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ระบบ Advanced Metering Infrastructure (AMI) สำหรับโครงข่าย ไฟฟ้าอัจฉริยะ (Smart Grids)



ดร.ประดิษฐ์ เพื่องฟู

กองวิจัย ฝ่ายวิจัยและพัฒนาระบบไฟฟ้า

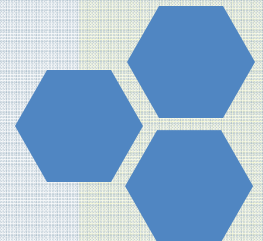
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สัมมนางานวิศวกรรมแห่งชาติ ปี 2554

วันที่ 26 มี.ค. 2554 ณ ไบเท็ค บางนา กรุงเทพฯ





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Smart Grids

Strong, Smart and Safety

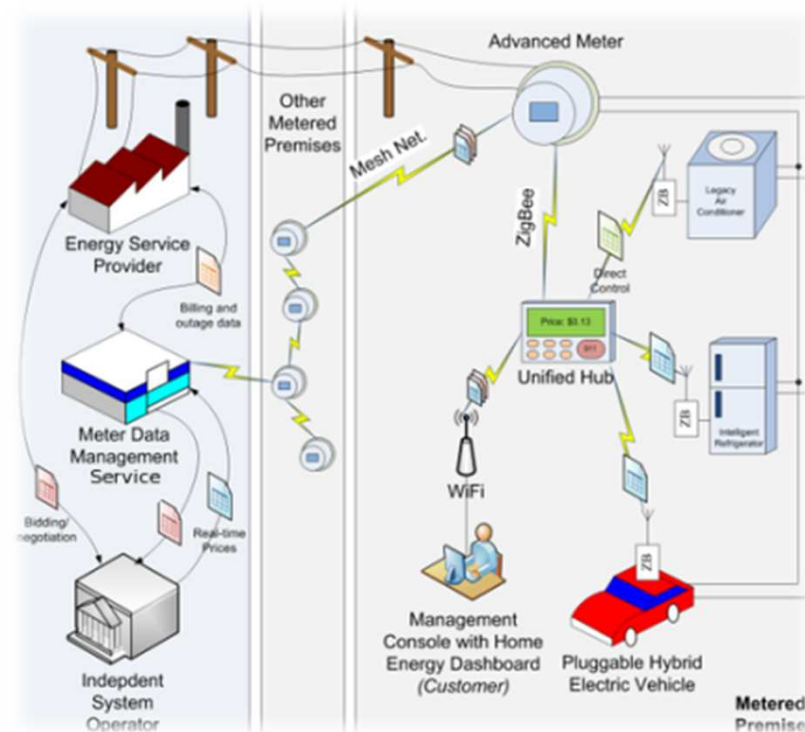




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Content

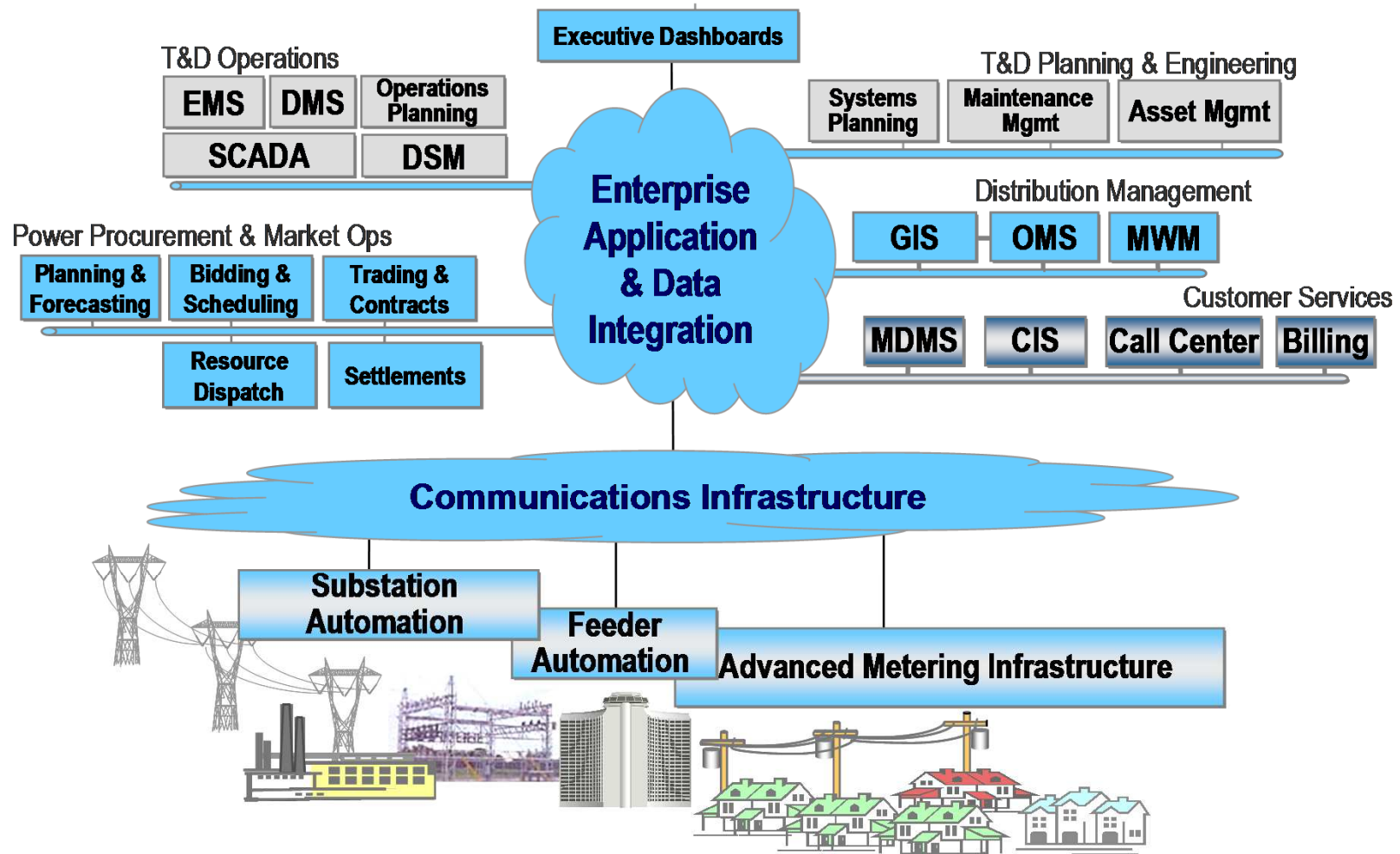
- Smart Meter & AMI
- Prepayment Using AMI
- Home Area Network





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The Intelligent Power System builds on the Communication and Information Infrastructure

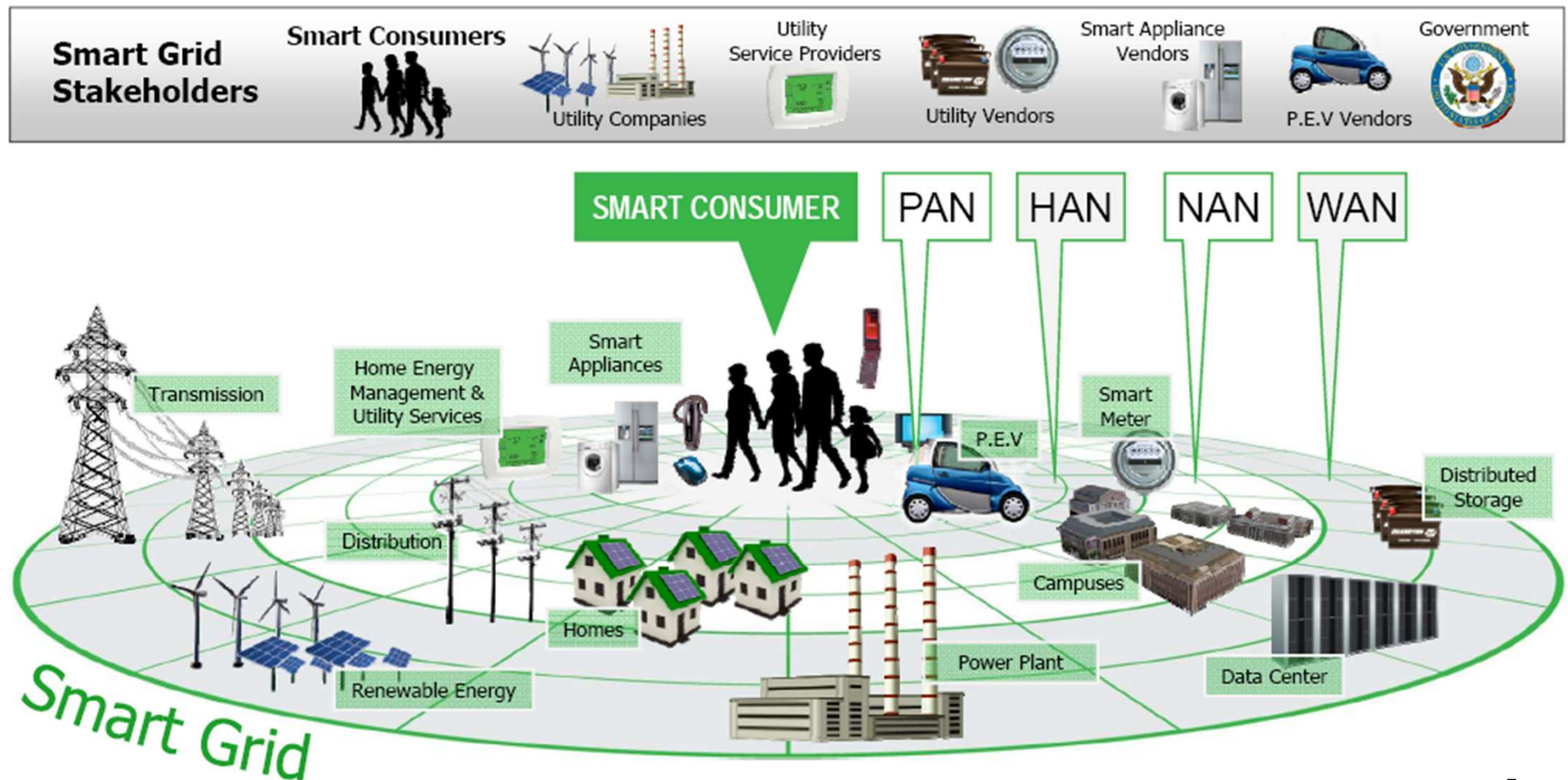




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Vision: Unleashing the Smart Consumer

- Utilize technology to bring behavioral changes (smart decisions & smart actions)
- These will lead to sustainable future & social wellness





