UCLA E183EW Presentation:

Smart Grid

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INTRODUCTION BY NINH

The Utility Grid

- 100 years old
- Infrastructure:
  - Centralized
  - Interconnected

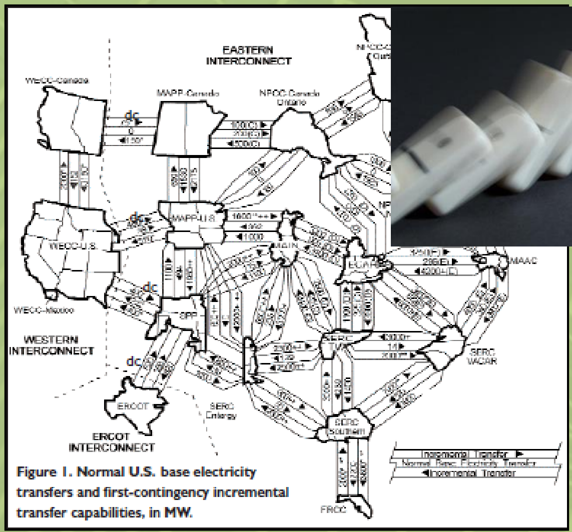
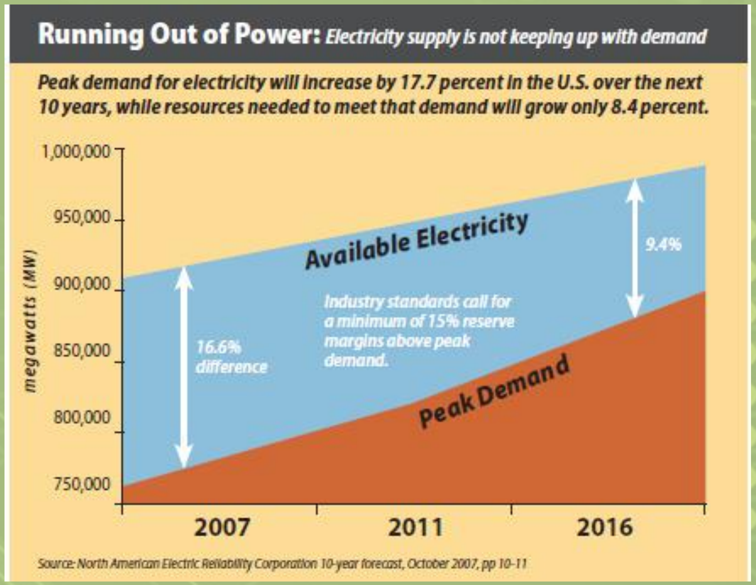


Figure 1. Normal U.S. base electricity transfers and first-contingency incremental transfer capabilities, in MW.

http://www.aip.org/tip/INPHFA/vol-9/iss-5/p8.html

- Running Out of Power:



http://energy.gov/oe/technology-development/smart-grid

Ninh Le

August 14, 1998

Northeast United States

September 8-9, 2011

from Mexico to Southern Orange County

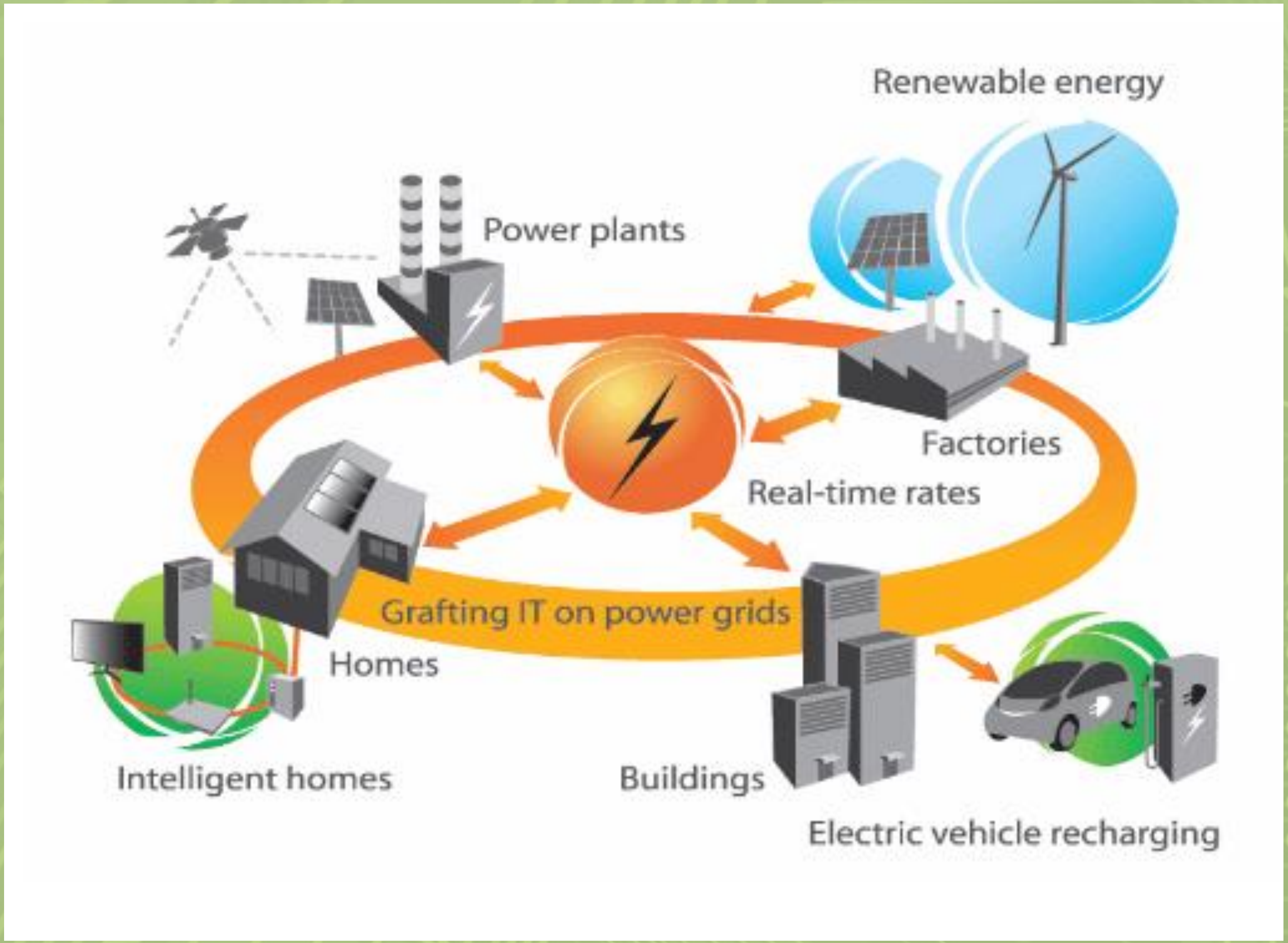
What are the Problems?

- Power outage and interruption
  - Silicon Valley blackout: $75 million in losses.
  - In 2000, one-hour outage at Chicago Board of Trade: $20 trillion in trades delayed.
- Security:
  - vulnerable to cyber attack
- Inefficiently managing peak load
  - Buy from **private company** vs. build **new plant**
  - Expensive → we are paying average price
- Management:
  - Worker: gather data, read meters, look for broken equipment

http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages%281%29.pdf

Ninh Le

Smart Grid



http://smartgrid.jeju.go.kr/eng/contents/index.php?mid=01

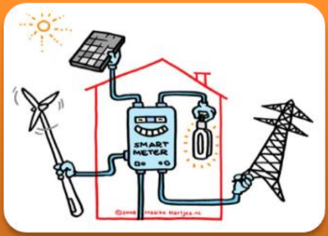
Potential of Smart Grid

- Supply for increasing demand
- Energy efficiency and reliability
- Save money: consumers and utility
- Smart home:
  - energy saving
  - reliable appliances
  - safety
- Environmental:
  - energy
  - land resource
  - reduce carbon emission

http://s430.photobucket.com/albums/qq25/7ustaGirl/?action=view&current=future.jpg&newest=1

Challenges

Technical



- Construction: generation, transmission, distributions
- Application: metering, application, security

Monetary

- Huge Investment

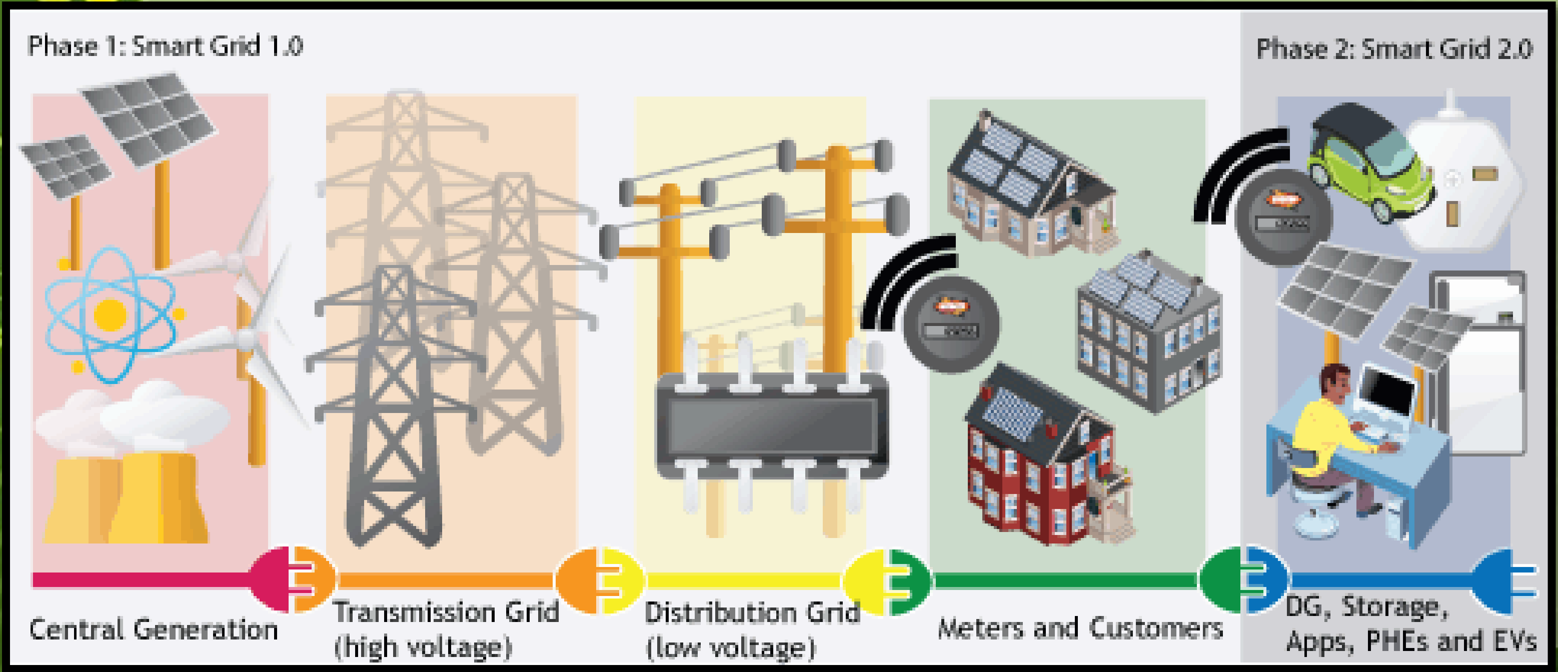
Societal

- Consumers: Privacy, Health, Pricing
- Society: Security, unexpected impacts
- Environment

TECHNICAL ISSUES BY WILSON

Actual Construction

- Huge investments by both government and companies
- Technological investments goes to developments of:
  - Electric Vehicles (EVs)
  - Advance Metering Infrastructure (AMI)
  - Home Area Network (HAN)
  - (NOTE: There are many more that are important toward smart grid research but only these few will be discussed)



(Austin Energy, 2012)

Wilson Lam

Electric Vehicles (EVs)

U.S. Department of Energy definition of EV – is an electric vehicle that can "draw electricity from a battery with a capacity of at least four kilowatt hours and (…) is capable of being charged from an external source."

