	High
Sea Level Rise	Low	Med	Med
Rainfall, flow variability & timing	High	Med	Low
Erosion and Sedimentation	High	Low	Med

*Biomass is highly sensitive to drought, while solar and wind have lower sensitivity
**Biomass has a higher level of sensitivity to temperature than solar and wind

Integration of Risks and Resilience into IRRP

- Step 3: Power System Performance Evaluation:
  - Evaluate hydropower performance in WEAP
  - Evaluate power system performance (given different investment choices) in IPM
  - Given different climate scenarios



Integration of Risks and Resilience into IRRP

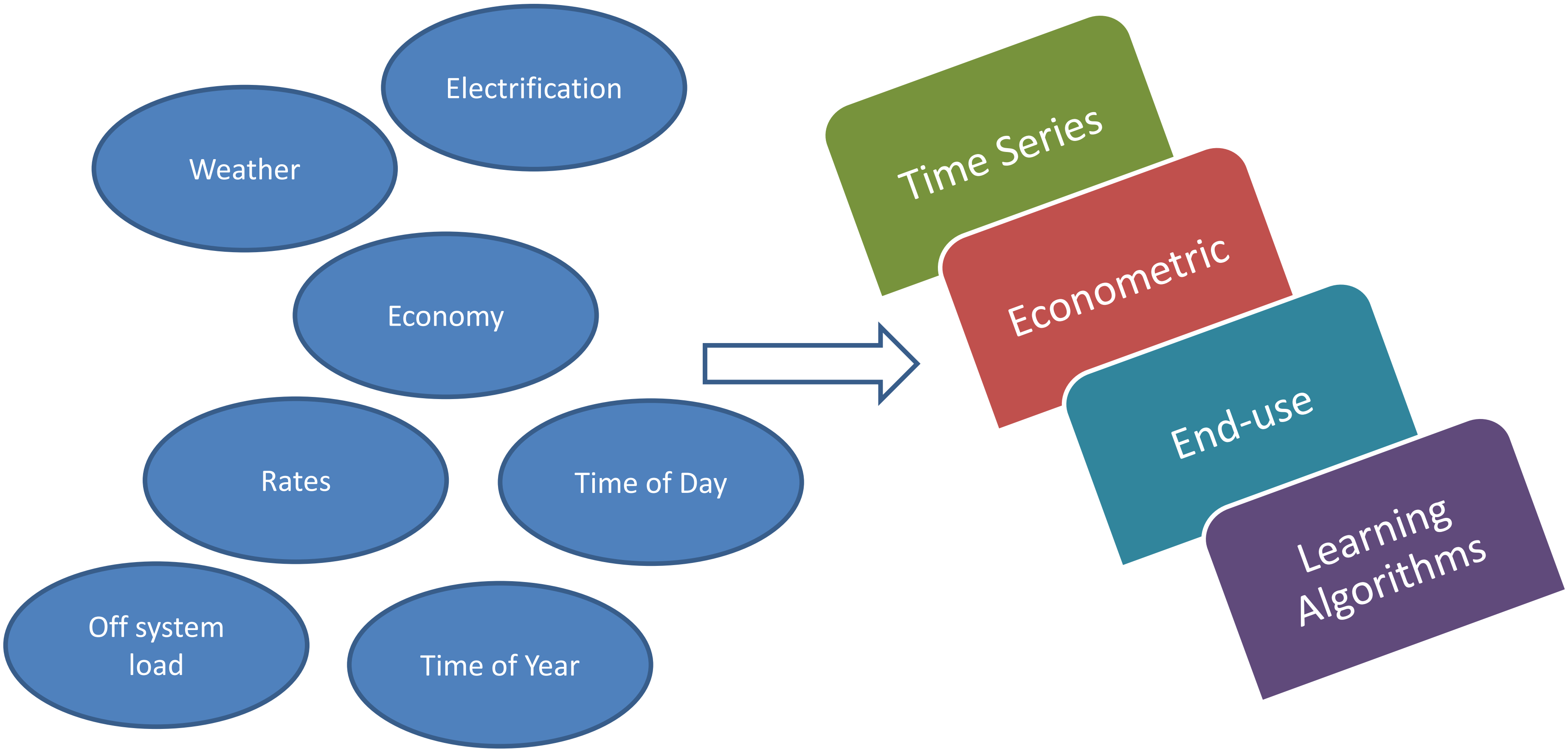
- Step 4: Integrate Results into Power System Master Plan:
  - Incorporation of risks and resilience measures based on participatory review of quantitative, qualitative assessments

Justification	Type	Adaptation Strategy	Already Pursuing?
No-regrets	Policy and Planning	Establish public education programs to promote lifestyles that are less energy-dependent	N
		Explore energy market mechanisms to meet demand. Consider power exchange agreements, purchasing from the spot market, and options purchasing.	Y
		Establish or expand demand-response programs which encourage consumers to voluntarily reduce power consumption during peak demand events	Y
		Time of Use Tariffs to encourage consumers to reduce power consumption during peak hours	Y
		Improve and enforce energy efficient building codes	Y
		Adopt mandatory minimum energy performance standards for buildings and appliances	Y
	Policy and Planning, Structural	Install smart meters and grids to reduce power consumption during peak demand events	Y
	Structural	Employ passive building design strategies to maintain minimum comfort or lighting levels even in situations where energy system losses occur	N

How is Demand Growth Projected?

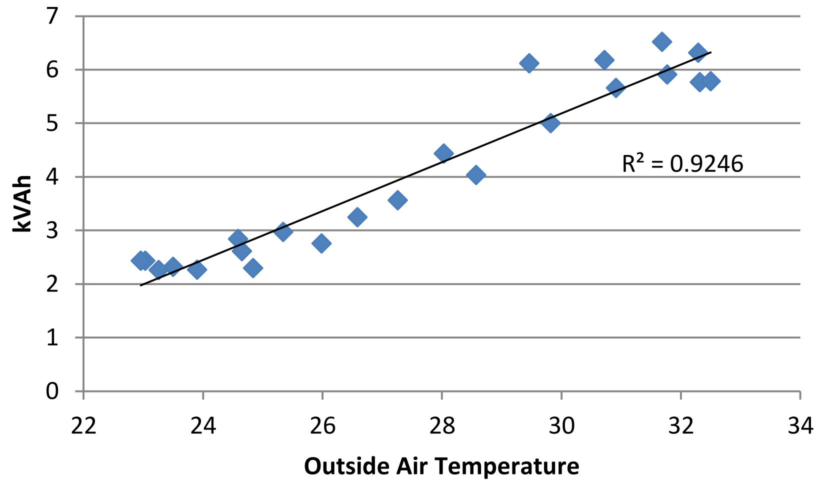
Presenter: Maria Scheller

Demand Analysis and Forecast Approach



Risk and Resiliency: Load Forecasting

- Temperature Increase
  - Net demand for electricity will increase (cooling driven)
  - Higher peak demands can be particularly challenging
- Extreme Events
  - Extremes increase the peak demand to cool and heat buildings.
- Adaptation Measures:
  - Developing demand-side/conservation management – Time of Use Tariff
  - Green buildings, energy efficient measures
  - Smart meters, grids



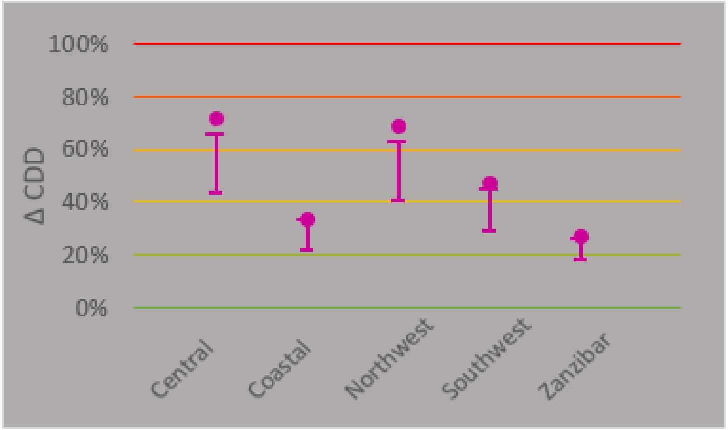


FIGURE 29. PROJECTED CHANGE IN CDD (USING AN 18°C THRESHOLD) BY 2045-2065. NOTE:

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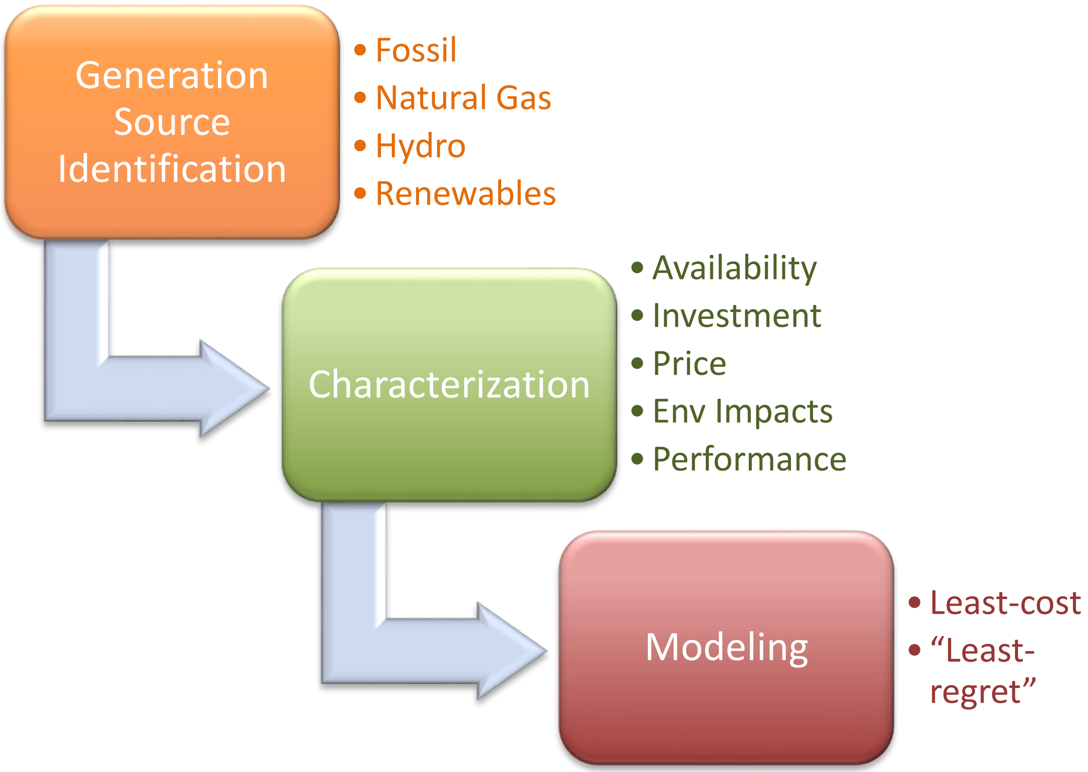
How are Supply Side Resources Considered?

