Demand Side Management (DSM) and Smart Grid Technologies

USAID – The Fundamentals of Energy Systems for Program Managers

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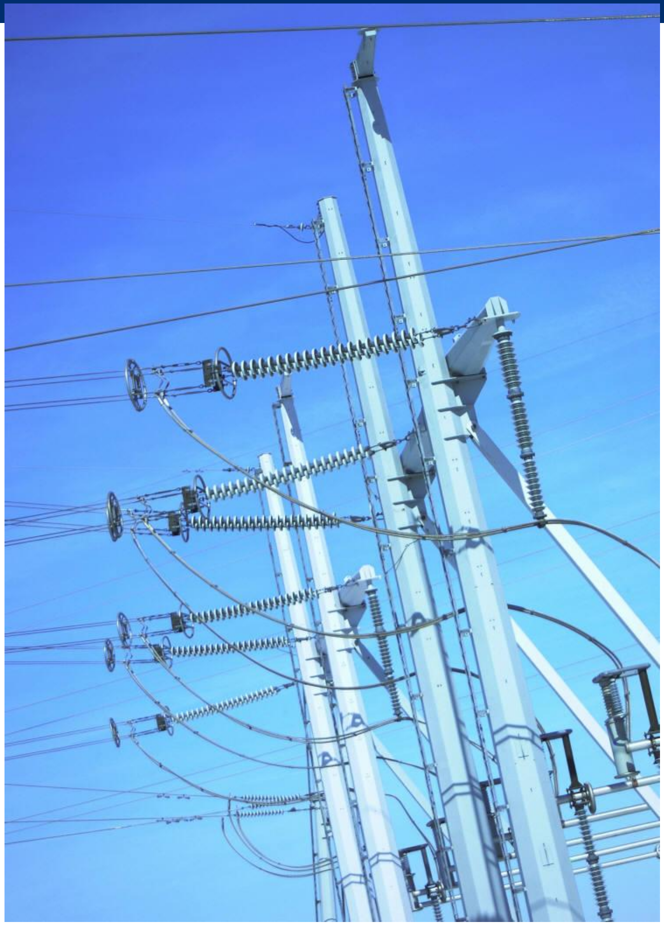
Overview and Takeaways

Part I - Demand Side Management (DSM) programs

Part II – Smart Grid Technology



What you will learn:

- The basic concepts of DSM and customer-oriented smart grid technologies
- Basic tools to evaluate the cost effectiveness of DSM technologies and activities
- Practical examples of the implementation of DSM and smart grid technologies
- How to evaluate challenges and opportunities for DSM

Part I – Demand Side Management

Why Pursue DSM?

Between 2010 and 2020:

Developing countries are projected to install half or more of all the buildings and other infrastructure that will be in place by the end of the decade.

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DSM Characteristics

Two Types:

1. **Energy Efficiency (EE)**
   - Permanent reduction in energy consumption
   - Reduction occurs across most hours of the load curve
   - May or may not reduce system peak demand (i.e. no guaranteed time component)
   - Provides same or better energy service with fewer kWh
   - More suitable for long-term control of consumption and demand
2. **Demand Response (DR)**
   - Temporary reduction in consumption
   - Reductions targeted at specific hours, typically coincident with system peak.
   - May or may not be associated with curtailment of service
   - More suitable for short-term control of demand

Examples of Commercial Sector DSM Measures

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

Examples of Residential Sector DSM Measures

Measure Category	End Use	Measure Type
Energy Efficiency	Cooling	Efficient mini-split AC
	Envelope	Insulation and Air Sealing
		Efficient Windows
	Lighting	CFLs
		LEDs
	Refrigeration	Efficient Refrigerator
Demand Response	Cooling	AC Direct Load Control

Examples of Industrial Sector DSM Measures

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

Electric Utilities & Energy Efficiency (EE) DSM

- Utilities often incentivize EE measures – such as replacing incandescent bulbs with CFLs and LEDs, or upgrading inefficient windows to Low-E, high reflectance windows.
  - (US EPA's ENERGY STAR program is a common platform used in the United States)
- EE programs typically focus on replacing existing technologies, improving operation of equipment, or encouraging adoption of higher efficiency standards for new construction.

Why?

Reducing the system load by incentivizing lower consumption of energy:

- alleviates supply issues,
- supports increased energy access efforts, and
- typically is cheaper than funding additional generation.

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Common EE Program Types

All Sectors	Industrial
Lighting Upgrade to CFL, LED or linear Florescent	Compressed Air Upgrades
Refrigerator Upgrade	Customized Projects (for specific applications)
Building Envelope Insulation Upgrade	Motor Upgrades
AC and Heating Equipment Upgrade	Process Cooling Upgrades
Air Sealing (reduce airflow to outside)	Process Heating Upgrades

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Question Set #1 – Understanding EE Savings

A commercial office property manager wants to decrease the building's electricity bill.

Assume there are one thousand 80 watt (W) incandescent lamps in the building. In one hour each lamp will consume 80 watt hours (Wh) of energy. If each lamp operates 12 hours a day:

- What is the annual energy consumption of the building in kWh (1 kWh is 1,000 Wh)?
- At 90 c/kWh, how much is the annual bill?
- How much money would the property manager save if he replaced all of his lamps with 12 W CFL lamps?
- At $5 per CFL lamp, is it worth it?
  CFL lamps can typically last 5-9 years.

  (Assume R 1 = $ 0.09)

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Question Set #1 – Answer Sheet

- Annual energy consumption for 1 lamp

  = 80W * 12 hours/day * 365 days/year = 350,400 Wh
- Annual energy consumption for 1,000 lamps

  = 350,400,000 Wh or 350,400 kWh
- Annual bill

  = 350,400 kWh * 90 c/kWh

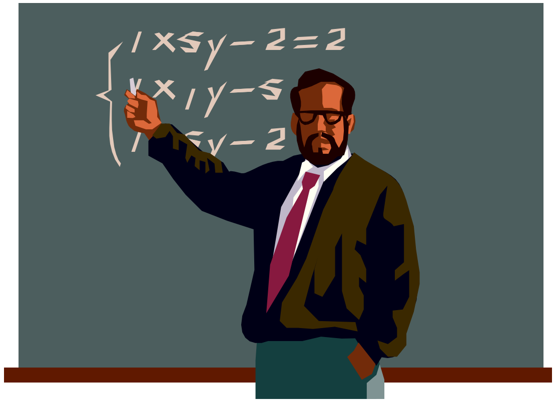
  = 31,536,000 c or R 315,360
- Annual bill for 12 W lamp