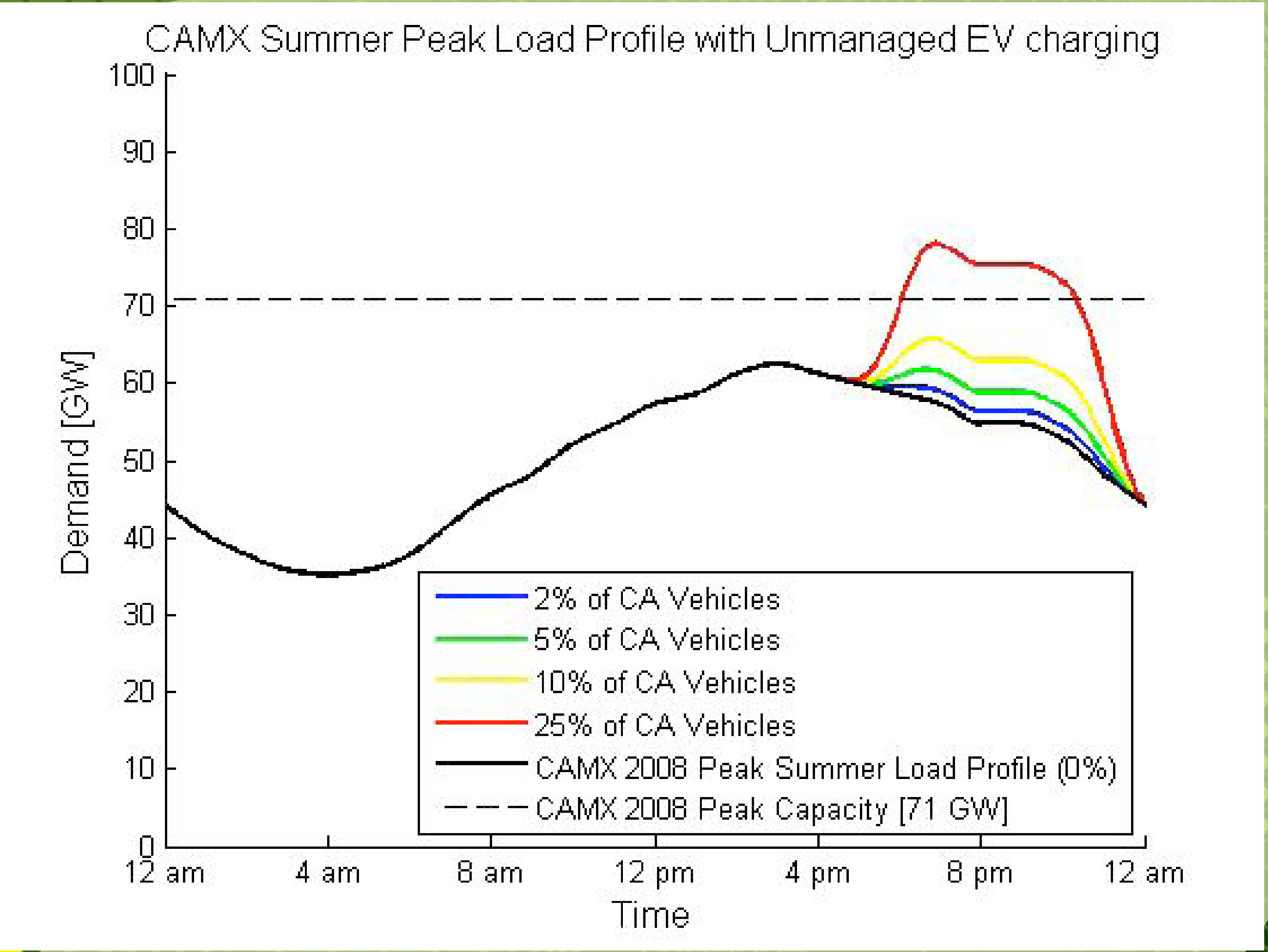
These technologies will enable better EVs connection with the smart grid:

- Grid to Vehicles (G2V) and Vehicles to Grid (V2G - problematic)
  - Infrastructure
  - Smart charging stations
  - Standards:
    - SAE 1772 (helps eliminate different plugs creation)
    - Grid tie inverter to convert DC to AC for V2G

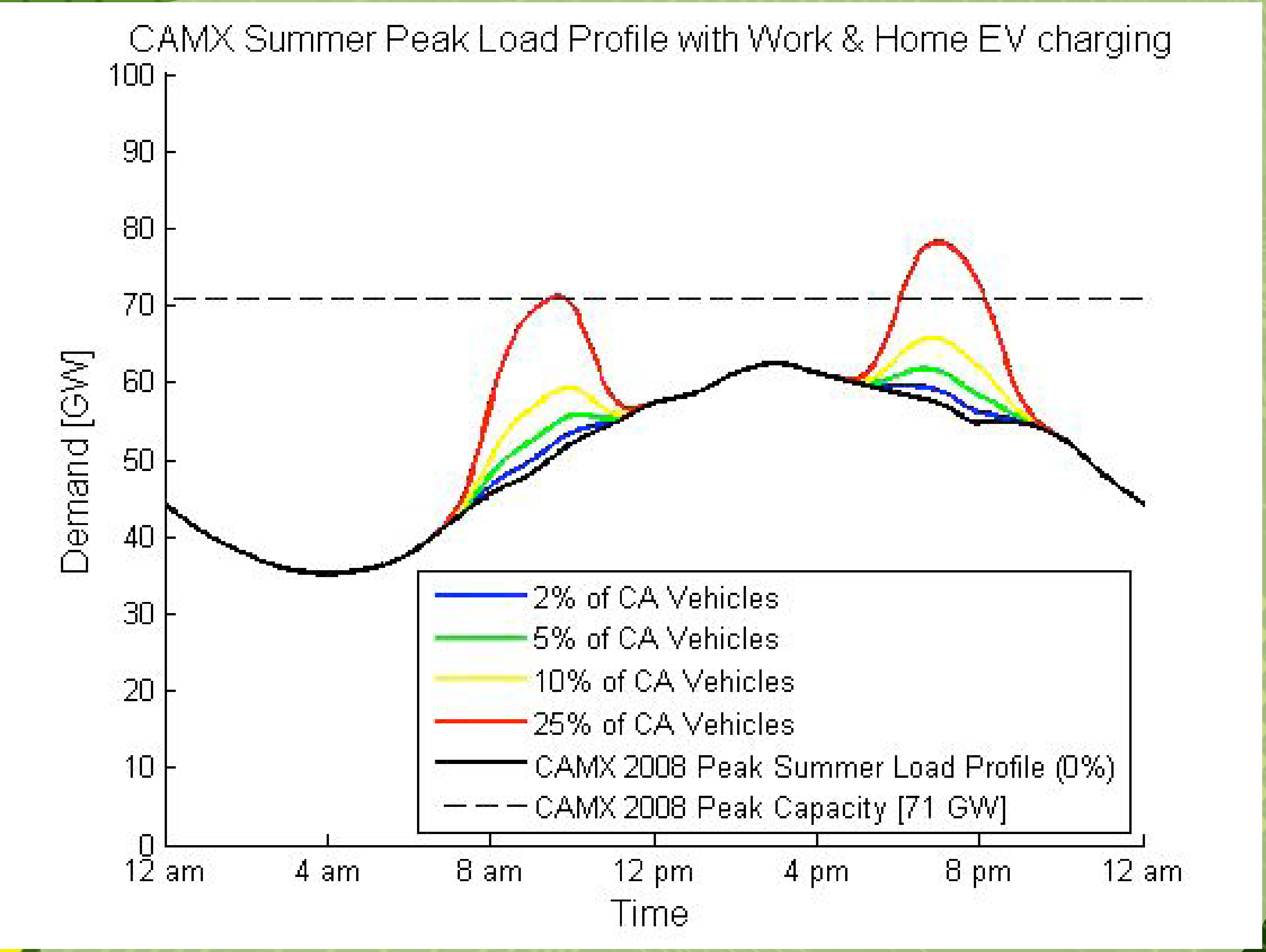
Wilson Lam

EVs - Issues

- Peak issues – occurs when electricity demand increase over the nominal greatly
- EVs will introduce more peak issues if charging time is unmanaged
- V2G (Grid Tie Inverter will fix this problem)
  - → Can result in phasors, voltage, and frequency issues
    - →Blackout
    - →Brownout