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SMART METER & AMI



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Advanced Metering Infrastructures: Illustrated



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AMI - The Evolution of Metering

Advanced Metering Infrastructure (AMI) is a communication network and meters providing usage information at regular intervals (at least hourly) and collected at least daily.
(Source Utilipoint, 2006)

Capabilities

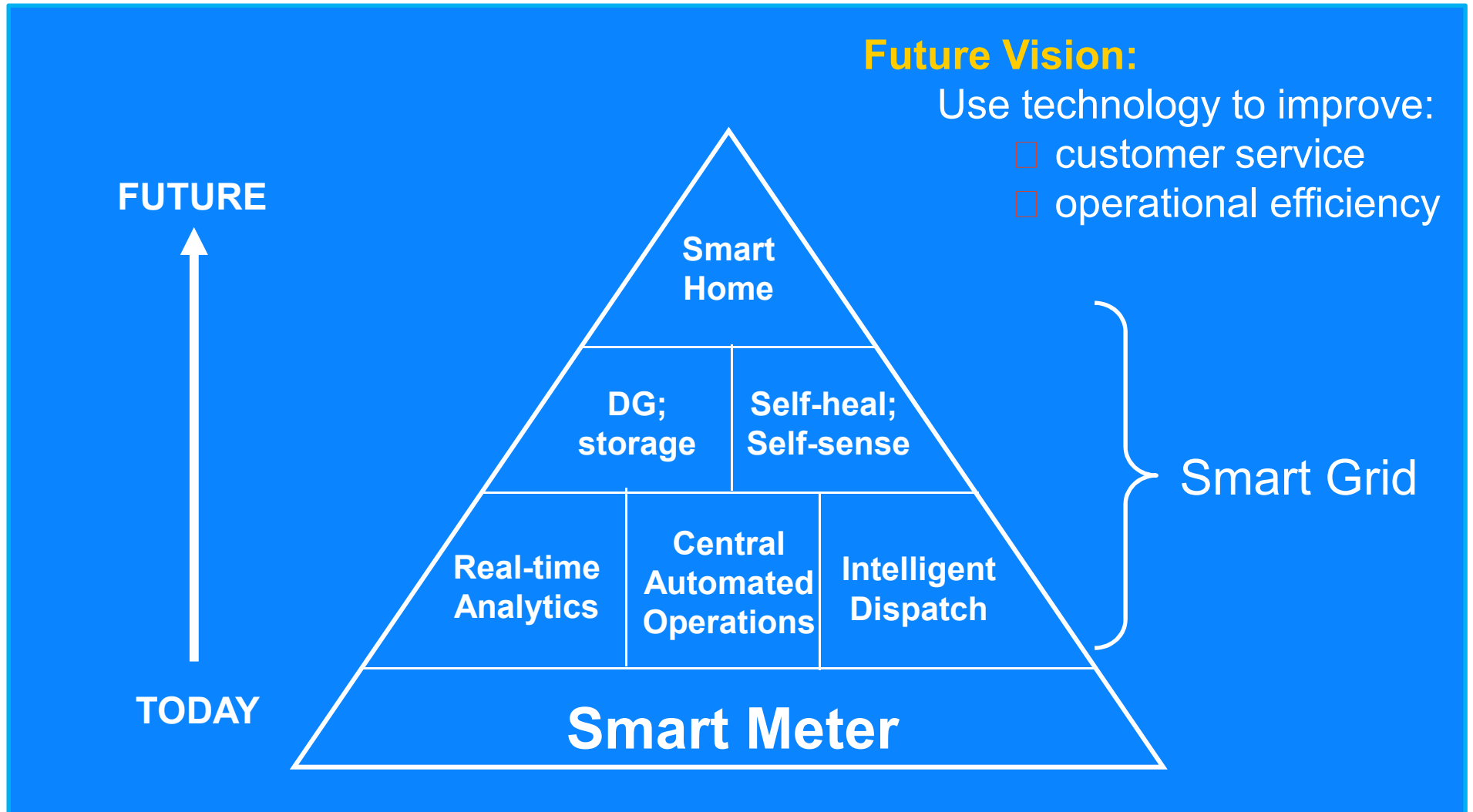
- ☐ Measure electricity, record consumption, and meter event information electronically
- ☐ Remote connection and disconnection
- ☐ Tamper detection
- ☐ Outage detection
- ☐ Quality of supply monitoring
- ☐ Demand limiting
- ☐ Communications interface to a range of devices like
 - ☐ in-property display
 - ☐ direct load control equipment





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Smart Meter: Foundational





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The AMI Data Chasm

Before AMI

- Batch files
- Forecasts and models using static data
- Point of sale data once a month
- Flat, average prices
- Customer communications on monthly bill



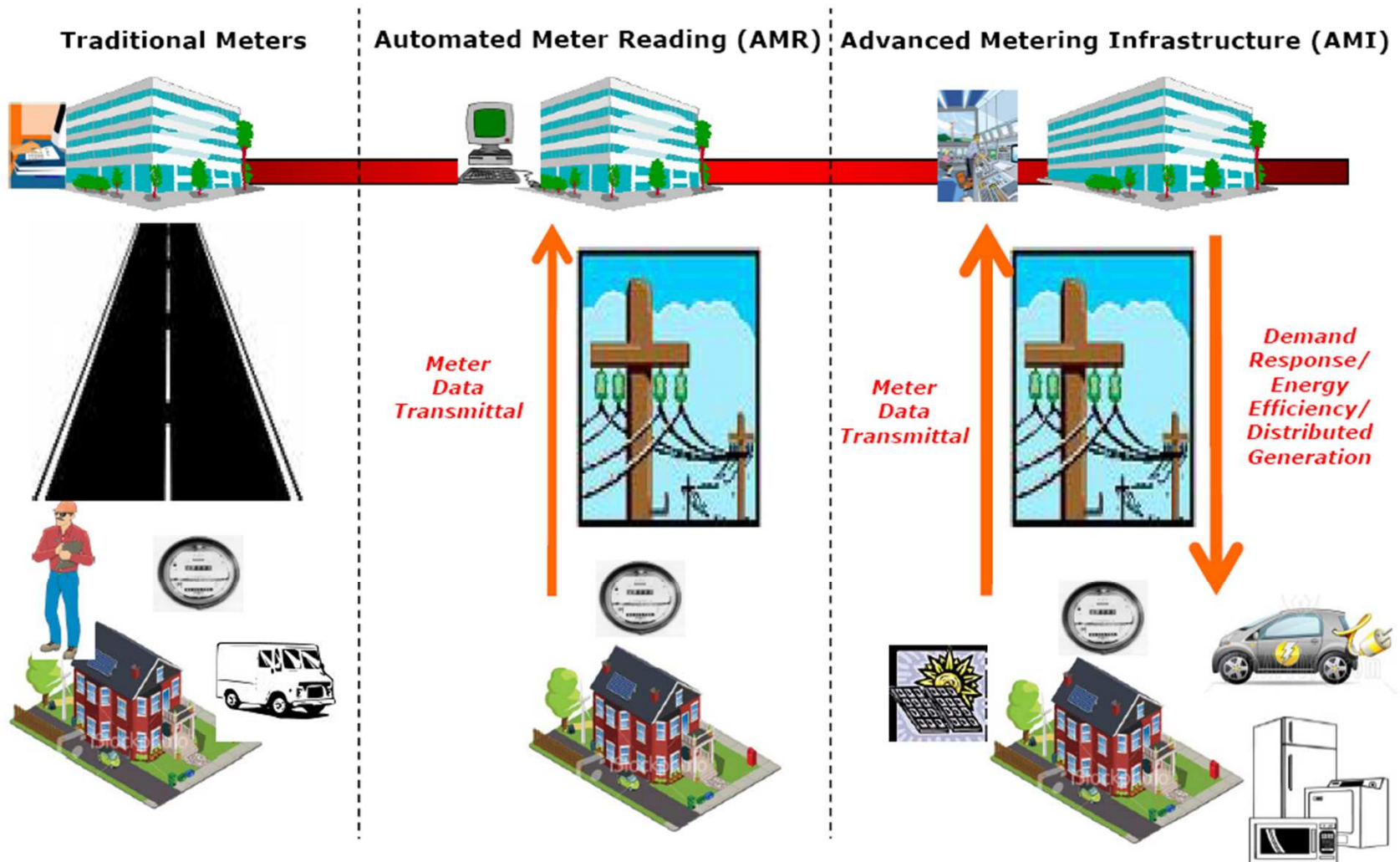
With AMI

- Real-time data files
- Actual, timely data used in Smart Grid operations
- POS data daily
- Time-based pricing options
- Customer engagement through online data and appliance controls



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Advanced Metering Infrastructure





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Is AMI same As AMR

- ☐ AMR is primarily focused on the ability to collect data
- ☐ Primary purpose of AMR systems is customer billing, and reduced costs of meter reading.
- ☐ AMR systems typically comprise of static meters fitted with communication devices, communication network (media) as well as supporting software to manage the data.
- ☐ AMI includes not only AMR, but, a system that collects time-differentiated energy usage from advanced meters.
- ☐ Capable of providing information which enables utilities to provide demand response products & customers participation.
- ☐ System supports other operational and customer service, e.g. outage management, connect/disconnect, customer load management etc.