  = R 315,360 * 12/80 = R 47,304
- Annual savings from 12 W CFL lamps

  = R 315,360 - R47,304

  = R 268,056 or 85% of the bill
- Cost of 1,000 CFL lamps

  = $ 5,000 = R 55,556

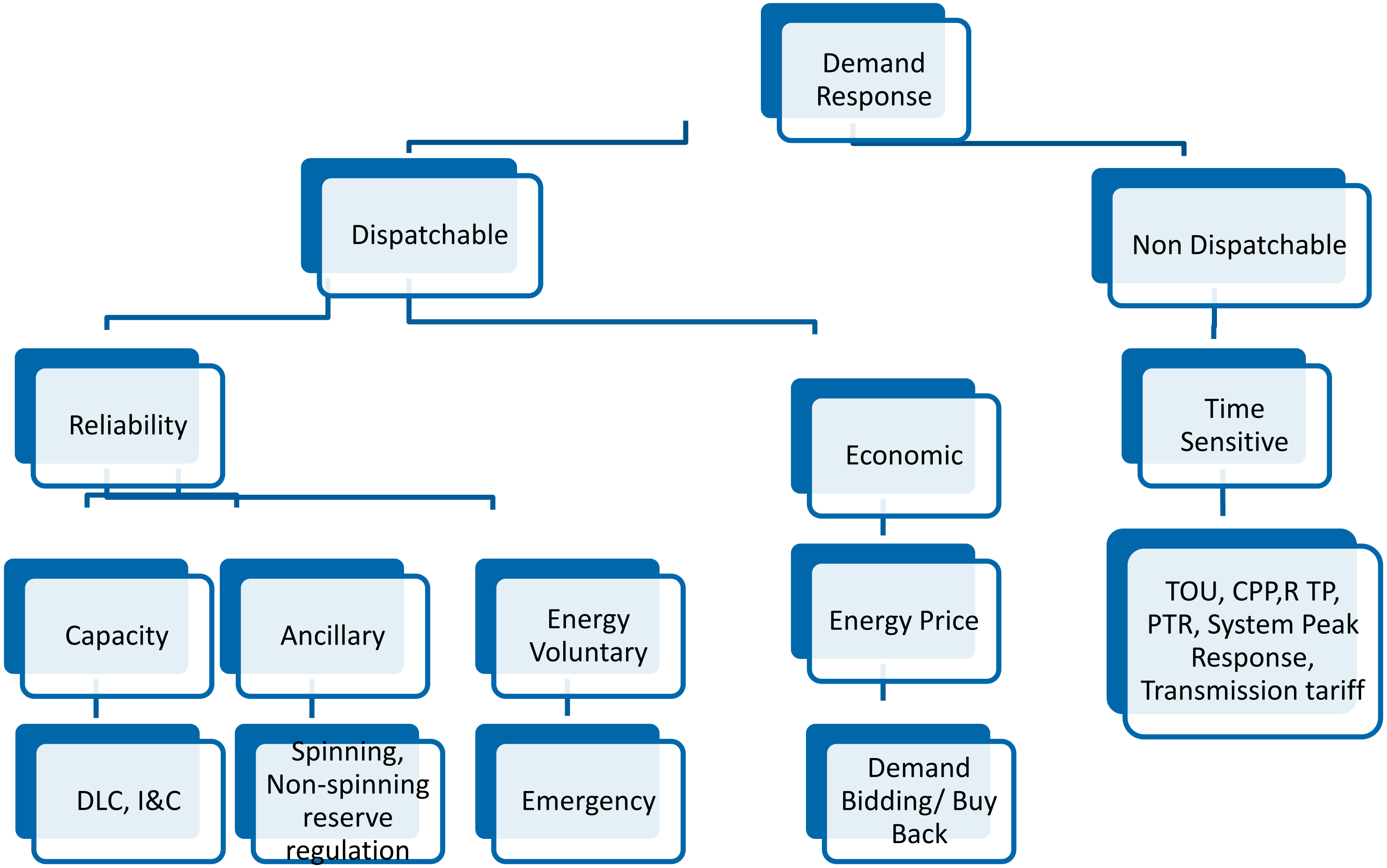


Understanding Demand Response

Video Link – Lawrence Berkeley National Laboratory, “Open Automated Demand Response (OpenADR)”

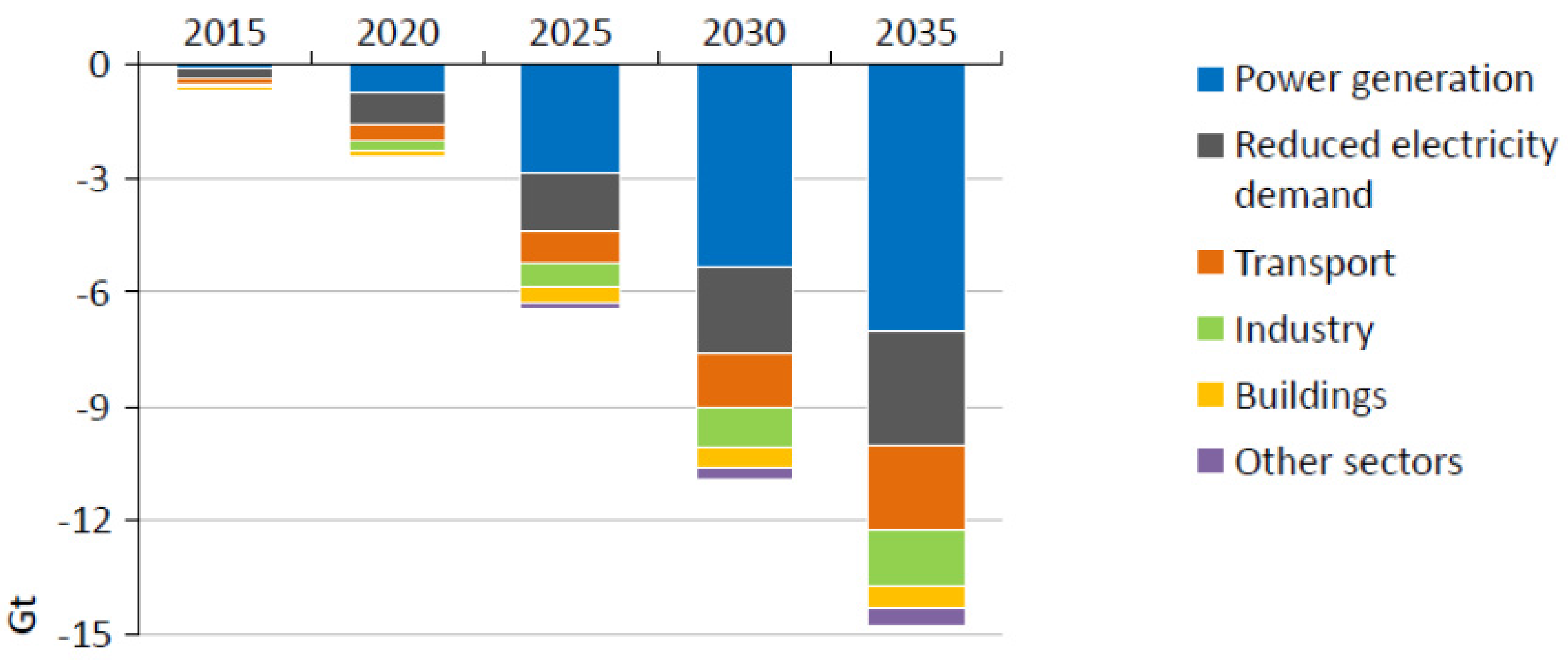
[http://vimeo.com/66098453]

Customer End: Demand Response Could Provide Options for Managing Flexibility of Power Supply



Delivering DSM Programs

Reducing electricity end use demand is expected to account for 1/3 of GHG global emission reductions through 2025 (International Energy Agency)



IEA 2011(a); "Energy Provider-Delivered Energy Efficiency", © OECD/IEA 2013

Utility DSM Programs

DSM programs can be delivered by government, NGOs, and/or utilities but utilities typically have:

- Strategic position in the market with power producers and energy consumers
- Relationships with large commercial consumers
- Technical capacity
- Service delivery infrastructure

Utilities may run programs in response to regulation, but also in response to other drivers such as improved systems operations, demand management, community relations, and business development.

Utility DSM Programs

Lessons Learned for Energy Providers:

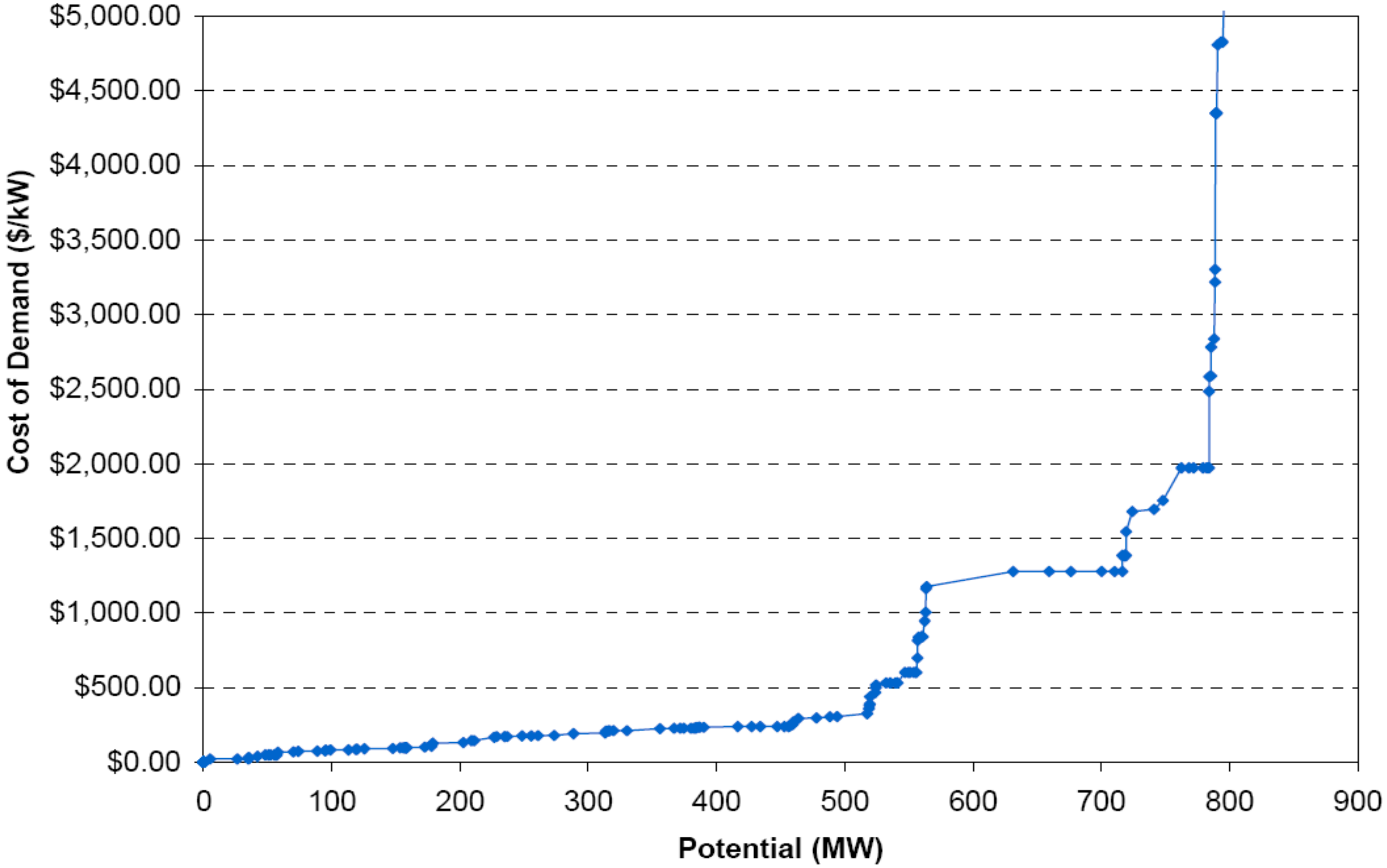
- Local partners increase the effectiveness of programs
- Stick to programs that leverage technical expertise

"Energy Provider-Delivered Energy Efficiency", © OECD/IEA 2013

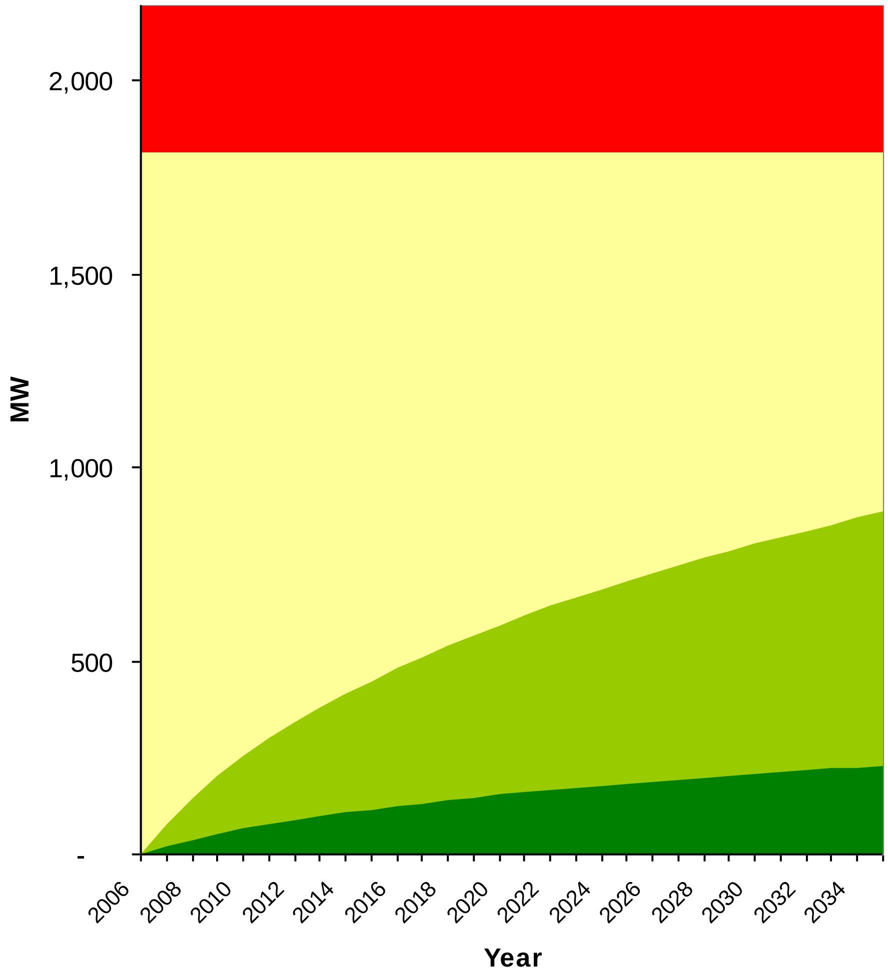
Lessons Learned for Policy Makers:

- Voluntary agreements on energy targets can be a successful option to setting target requirement
- Collaborate with utilities on bundling goods, services, and program offerings to create attractive offers to customers.

Residential DSM Supply Curve:
How Far to Pursue Options?



DSM Technical and Economic Potential

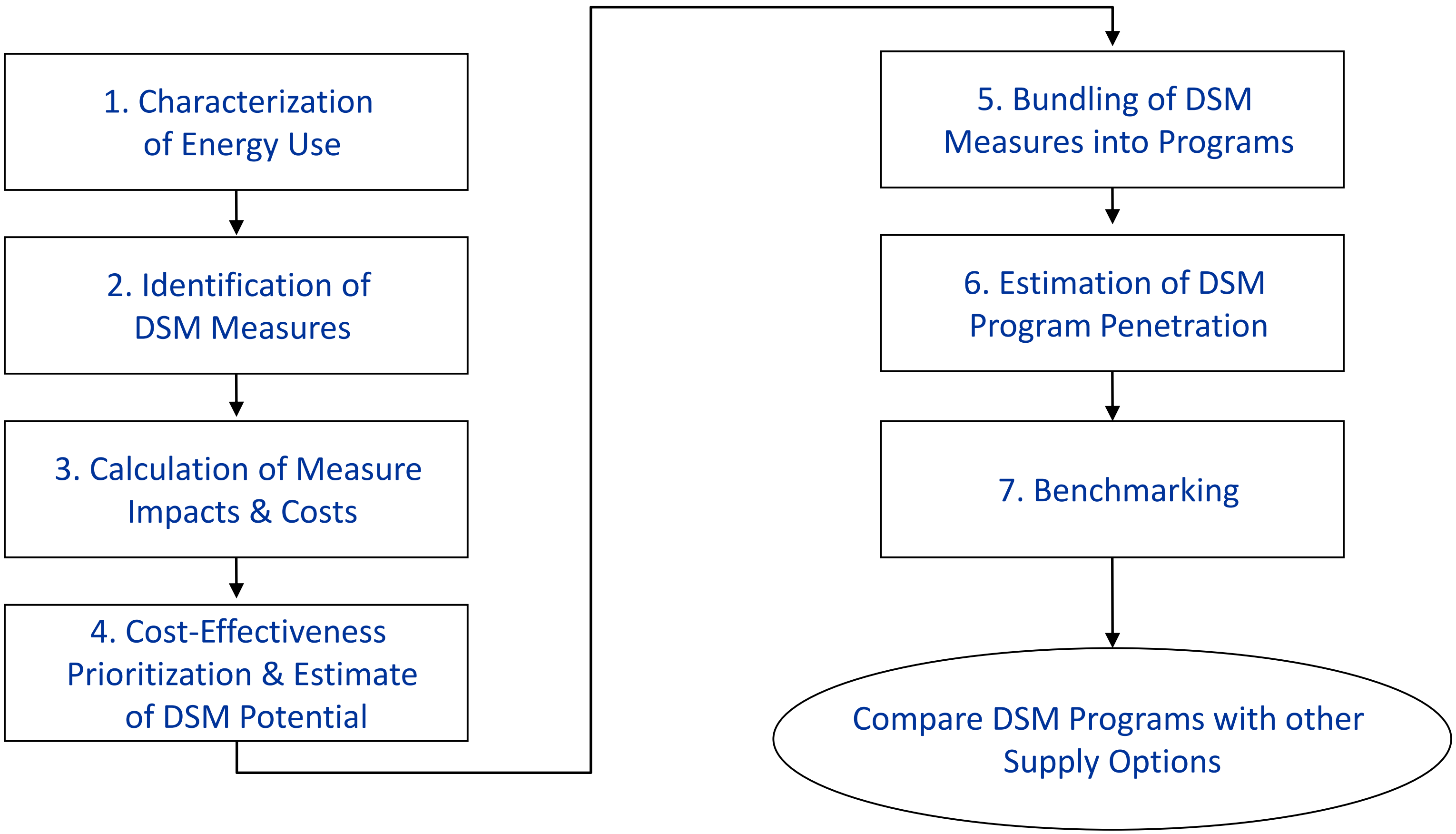


- Technical Potential if everyone installed the efficient measure without regard to TRC cost-effectiveness. 2,193 MW
- Economic Potential if everyone installed all measures passing the TRC test. 1,817 MW
- Market Potential: the subset of Economic Potential that we can expect to adopt the measures under a variety of scenarios