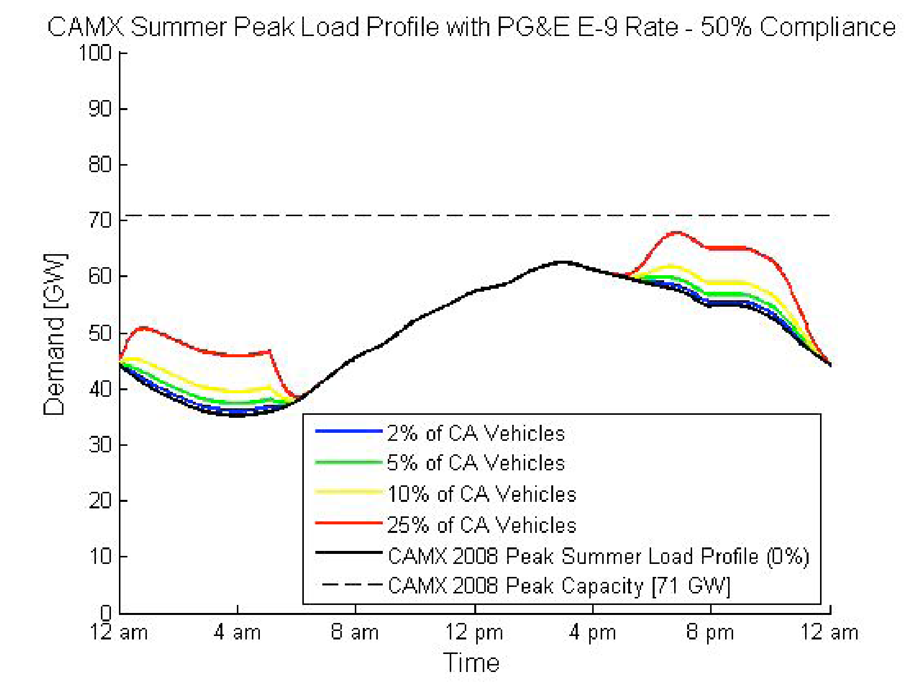


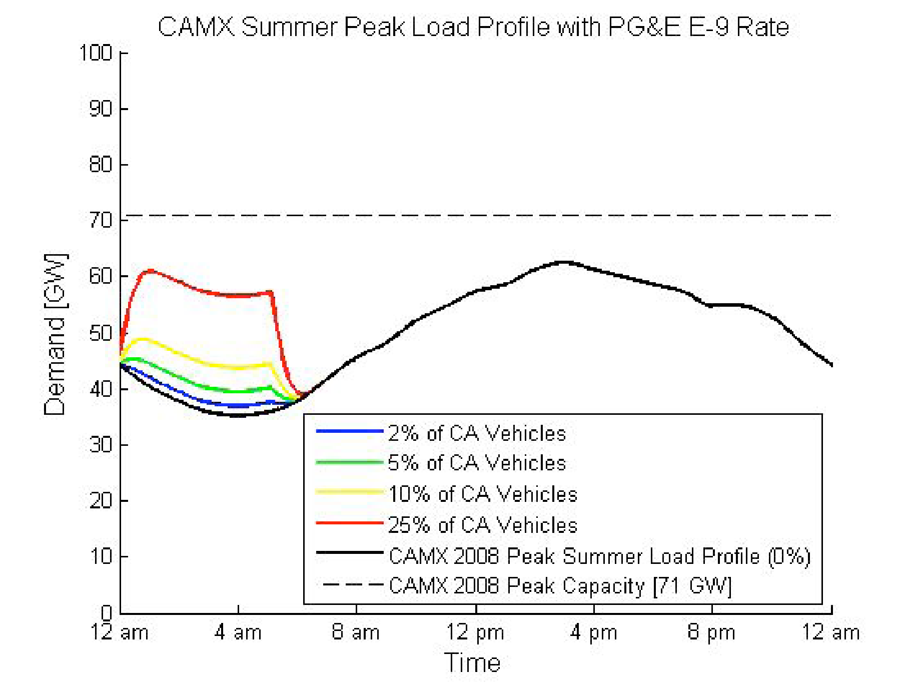
(DeForest, Funk, Kaminsky, Lorimerm, Sidhu, Tenderich, and Ur, 2009)



(DeForest, Funk, Kaminsky, Lorimerm, Sidhu, Tenderich, and Ur, 2009)

EVs – Solutions





- Creating incentives can help prevent people from charging during peak times

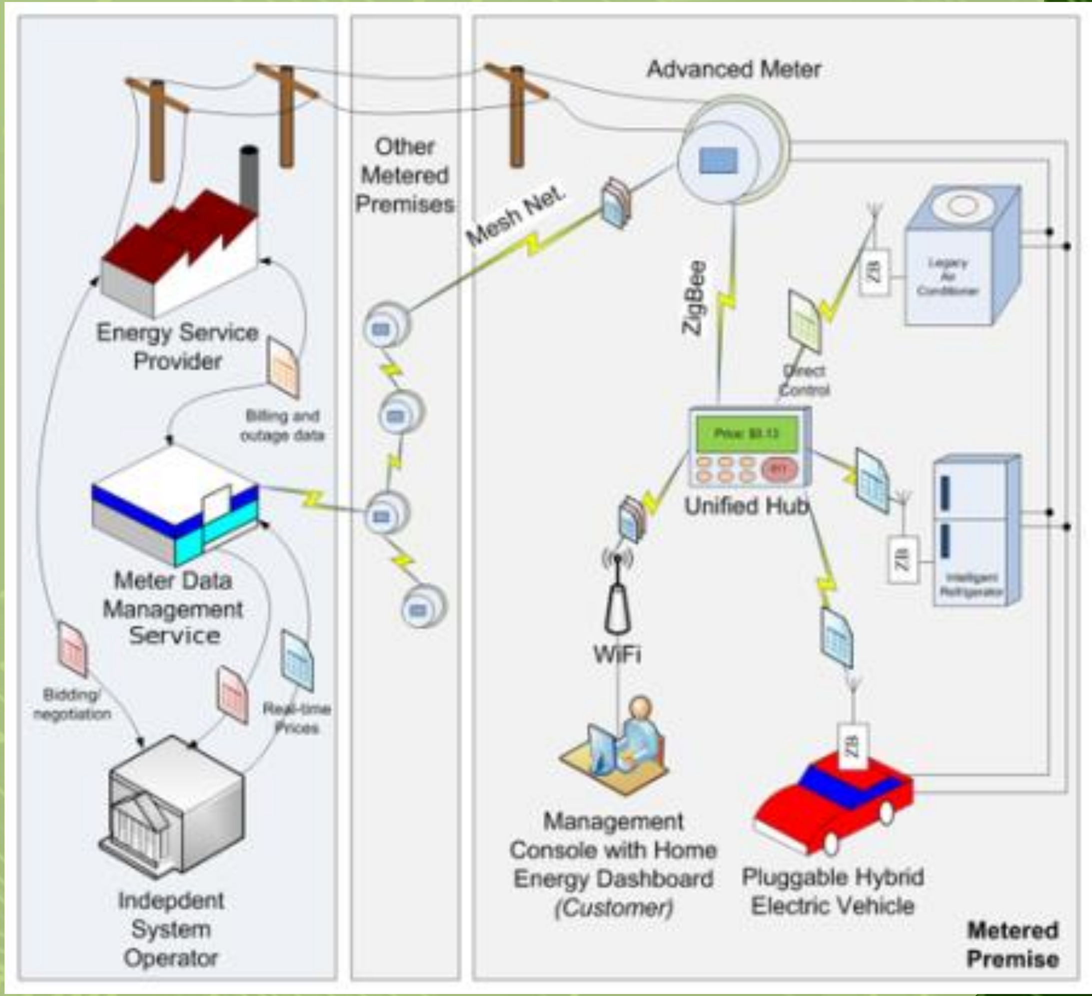
- Results: 97% of existing peak
- If EVs participate in DR market and sell electricity back to the grid better peak shaving can be achieve

Both Figures are from:
(DeForest, Funk, Kaminsky, Lorimerm, Sidhu, Tenderich, and Ur, 2009)

Wilson Lam

Advanced Metering Infrastructure (AMI)

- AMI – manage, collect, store, and transmit data
- Bi-directional flow of data between the consumers and grid managers
- Collected data are processed and used to predict best method to manage the utility grid



(Illinois Security Lab, 2011)

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AMI – Issues

- Development of technology
- Installation of smart meters
- Fear of risk in AMI and technologies slow down process of AMI
- Large investments must be made by governments and companies before AMI can grow and become self-regulating
- Technologies that can be integrated with AMI are still mostly in the research stage (fear of AMI abandonment if AMI usefulness does not reach expectation)

(Steiger, 2012)

(Steiger, 2012)

Wilson Lam

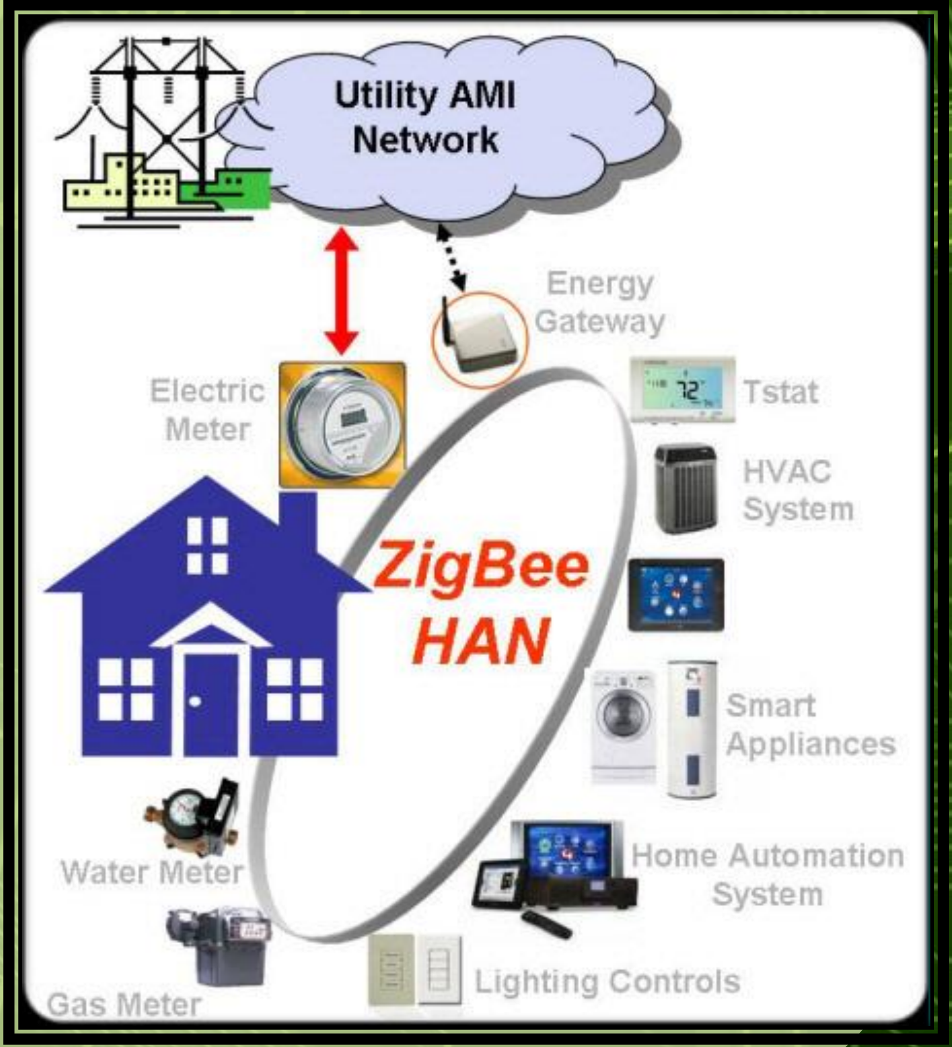
AMI – Solutions & Success

- **Glendale Water and Power (GWP)**
  - Operational wireless communication
  - Data → smart meter → bills (electricity & water meter are integrated)
- **Government funded $20 millions (DOE) + companies investments**
- **Returns and savings:**
  - Better monitoring of grid health
  - Reduce electricity consumption
  - Prevent electricity peaks