Presenter: Maria Scheller

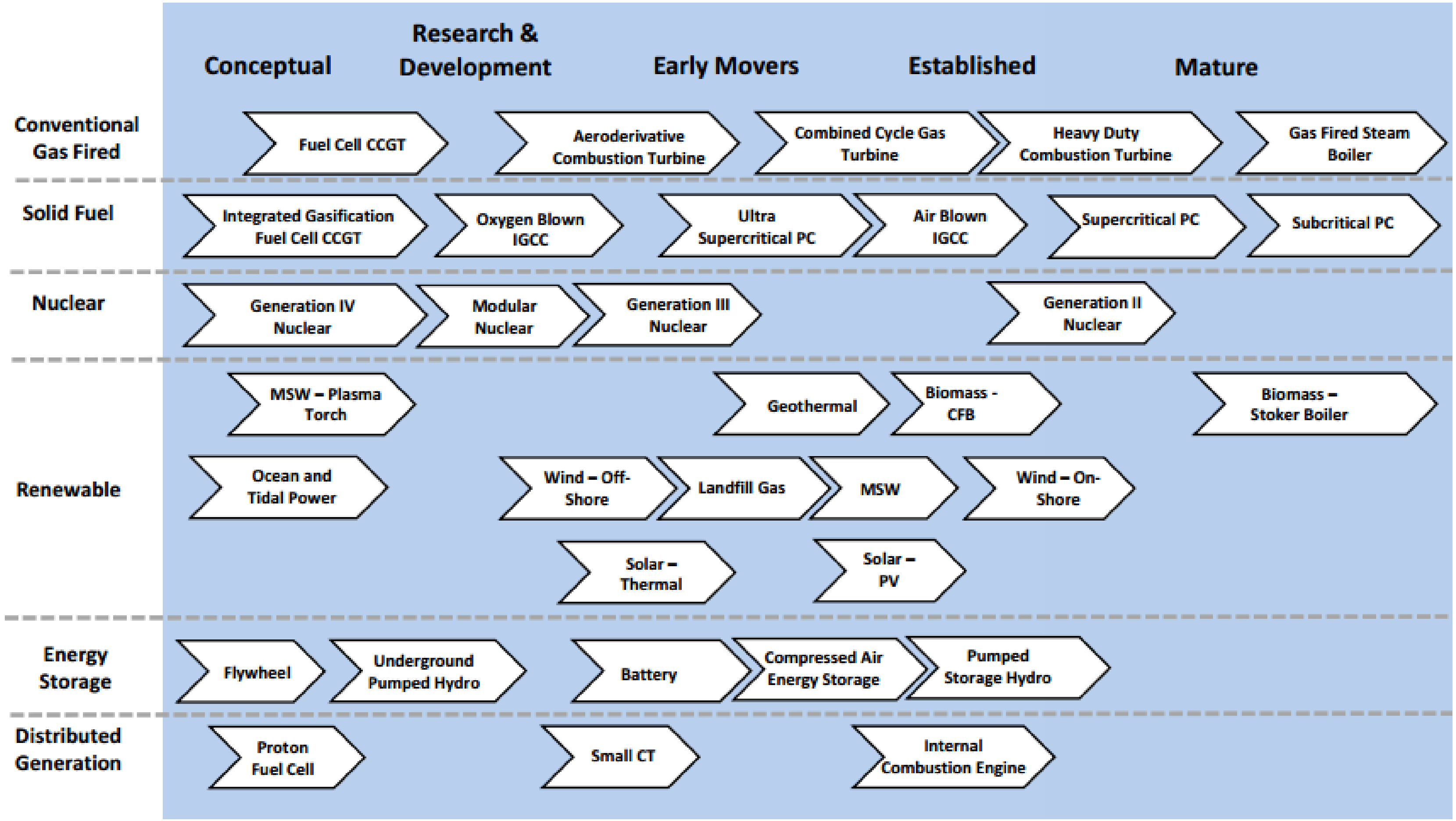
Supply-Side Resource Analysis

- Central Generation
  - Natural gas
  - Hydro
  - Fossil
  - Renewables
  - Other
- Analysis Components
  - Available capacity
  - Fuel price
  - Performance expectations
  - Capital and operating costs
  - Environmental impacts



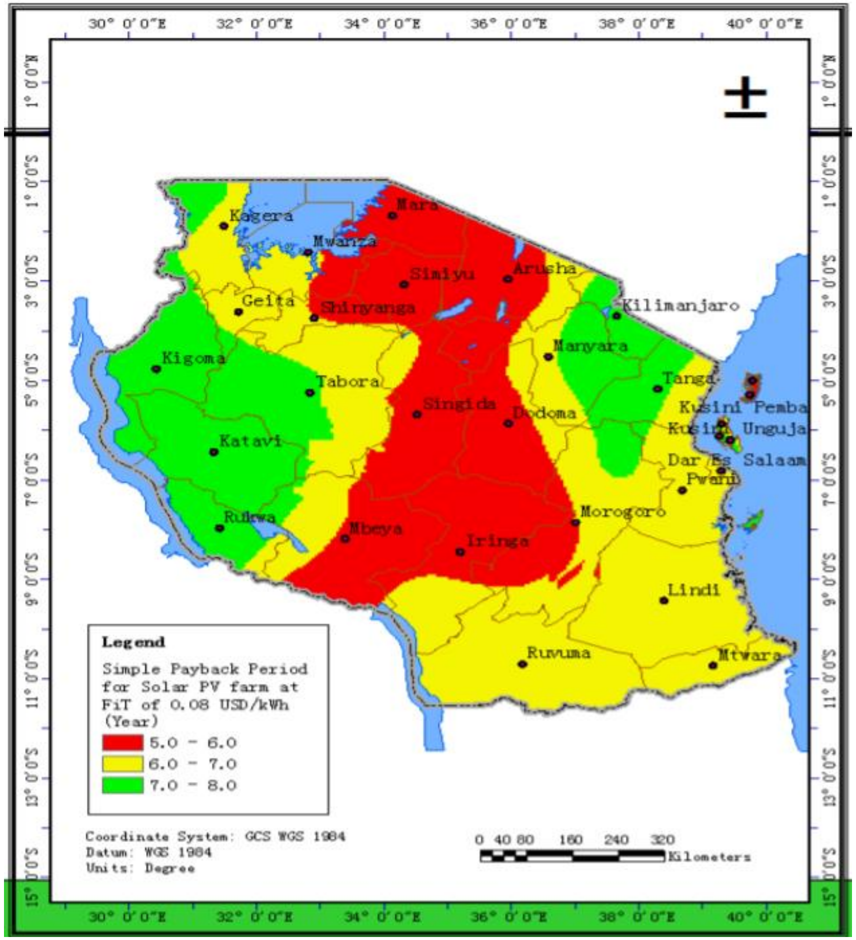
To what extent should repair and refurbishment costs of current sources be analyzed?

Generation Technology Assessment and Inventory



Source: Generation Technology Assessment, Cost & Performance, Entergy, May 5, 2014.

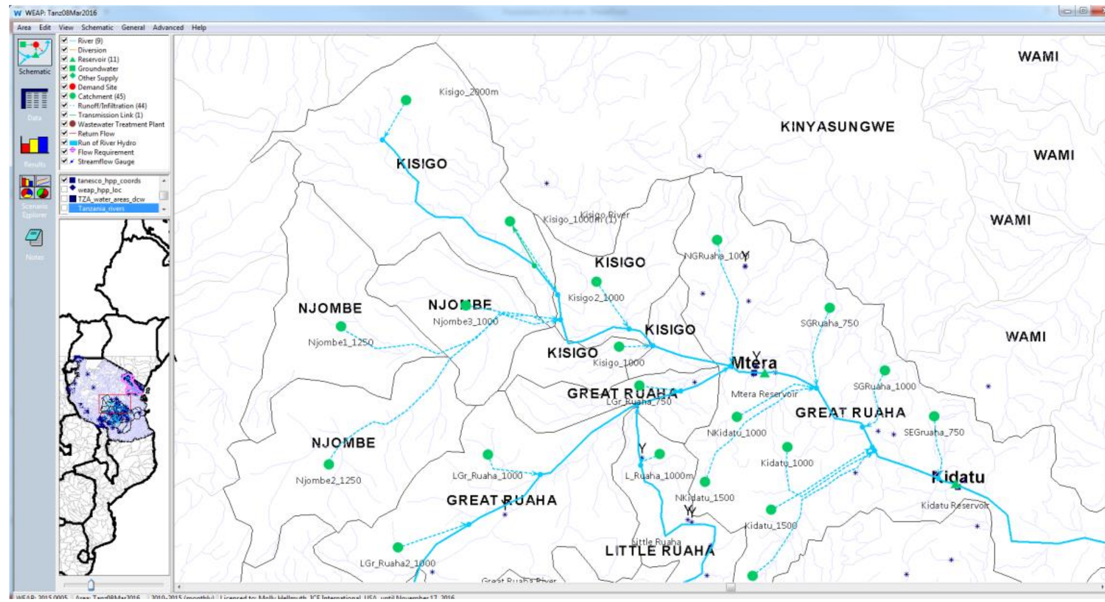
Renewable Resource Potential is High?



- Raw potential for renewable resources is a strength in many developing countries
- However, limited information on the total potential for resources, the impact of those resources to land and other competing uses, or the interconnection capability tends to be available.

Risk and Resiliency: Generation

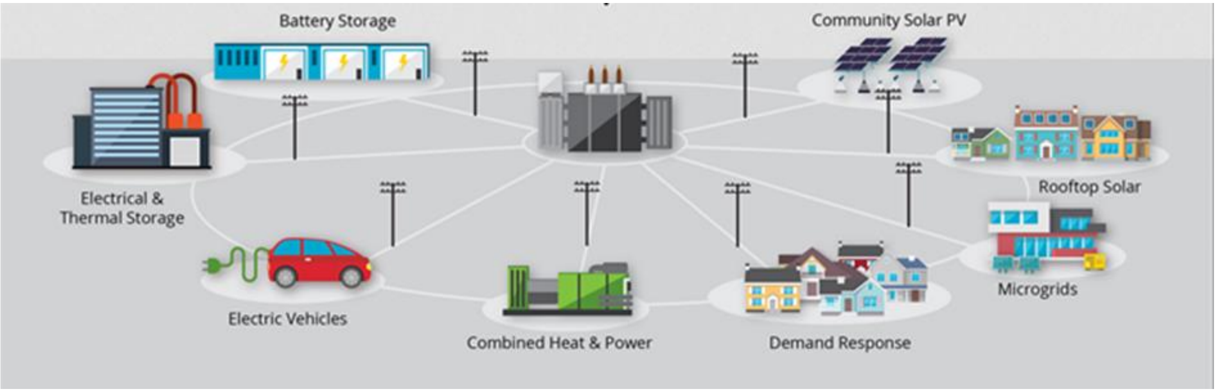
- Changing flow
  - Changed hydropower generation
- Extreme Events
  - Direct flood damage
  - Increase/decrease hydropower generation
  - Increase competing water demands
- Adaptation Measures:
  - Hardening, building redundancy into facilities, relocating vulnerable facilities
  - Reducing water consumption, increasing water supply, adding peak generation, power storage capacity



How are Distributed Energy Resources Considered?