AMI vs AMR

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PROVINCE

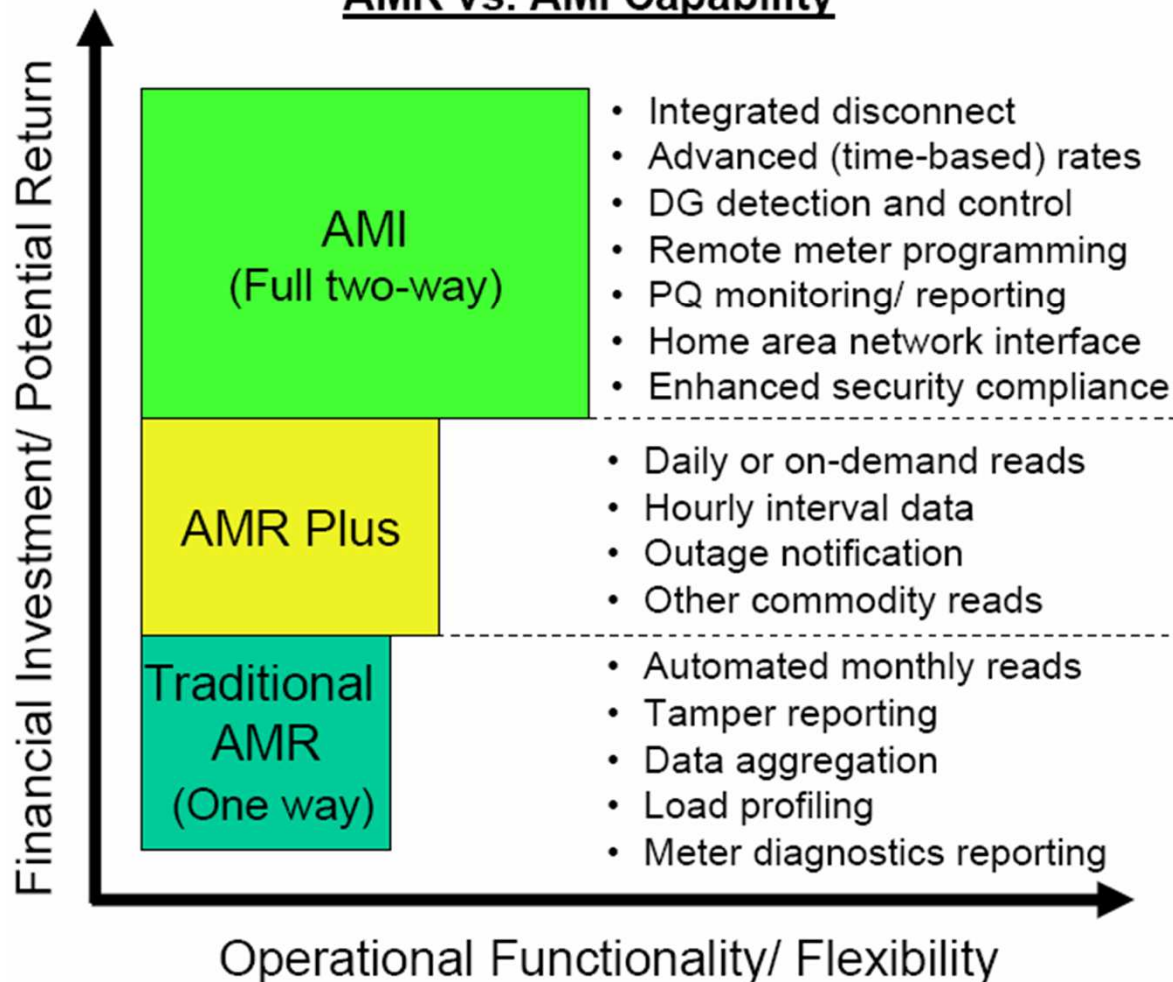
Business processes	Automatic Meter Reading (AMR)	Advanced Metering Infrastructure (AMI)
Meters	· Electronic	· Electronic with LAN, HAN, load profile and disconnect.
Data Collection	· Monthly	· Remote using LAN communication, more frequent
Data recording	· Cumulative kWh	· Half hourly so that dynamic prices can be applied.
Business opportunities	· Monthly consumption based billing	· Customer payment option · Pricing options · Utility Operations · Demand response · Emergency response
Key business processes	· Billing · Customer information system	· Billing · Customer information system · Customer data display · Outage management · Emergency demand response.
Customer's participation	None	In Home Display, cost and environmental consciousness. Demand response programs
Additional devices	None	Utility controlled customer load Smart thermostats / Compressor

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Smart Metering Systems

AMR vs. AMI Capability



Stakeholders/ Benefactors

External Stakeholders ¹	Meter Reading	Field Collections/ Field Services	Customer Care/ Call Center	Billing, Accounting, Remittance Processing	T&D Operations	T&D Engineering/ Planning	Information Technology	Marketing/ DSM	Load Forecasting	Power Procurement	Unregulated Services
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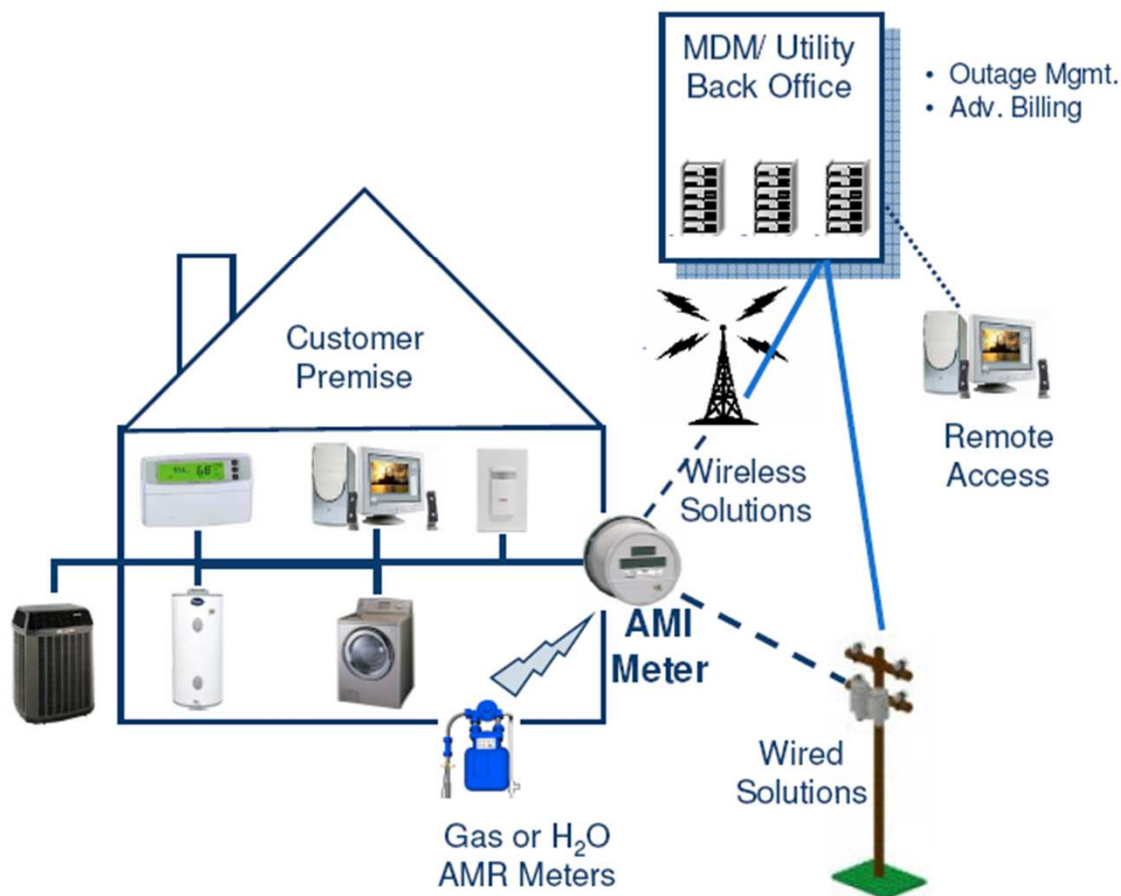
Source: KEMA



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AMI provides increased network connectivity and communications between the customer and the utility

AMI Connectivity (illustrative)



AMI Communications Trends

- Full two-way (bi-directional)
- Near real-time data read/access
- Higher bandwidth
- Increasing number of communications nodes
- Robust Meter Data Management systems to interface with back office
- Peer-to-peer mesh networks
- Distributed generation control
- Multiple backhaul integration
- Device interoperability
- Open communications protocols
- Self-diagnostics and programming
- Minimal network administration
- Self-registry capabilities
- Price signals to smart appliances
- Meter as a premise "portal"



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AMI Overview

AMI Meter Capabilities



- ☐ Daily/Hourly/15 Minute Interval Meter Reads
- ☐ Customer Move In/Out and Other On-Demand Meter Reads
- ☐ Remote Upgradeability of Firmware
- ☐ Interoperability
- ☐ Radio Frequency (RF) Communication to Field Network Devices
- ☐ Radio Frequency (RF) Communication to In-Home Devices via Zigbee Protocol
- ☐ Connect/Disconnect Switch
- ☐ Load Limiting Capabilities
- ☐ Bi-Directional Metering
- ☐ Interval Register Data
- ☐ Voltage Readings/Power Quality
- ☐ Outage Notification, Power Restoration, and Energized Meter Verification
- ☐ Configurable Settings and Internal Clock
- ☐ Diagnostic Alarms, Tamper Flags, and Outage/Switch Counters
- ☐ 45 Days Non-Volatile Storage of Data
- ☐ Register Display
- ☐ Support for Home Area Network, Distribution Automation, and Demand Response
- ☐ Tamper reporting



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AMI Overview

Functionality of AMI System



Item No.	Feature/Functionality	Benefit
1	Hourly interval data recording for electric customers, depending on their rate. (Note meters are capable to be programmed to obtain 15 minute interval data)	Enable innovative rate structures, e.g., Critical Peak Pricing (CPP), CPP Rebate, & Hourly Pricing. Present customers with energy usage data. Provide customers with improved response to billing & other inquiries. (Requires integration with the meter data management system, customer billing system and "My Account" web functionality)
2	Two-way radio frequency communication to the meter	Reduce manual meter reading while improving accuracy and lowering the number of estimated bills. Less intrusive to customers by not having meter reading personnel in or near the customer's home or business.
3	American National Standards Institute (ANSI) certified 200A full-load remote disconnect switch and on-demand meter reading	Enable remote turn-on/off reducing field visits and enhancing customer service, e.g. faster and better scheduled turn-ons/offs.
4	Tamper reporting and diagnostic alarms	Enhance tampering detection. Detect meter malfunctions sooner and reduce number of incorrect bills. Integration with the revenue protection module in the MDMS will help the Company proactively reduce theft of service.
5	Configurable outage definition and time stamped outage and power restoration reporting	Enhance detection and location of outage causes. Provide outage notification and estimated time of restoration information to customers as an optional service offering.
6	Bi-Directional Metering, Net energy metering capability	Enable innovative rate structures, supporting renewable energy sources. <i>(Requires integration with the meter data management system and the customer billing system)</i>
7	On-demand remote meter "ping" capabilities	Support move in/out process. Provide improved customer service by remotely verifying that a meter is currently in or out of service, helping to alert the customer that the problem may be on the customer side of the meter.
8	Web presentation	Includes the implementation and configuration of Load and Rate Analysis Module, the development of a meter read relational database, and the integration of the Load and Rate Analysis Module with this database and SSN system to support web presentation of electric and gas consumption profiles.