All 3 images are from same source GWP (Steiger, 2012)

Home Area Network (HAN)

- HAN gather data, operate, and sent information
- HAN is basically a home smart appliance controlling device
- Sent and receive information from utility grid managers to manage appliances
- Consumers can control, input, and set schedule for smart appliances electricity consumption



(Skip, 2008)

HAN – Issues & Solutions

Issues

1. Technologies of smart appliances that can be integrated with HAN are still in research stage
2. Communication network for HANs consideration
3. Financial burden of cost of HAN technologies installation

Solutions

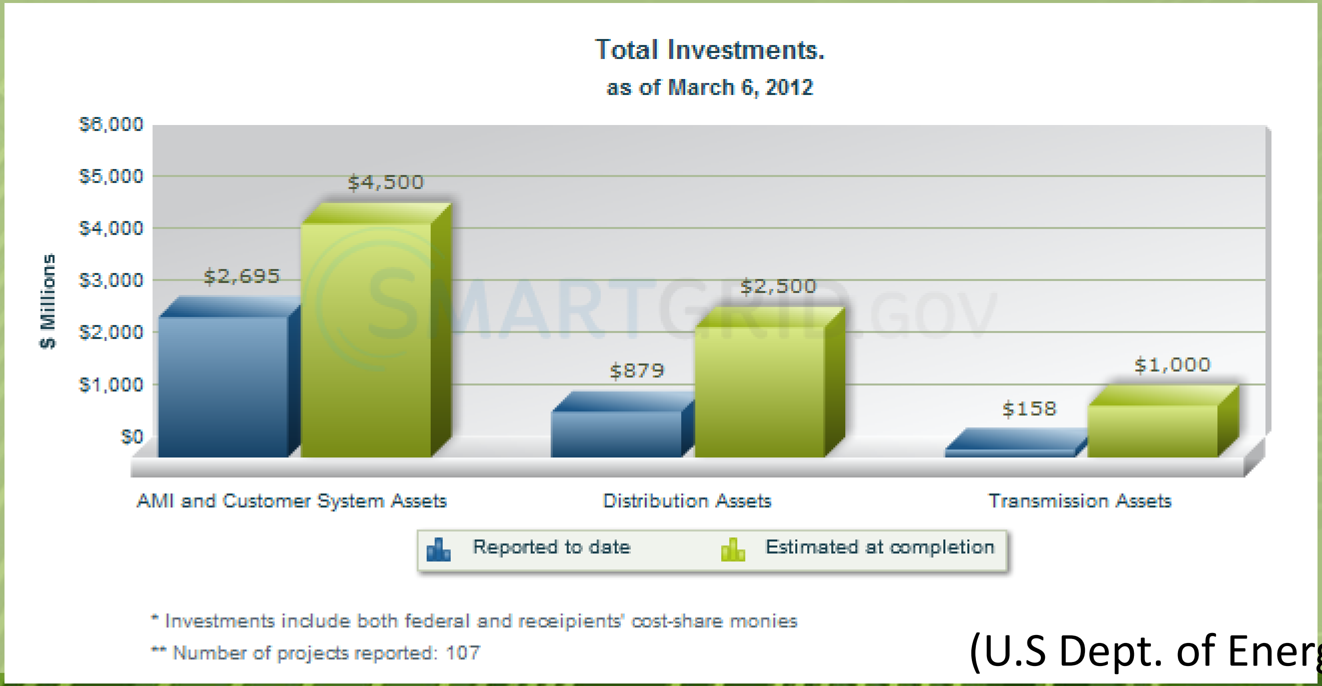
1. Pour more money into research
2. Zigbee, Z-Wave, and Wi-Fi are possible solution for easy communication home appliances
3. Utility companies can create incentives for consumers to participate in HAN

TECHNICAL ISSUES BY RAY

Cost Vs. Return

Cost In development of infrastructures

- Estimated cost of Smart Grid Deployment: approx. $8 billion
- United States Investment: $3.4 billion
- Smart Grid Investment Grant Program: approx. $4.6 billion



(U.S Dept. of Energy , 2012)

Ray Avalos

Cost Vs. Return

- Does Return of Investment outweigh Cost of Installation?
  - Case: San Diego Smart Grid Study Report

Scenario	Regional IRR* (%)	NPV ($M)	Point of Positive Cash Flow** (Yrs)	First Year Annual Benefits Top $50M
Earliest Positive Cash Flow	75%	403	3.5	2017
Maximum Benefits Early	26%	508	7.0	2012
Optimized IRR	44%	416	5.5	2014

Total Investment: $450 million

Total Savings: $1.4 billion

(SAIC Smart Grid Team, 2006)

Ray Avalos

Cost vs. Return

- Options in Smart Grid Communications Technologies
  - Must handle output data to deliver reliable, secure and cost-effective service through system

SMART GRID COMMUNICATIONS TECHNOLOGIES

Technology	Spectrum	Data Rate	Coverage Range	Applications	Limitations
GSM	900-1800 MHz	Up to 14.4 Kpbs	1-10 km	AMI, Demand Response, HAN	Low date rates
GPRS	900-1800 MHz	Up to 170 kbps	1-10 km	AMI, Demand Response, HAN	Low data rates
3G	1.92-1.98 GHz 2.11-2.17 GHz (licensed)	384 Kbps-2 Mbps	1-10 km	AMI, Demand Response, HAN	Costly spectrum fees
WiMAX	2.5 GHz, 3.5 GHz, 5.8 GHz	Up to 75 Mbps	10-50 km (LOS) 1-5 km (NLOS)	AMI, Demand Response	Not widespread
PLC	1-30 MHz	2-3 Mbps	1-3 km	AMI, Fraud Detection	Harsh, noisy channel environment
ZigBee	2.4 GHz-868-915 MHz	250 Kbps	30-50 m	AMI, HAN	Low data rate, short range

(IEEE Transactions on Industrial Informatics, 2011)

Consumer Concerns

- Appliance Compatibility
  - Applications, techniques, and solutions are being developed
    - Need for adoption of interoperability standards
- Risk of Cyber-Attacks/System Stability and Reliability
  - Harnessing Modern/Secure Information Protocols
  - Faster/More robust control devices
  - Embedded Intelligent Devices

Image From: https://www.pikeresearch.com/

Ray Avalos

Consumer Concerns

- Carbon Emissions
  - United States is 2^{nd} Largest Carbon Emitter in the World
  - Creates drastic climate change from global warming
  - Smart Grid is designed to reduce carbon emissions. How?

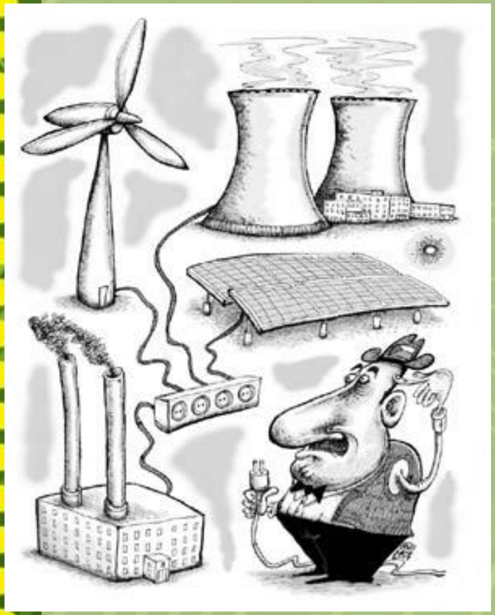


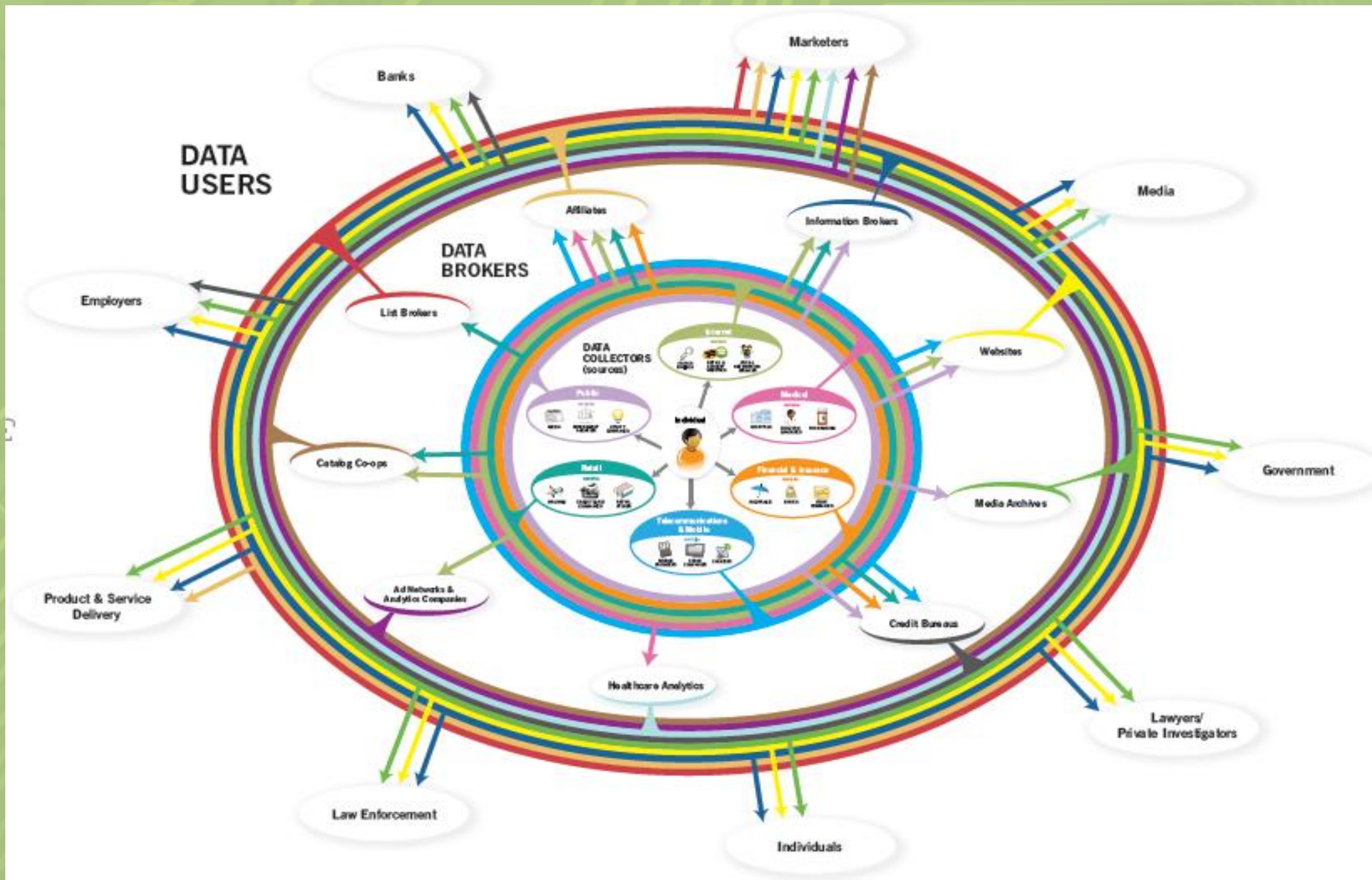
Image From: http://www.renewable-energy.fr/