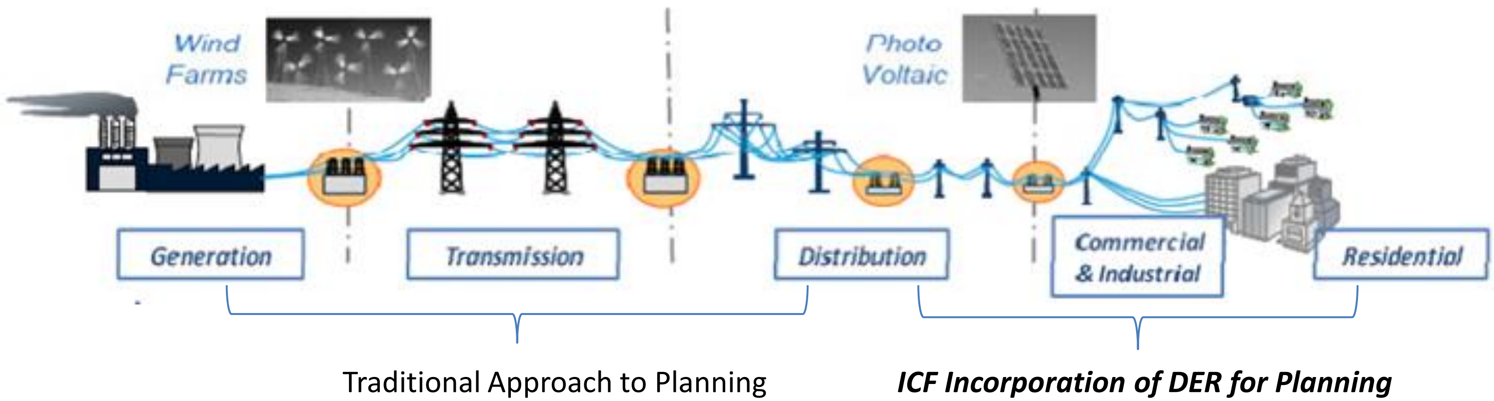
Presenter: Sanjay Chandra

What are Distributed Energy Resources (DER)?



- Distributed energy resources (DER) are smaller power sources that can be aggregated to provide power necessary to meet regular demand.
- Planning is now more complex as increases in DER deployments are occurring on the system whether through organic adoption or policy driven.
- Lack of information on the type of DER, amount, and speed of deployment creates a challenge to the traditional long term planning process
- Analysis not just focused on planning, but on the impacts as well
  - Impact intermittent generation from technologies such as solar, small wind
  - Loading on a feeder, potential of two-way power flows for safety and reliability

DER is Changing Today's Planning Processes



- Traditional Grid Planning typically focuses on generation, transmission, and distribution segments, ignoring activities at the "edge of the grid"
- Today, rapidly increasing deployments of "DER" technologies such as solar, storage, advanced communications and controls are causing planners to re-think this approach
  - DER is now beginning to be viewed as a grid asset and part of planning processes
- **DER planning can help developing countries leapfrog the traditional distribution and IRP planning processes and move to the next level**

Why is Change Occurring?

Convergence of a Number of Factors!

- Drivers such as emissions, environmental, and siting concerns are making traditional solutions more difficult to implement and increasing the deployment timeline as well
- Decreasing cost of advanced technologies are making distributed resources more accessible to commercial and residential customers
  - Solar PV, Energy Efficiency, CHP
- Coupling DER with advanced controls, communications, and additional technologies can “firm” and “control” technologies – transforming them into reliable, grid assets
  - Solar PV + storage
  - “Targeted” Energy Efficiency and Demand Response
  - Microgrids
- **Incorporation of DER enhances planning solutions and complements traditional approaches**
  - ICF incorporates its DER capabilities into our IRRP approach, maximizing options with Energy Ministries and Utilities
  - Integrated approach accelerates solution deployment by utilizing all potential grid assets

How do we Approach DER Analysis?

Scenario based distribution planning

- Uncertainty of the types, amount and pace of DER make singular forecasts ineffective. Inputs from ICF's DEEP tools provide an accurate, data-based range of geo-specific forecasts of DER penetration.

Hosting capacity

- ICF works with utility feeder data to determine the amount of DER a feeder can accommodate within three principal constraints: thermal, voltage/power quality and relay protection limits.

Locational value of DER

- Sourcing locational infrastructure or operational requirements from DER may result in positive or negative costs and benefits. ICF has developed frameworks with utility clients to capture and optimize them.

Probabilistic-based engineering analysis

- Issues from increased DER penetration – variability of loading, voltage —require probabilistic analysis. ICF models these probabilities.

Integrated T&D planning

- At high DER, net load characteristics have impacts on transmission system / bulk power system operation, requiring transmission-distribution interaction analysis. ICF is helping to write the book on these issues in California.

How do we Approach DER Analysis?

- Deploying DER in a widespread, efficient and cost-effective manner requires complex integration with the existing electricity grid
- ICF models and analysis drive the new distribution planning framework
  - Basic building blocks of a "distribution" planning framework
  - Individual Blocks can be initiated to simply understand the potential of DER on a electricity system

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DER Analysis Should be Integrated in Planning Decisions

- Approach leverages the current trends of the movement and migration of generation assets to the edge of the grid
- Incorporates the DER assets as tools for grid operations, leading to advantages of:
  - Leveraging deployments that may already be occurring by commercial and residential customers
  - Potentially avoiding large capital cost of deploying a centralized solution, shifting to a more local solution for specific area
  - Potentially avoiding environmental hurdles increasingly seen in traditional approaches
  - Adding additional options to consider in addressing IRRP needs; IRRP assessed the ability to solve locational problems quickly with DER versus potentially longer term ability to better manage load growth centrally

How is the Transmission System Analyzed?

Presenter: Ken Collison

Transmission Network Analysis

Power System Reliability & Planning

Resource Adequacy

Maintaining sufficient capacity to meet customer needs in spite of scheduled and unscheduled outages

Transmission Security

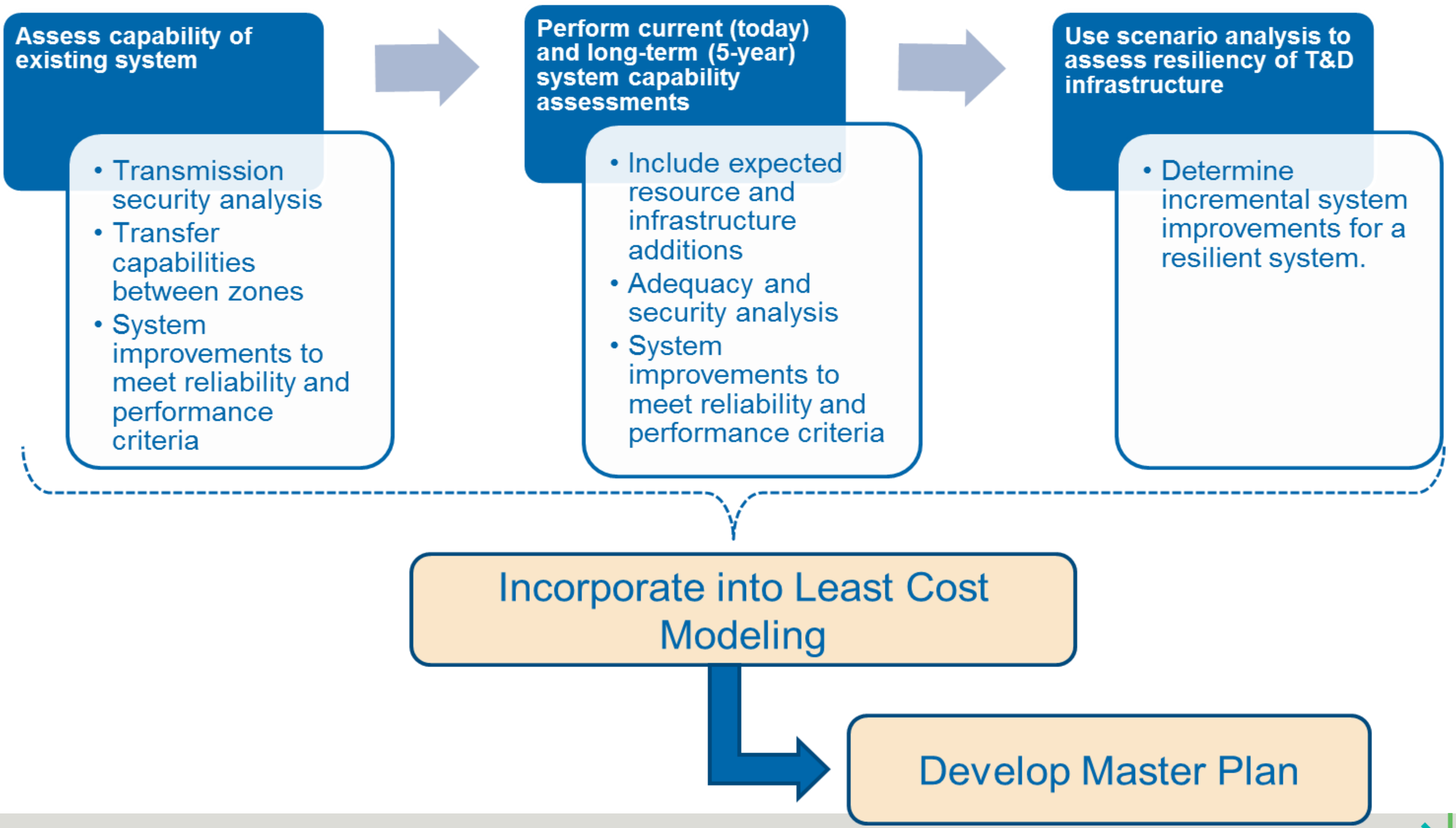
The ability to continue operating reliably following sudden and unexpected contingencies

Transmission Adequacy

Having sufficient transmission capacity to move power across key interfaces and corridors in the system

