The Global *Tao* of the Smart Grid

PRESENTED TO

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The Peninsula Hong Kong

PRESENTED BY

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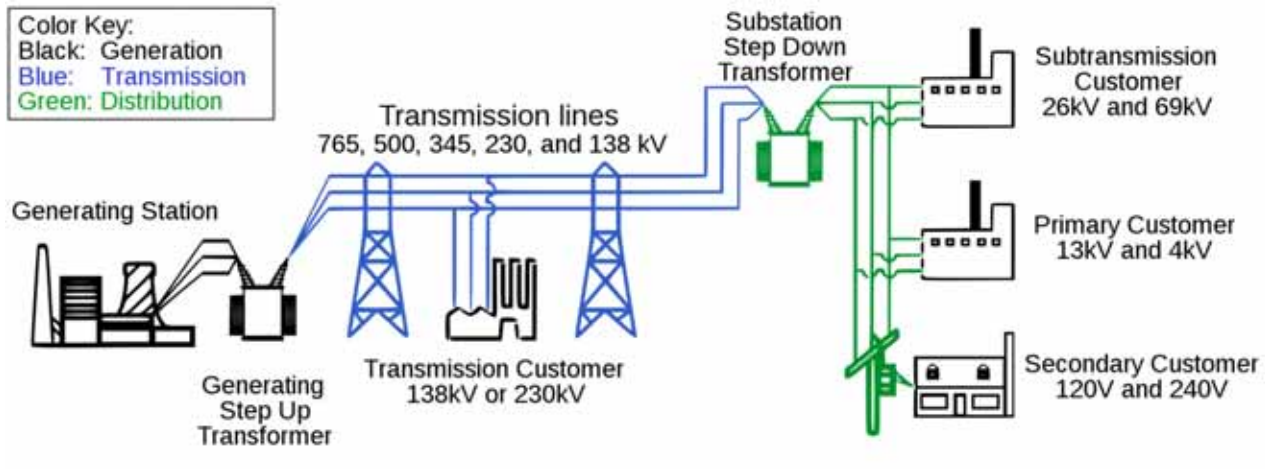
THE Brattle GROUP

The Smart Grid encompasses the entire value chain, from power plant to customer

Customers will notice changes due to the smart grid

- Physical changes: new meters, smart appliances
- Non-physical changes: dynamic pricing, increased reliability



Source: http://en.wikipedia.org/wiki/Electric_power_transmission

Smart grid strategies in the US

Many states are modernizing their grid to improve reliability, lower energy costs and have a cleaner environment. Notably, they have approved investments in advanced metering infrastructure (AMI), which now reaches a third of the households

At the federal level, $4.5 billion has been invested in a hundred projects, with two-thirds of the funding going to advanced metering infrastructure (AMI), one-quarter to distribution automation and the remainder to phasor measurement units

Benefits have been more than twice the size of the investments (www.smartgrid.gov)