Image From: http://www.siliconrepublic.com/

Ray Avalos

ETHICAL ISSUES BY ALAN

Consumer Privacy Issues



http://www.ftc.gov/os/2010/12/101201privacyreport.pdf

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Privacy Solutions

Consumer Responsibility

http://www.surrey.police.uk/about/dp.asp

Centralized Monitoring

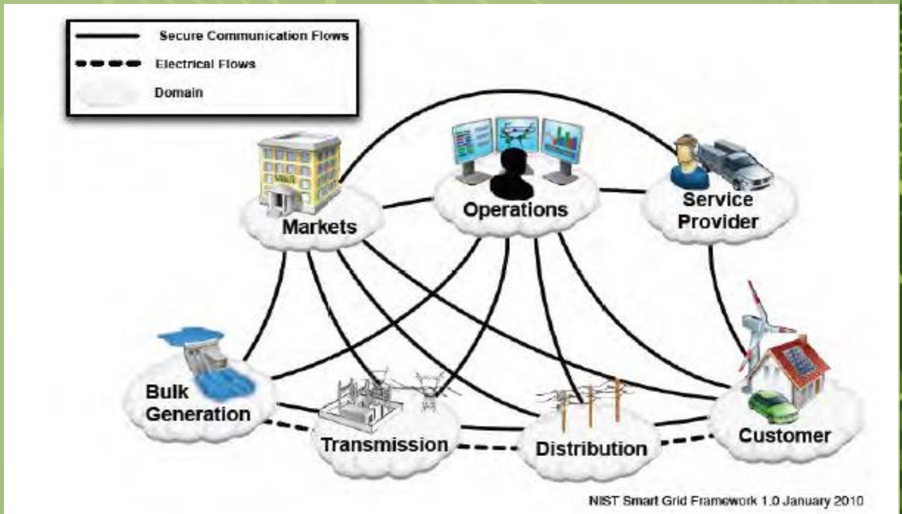

Figure 2-1 Interaction of Actors in Different Smart Grid Domains through Secure Communication Flows

http://www.lawandenvironment.com/articles/renewable-energy/

Smart Standards and Regulations

http://www.infosecurity.us/blog/2011/5/12/nist-request-for-comments-cloud-computing.html

http://hps.org/hpssc/

http://www.iecee.org/

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Pricing/Availability Concerns

http://en.wikipedia.org/wiki/Disability

http://www.post-gazette.com/pg/09224/990133-68.stm

http://occupywinstonsalem.org/2012/02/10/over-300-million-in-corporate-greed-protest-unfair-job-cuts/#.T1gvoVSqnTo

Alan Yip

Dynamic Pricing

http://mediatransparent.com/wp-content/uploads/2010/10/price_is_right_logo.jpg

- Actually fair for everyone
- Requires little participation of consumer
- Can be used with current grid, but it’s effect would be maximized with the smart grid

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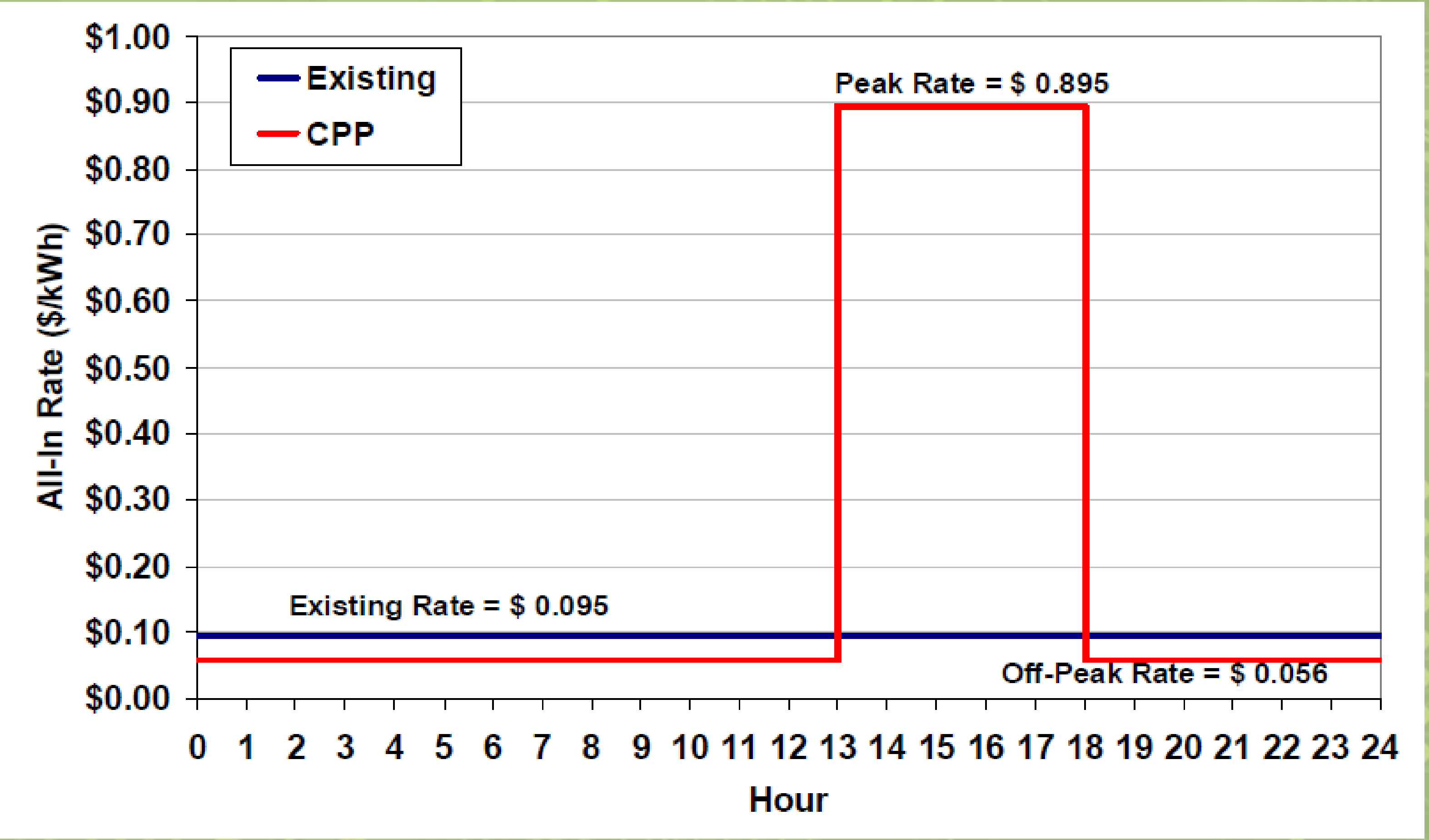
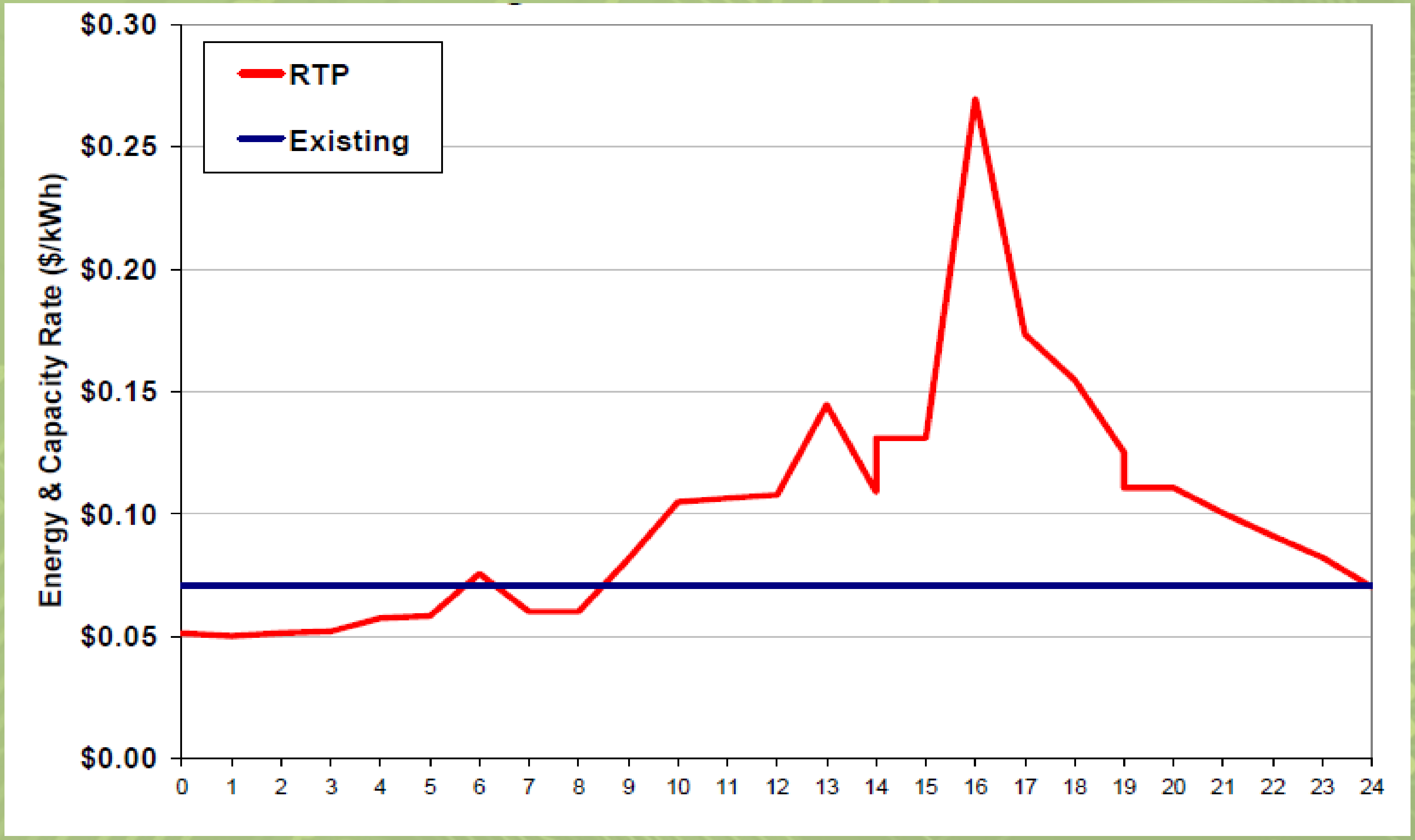
Critical Peak Pricing