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Benefits Achieved



- ☐ **Meter Reading**
 - ☐ Daily Readings for All Meters
 - ☐ Reduced Estimated Bills
 - ☐ Web Presentation of Interval Data
- ☐ **Outage Management**
 - ☐ Using the Smart Meters to identify outages, verify power status and confirm that power has been restored
- ☐ **Revenue Protection**
 - ☐ Using the AMI System to identify when meters are tampered with and more effectively dispatch field forces where required
- ☐ **Data Analytics**
 - ☐ Using meter readings to support Load Studies, Power System Planning, Maintenance Programs and Asset Management



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Smart Meter Benefits



Enhances reliability and outage detection,
and quicker restoration



Gives customers more control over their
everyday energy usage, opportunity for
lower bills



Improves customer service and allows for a
more proactive workforce



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Smart Metering Benefits

Customers have the information and controls to take ownership of their energy usage



Advanced Rates

Home Area Network

Demand Response

Smart Metering

Load Control Devices

Automated Gas Reads

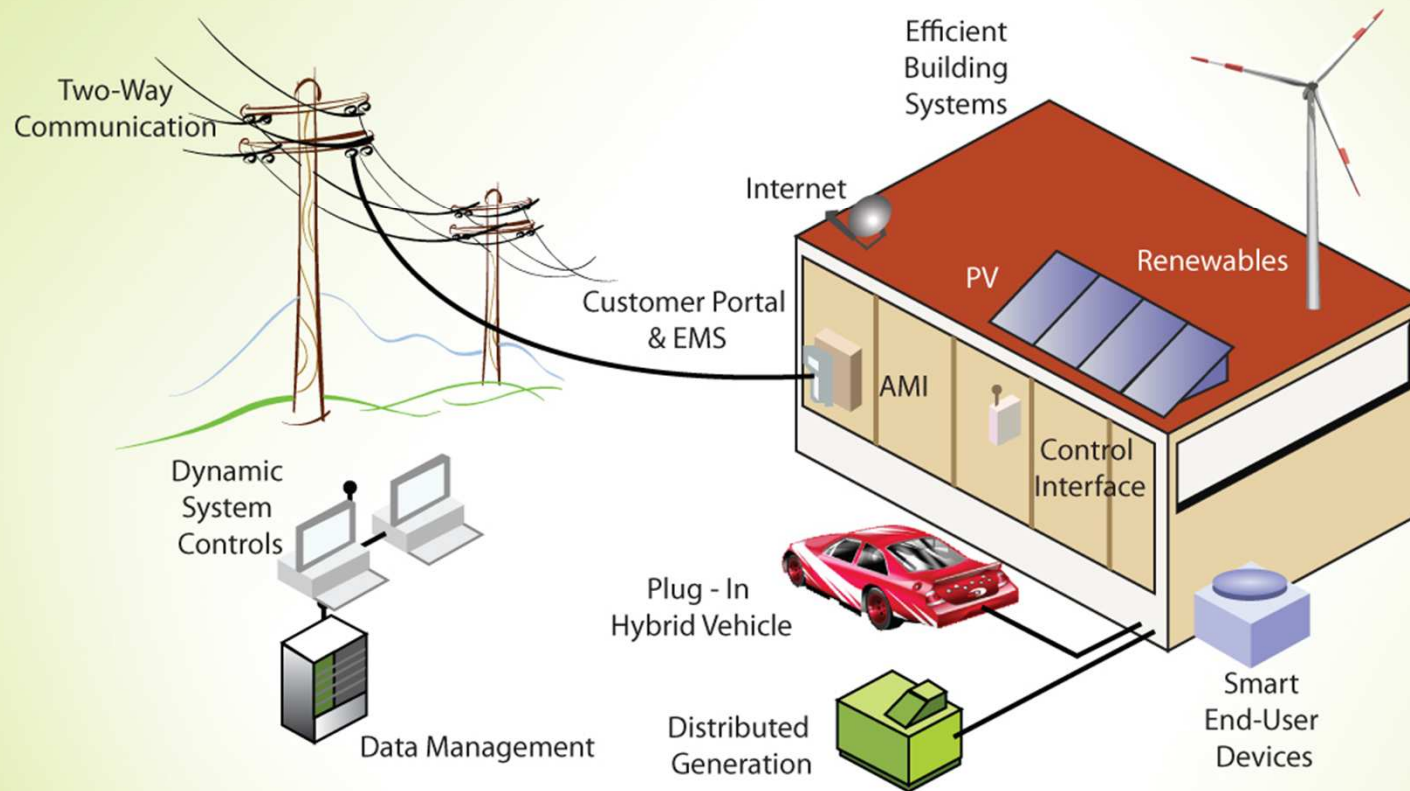




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Smart Metering Benefits

Integration of Consumer Systems with Grid Operation

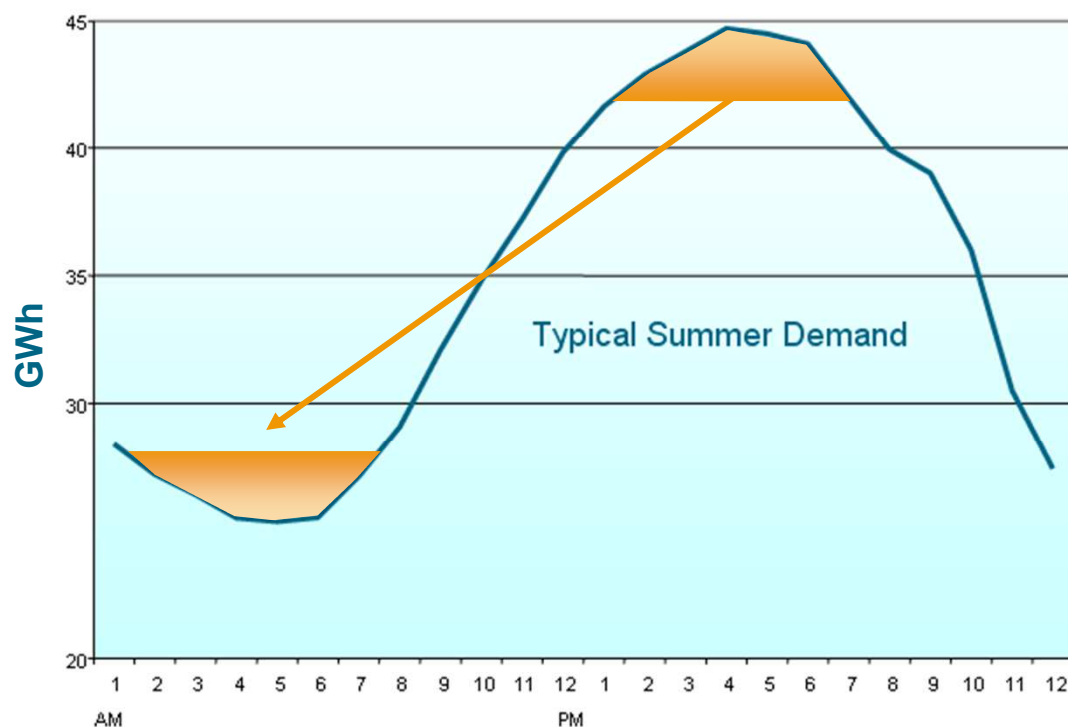




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Paradigm Shift: Customer Energy Management

Time-shifting Electricity



In-premise Network



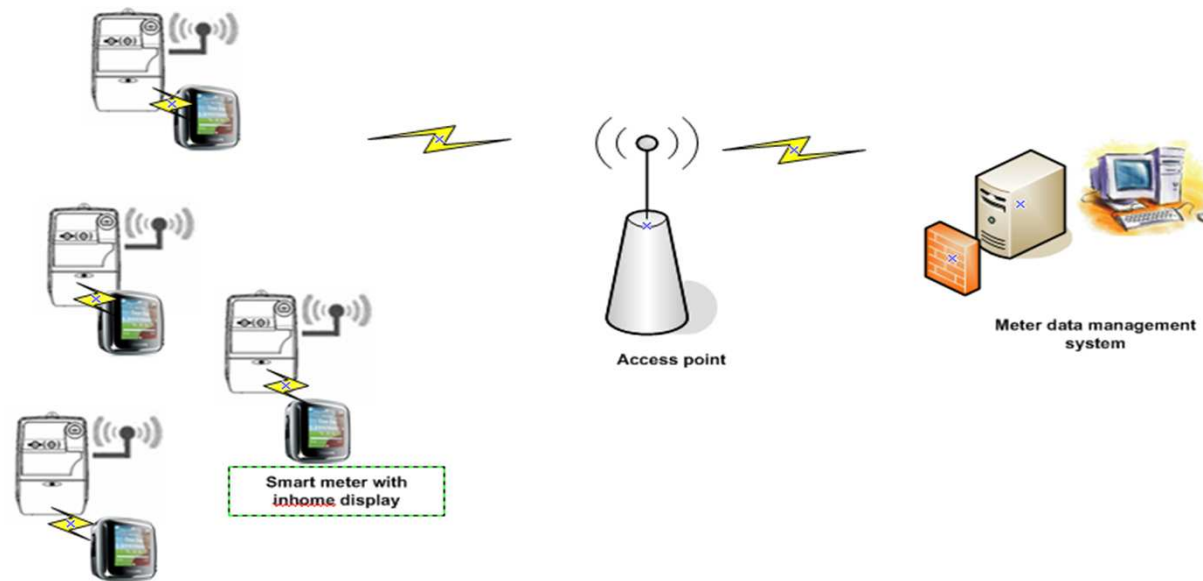
AMI / Smart Grid



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AMI Components

- Advance Meter
- In Home display
- Suitable two way communication system
- Network management system (NMS)
- Meter Data Management (MDM)





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AMI Components – Advance Meter



Electronic meter with

- two way communication,
- time differentiated registers
- price based demand
- connect / disconnect
- load Control,
- interface with In-Home devices.



AMI / Smart Metering with various communication technology.



The products are 1Phase, 3Phase, CT/PT operated meters.