Primary focus of Transmission Assessment

Transmission Network Analysis

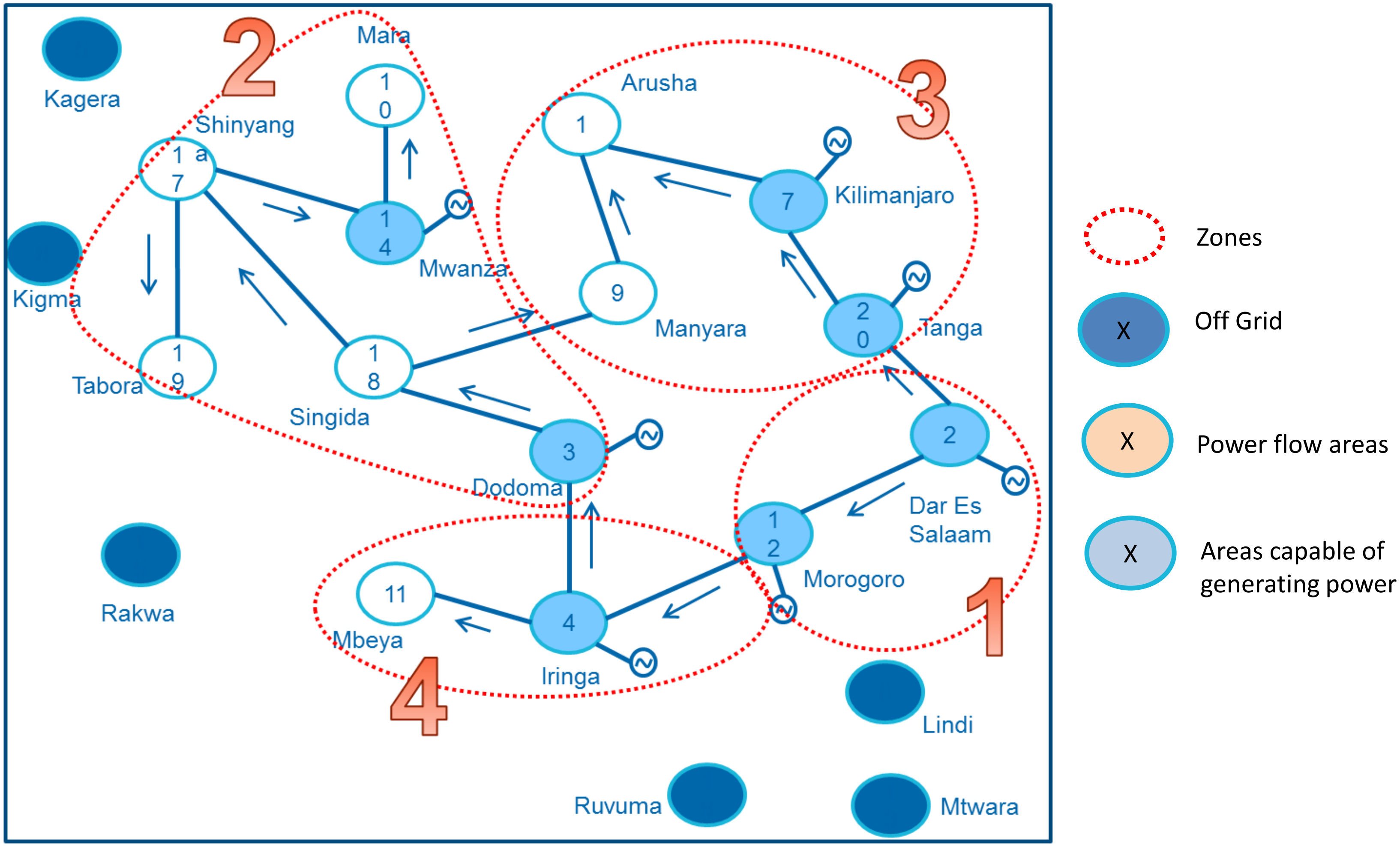


Transfer Capability Analysis

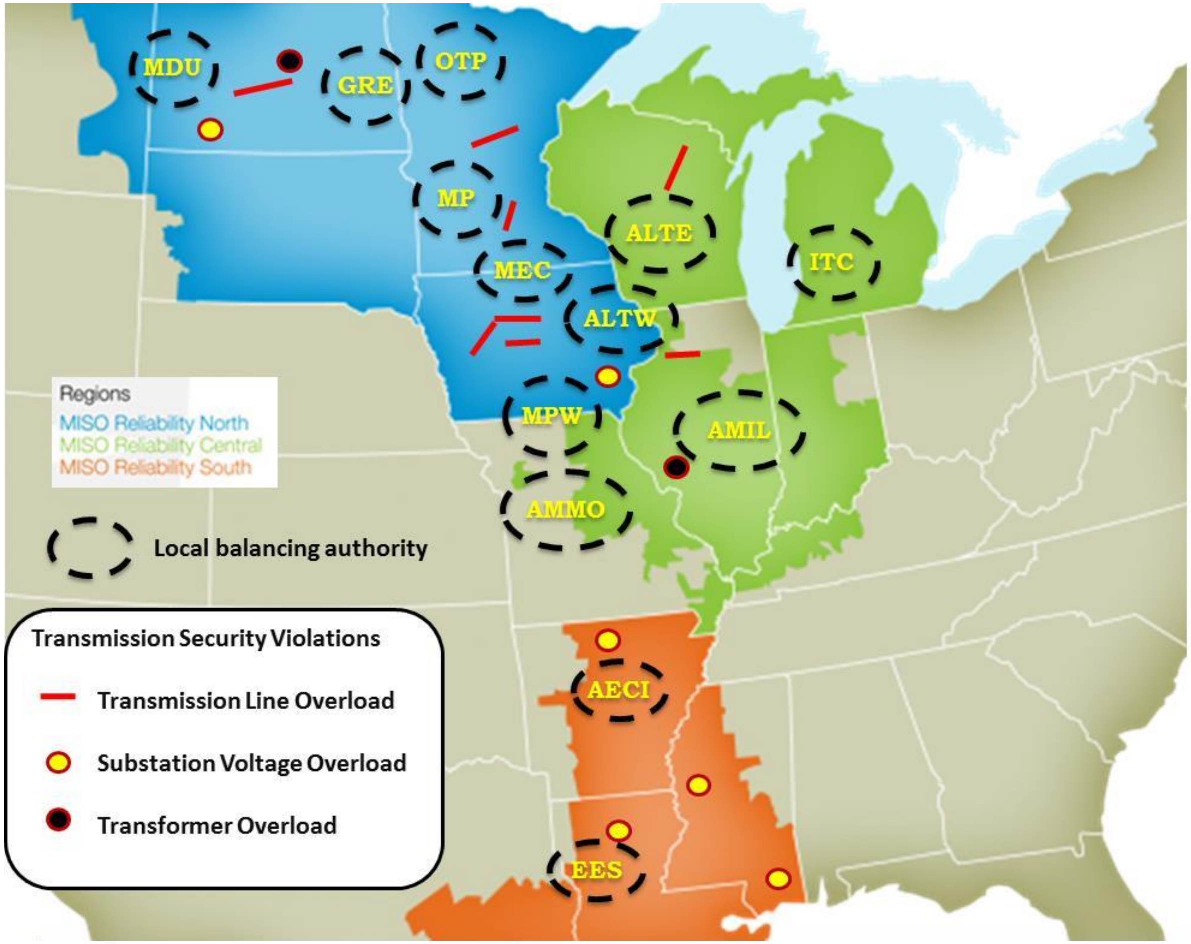
Having sufficient transmission capacity to move power across key interfaces and corridors

1. Establish the zones based on geography, generation resources, and load demand
2. Establish the interface as defined by the combination of lines connecting two zones
3. Determine transfer capability by adjusting generation and load between the zones
4. Repeat this for all identified combination of zones

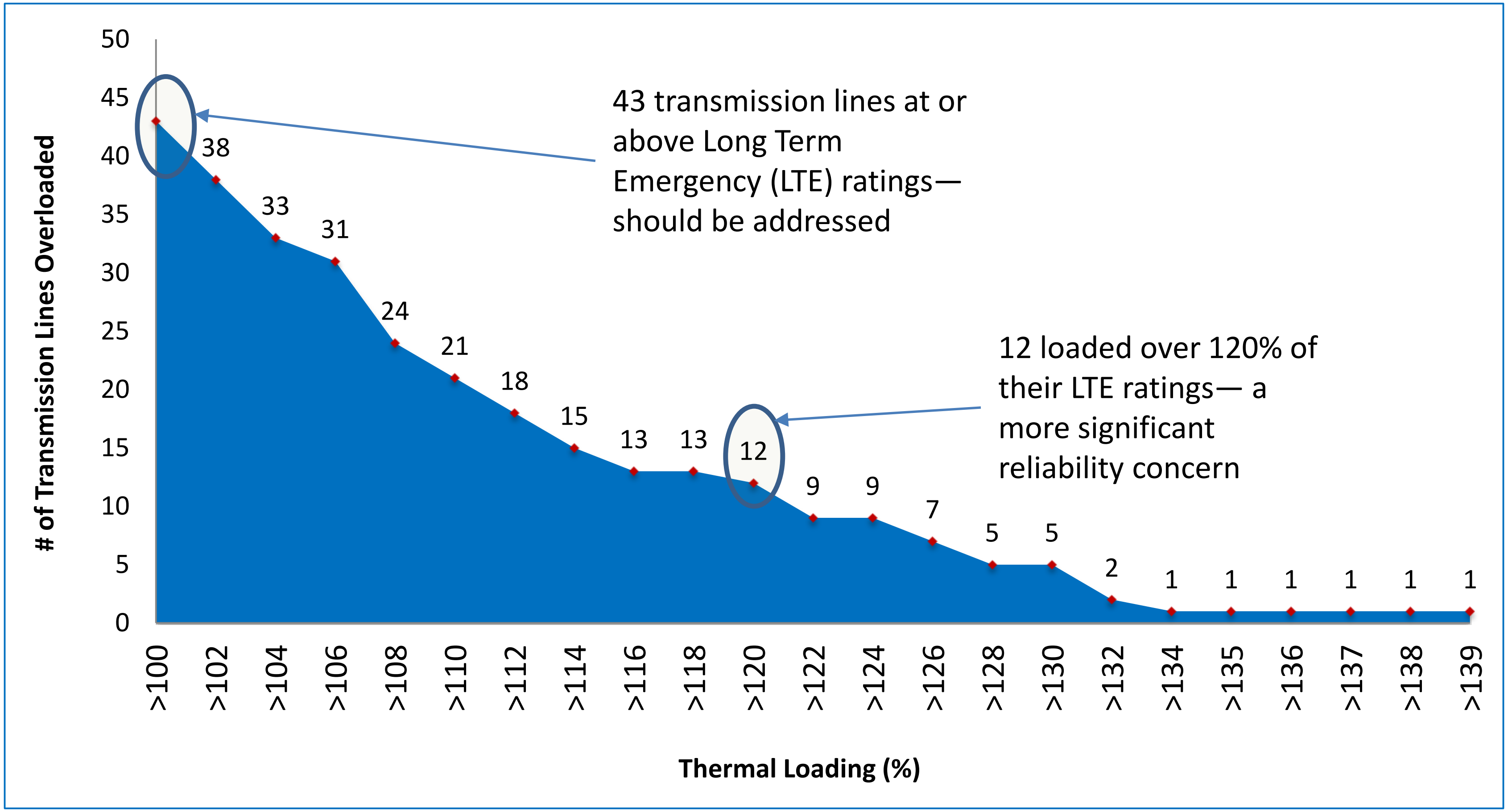
Case Study: Transfer Capability Assessment for Tanzania Grid



Transmission Security Violations and Affected Equipment



Transmission Security Violations – Summary



Case Study: Transformer Overloads in Tanzania:
Dar es Salaam, Tanga, Kiliminjaro and Morogorro

Top Thermal Violations - Base Case					
From Bus Name	**From Nom kV**	**To Bus Name**	**To Nom kV**	**Area**	**pu Loading**
UBU132MB	132	JACOBSEN	11	Dar es Salaam	0.93
OYS132MB	132	OYS 33	33	Dar es Salaam	0.94
OYS132MB	132	OYS 33	33	Dar es Salaam	0.94
KIY132MB	132	KIY033B1	33	Kilimanjaro	0.94
KIY066MB	66	KIY033B1	33	Kilimanjaro	0.93
KIY066MB	66	KIY033B1	33	Kilimanjaro	0.93
SAM132MB	132	SAM033MB	33	Kilimanjaro	0.93
HAL033B1	33	HAL011G1	11	Tanga	0.98
TAN132MB	132	TAN033B1	33	Tanga	1.07
TAN132MB	132	TAN033B1	33	Tanga	1.07
TAN132MB	132	TAN033B1	33	Tanga	1.06
KID011G3	11	KID220MB	220	Morogoro	1.41

Source: Mysani, C.M. (2013). USEA - Washington D.C (25th Feb- 3rd Mar)