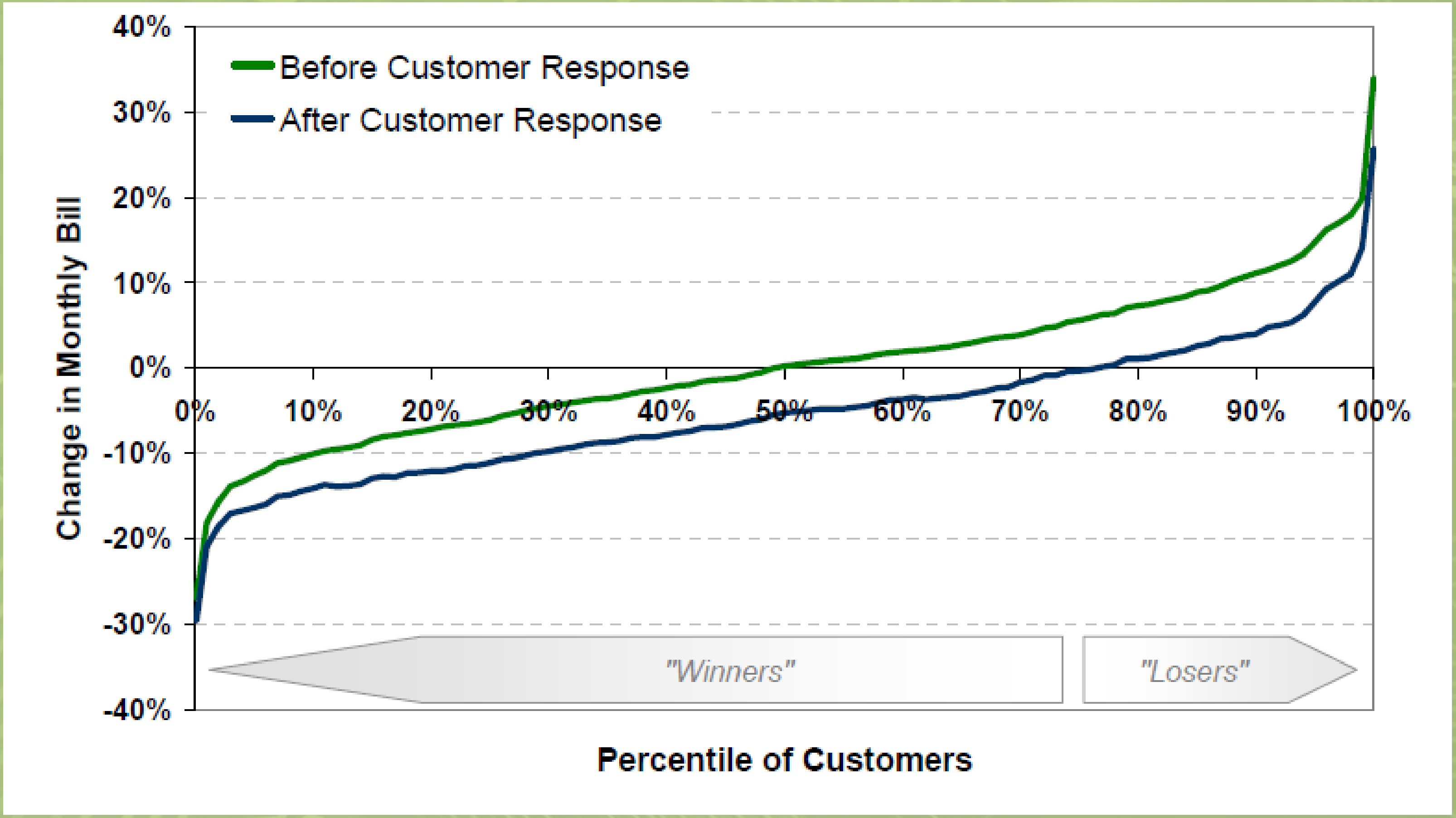
(Faruqui, 2010)

Real Time Pricing



(Faruqui, 2010)

Bill Effects



(Faruqui, 2010)

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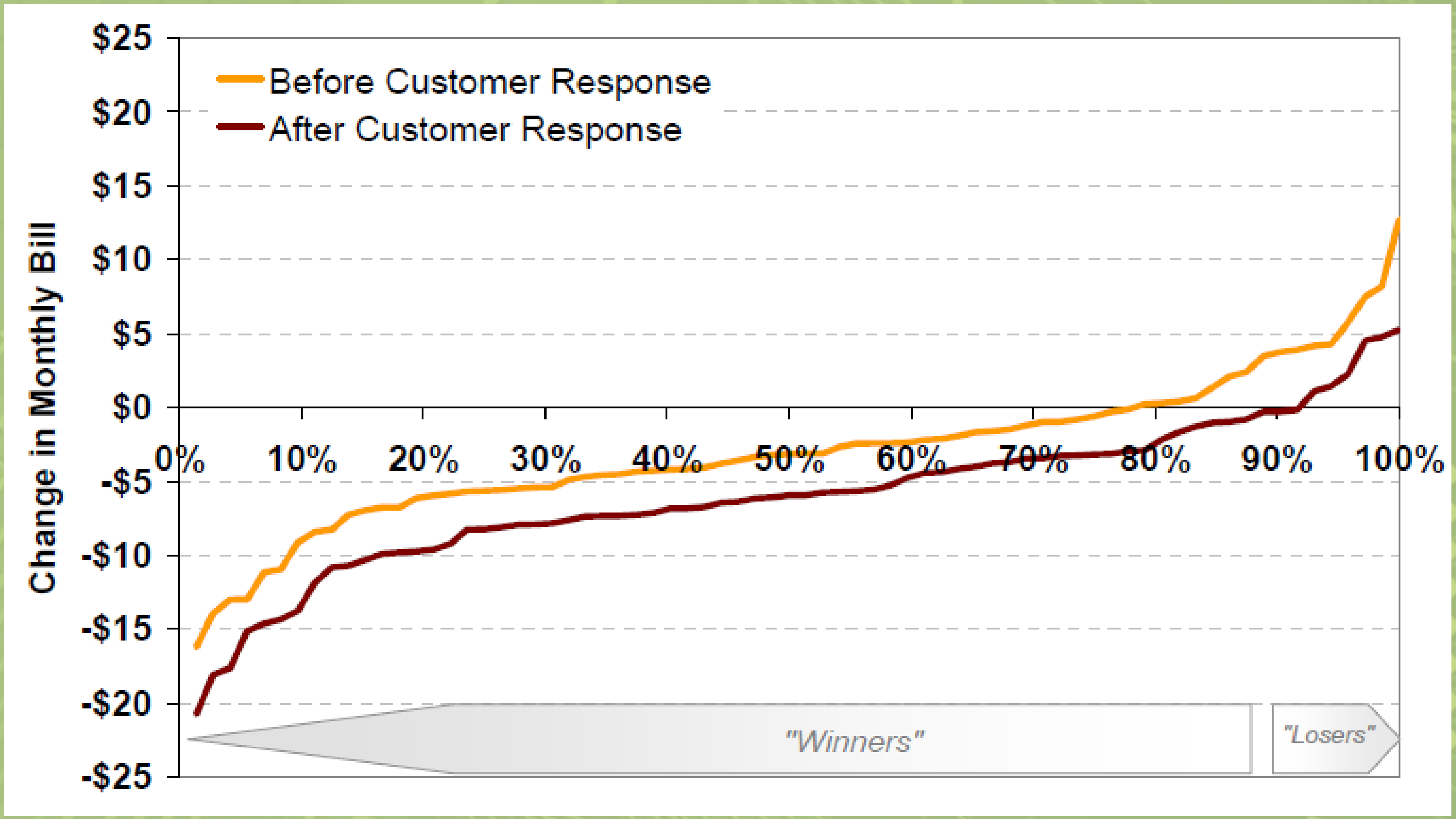
Bill Effects for Low Income Consumers



(Faruqui, 2010)

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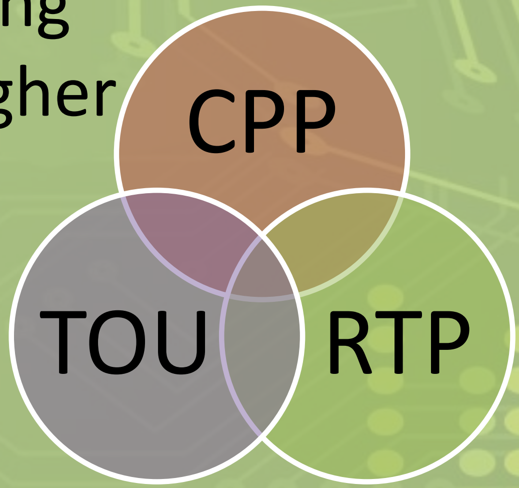
Dynamic Pricing Requirements

- Bill Protection
  - Protect consumers from having to switch to a price that is higher than what they currently pay



- Consumer Choice of plan
  - Combine different types of plans (CPP, TOU, RTP) for customized payment plan

Current Uses of Dynamic Pricing

http://uhaweb.hartford.edu/mailloux/Planes.html

http://sfappeal.com/news/2010/10/cops-caution-against-buying-world-series-tickets-from-scalpers-say-some-who-did-now-out-biug-bucks.php

http://www.nvudev.com/green-techs-for-cell-phones.html

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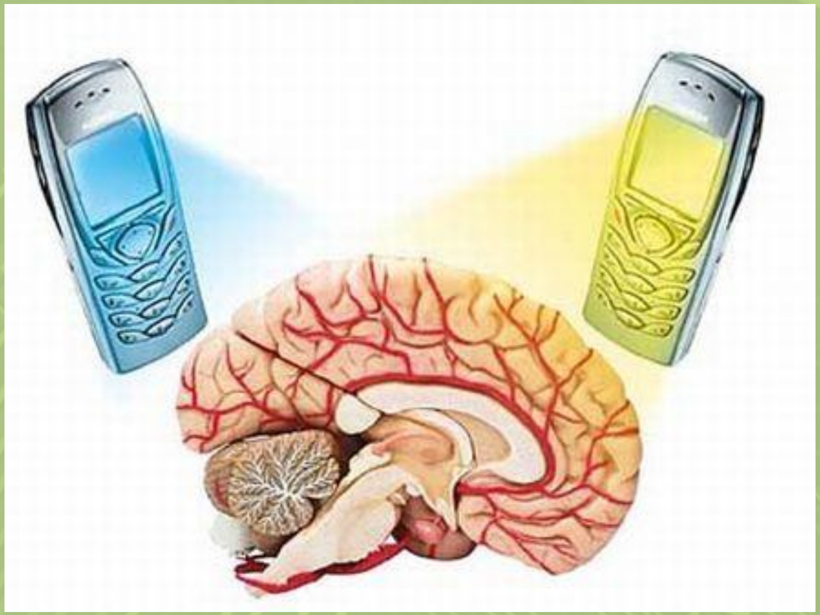
Health Concerns