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AMI Components: In-Home Display

- A device which details the usage data in a graphical and user friendly manner.
- The in home display device can be connected to a meter to create a Home Area Network via
 - ZigBee communication device
 - Hardwire connection between the meter and IHD



Network management System

- ☐ NMS is a combination of Hardware and Software used to monitor and administer a network.
- ☐ This NMS needs to be linked to the ERP system
- ☐ What this system needs to do?
 - ☐ Manage connect/ disconnect
 - ☐ Manage alarm, events and other notifications

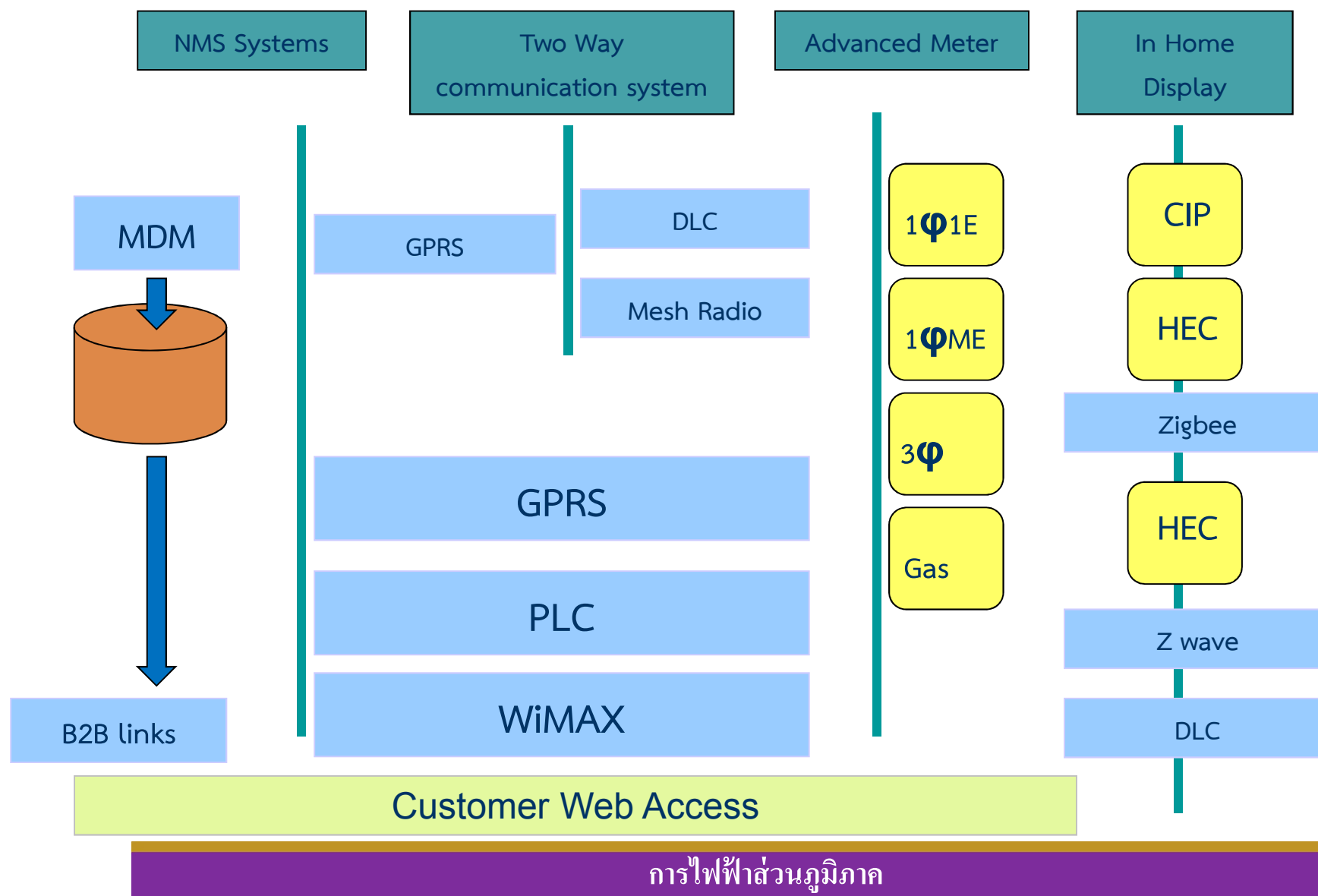
Meter Data Management (MDM)

- ☐ The definition of a meter data management solution can vary based upon the implementation.
- ☐ At a minimum, MDM provides a database repository and utility-specific business logic to:
 - ☐ Automate and streamline the complex process of collecting meter data from multiple meter data collection technologies
 - ☐ Evaluate the quality of that data and generate estimates where errors and gaps exist
 - ☐ Deliver that data in the appropriate format to utility billing systems
- ☐ The critical role of an MDM system is to pre-process granular interval meter data at large volumes very quickly.



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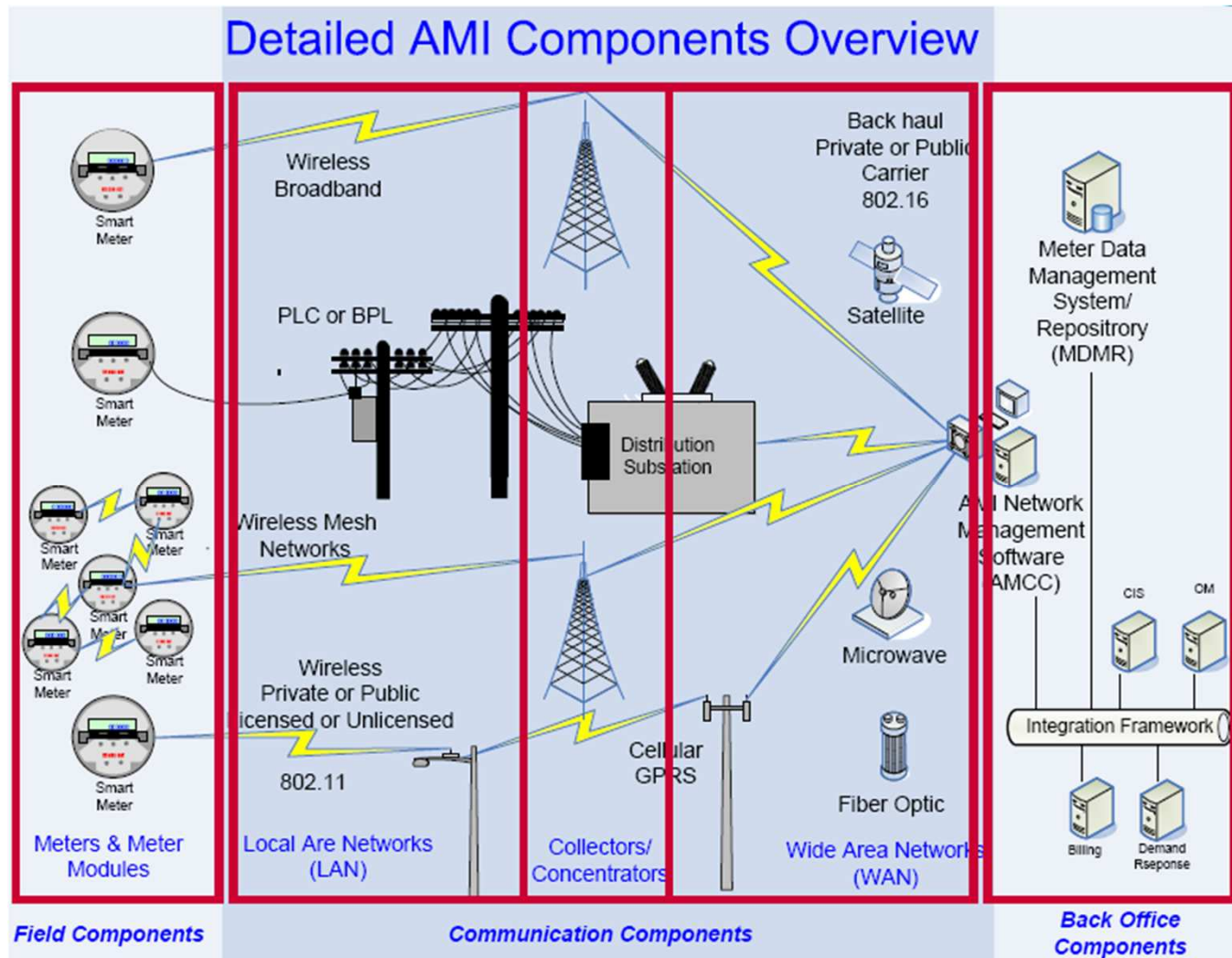
Technical Architecture / Landscape





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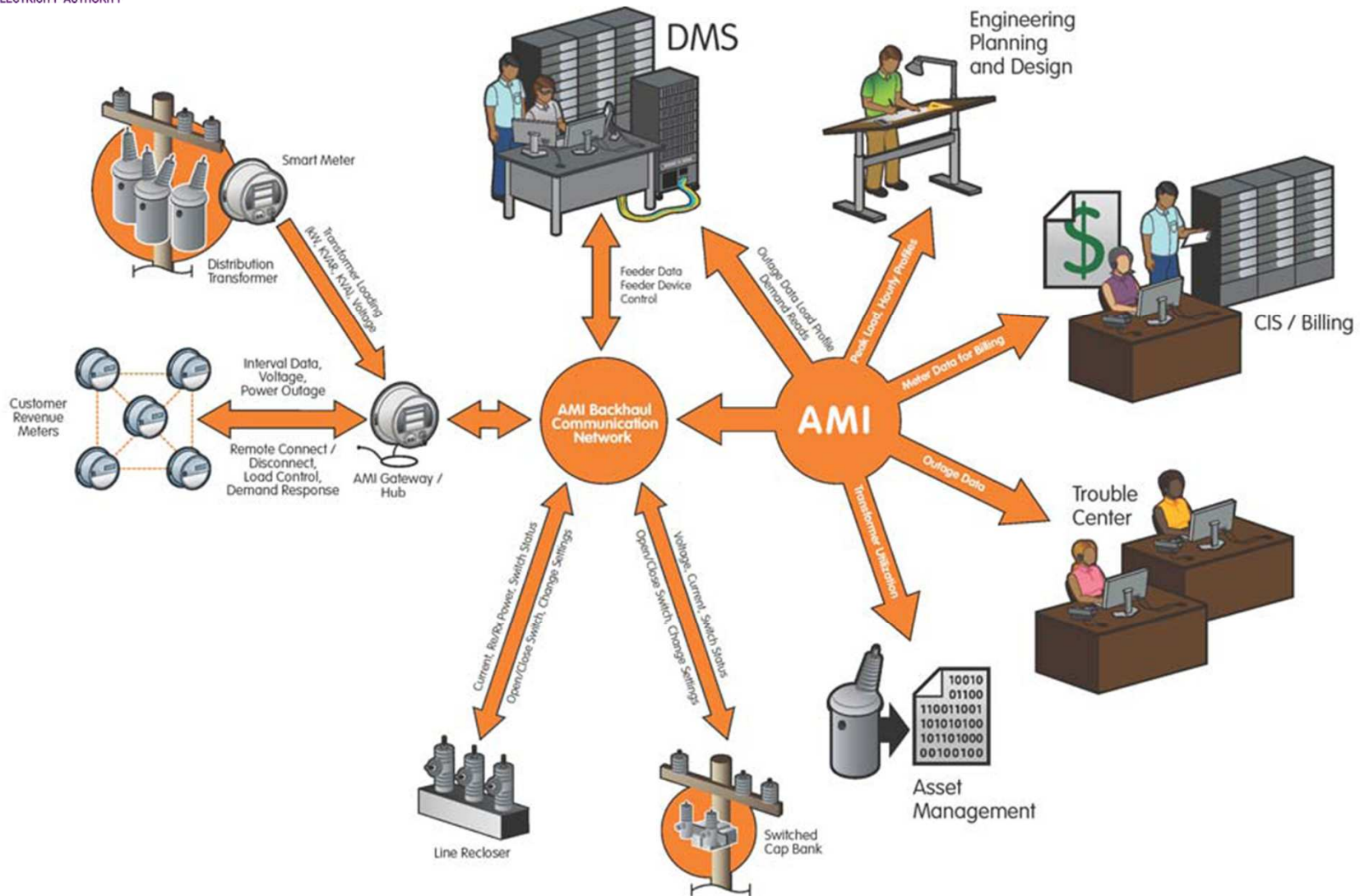
Smart Meter System Components