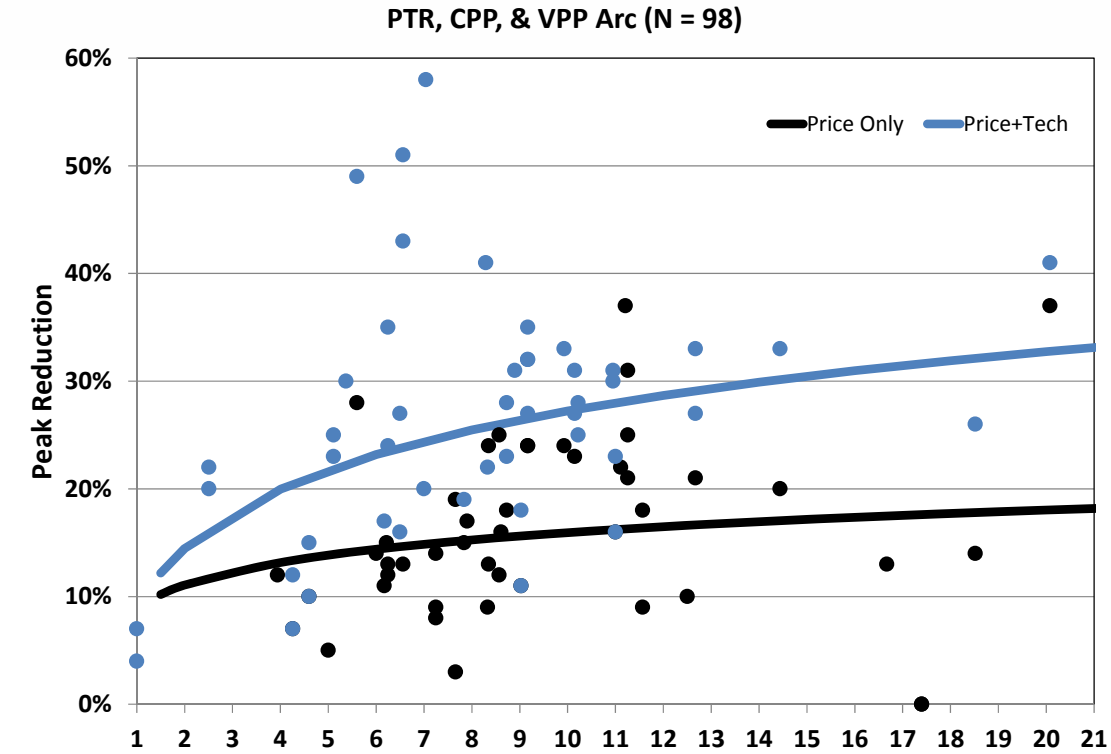
Using *iGrid*, we project that the customer-side benefits of AMI are nearly $400 billion in the US

Smart Grid Valuation Summary, 2010 - 2050
Present Value of Avoided Costs, Millions of $

	Meter O&M	Generating Capacity	Energy from Electricity*	Energy from Gasoline	Carbon	Reliability	Total
AMI	$44,618	$0	$0	$0	$0	$0	**$44,618**
DR (Dynamic Pricing)	$0	$25,080	$4,644	$0	$999	$0	**$30,723**
DR (Enabling Technology)	$0	$11,064	$2,139	$0	$460	$0	**$13,663**
EE (IHDs)	$0	$6,086	$38,559	$0	$8,294	$0	**$52,939**
EE (Building Commissioning)	$0	$7,869	$35,396	$0	$7,613	$0	**$50,878**
DERs	$0	$4,191	$10,088	$0	$1,113	$8,019	**$23,411**
Total without PHEVs	$44,618	$54,290	$90,828	$0	$18,479	$8,019	**$216,233**
PHEVs	$0	-$5,740	-$112,118	$297,418	$1,626	$0	**$181,185**
Grand Total	**$44,618**	**$48,549**	**-$21,290**	**$297,418**	**$20,105**	**$8,019**	**$397,418**