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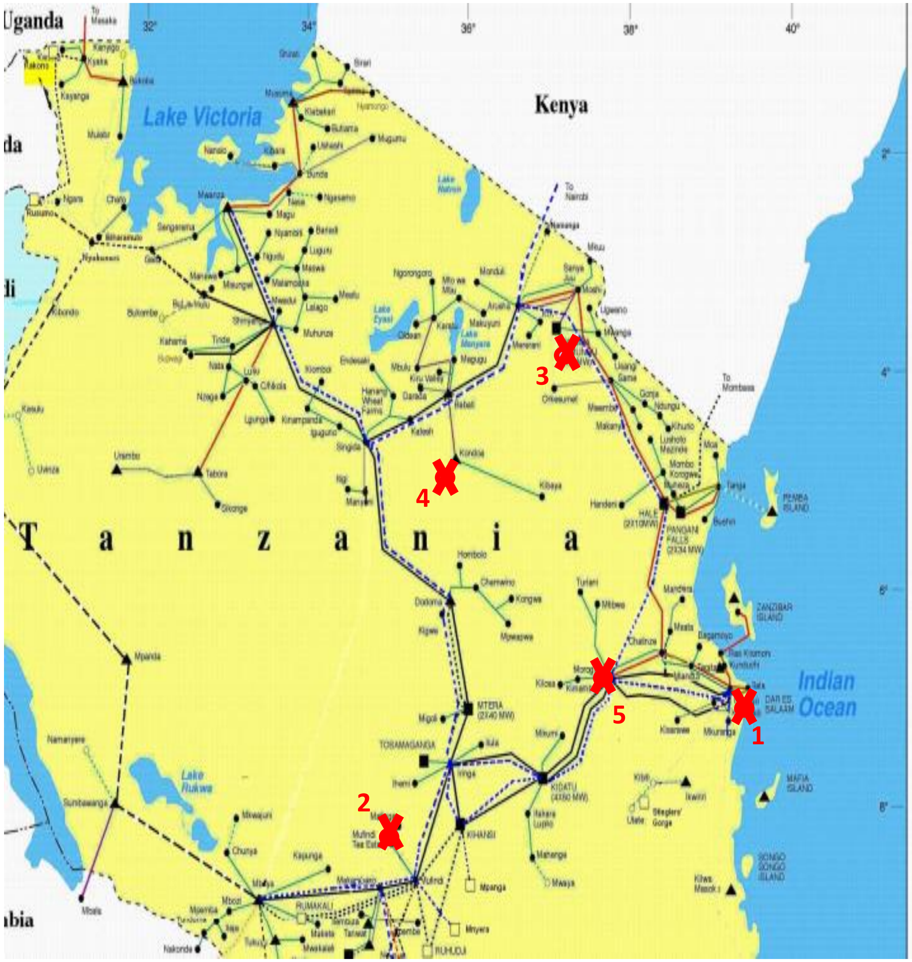
Case Study: Voltage Violations in Tanzania

- Base Case has a few voltage violations at 33 kV and below.
- These violations are also seen in the N-1 contingency analysis

Top Voltage Violations - Base Case			
Areas	**Nom kV**	**Per Unit**	**Substation**
Dar Es Salaam	11	0.89	Jacobsen
Iringa	11	0.87	Mufindi
Kilimanjaro	11	1.08	Nyumba
Manyara/Dodoma	33	1.08	Kondoa
Morogoro	33	0.94	Morogoro



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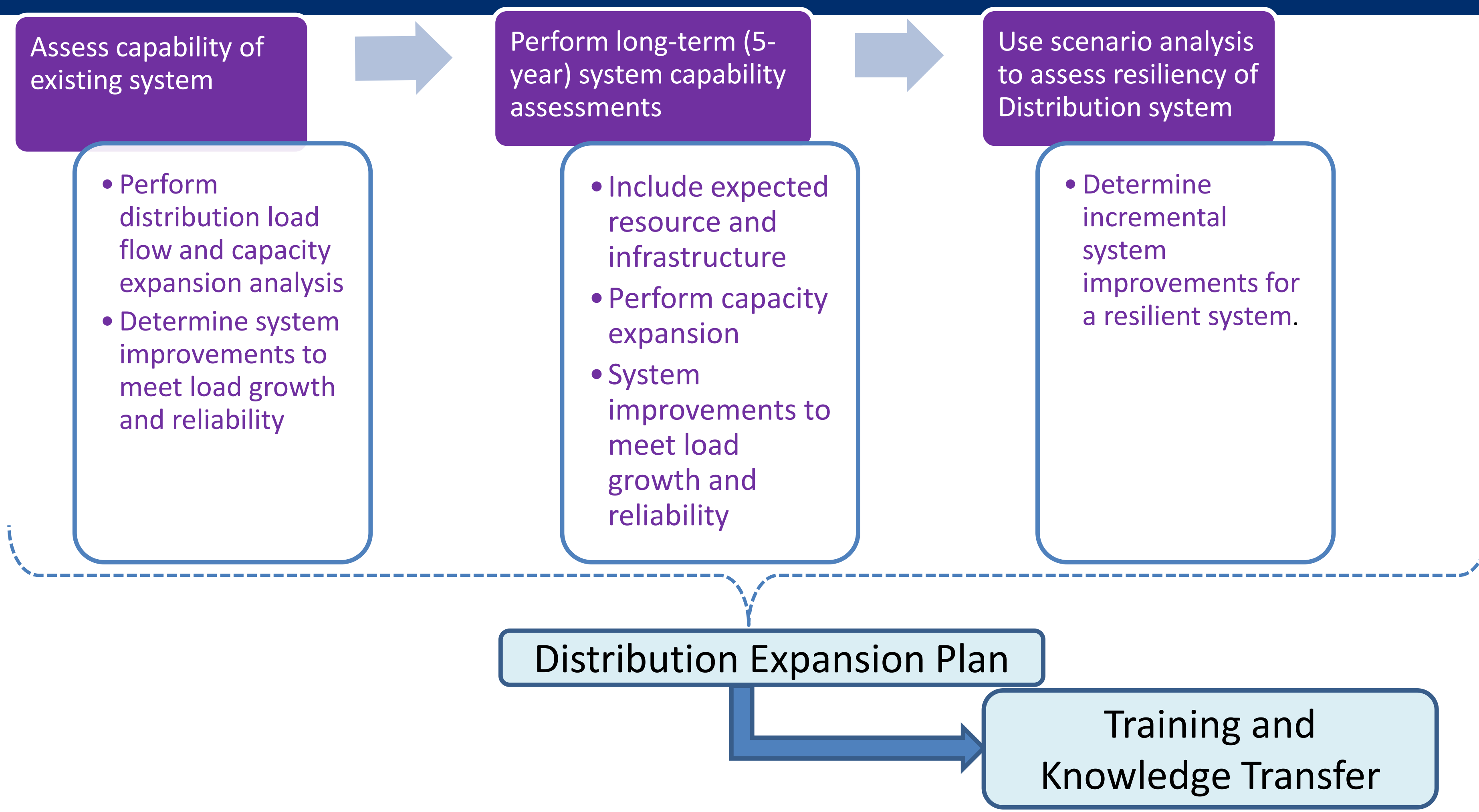
Risks and Resiliency: T&D

- Temperature Increase
  - Decreases the efficiency of electrical transmission
- Extreme Events
  - Line sag and power disruption
  - Structural damage
  - Tree-on-line damage
- Sea Level Rise & Storm Surge
  - Scouring of transmission tower bases
  - Corrosion of electrical components
- Adaptation Measures
  - Back-up power supply, intelligent controls, and distributed generation
  - Insulating equipment

How is the Distribution System Analyzed?

Presenter: Ken Collison

Distribution System Analysis



Case Study: Distribution System Analysis for Tanzania

Assess development plans of TANESCO and REA

Perform distribution expansion planning to accommodate load growth and grid connectivity

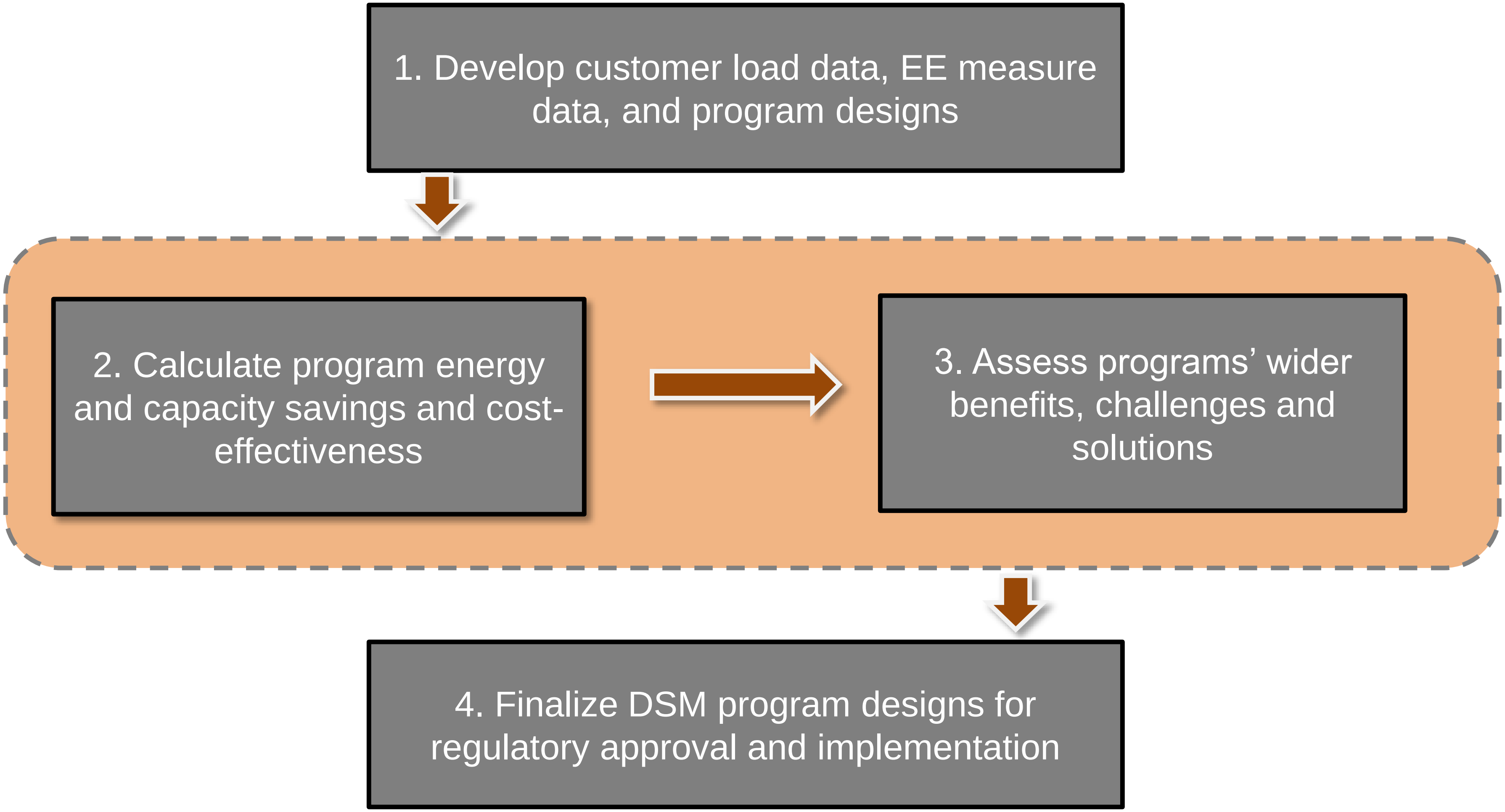
Assess the effect of loss reduction programs and advanced metering

Training on best practices and knowledge transfer

What are the Methods and Tools for DSM?