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AMI system

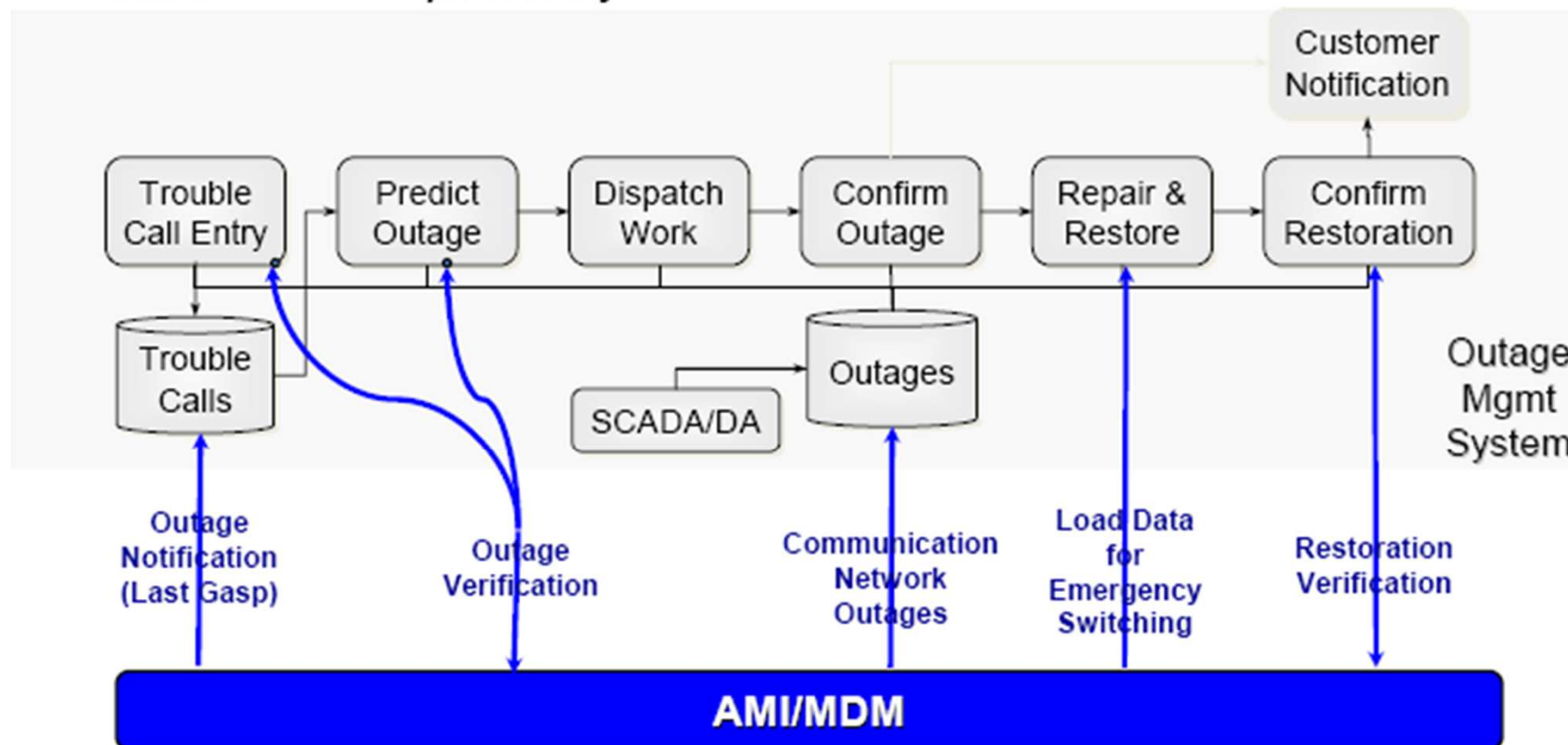




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AMI/MDM Integration

- **Better customer perception**
- **Reduced outage duration**
- **Increased crew and dispatch productivity**
- **Reduced outage duration**
- **Improved AMI data availability**
- **Reduced outage duration**
- **Increased crew productivity**
- **Better customer satisfaction**

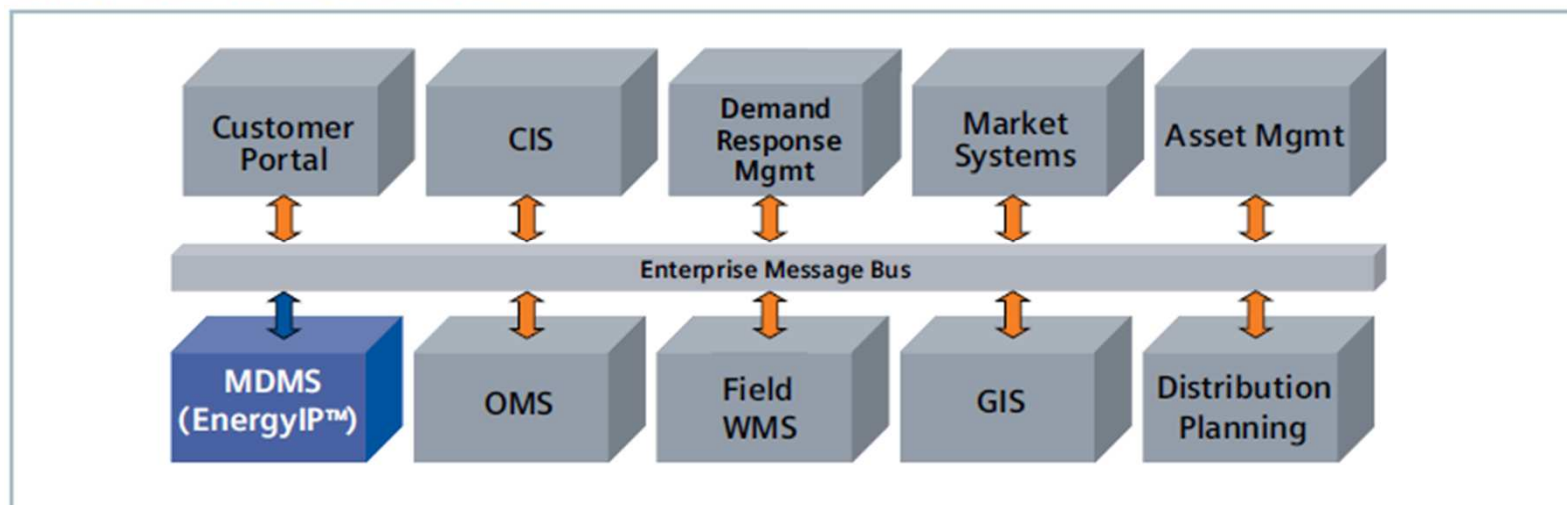




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MDMS Architecture - (Siemens)