* Also includes value of ancillary services for DERs

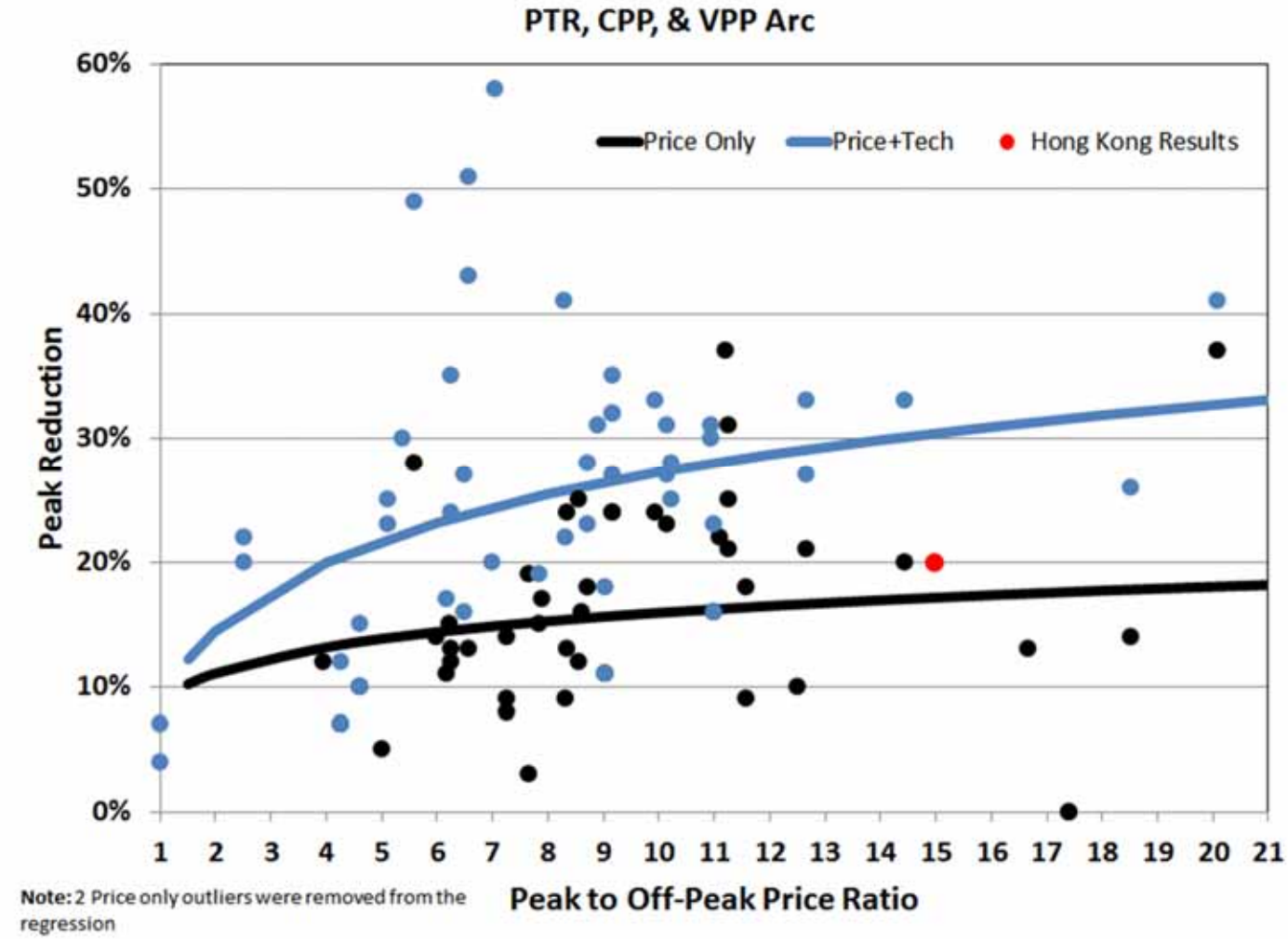
Many benefits arise from dynamic pricing which has been tested internationally



Note: 2 Price only outliers were removed from the regression

These "arcs of price response" were derived from a review of results from 34 projects in 7 countries across 4 continents that contained over 160 pricing treatments

CLP Power's new results are consistent with the international experience



Note: 2 Price only outliers were removed from the regression

Smart meters enable smart pricing in the US

Arizona

- Over two decades, APS has enrolled 51% of its customers on a voluntary TOU rate and the SRP has enrolled about 30% of its customers on a voluntary TOU rate
- In both cases, the TOU rate appeals to large consumers who avoid the upper tier of an inclining block rate by going with TOU

California

- PG&E has enrolled nearly 120,000 customers on an opt-in CPP program and a third are low income customers
- SCE is offering PTR on an opt-in basis and more than 2 million customers have signed on
- SDG&E is offering PTR on an opt-out basis to 1.2 million customers
- SMUD plans to roll out TOU pricing to all its half million customers in four years as the default rate

Smart pricing in the US (concluded)

Illinois

- Both the investor-owned utilities, ComEd and Ameren, have enrolled about 25,000 customers on RTP in Illinois
- A new state law calls for opt-in PTR to be offered statewide