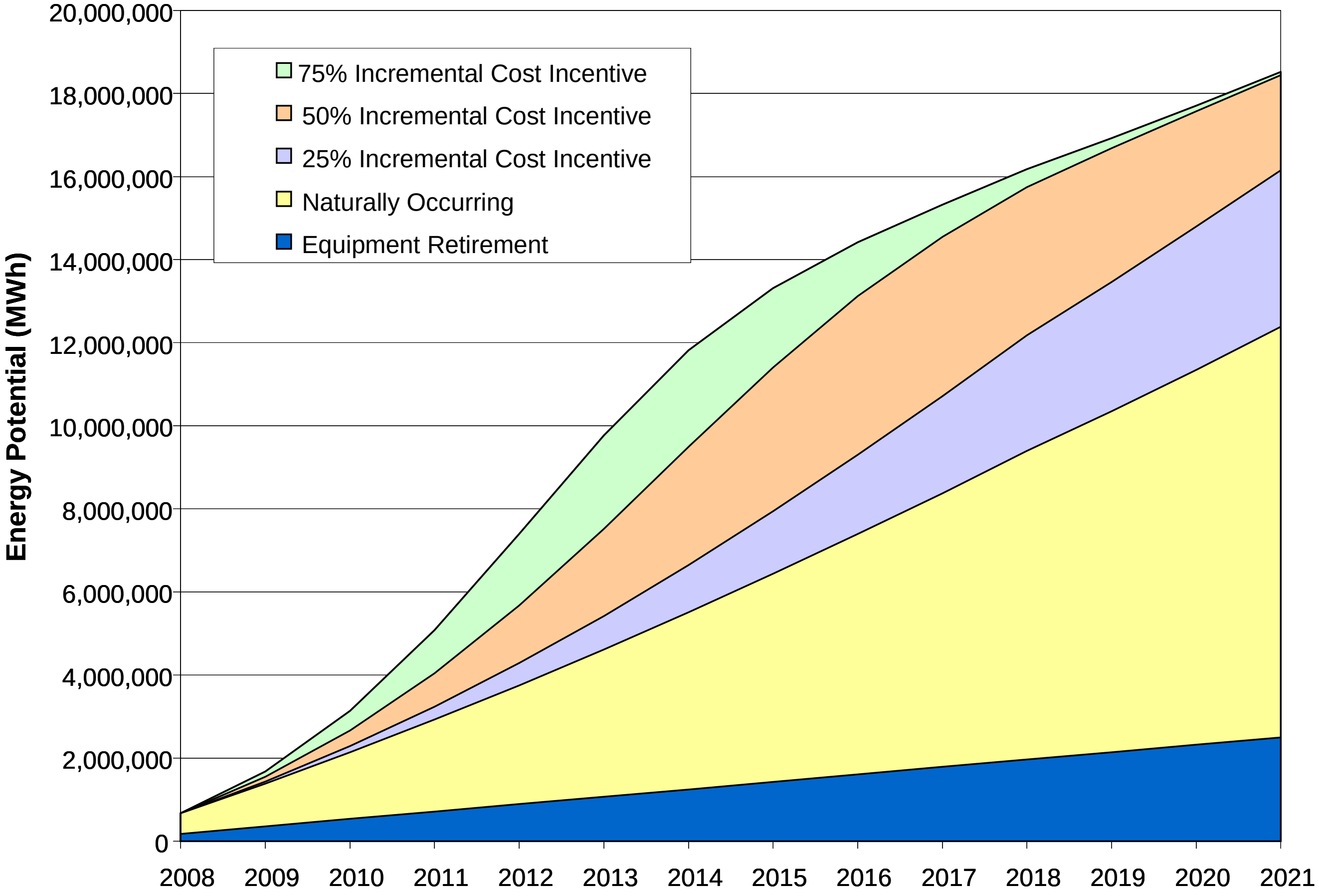
How to Quantify System-wide DSM Potential?

1. Develop demand and energy savings potential
2. Research measure costs
3. Estimate avoided utility costs
4. Estimate current technology penetration and develop participation estimates
5. Develop technical potential
6. Estimate cost-effectiveness
7. Develop economic potential

Typical DSM Planning Process



Illustrative DSM Incentive Scenarios



Industrial Best Practice Benchmarking

Case Study: Bangladesh

- Motivation:
  - Rapid economic and industrial growth led to natural gas shortages resulting in problems for industries as well as power outages (natural gas is used to generate electricity)

- Solution:
  - Improve EE in the industrial sector (one of largest consumers of natural gas and electric energy in Bangladesh)
    - Determine sectors with greatest EE opportunities
    - Identify key interventions to advance improved EE
    - Identify options and strategies for financing these interventions

Industrial Best Practice Benchmarking

Case Study: Bangladesh

Major Findings:

1. Because individual EE measures vary in cost and achievable savings, a portfolio of measures provides a strategy to implement some measures with high savings but longer paybacks. They are balanced out by other measures with quicker returns or lower costs. Companies will achieve a higher overall energy savings impact, relative to an ad hoc approach with individual measures.

2. Bangladesh banks need to become important actors in the development of a successful EE market. The business case for their participation is based on the volume of potential business. Financing multiple EE measures at one time not only reduces the transaction costs for lending, but these portfolios best reflect the volume and depth of opportunity that would attract the interest of the banking sector.

Time-of-Use (TOU) Tariff
Case Study: Tanzania

- **Motivation:**
  - System outages during peak hours
  - Industrial operating schedules do not account for the time-varying cost of electricity production
  - 0.1% of the total customers use 35% of the system electricity
- **Solution:**
  - Implement simple TOU tariff with a critical peak pricing (CPP) component
  - Shift the critical peak demand (2% of the total hours)
  - Keep on-to-off peak price variation minimal to avoid shifting peaks

Tanzania: Program Goals Matrix

Program	TANESCO's Goals					Additional Considerations		
	Achievable MWh Savings Potential (Cumulative, 2018)	Achievable MW Savings Potential (Cumulative, 2018)	Market Transformation Potential	Equity	Political Feasibility	Program Complexity	Implementation Risk	Net Utility Benefits ($Millions)
Residential Refrigerator	46,498	3	Low	Equitable	Medium	High	Medium-High	$15.40
Residential Lighting	59,743	25	Low	Equitable	High	Low	Low	$37.70
Energy Solutions for Commercial	11,472	6	High	Equitable	Medium	Medium	Medium	$4.70
Commercial Refrigerated Vending	3,285	1	High	Equitable	High	Low	Low	$1.40
Commercial Direct Load Control	Not applicable.	25	Not applicable	Equitable	Medium	Medium-high	Medium-high	$8.20
Energy Solutions for Industrial	21,069	6	High	Equitable	High	High	Medium	$8.50
Industrial Time-of-Use Tariff	Not applicable.	87	Not applicable	Equitable	High	Low	Low	$18.90