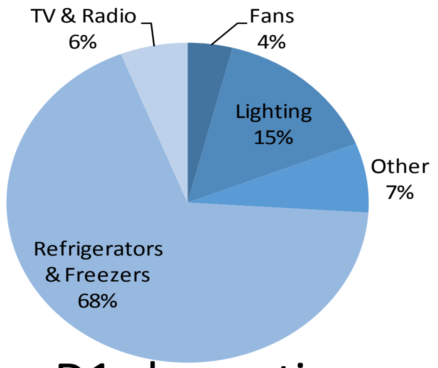
Presenter: Bill Prindle

DSM Methodology Overview

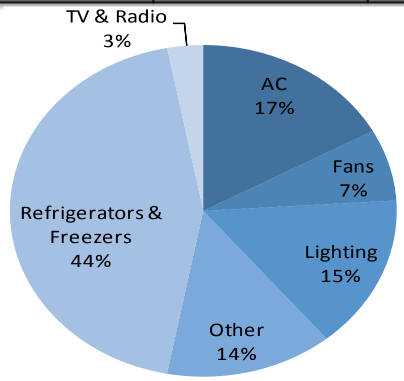


Step1: Develop load data by customer class

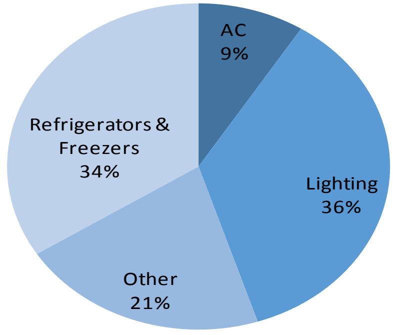
Tariff Class	Customers in Tariff Class	% Total Cust.	Total Sales (GWh)	% Sales	Average Annual Sales per Customer (kWh)
D1—Domestic Low Usage	613,618	47%	515	10%	839
T1—General Usage	699,287	53%	2,203	43%	3,150
T2—Low Voltage Supply	2,483	0.2%	634	12%	255,336
T3—High Voltage Supply	461	<0.1%	1,804	35%	3,913,232
Total	1,315,849		5,156		



D1-domestic

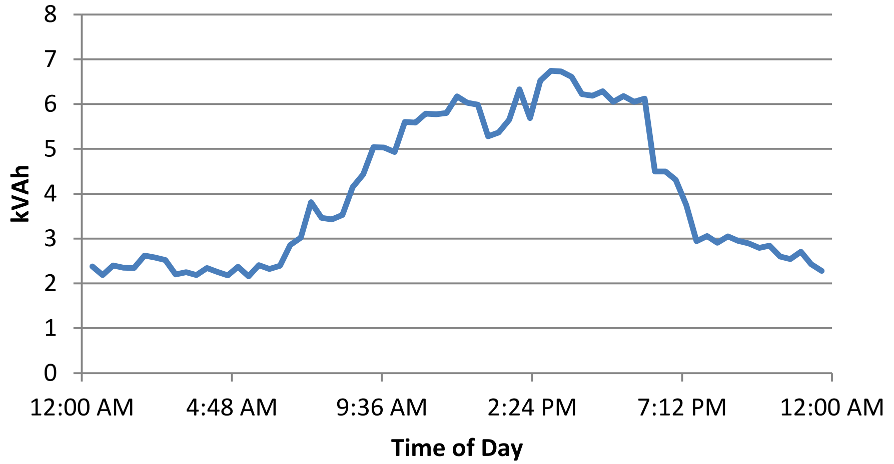


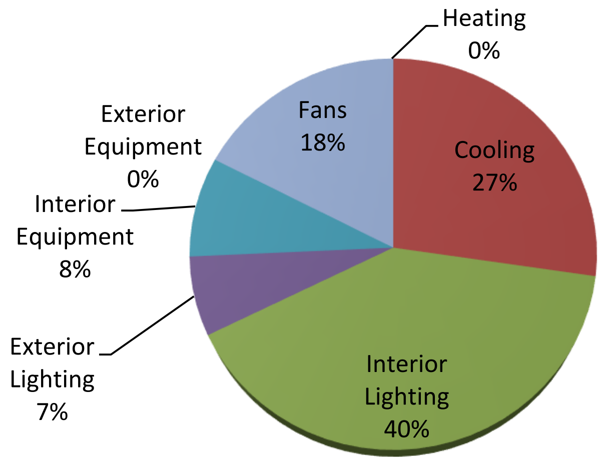
T1--Residential

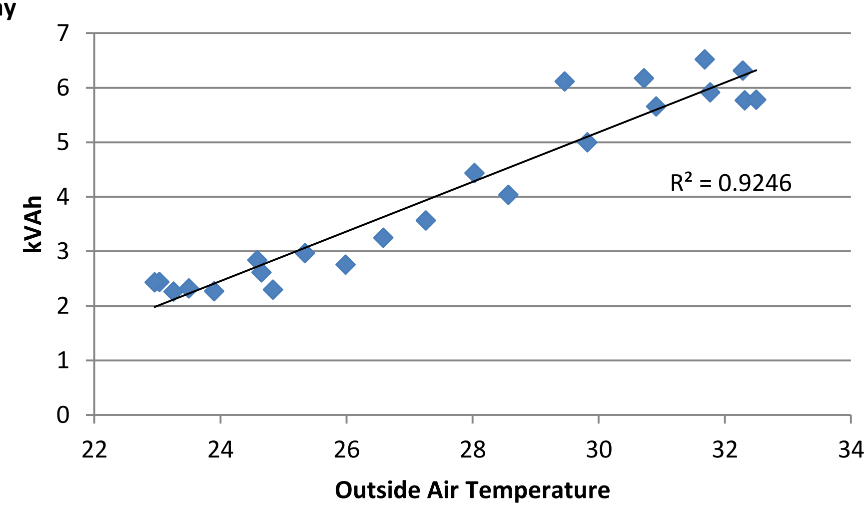


T1--Commercial

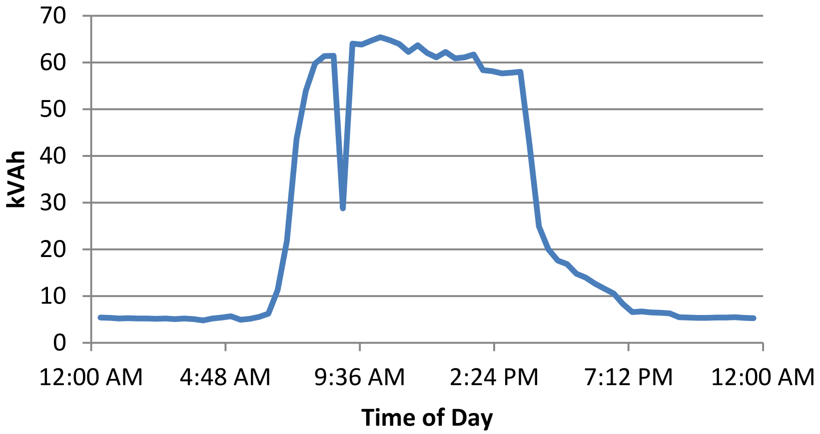
Step 1: Develop customer load profiles by type (Example: retail store)

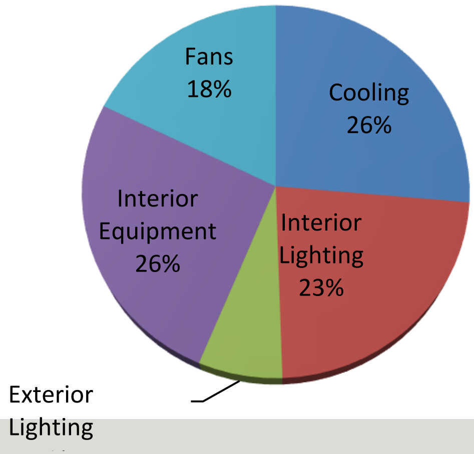


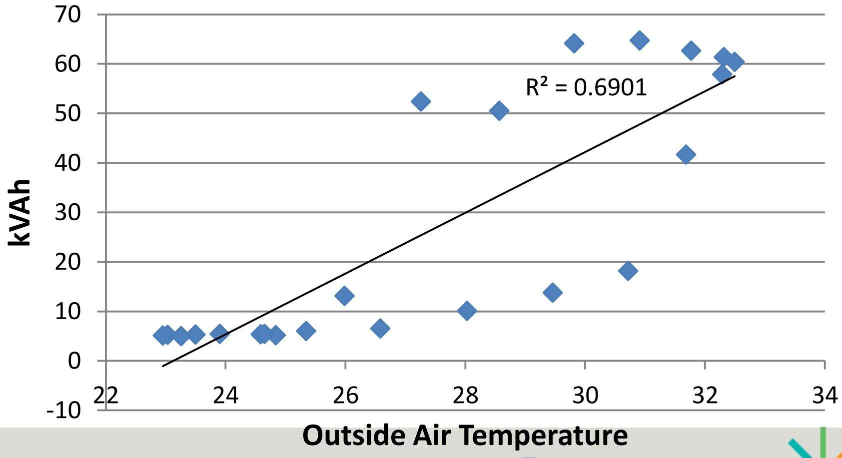




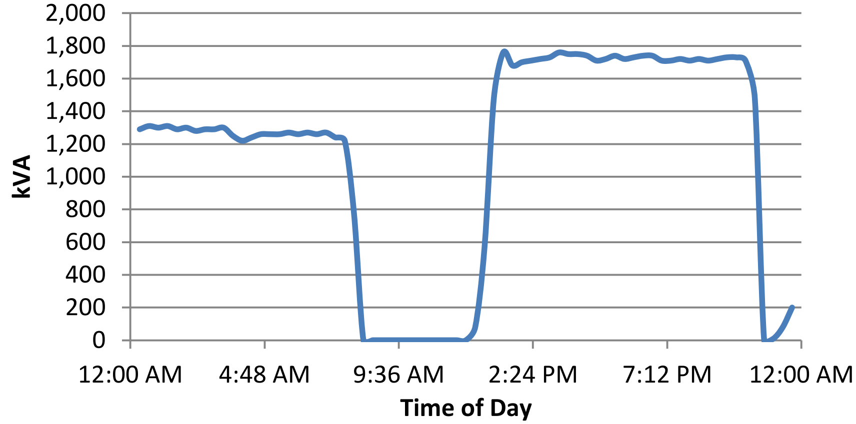
Customer Load Profile: Medium Office

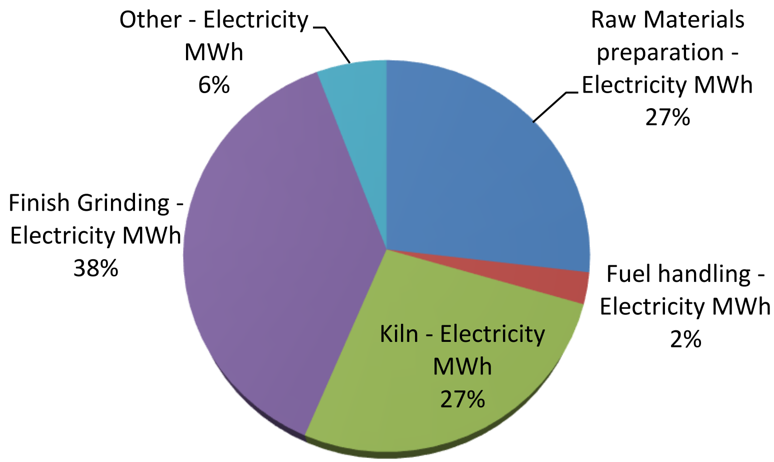


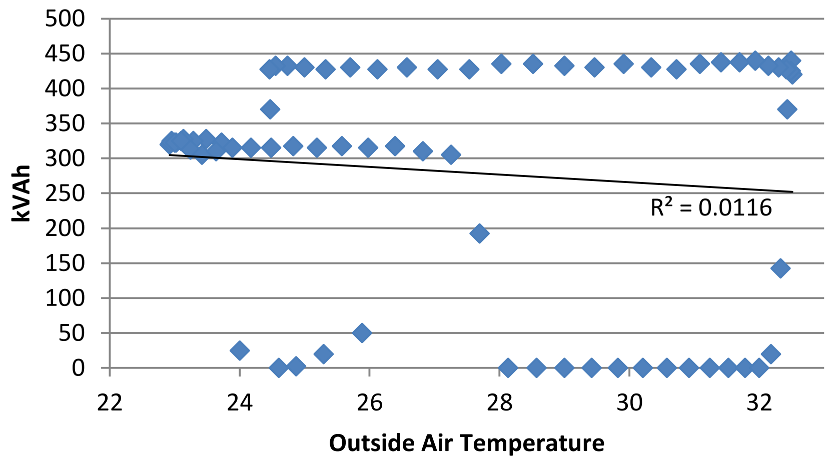




Customer Load Profile: Cement Plant







Develop DSM Measures

Residential

Tariff Class	End Use	Measure Type
D1	Lighting	CFL
	Refrigeration	Efficient Refrigerator
T1	Cooling	Efficient AC
	Envelope	Air Sealing
	Lighting	CFL
	Refrigeration	Efficient Refrigerator