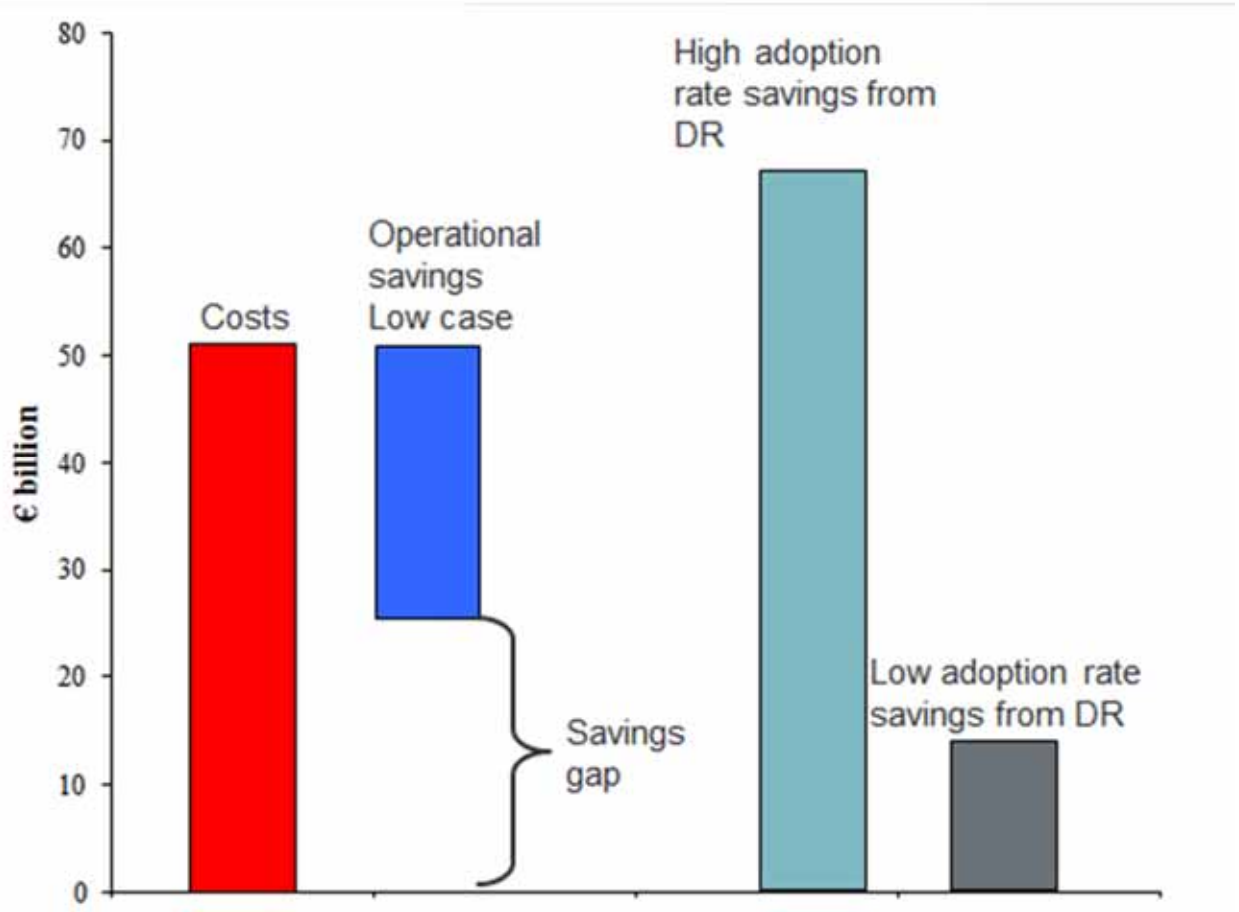
Mid-Atlantic Region

- BGE and PHI are rolling out PTR to 2 million customers in Delaware and Maryland
- PJM is allowing price-responsive demand to be bid into its multi-state capacity markets, as AMI and dynamic pricing are rolled out in its footprint of 51 million customers
- PEPCO has proposed PTR in District of Columbia

Oklahoma

- OG&E has 81,000 customers enrolled on VPP and/or TOU pricing
- In 2012, OG&E's VPP and TOU pricing programs cut demand by 135 MW

In the EU, dynamic pricing alone could yield nearly *€70* billion in net benefits



A brief survey of international smart grid strategies

Australia

Brazil

Canada

Egypt

Italy

Japan

Korea

United Kingdom

Smart Grid Developments in Australia

Australia has primarily focused on customer choice in its movement towards a smarter grid

Australia has funded a $100 million trial project called Smart Grid, Smart City to test smart grid technologies

- The project duration is 2010 to 2014 with up to 30,000 households participating

The Australian Government has launched a Solar City program in seven areas of Australia