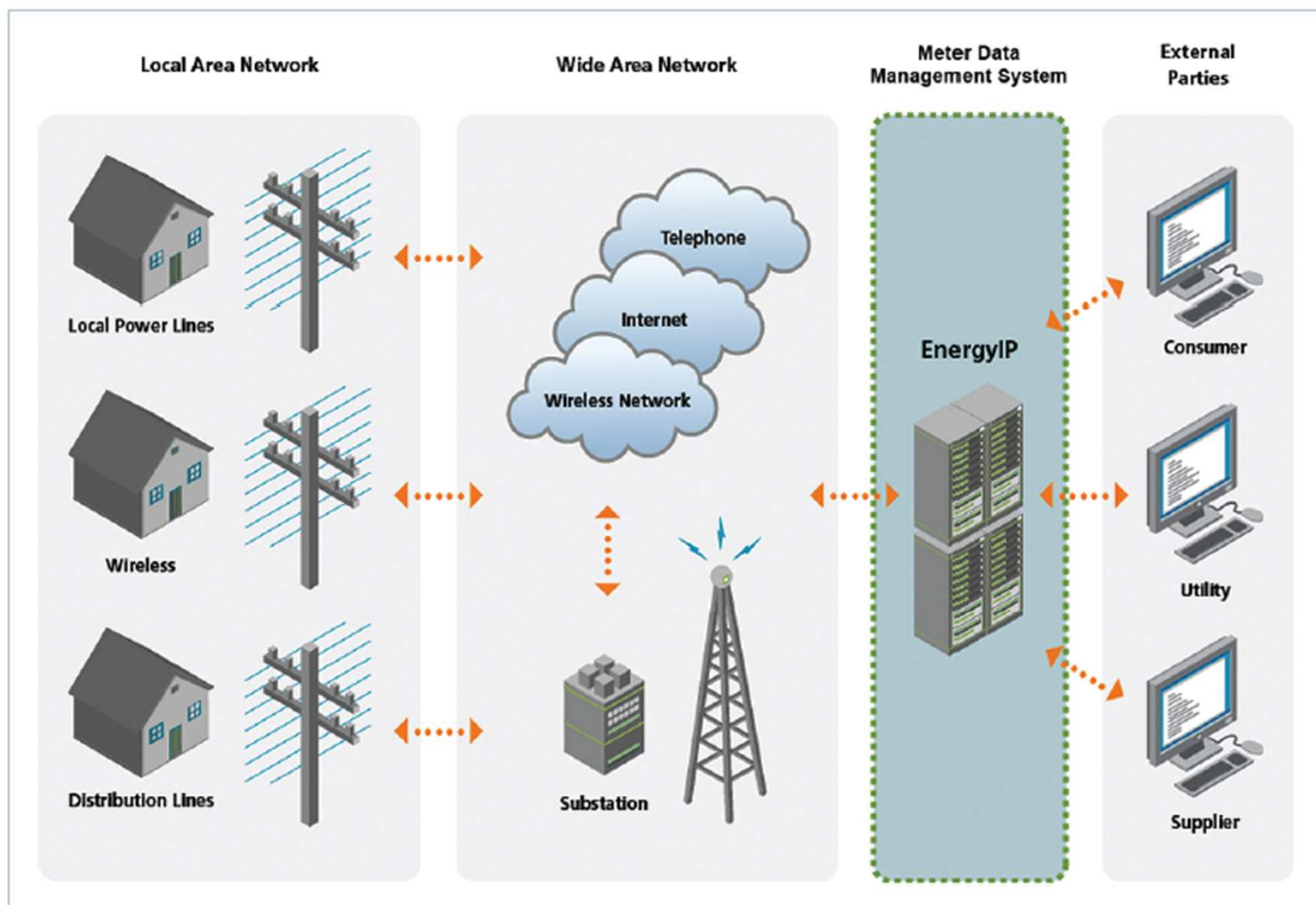
Best-in-class MDMS architecture





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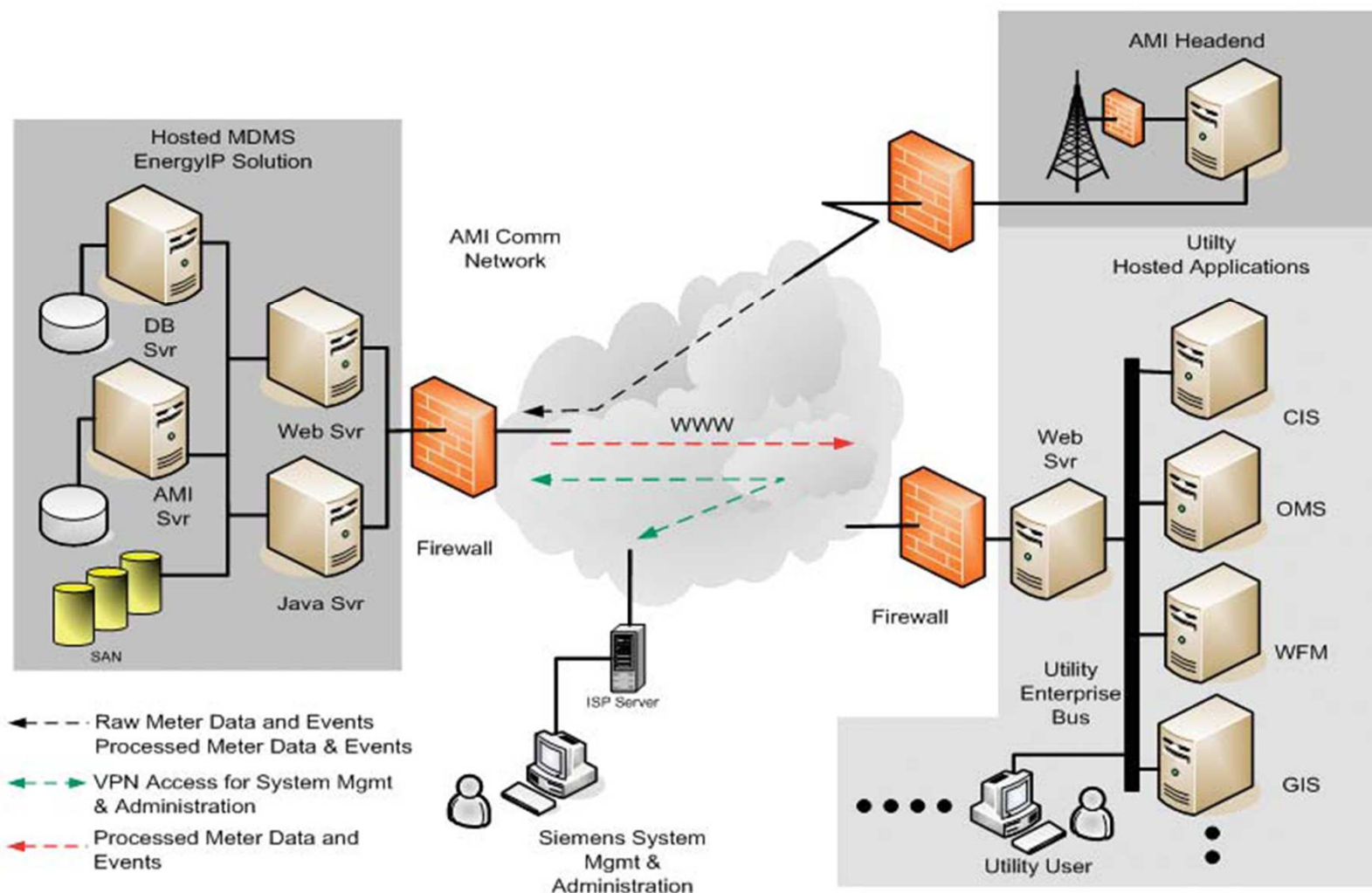
The EnergyIP™ MDMS solution (Siemens)





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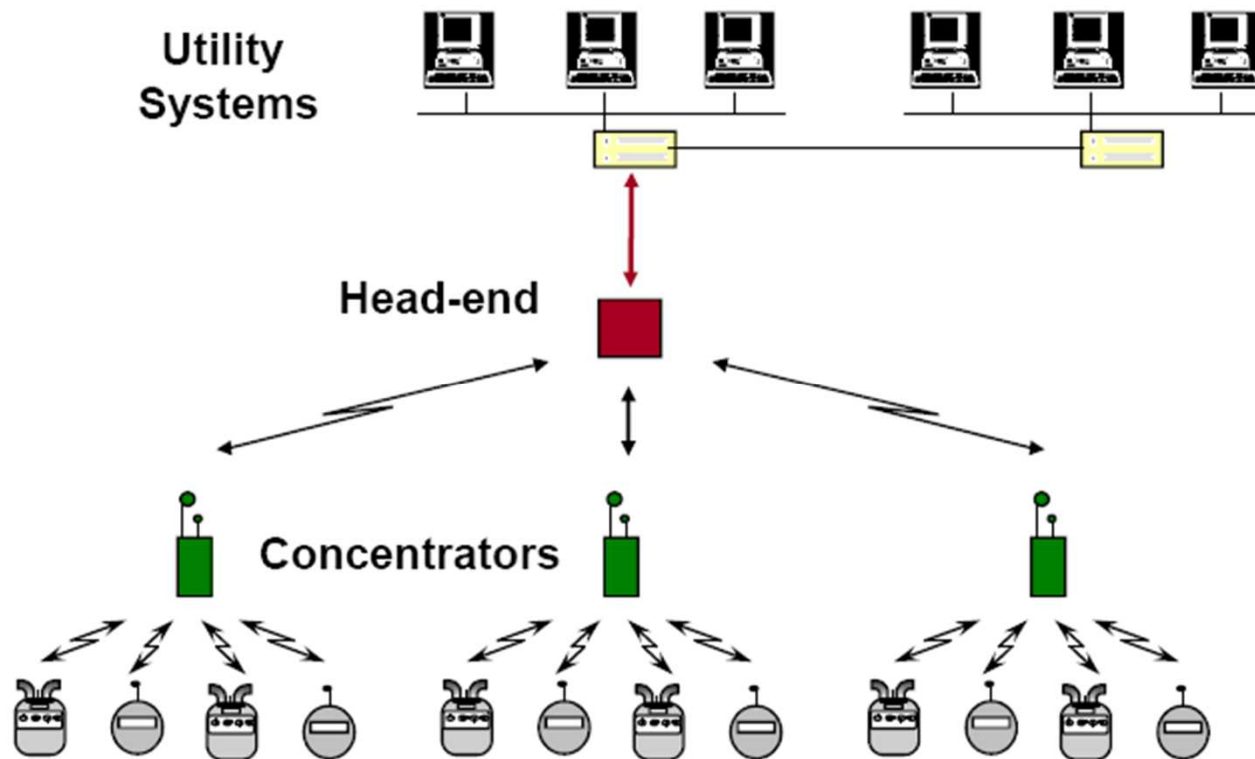
The EnergyIP™ MDMS solution (Siemens)





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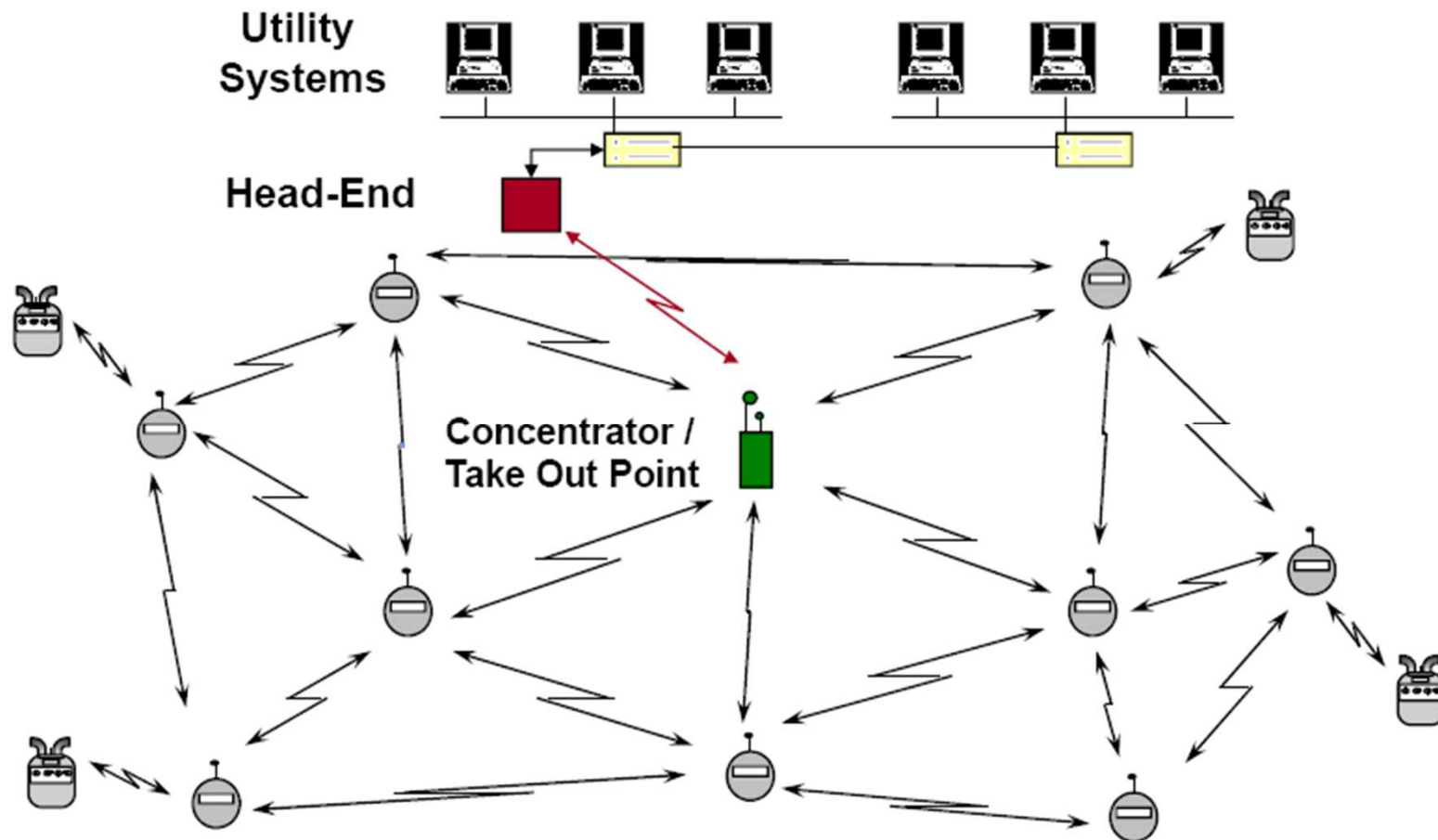
AMI Network Types: Hierarchical