Commercial

Measure Category	End Use	Measure Type
Energy Efficiency	Cooling	Efficient Split AC
	Envelope	Air Sealing
	Lighting	CFL
		LED Reflector Lamps
		Lighting Occupancy Sensor
		Linear LED Lamps
		T8/T5 Linear Florescent
	Refrigeration	Efficient Refrigerated Case Display
		Efficient Refrigerator
Demand Response	Cooling	AC Direct Load Control

Industrial

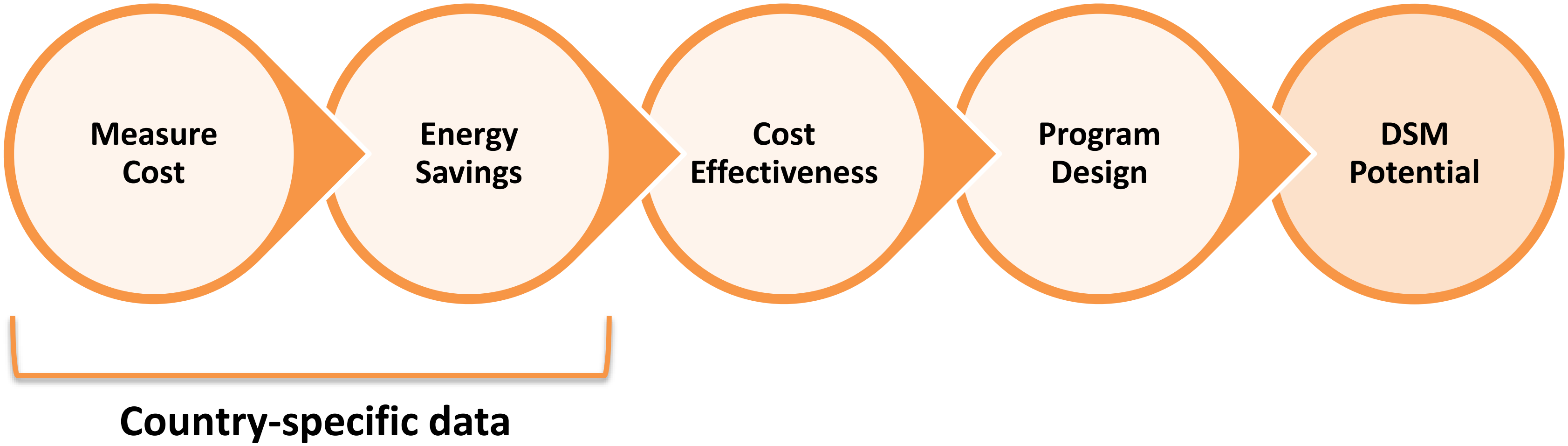
Measure Category	Measure Type
Energy Efficiency	Compressed Air Upgrades
	Custom Project
	Lighting Upgrades
	Motor Upgrades
	Process Cooling Upgrades
	Process Heating Upgrades
	Variable Speed Drives
Demand Response	Time-of-Use Rate

Step 1: Compile EE measures into programs

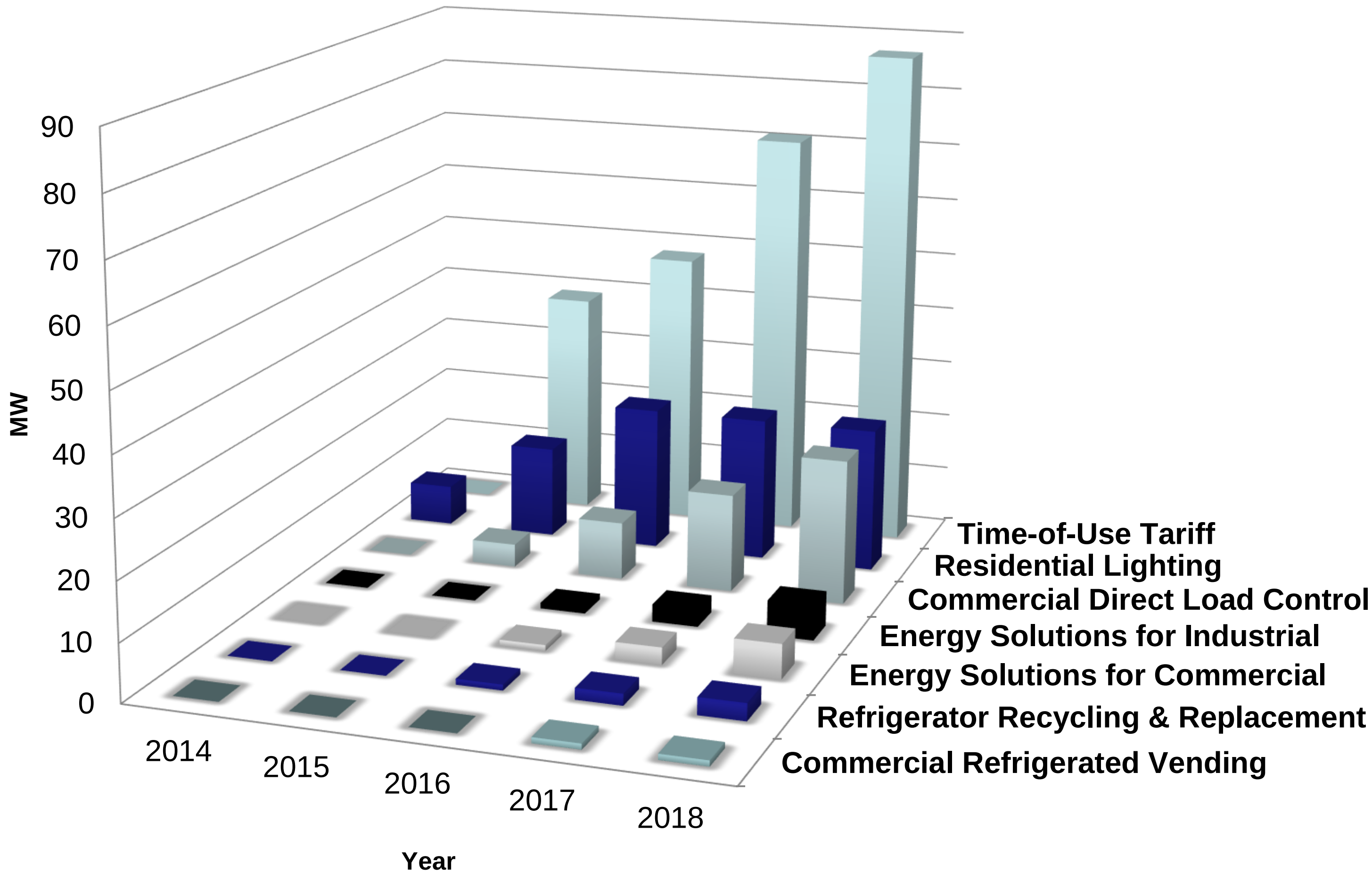
- **Data gathering**
  - Compile list of available measures, impacts and costs
- **Program build-up**
  - Package multiple energy efficiency measures into programs

Residential Water Heating	
	Solar Hot Water Heater with controller - Res
	Heat Pump Hot Water Heater
	Tankless Water Heater (in-line electric)
	Low Flow Showerhead
	Tank Insulation

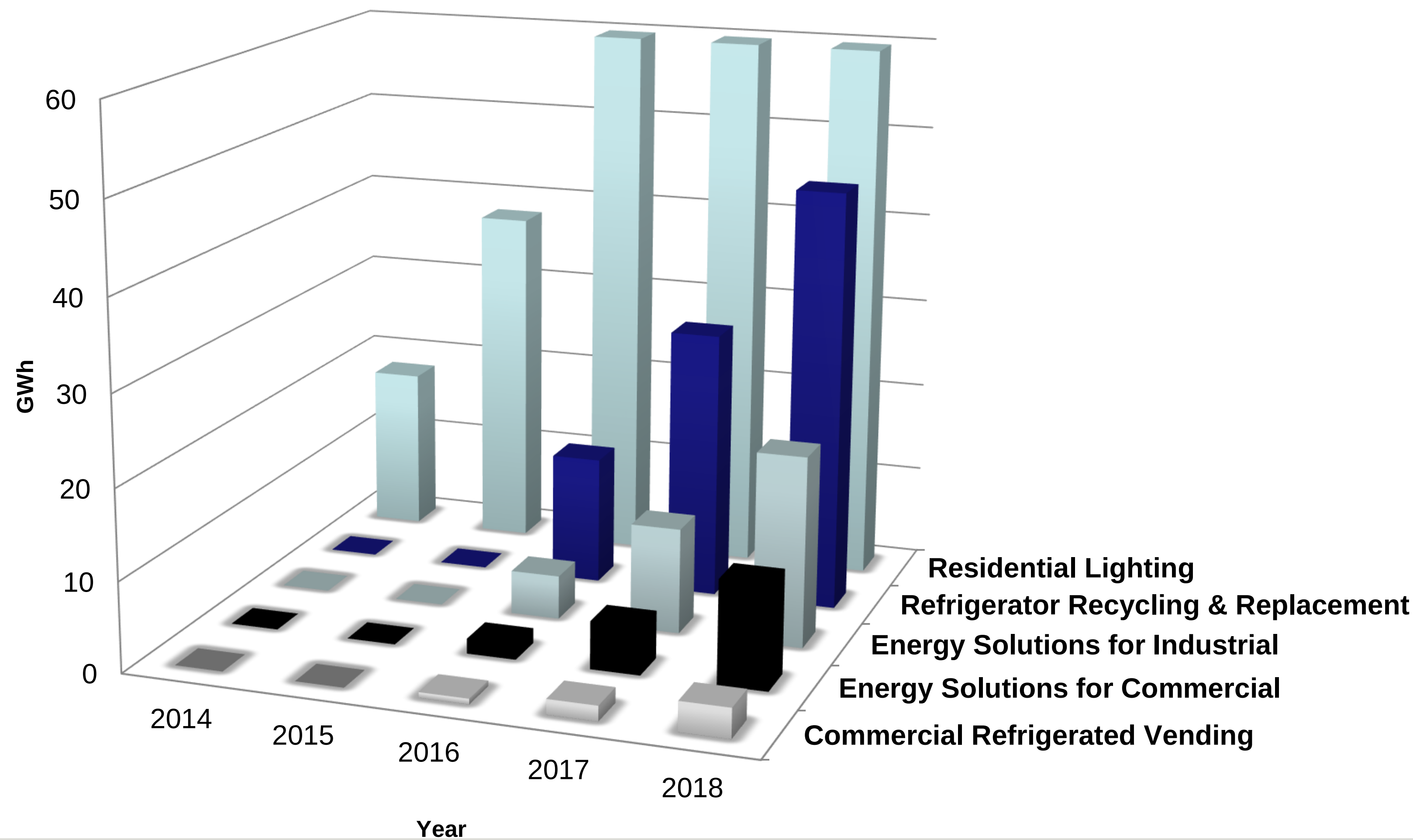
Step 2: Calculate impacts and cost-effectiveness