- The Solar City program incorporates PV into the local grid

Sources: "Smart Grid, Smart City." http://www.smartgridsmartcity.com.au/
"Solar Cities." Australian Government: Department of the Environment.
http://www.climatechange.gov.au/energy-efficiency/solar-cities

Smart Grid Developments in Australia (concluded)

The Victorian AMI roll-out is due to be completed by the end of 2013

- Smart meters are being installed for residential customers and all industrial and commercial customers with annual consumption less than 160 MWh

The State of Victoria is testing the integration of electric vehicles with smart grid technologies in its electric vehicle trial, which will run until mid-2014

Sources: "Electric Vehicle Trial." State Government of Victoria: Department of Transport Planning and Local Infrastructure. http://www.transport.vic.gov.au/projects/ev-trial

Smart Grid Developments in Brazil

By 2023, the smart grid market in South America will reach $50 billion including investments in AMI, automated distribution, home energy management, and information technology

- Ecuador has set a smart grid timeline, while Colombia and Peru are both drafting smart grid plans
- Chile is developing smart city projects, and Argentina is funding smart grid R&D
- Brazil leads the way in smart grid roll-out with over 1 million smart meters deployed

Sources: Northeast Group, llc. “South America Smart Grid: Market Forecast (2013-2023).” Volume II. June 2013.
“Smart Grid Forum/2012: 2012 Report.” V Smart Grid Latin American Forum/2012. http://www.smartgrid.com.br/eventos/smartgrid2012/sg12_REPORT_2012.pdf

Smart Grid Developments in Brazil (cont.)

Resolution #502 requires that distribution companies provide smart meters to any low voltage customer upon request

- By requesting a smart meter, customers agree to a TOU tariff
- Smart meter installation will begin in 2014, and 100,000 meters are expected to be installed by the end of 2015

The Brazilian Electricity Regulatory Agency (ANEEL), the Brazilian Development Bank (BNDES) and the Brazilian Innovation Agency (FINEP) have a joint initiative called Inova Energia which will provide $1.4 billion (USD) for smart grid projects

Source: Ferreira, Rafael. PSR, Sao Paulo, Brazil.

Smart Grid Developments in Brazil (cont.)

Brazilian utility Ampla is executing a Smart City Project in Buzios

- The focus is on public lighting, electric vehicles, telecommunications, energy storage, renewable generation, and conscious customers

Portuguese utility EDP is spending ~4.6 million USD on the INOVGRID project in Aparecida do Norte

- The project focuses on technologies related to electronic measurement, distributed generation, energy efficiency, electric mobility, efficient public lighting, and community outreach

Source: "Smart Grid Forum/2012: 2012 Report." V Smart Grid Latin American Forum/2012. http://www.smartgrid.com.br/eventos/smartgrid2012/sg12_REPORT_2012.pdf

Smart Grid Developments in Brazil (concluded)

Challenges for a Brazilian smart grid:

- Expansion of renewable energy will not be a driver of smart grid design as in other countries because 75% of the country's 120,000MW installed capacity is already hydropower
- There is little opportunity for consumption reduction
- Hydro modulation keeps prices stable throughout the day, so demand response may be less important than in other countries

However, a Brazilian smart grid is still important:

- Nontechnical losses need to be reduced from 15.5%
- There are a lot of opportunities to improve reliability and quality of service

Source: Barroso, Luiz. "Smart Grids and Demand Response in Brazil: state-of-the-art and Analysis of Recent Proposals from the Regulator." PSR. IIT, Madrid 2012.

Developments in Canada

The province of Ontario has deployed AMI to 4.5 million households

The regulated retail rate plan features a time-of-use rate with peak, intermediate and off-peak periods

Most customers have chosen to receive service on this rate plan and the Ontario Power Authority is currently evaluating the impact of time-of-use rates on peak demand in the province

Sources: http://www.energy.gov.on.ca/en/smart-meters-and-tou-prices/;
http://www.powerauthority.on.ca/about-us/electricity-pricing-ontario/linking-costs-electricity-bill;
http://www.ontarioenergyboard.ca/OEB/Consumers/Electricity/Electricity+Prices