Part II – Smart Grids

SMART GRID - Question Set #2

1. Smart Grid is a relatively new idea, it has never existed in the past
   - True?
   - False?

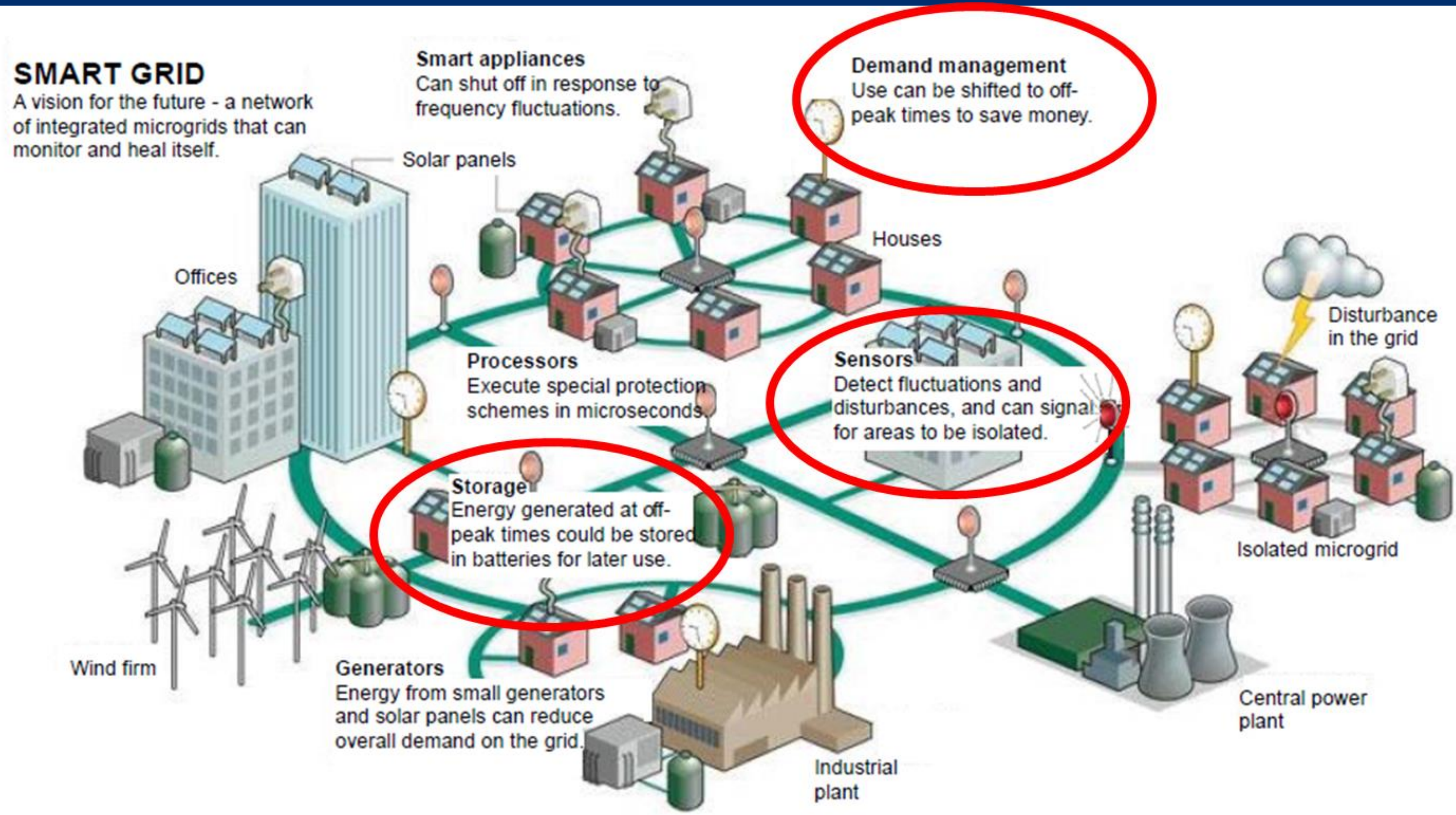
2. Are certain portions of the electric system "smarter" than others? Why?

What is Smart Grid?

Smart Grid Video

http://www.youtube.com/watch?v=JwRTpWZReJk

What is Smart Grid?



We will focus on prominent technologies in the transmission, customer and distribution related domains

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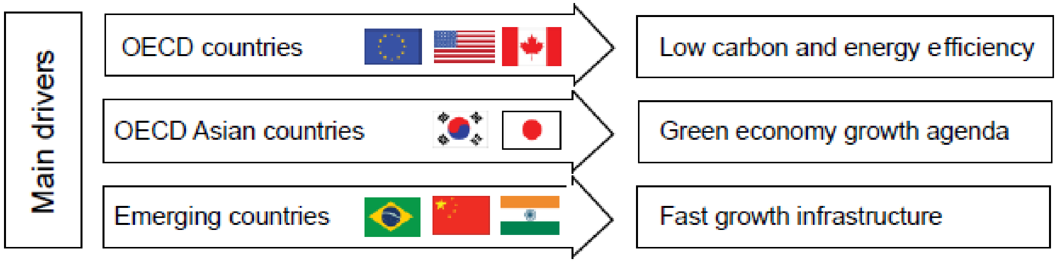
Solar Energy Revolution in Namibia using Smart Grid

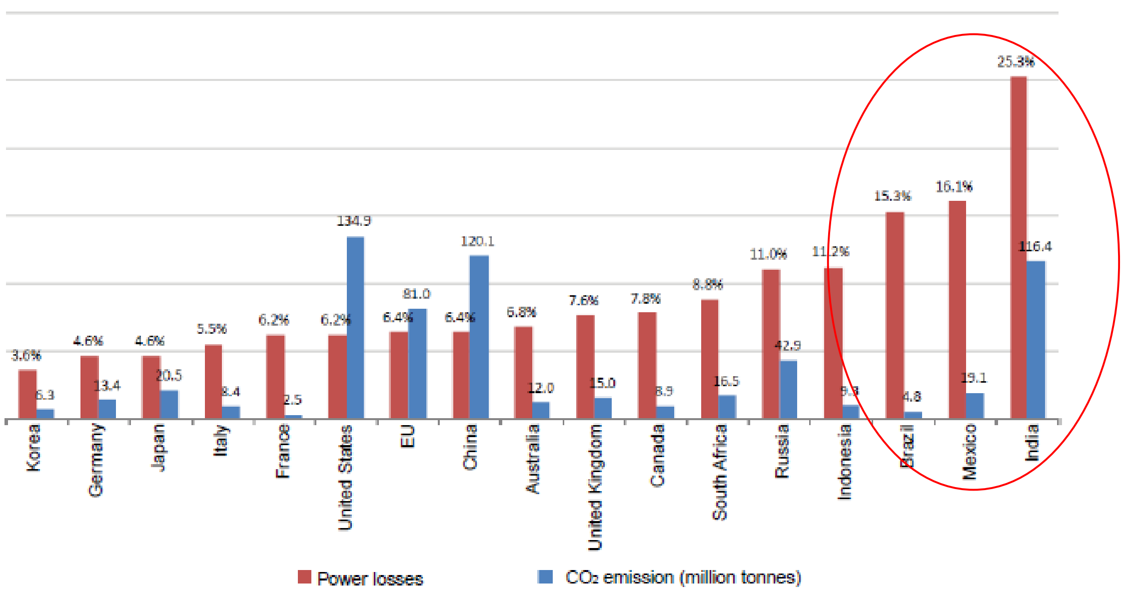
https://www.youtube.com/watch?v=mUmIe-ijIVE

Global Drivers of Smart Grid: Reduction of Losses and Power Theft Are Key Items in Developing Countries



Power losses at the grid and resulting CO_2 emissions of MEF countries in 2006

Source: Major Economies Forum on Energy and Climate, December 2009, *Technology Action Plan: Smart Grids*



Economic Attractiveness of Smart Grid Technologies: U.S National Example

Summary of Estimated Costs and Benefits of the Smart Grid

Attribute	Net Present Worth (2010) $B	
	Low	High
Productivity	1	1
Safety	13	13
Environment	102	390
Capacity	299	393
Cost	330	475
Quality	42	86
Quality of Life	74	74
Security	152	152
Reliability	281	444
Total	1294	2028

	20-Year Total ($billion)
Net Investment Required	338-476
Net Benefit	1,294 – 2,028
Benefit-to-Cost Ratio	2.8 – 6.0

Economic benefits in developing countries could be even higher

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Question Set #3

Deployment of Smart Grid technology will generate which of the following benefits for the consumer?

- Reduced power cuts and outages
- Better quality of supply
- Reduced electricity bills
- All of the above

Distributed Generation (DG) Implementation in Rural Areas

Case Study: Shanquan Village, Jiangyin city (China)

Solar PV Installation

- Investment: $1.79million
- Installed 4,098 PV panels covering more than 10,000 m^2 roofs in the village.
- Maximum Generation Capacity: 1.024MW per hrs.