Radio Frequency (RF) Radiation



http://scienceinthetriangle.org/wp-content/uploads/2011/03/cellphone-radiation.jpg

Symptoms:

- Cancer
- Immune System Deficiency
- Fertility Problems
- Sleeplessness
- Dizziness
- Memory Loss
- Headaches
- Fatigue

(Perlingieri, 2011)

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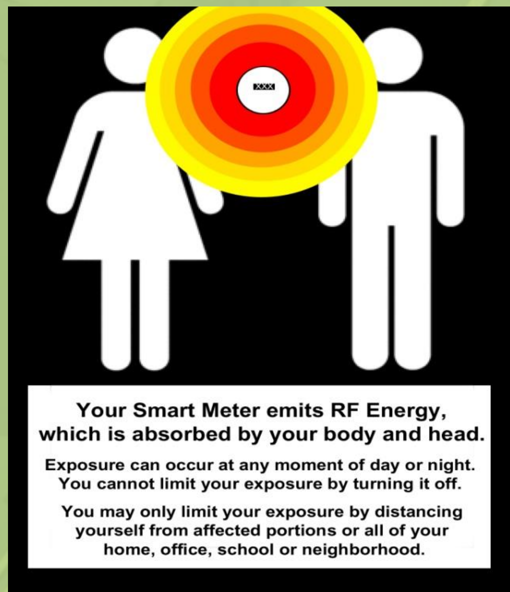
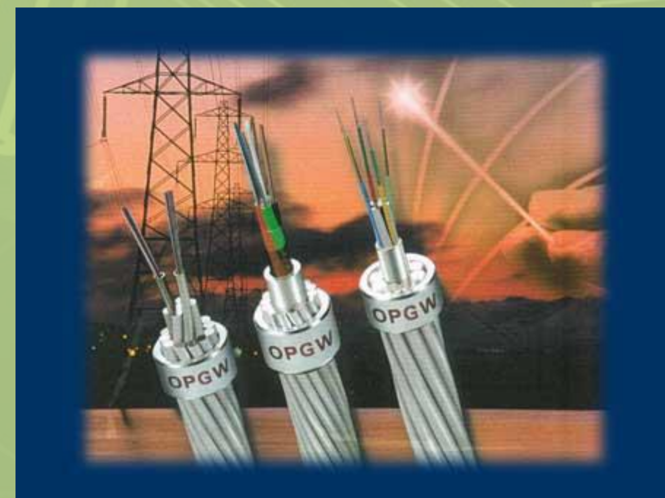
Solutions to Health Concerns

Research on Smart Meter appliances



http://stopsmartmeters.org/wp-content/uploads/2011/10/RTW-Smart-Meter-Warning2.jpg

Fiber Optics/Wired Solutions



http://bmpjakarta.com/slide/images/OPGW2.jpg

Smart Standards and Regulations

NIST

http://www.infosecurity.us/blog/2011/5/12/nist-request-for-comments-cloud-computing.html

ANSI
ANSI Accredited Standards Developer

http://hps.org/hpssc/

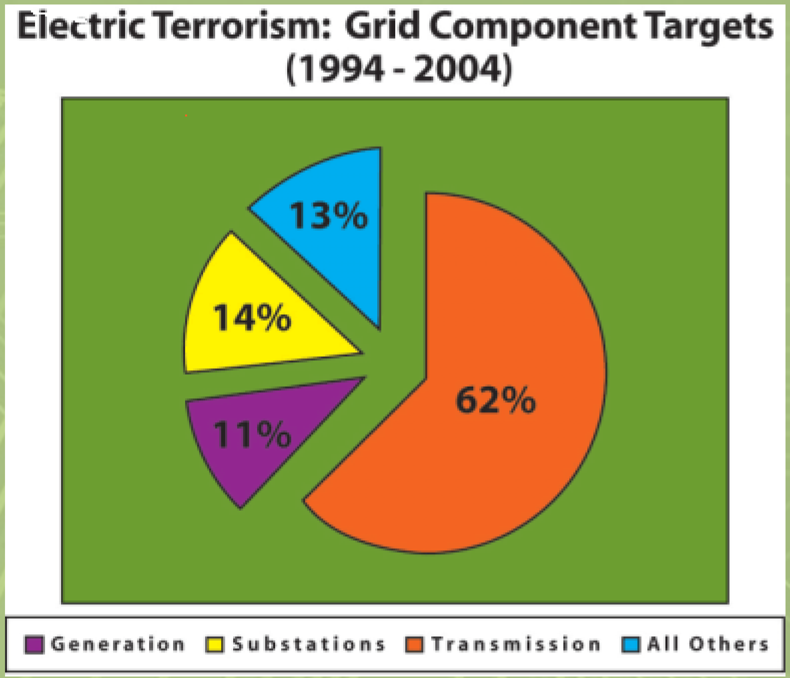
IEC

http://www.iecee.org/

Alan Yip

National Cyber Security

– Estimate that 80% of the intelligence needed to plan a successful attack on the US and the smart grid can be found on open sources such as the internet
– $500 of equipment and basic electrical knowledge is sufficient to gain access and control of the smart grid



(Clemente, 2009)

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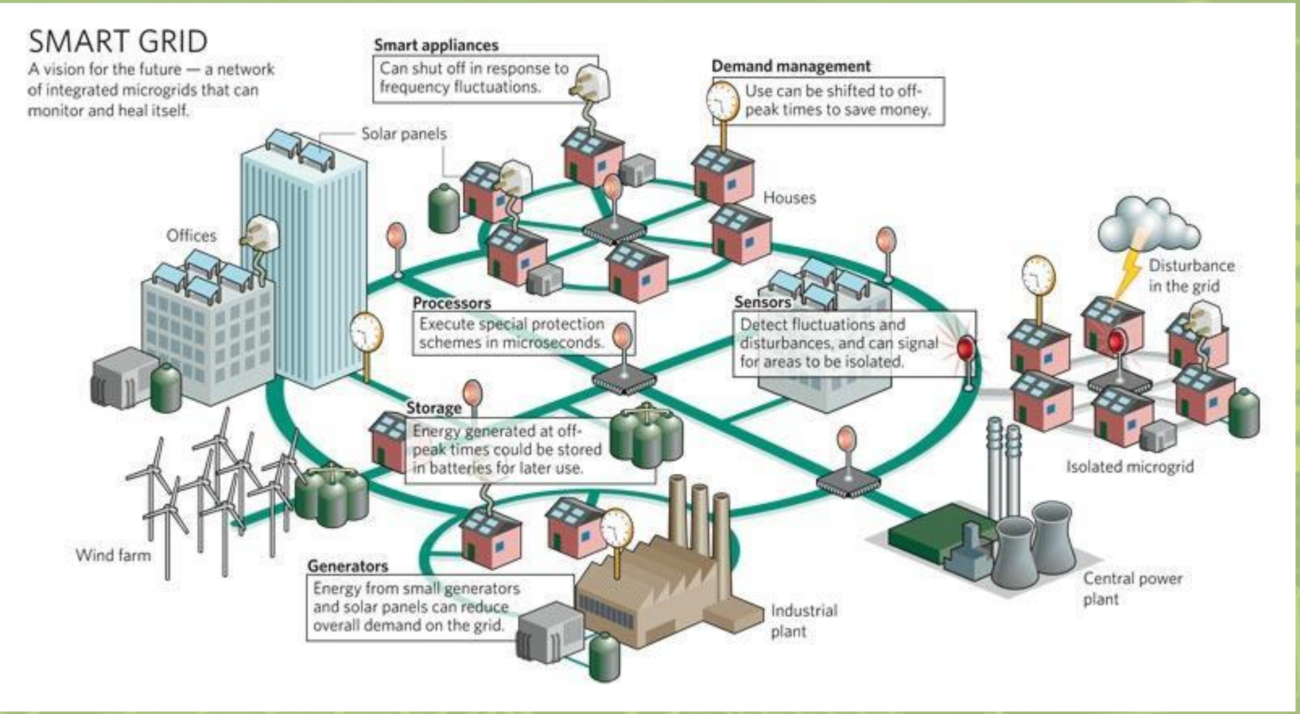
Achieving Cyber Security

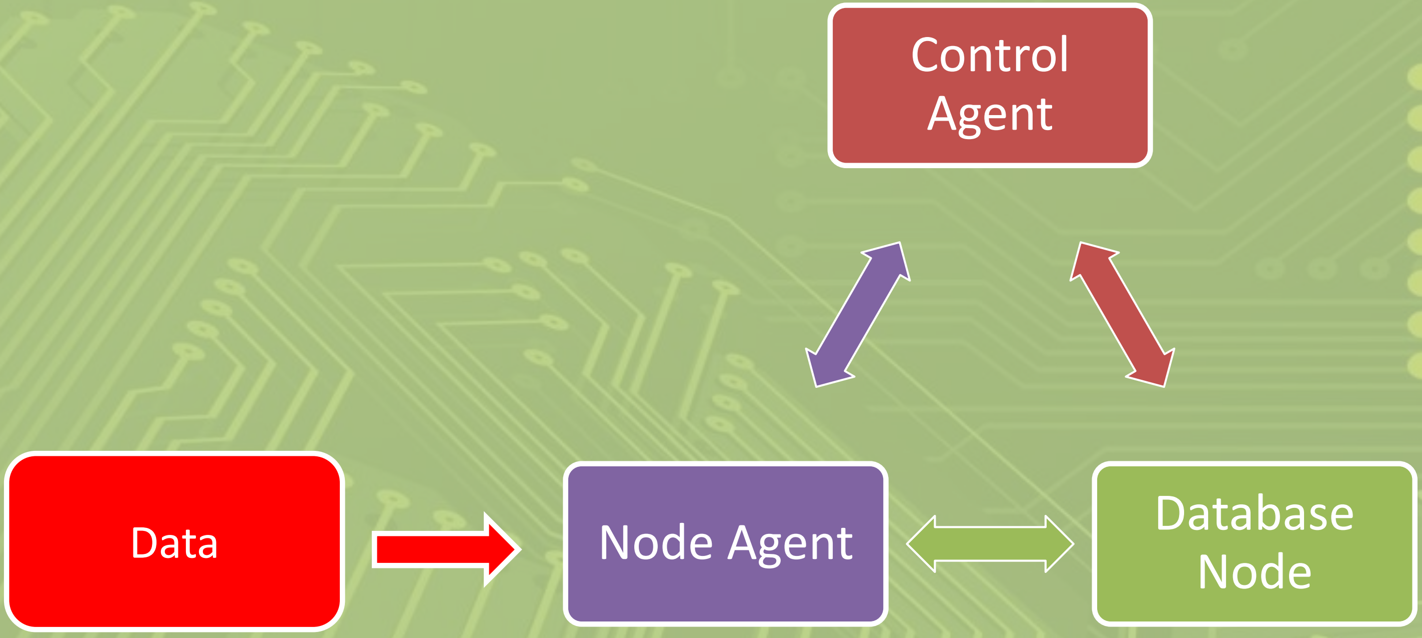
- SRAC (Smart Grid Role-based access control)
  - Sub-divided grid so that the whole system won't be compromised in an attack (Liu, 2012)



http://futurepredictions.com/wp-content/uploads/2011/02/smartgrid.jpg

Achieving Cyber Security

- Anomaly detection
  - Multi-agent based fault location algorithm
    - Nodes (agents) communicate to identify faulty information (Liu, 2012)