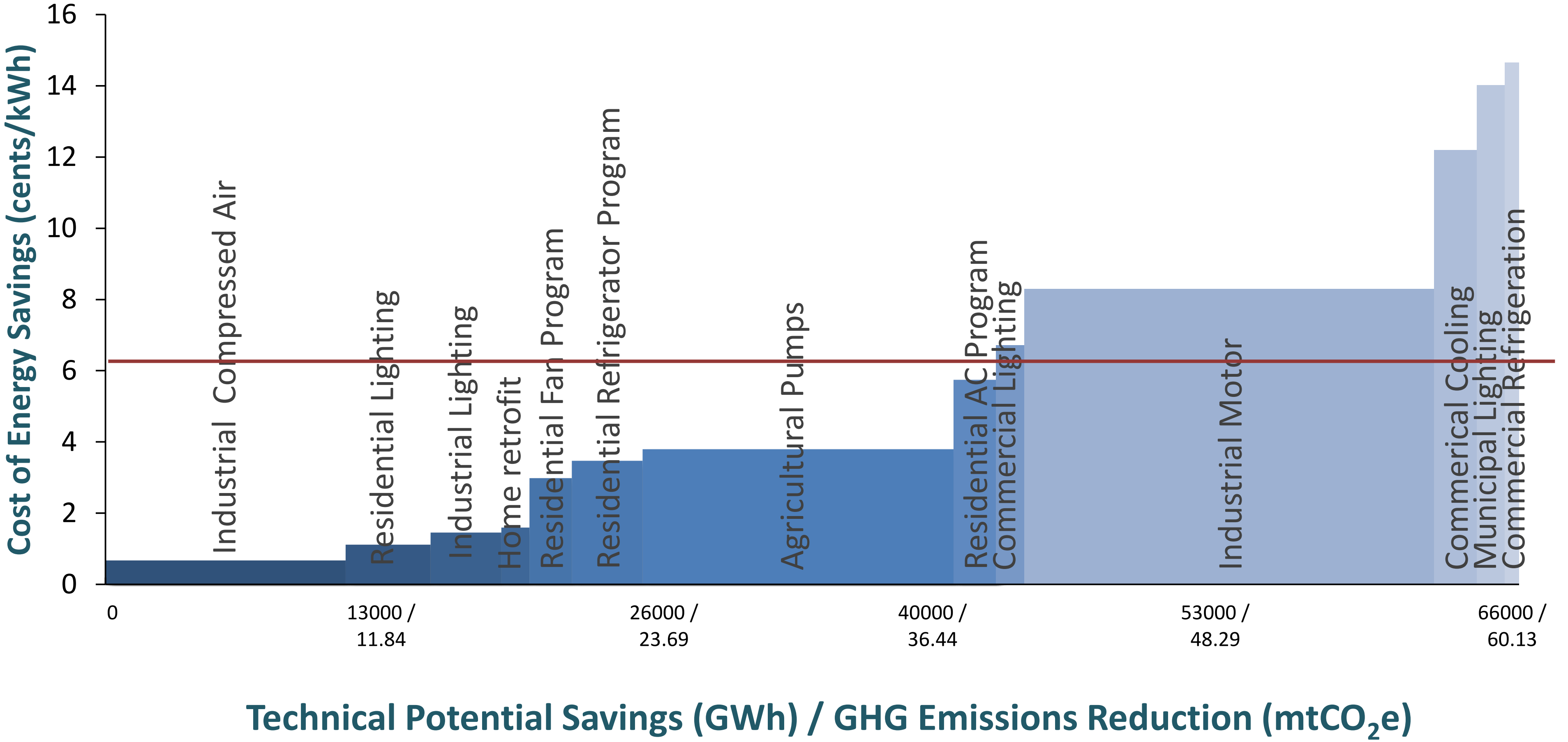
Step 2: Calculate demand impacts (MW)



Step 2: Calculate energy impacts (GWh)



Step 2: Calculate cost-effectiveness

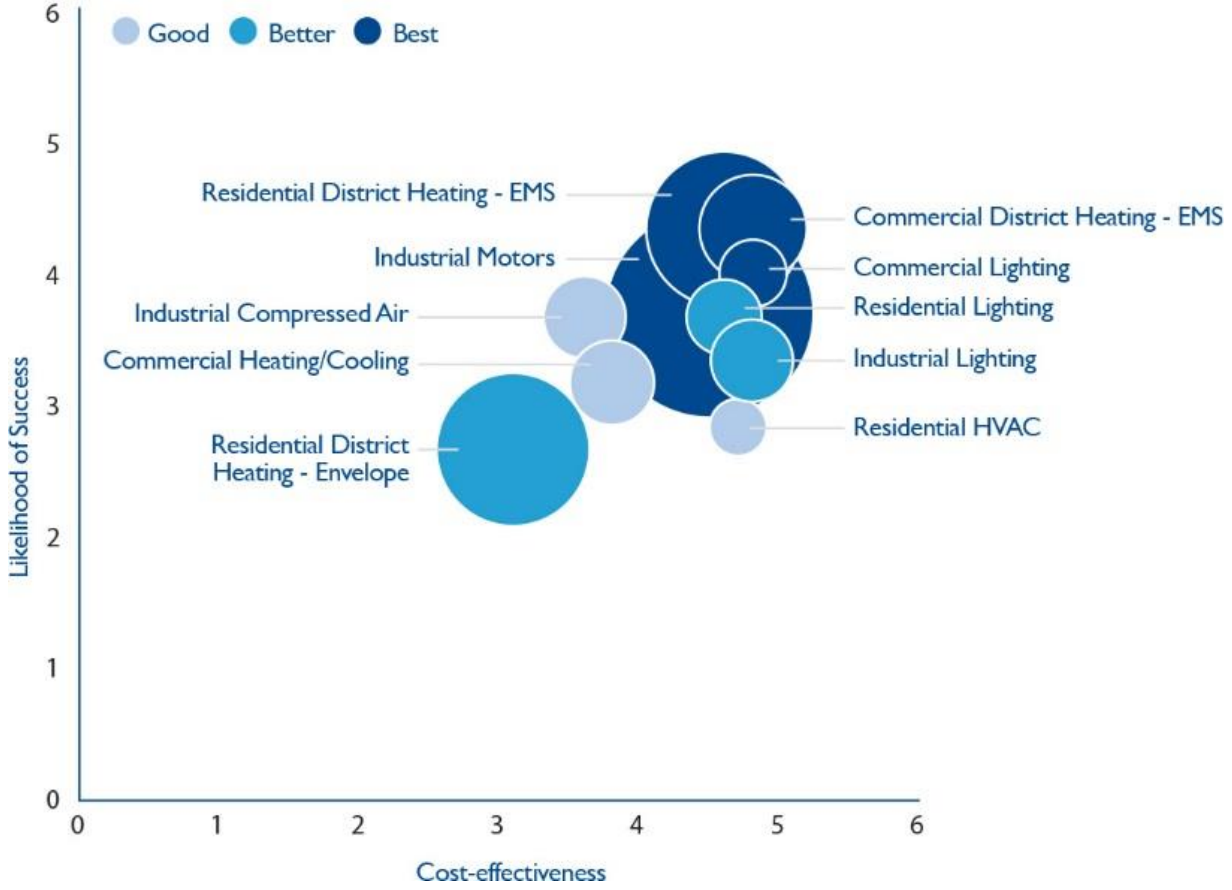


Step 3: Estimate overall benefits vs. likelihood of success

Indicator	Description
Market Transformation Potential	The potential for programs to influence their relevant market channels over the long run (e.g., the extent to which the program may change retailer stocking practices over time) and the likelihood of changing purchasing decisions (e.g., the probability that consumers would use energy-efficiency products once a financial incentive is no longer available).
Political Feasibility	How likely local utility and government stakeholders are to accept and support the program. Without buy in from key stakeholders, a program is likely to never make it out of the planning stage. This may be affected by key stakeholders having backed a similar program in the past that did not have positive results.
Program Complexity	Marketing, administration, and evaluation burden all add to the complexity of implementing programs. This factor is evaluated based on available resources, experience, and expertise in these areas. The score could be high if a particular country has implemented similar programs recently that can be leveraged when implementing a new activity.
Environmental Aspects	The lifecycle impact of the program on waste, water use, and emissions. For example, if facilities and infrastructure for recycling CFL lamps are not present in the country, a CFL lighting program may score poorly in that country.
Economic Aspects	The potential to increase jobs and development of the local manufacturing industry. If, as a part of the program, manufacturing demand is increased or jobs are created as people are needed for energy audits or installations, this score will be high.
Equity / Affordability	How a program would perform in providing DSM options to customer class within each of its target sectors. The score relates to the relative benefit to one particular market segment over another.

Step 4: Identify top programs for implementation

Figure 1: Top 10 Energy Efficiency Opportunities



Steps 2-4: EE Opportunity Study Tool

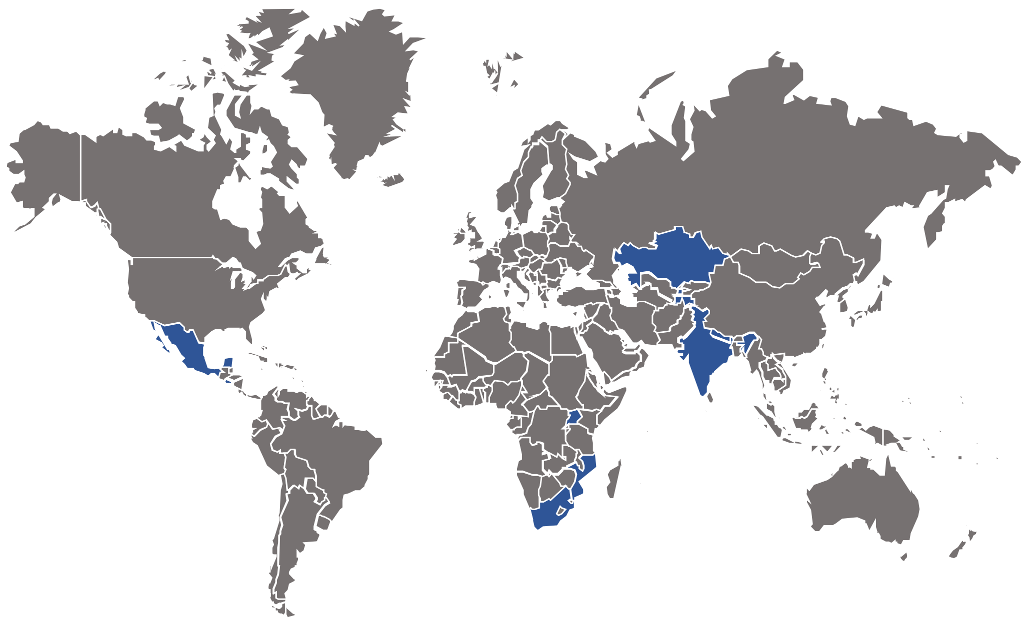
Energy Efficiency Opportunity Assessment

Country
Uganda

← Select Country

Add New Country

Countries currently available in this tool



- Country Selection
- EE Building Block Assessment
- Program Indicators
- Advanced Inputs Country
- Advanced Inputs EE Measure DB
- Advanced Inputs Program
- Top EE Opp Technical
- Top EE Opp Achievable

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Calculator Version: A3