Outcomes

- Estimated power generation: 1 million+ kWh per year
- Energy Saving: 370 tce
- CO2 emission reduction: 1070 ton

DG Implementation By Individual

Case Study: Yihantong Village, Fangzheng Town (China)

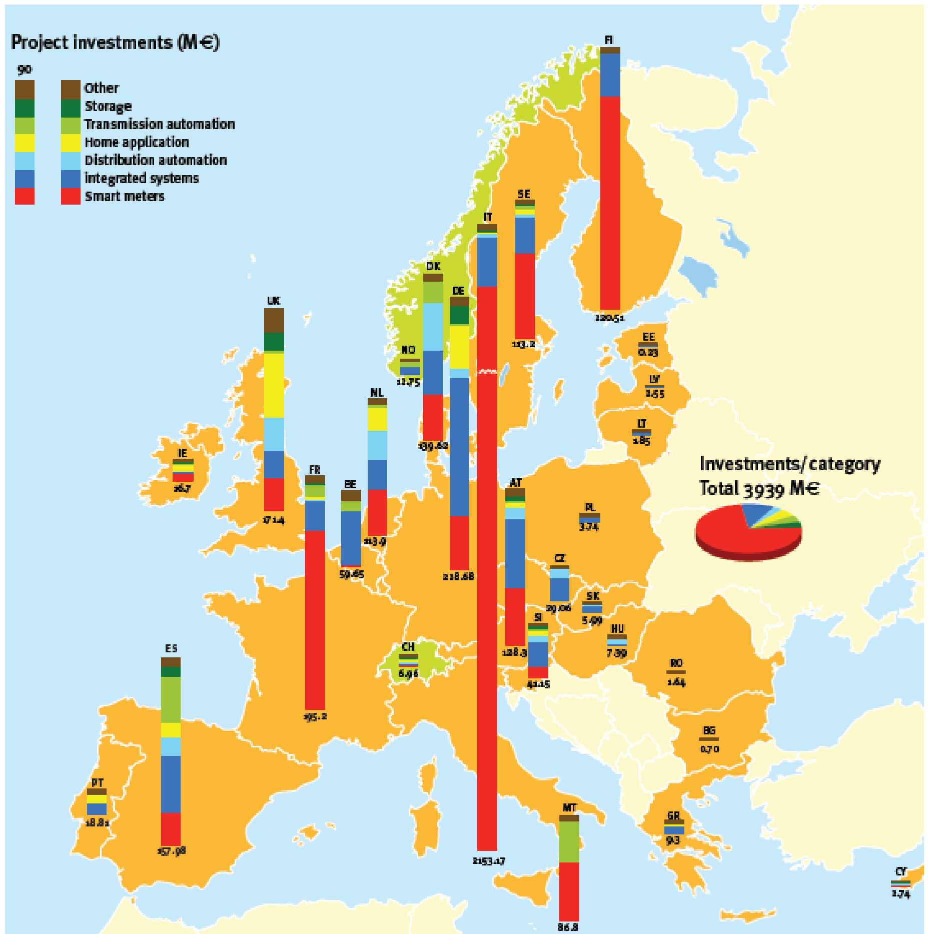
Solar PV Installation by individual

- Investment: $9776
- Capacity : 5.17kW

Outcomes

- Generate power 14.4 MWh annually
- Pay back is estimated as 5-6 years.

Europe: Smart Grid Investments and Technology Breakdown – Smart Meters Dominate



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Tanzania Example – AMR System Reducing Energy Theft and Losses

Impact of AMR Meters on Losses

	Before AMR Year 2006	After AMR Year 2010
Total Energy Theft Cases	**62**	**12**

Energy Theft Cases DROPPED from 62 cases involving LPUs in 2006 to 12 cases only in 2010

Overall Losses dropped from 26% in 2006 to 20% by the end of December 2010.

Major contributing Factor is AMR Metering System.

Why?: Several customers who tried to tamper were caught following the alarms sent by the system. Information spread to others so they are scared to attempt!

Advanced Metering Infrastructure (AMI) Coupled with Demand Response (DR) – Significant Potential for Reducing Theft, Increasing Efficiencies

AMI (Full Two way)

- Integrated service switch
- Time based rates
- Remote meter programming
- Power quality
- HAN Interface

AMR Plus

- Daily or On Demand Reads
- Hourly Interval Data
- Outage Notification
- Other Commodity reads

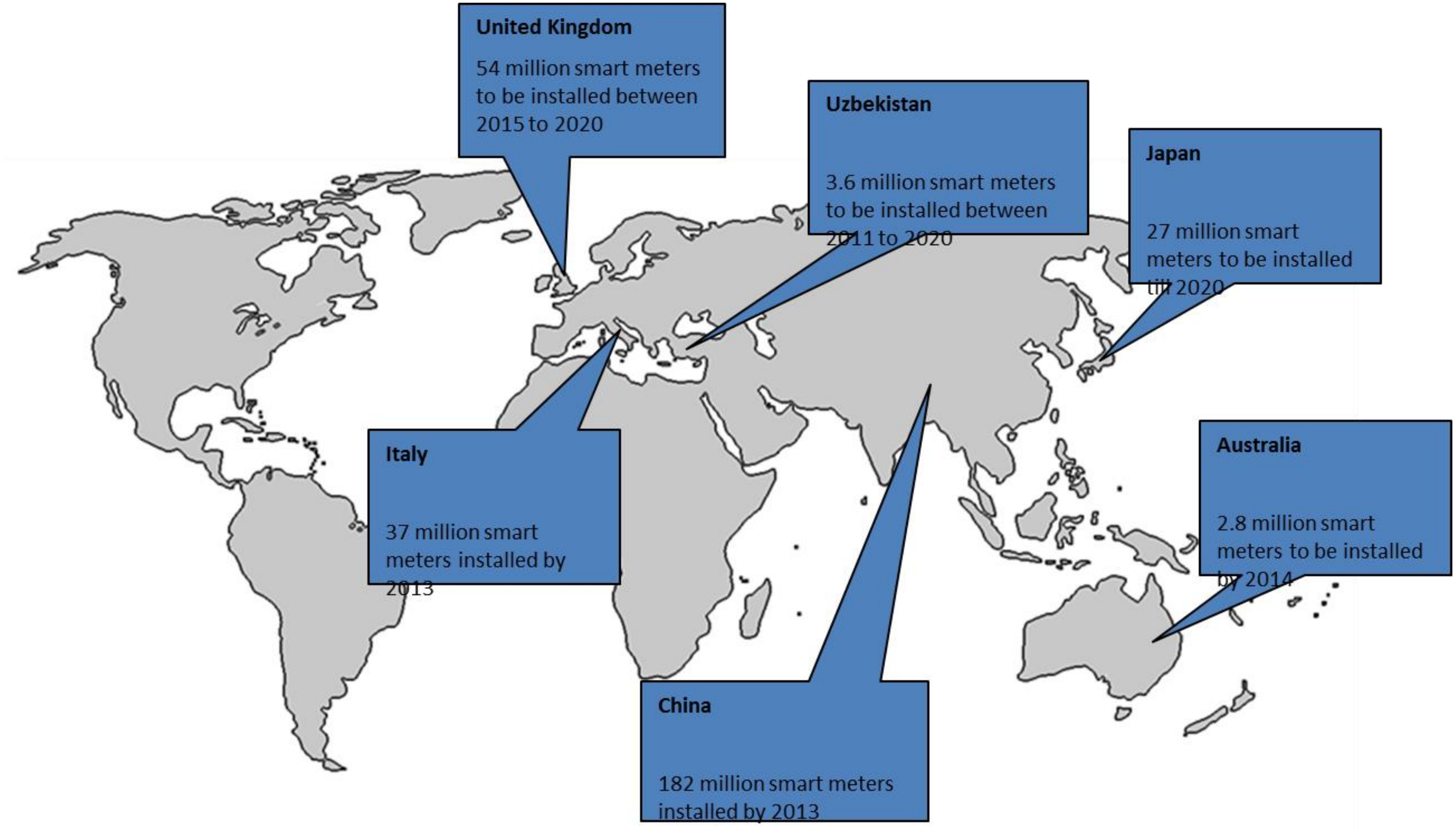
AMR (One way)

- Automated Monthly Read
- One Way Outage Detection-Last Gasp
- Tamper Detection
- Load Profiling