Egypt is considering the development of a smart grid

Egypt plans to integrate its grid with Europe through the Desertec project

A new transmission line will link Egypt to the Gulf Cooperation Council through Saudi Arabia, allowing the two countries to share 3,000 MW and draw from each other's supplies at different peak hours

Source: ElShenanawy, Tarek Ibrahim and Amr Abou-Ghazala. "Applying the Smart Grid Concept in Egypt: Challenges and Opportunities." January 2012. http://works.bepress.com/tarek_elshennawy/6

Egypt is considering the development of a smart grid (concluded)

Development of a smart grid would help Egypt harness its excellent wind and solar resources

Challenges include:

- Extreme air pollution can result in a black cloud phenomena over Cairo and Delta cities
- Hydropower is mostly exhausted
- Many projects are on hold as a result of political instability

Source: ElShenanawy, Tarek Ibrahim and Amr Abou-Ghazala. "Applying the Smart Grid Concept in Egypt: Challenges and Opportunities." January 2012. http://works.bepress.com/tarek_elshennawy/6

Smart Grid Developments in Italy

AMI has been rolled out to all 29 million households

- Default time-of-use pricing for 23 million residential and small-medium enterprises

A recent analysis of Italy's mandatory TOU concluded that more than half of customers have shifted consumption patterns in the first year

- The overall customer savings were € 2.54 million in the first year

Italy's Energy Authority has approved a percentage bonus on the authorized rate of return for smart grid pilots, investments in electric vehicles, and storage systems

- On the distribution side, 7 projects have been selected to pilot smart grids
- On the transmission side, 6 projects have been selected to pilot electrochemical storage

Sources: Velente, Francesca. Enel. Schiavo, Luca Lo. AEEG. Service Quality and Consumer Affairs, Deputy Director. "Smart Regulation in Italy in From of the Energy Transition." October 2013. Benini , Michele et al.. "Impact of a Mandatory Time-of-Use on the Italian Residential Customers." R.S.E.. Email correspondence with Luca Lo Schiavo of Italy's Energy Authority

Smart Grid Developments in Japan

Japan has had four Smart Community Projects piloting smart technologies and pricing in specific cities:

- **Kyoto:** the Keihanna Eco-City Next Generation Energy and Social Systems program enrolled 680 customers on TOU pricing and variable CPP. Also, 1,000 households installed PV
- **Yokohama:** the Yokohama Smart City Project enrolled 3,000 customers with TOU pricing and CPP. 27MW of PV were deployed in conjunction with the project
- **Fukuoka:** the Kitakyushu Smart Community Project enrolled 230 customers with variable CPP. Smart meters had real time energy management capabilities
- **Toyota:** the Toyota City Low-carbon Society Verification Project enrolled 160 customers with CPP

Source: Hattori, Toru. "Demand Response Experiments in Smart Grid Projects in Japan." CRIEPI. October 17, 2013.

Smart Grid Developments in Japan (concluded)

Stanford's Koichiro Ito evaluated Japan's four Smart Community Projects and concluded that customers *do* respond to hourly marginal prices

- Ito found that the various CPP treatments reduced consumption by 11% on average

Other major Japanese cities are piloting smart meters and smart pricing:

- **Tokyo and Osaka:** the Smart Meter Pilot Project involved 900 customers with TOU pricing, CPP and direct load control
- **Kyushu:** the Kyushu Electric Power Company enrolled 1,050 customers on TOU pricing and CPP

Sekisui House, Japan's largest homebuilder, puts solar power in 80% of all new houses and fuel cells in 50%

Sources: Ito, Koichiro et al. Stanford University. "Using Dynamic Electricity Pricing to Address Energy Crises Evidence from Randomized Field Experiments." March 2013. http://www.econ.kyotou.ac.jp/~ida/4Hoka/smagri/20133023Ito_Ida_Tanaka_Dynamic_Pricing.pdf
Berst, Jesse. Smart Grid News. "Grid Divorce, Japanese Style. Will it come to a country near you?" September 25, 2013. http://www.smartgridnews.com/artman/publish/Business_Strategy/Grid-divorce-Japanese-style-Will-it-come-to-a-country-near-you-6054.html#.UmluF_mkqtY

Smart Grid Developments in Korea

On August 18th, the Ministry of Trade, Industry, and Energy decided on several measures to promote a demand management-oriented grid:

- Wind power generators will receive renewable energy certificates that incentivize contributions to peak load through energy storage systems
- New buildings with over 10,000 square meters of floor space and factories that consume over 23,000 MWh of electricity will be encouraged to install energy management systems
- For smaller companies, the cost of energy management systems may be compensated 50%

Source: Energy Korea. "Power Stored in ESSs Can Be Sold for Higher Prices in New Market." August 20, 2013. http://energy.korea.com/archives/58278

Smart Grid Developments in Korea (concluded)

Jeju Island is one of the South Korea's nine provinces (population=583,284)

- In 1996, the island's power grid was connected to the mainland with the HVDC Haenem-Cheju, a 101 km submarine cable. Jeju also has some of its own generating facilities including the Jeju Thermal Power Plant. The grid is overseen by the Korea Electric Power Corporation, KEPCO
- In February 2012, the director of the Electricity Market and Smart Grid Division at the Korea Ministry of Knowledge Economy signed a letter of intent to share information about smart grid technologies with the governor of Hawaii
- The Jeju smart grid was initially installed in 6,000 homes and is being expanded
- South Korea has the goal of a nationwide smart grid by 2030, and the pilot on Jeju island is the first step towards that goal

Source: The Jeju Weekly. "Korea and Hawaii Join Forces in Smart Grid Venture." February 24, 2012. http://www.jejuweekly.com/news/articleView.html?idxno=2417

Developments in the United Kingdom

According to the Government Renewable Energy Strategy, 35% of UK electricity demand will be met with renewable generation by 2020

If the targets proposed by the UK Government Committee on Climate Change are met, almost 100% of the UK electric power grid will be decarbonized by 2020

Full penetration of electric vehicles and heat pumps could increase daily electricity consumption by 50%. However, optimal demand response could restrict the peak increase to 29%

Sources: Strbac, Goran et al. “Benefits of Advanced Smart Metering for Demand Response based Control of Distribution Networks .” Imperial College London. April 2010. http://www.energynetworks.org/modx/assets/files/electricity/futures/smart_meters/Smart_Metering_Benerfits_Summary_ENASEDGImperial_100409.pdf

Developments in the UK (concluded)

The UK government plans to install a smart meter in every home by 2020, spelling an end to estimated billing

- Over the next 20 years the installation of smart meters will provide £6.7 billion net benefits to the UK: the program will cost £12.1 billion and provide £18.6 billion in benefits

British Gas expects the smart meters to "transform the way people think about and use energy", encouraging them to reduce usage by as much as 5%, which would save £65 off an annual dual fuel bill

- The company says the meters could also reduce the strain on Britain's power grid by enabling new tariffs that reward customers for shifting their usage to times of lower national demand

Sources: https://www.gov.uk/government/policies/helping-households-to-cut-their-energy-bills/supporting-pages/smart-meters.
http://www.telegraph.co.uk/finance/newsbysector/energy/10310720/British-Gas-contract-creates-600-jobs-as-smart-meter-roll-out-begins.html.

Conclusions

Smart grid strategies vary widely across countries, reflecting their unique circumstances and policy drivers

- However, a common element across all countries is a strong emphasis on the consumer's wellbeing

Smart grid has the potential for providing significant gains to electricity consumers in the form of higher reliability, lower bills and cleaner air

A variety of pilot programs, many involving smart communities and smart cities, are being deployed around the globe to bring this vision to reality

Presenter Information

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Dr. Ahmad Faruqui is a Principal with The Brattle Group who specializes in analyses and strategy relating to the customer. He has helped design, monitor and evaluate energy efficiency investments for a wide range of electric and gas utilities and testified before a dozen state and provincial commissions and legislative bodies. He has also worked for the Alberta Utilities Commission, Edison Foundation, the Edison Electric Institute, the Electric Power Research Institute, the Federal Energy Regulatory Commission, the Ontario Energy Board and the World Bank. His work has been cited in publications such as *The Economist*, *The New York Times*, and *USA Today*, and he has appeared on Fox News and National Public Radio. The author, co-author or editor of four books and more than 150 articles, he holds a Ph.D. in economics from The University of California at Davis and B.A. and M.A. degrees in economics from The University of Karachi.

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