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Achieving Cyber Security

- Accountability
  - Recordable and traceable changes in a host or network to act as evidence in future

http://csid.unt.edu/images/accountability1.jpg

http://www.biggergod.com/images/judgment.jpg

Smart Standards and Regulations

NIST

http://www.infosecurity.us/blog/2011/5/12/nist-request-for-comments-cloud-computing.html

ANSI

ANSI Accredited Standards Developer

http://hps.org/hpssc/

IEC

http://www.iecee.org/

ETHICAL ISSUES BY RICHARD

Building Quickly versus Building Correctly

- Building Quickly:
  - Advantage/Intent: Investment in leading the global market in smart grid technology
  - Disadvantage: Markets and Consumers are left to the short-term problems of smart grid implementation
- Building Correctly:
  - Advantage/Intent: Addresses local economic instabilities by leveling the playing field and reducing shortcomings of the smart grid
  - Disadvantage: Smart grid technology will continue to pursue forerunner’s technology, leaving behind economic growth.

Exemplified Forerunner: China

- Pushing the frontier of smart grid technology through:
  - A fiber optic backbone communications network
  - Centralized access of big power by implementing “clean energy”
  - Utility of Ultra-High-Voltage power grids
- Pursuits that have become reality → Research Investment by China
- Problem: United States is not at this stage, yet.

Figure: Adapted from John Whitney's “Ultra High Voltage (UHV) Transmission is the Renewable Energy Interstate

Richard Abrantes

Cautious Implementer: South Korea

- Focus on five areas of the smart grid: power grid, place (metering system), transportation, renewable energy, and electricity service
- Built the Jeju Smart Grid Test Bed in 2009
  - Serviceable for international community to test grid syste

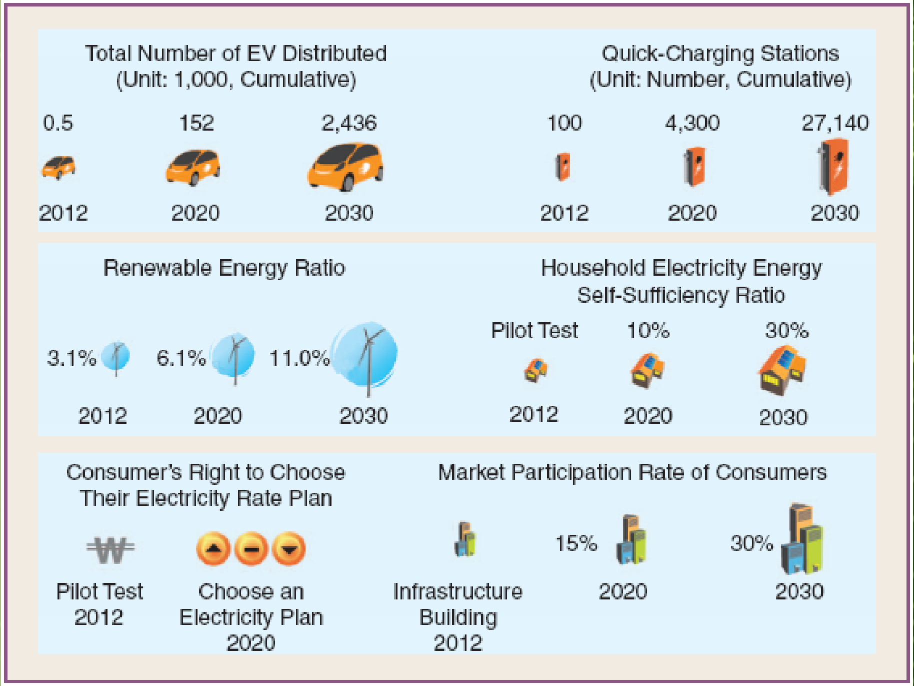

figure 3. Key implementation targets for smart transportation, renewable energy, and electricity service.

Figure: Drawn from Kim et. al.: "A National Vision: Institute of Electrical and Electronics Engineers Power and Energy Magazine

Features of the Jeju Test Grid

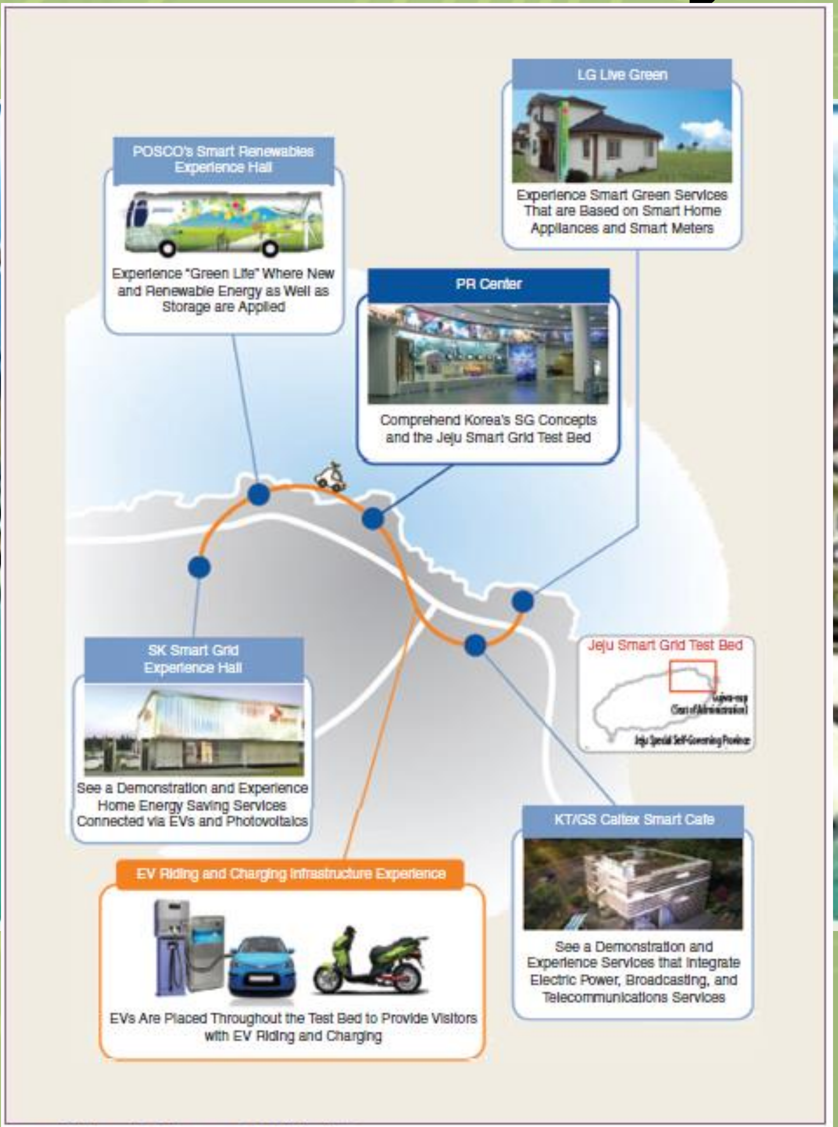

figure 7. Jeju test bed PR center and exhibition halls.

Figures: Drawn from Kim et. al.: "A National Vision: Institute of Electrical and Electronics Engineers Power and Energy Magazine

Richard Abrantes

National Security: Government Involvement

- Capitalism: Government tends to get involved for the sake of regulation.
- Authors Haas and Auer have termed the necessary "unbundling" between generators and suppliers.
- Fair accessibility into the market and competition → maintain laissez-faire

Unexpected Contributions

- DoD's F-15 Case Study:
  - Led to the development of the intelligent flight control system. Later became damage-adaptive.
- This spurred the development of the Complex Interactive Networks/Systems Initiative (CIN/SI).
  - Contribution: Self-healing power system within the smart grid.

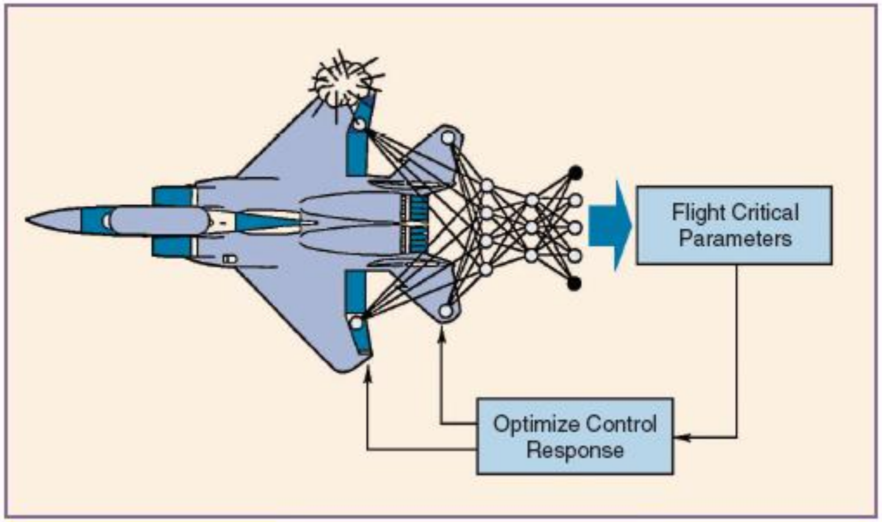

figure 1. The IFCS design goal is to optimize controls to compensate for damage or failure conditions of the aircraft. (Picture courtesy of Boeing and NASA.)

Figure: Drawn from Amin and Wollenberg's "Toward a Smart Grid"

A Need for Guidance

- Laissez faire vitalizes the individual firms and consumers.
- Government is capable of remedying the situation, such as economic drought, during times of distress.
- Government as a **mode of unity**.

Conclusion

- Overall Goal: Implement the Smart Grid
  - Management of the Smart Grid will be pushed forward by research ventures
  - Valuable returns of the grid in finances and clean energy promote the desire to install the Smart Grid
  - Raised awareness, regulations, and standards for overall concrete functionality of the grid
  - Effort between government and community to invest in the grid

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