Customer End – AMI and DR Costs Reasonable Compared to Generation Options

Technology	Capital and O&M costs	Typical payback	Risks/ Disadvantages
Advanced metering infrastructure (AMI)	$50-$250/meter; up to $500/meter including com-munications and IT; O&M $1/meter/ month	3- to 10-year pay-back; depends on existing and new systems	PR/education issues can be touchy
Demand response (DR)	$240/kW capacity (vs. $400/kW for gas peaking plant); O&M costs low	<3 years	PR/education is-sues can be touchy; trade-off with user comfort

Smart Meter Installations across the World



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Cape Town, South Africa—Phambli Nombane Energy Initiative

Use of a separate community-based distribution company (i.e., PN Energy) as the interface between local utility and community

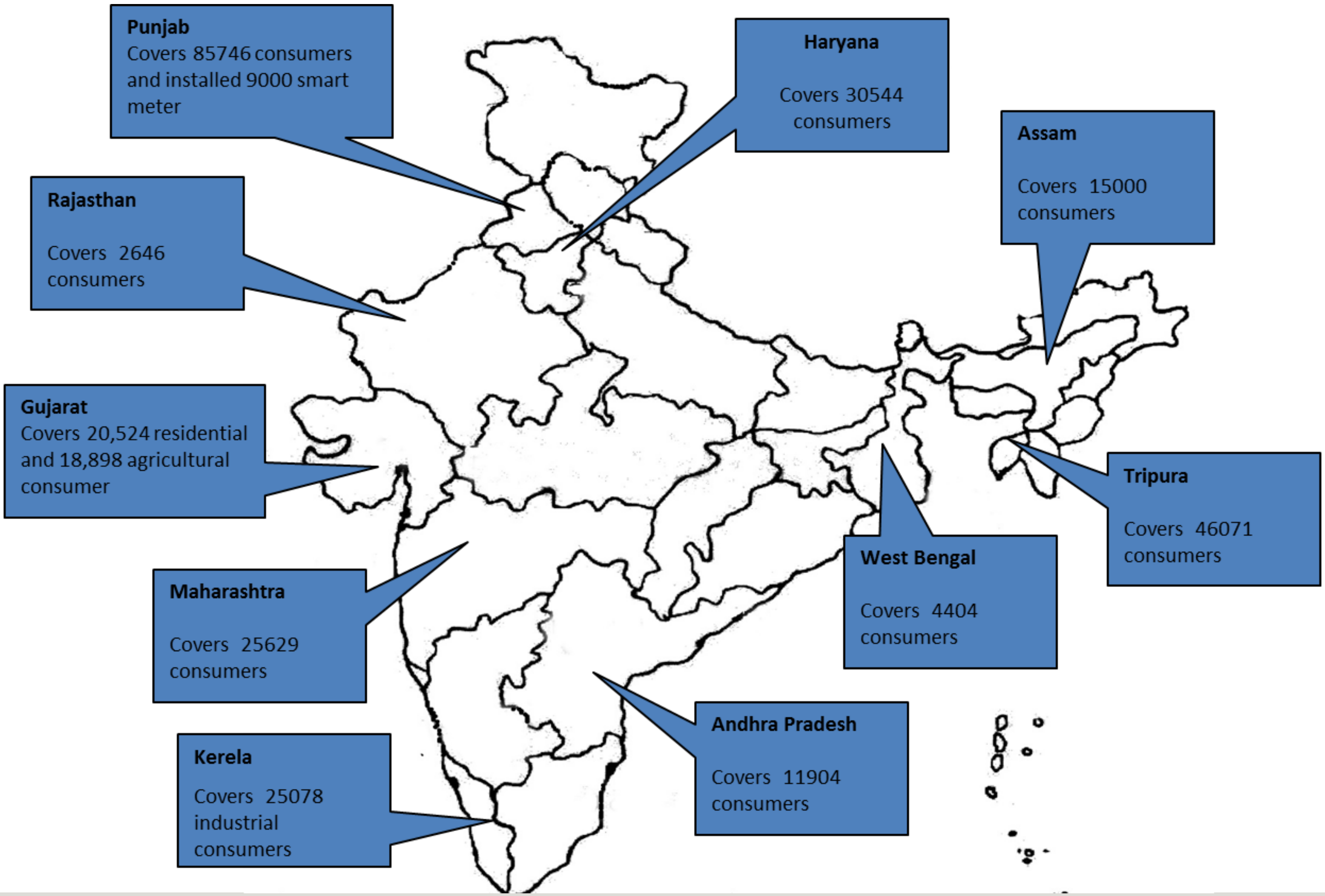
Reduced theft with service drops high on utility poles easily seen from the road, and reduced non-payment with prepaid meters

PN Energy achieved an increase of 60,000 connections from 1994-2003 as well as reductions in non-payment from 70% in 1994 to 5% in 1998

Lower costs of connection (through subsidization and house wiring with “ready boards”) and pre-payment that allowed households to use their budgets better

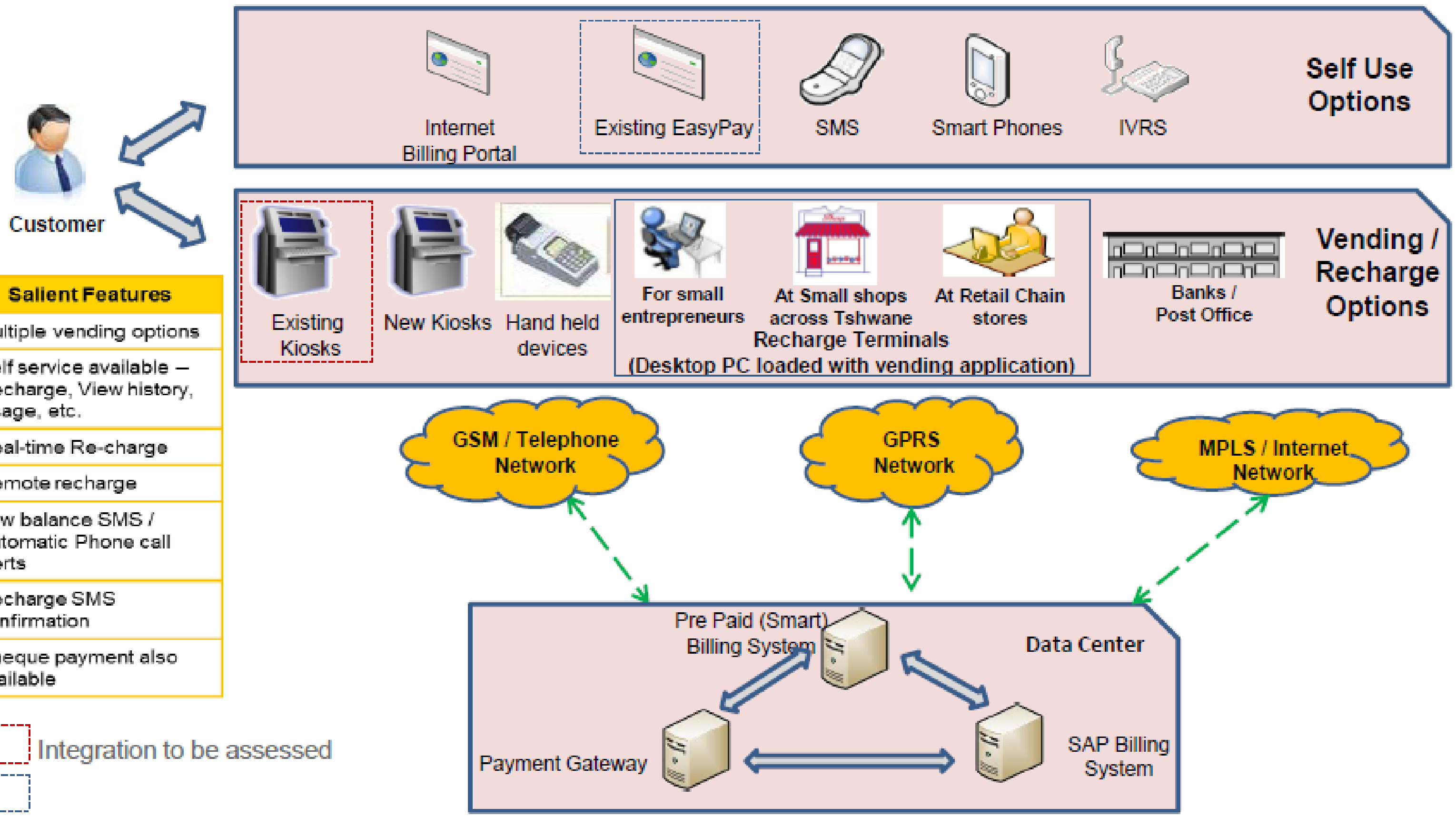
Constant surveillance of consumption and physical structures to catch problems early, higher profitability

Automated Meter Infrastructure (AMI) Projects across India



Smart Prepaid Electricity Meter Case Study:

City of Tshwane (CoT) - Zambia



Salient Features
Multiple vending options
Self service available – Recharge, View history, Usage, etc.
Real-time Re-charge
Remote recharge
Low balance SMS / Automatic Phone call alerts
Recharge SMS confirmation
Cheque payment also available

Integration to be assessed

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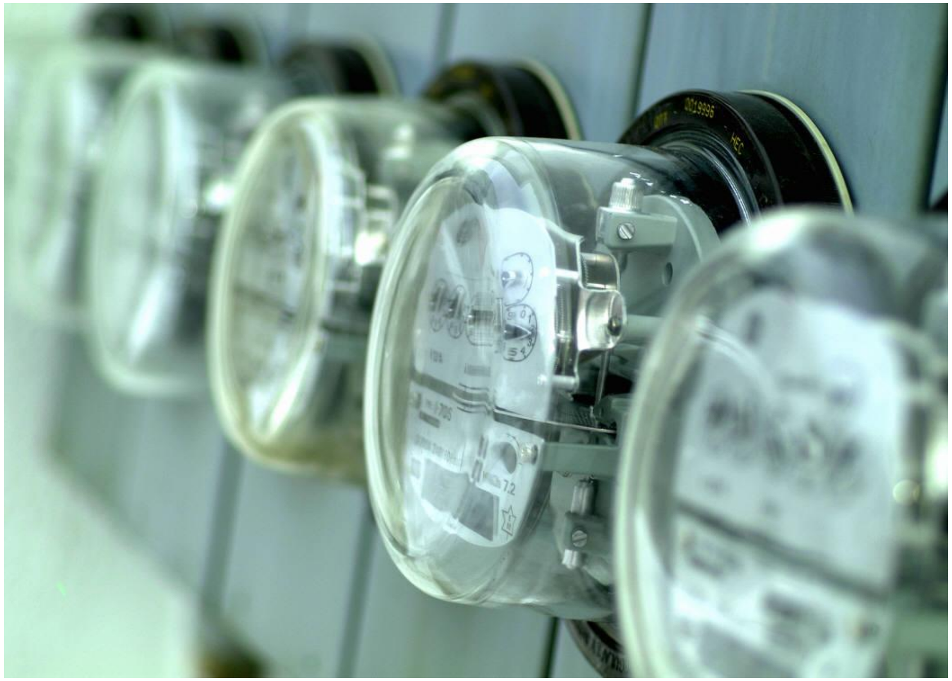
Customer End - Smart Meters Helping Xcel Energy

http://www.youtube.com/watch?v=V1cyxBCkIgo

Question Set #4

1. Cost is the only impediment for implementation of Smart Meters and AMI
   - True?
   - False?

2. What are some of the key challenges to any smart grid implementation program?



Discussion

What are the implications of smart grids for the electricity sector programs that you work with in developing countries?

- Participant examples

Case Study: South Korea Jeju Smart Grid Test Bed

Smart board – Real-time system monitoring

Jeju System Screen

- Jeju system monitoring
- Gen. output, power flow, topology
- 4-second data acqusition

Daily Load Screen

- Jeju daily load scan
- Historical data & search

Renewable Monitoring Screen

- Real-time monitoring
- Solar/wind/Bess status
- 2-second data acqusition

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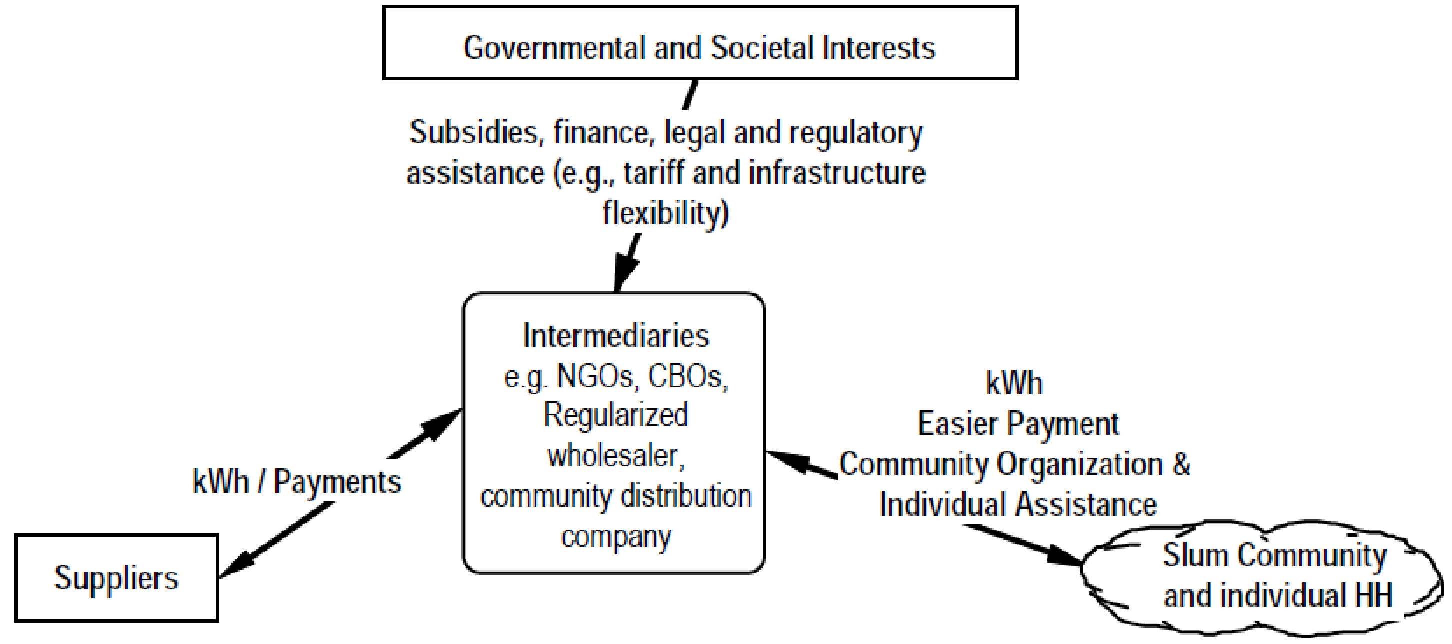
DG Programs for Rural Electrification Projects



Intermediary: A separate entity that contracts (or works) with the supplier to perform services such as payment collection or even distribution system maintenance

Case studies show that a notable departure from the traditional approaches to slum electrification was the engagement of all stakeholders and the efforts made to meet their needs.

Case Study - Slum Electrification in Sao Paulo (Brazil)

Project Components:

Pre-regularization	• Community leadership • Customer mapping and registration • Campaigns
Regularization	• Installation of new service drops and meters for the new (or returning) customers, and the start of billing and collections. • Anti-theft cables, remotely controlled meters, and efficient transformers.
Post-regularization	• New efficient lights, replacement refrigerators, replacement of internal electrical wiring

Case Study - Slum Electrification in Sao Paulo (Brazil)

Key Indicators	Results of Pilot
Investment Requirements	$1.8 M or $421 per customer
Change in revenue (in terms of losses or debt reduction)	67% reduction in debt
Payback	<1.4 years
Change in affordability of electricity service	Bills dropped from $354 to $213 per customer per year
Reduction in inefficient consumption achieved	Consumption reduced by 99 kWh or 40% per customer
Improvement in the reliability of electricity service	One of the top cited benefits of the project by those polled
Improved legal and institutional status within society	
Improvement in personal safety and physical environment	
Satisfaction with customer service including Community Agents	75% satisfied with the new service although some complained of problems during start-up

Ahmedabad, India-Slum Electrification Pilot Program

Local utility worked with NGOs for the Pilot Project in India.

Subsidized connections for 820 households and provided each household with a legal private meter and a compact fluorescent bulb.

Costs for connecting the customer and installing internal wiring was split between the household, USAID and utility

The Slum Electrification Program augmented an existing slum upgrading scheme called "Parivartan"