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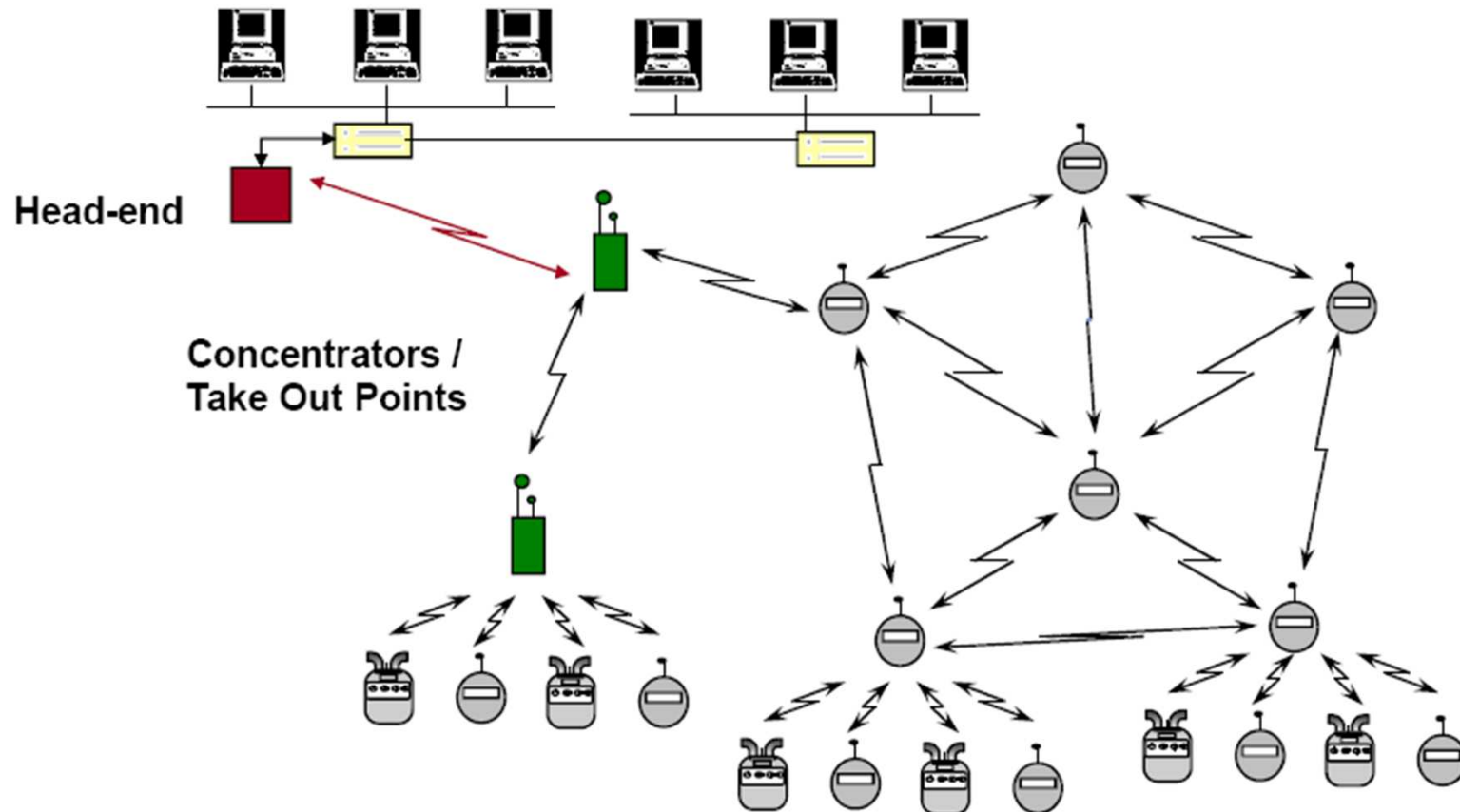
AMI Network Types: Peer-to-Peer





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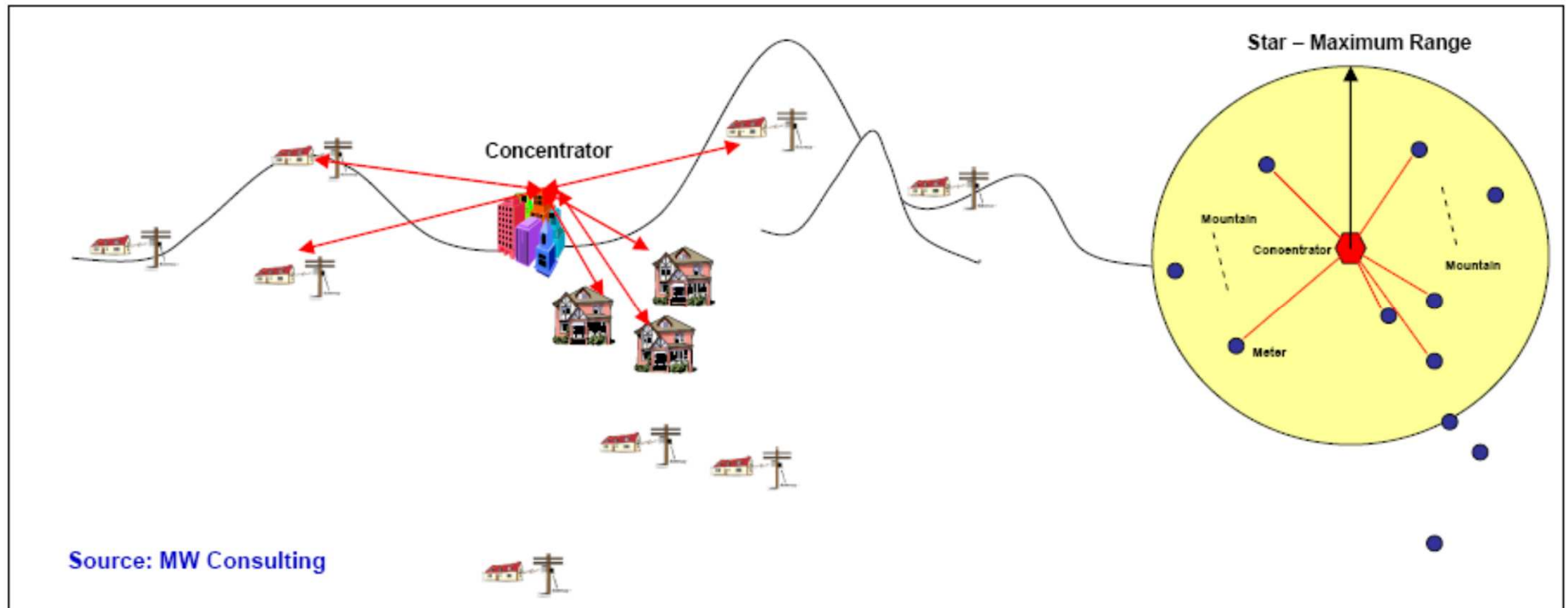
AMI Network Types: Hybrid





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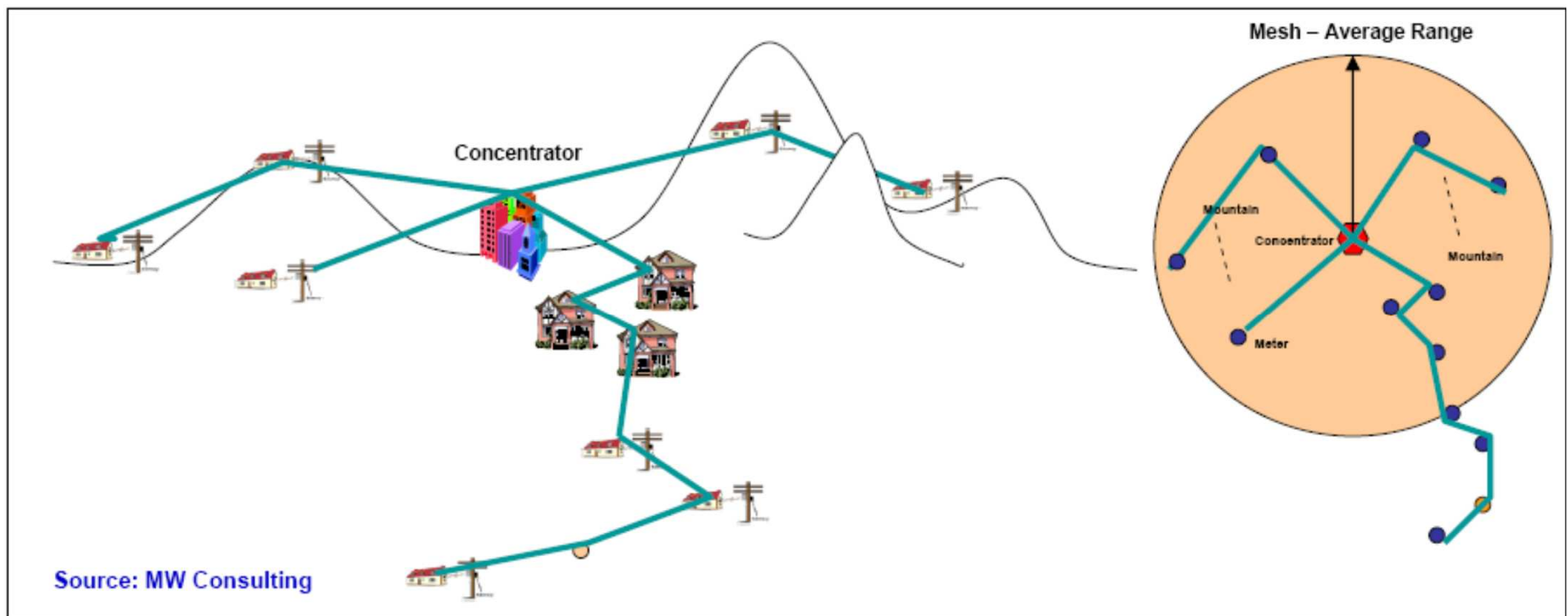
Hilly terrain limits the effectiveness and increases the cost of Star systems





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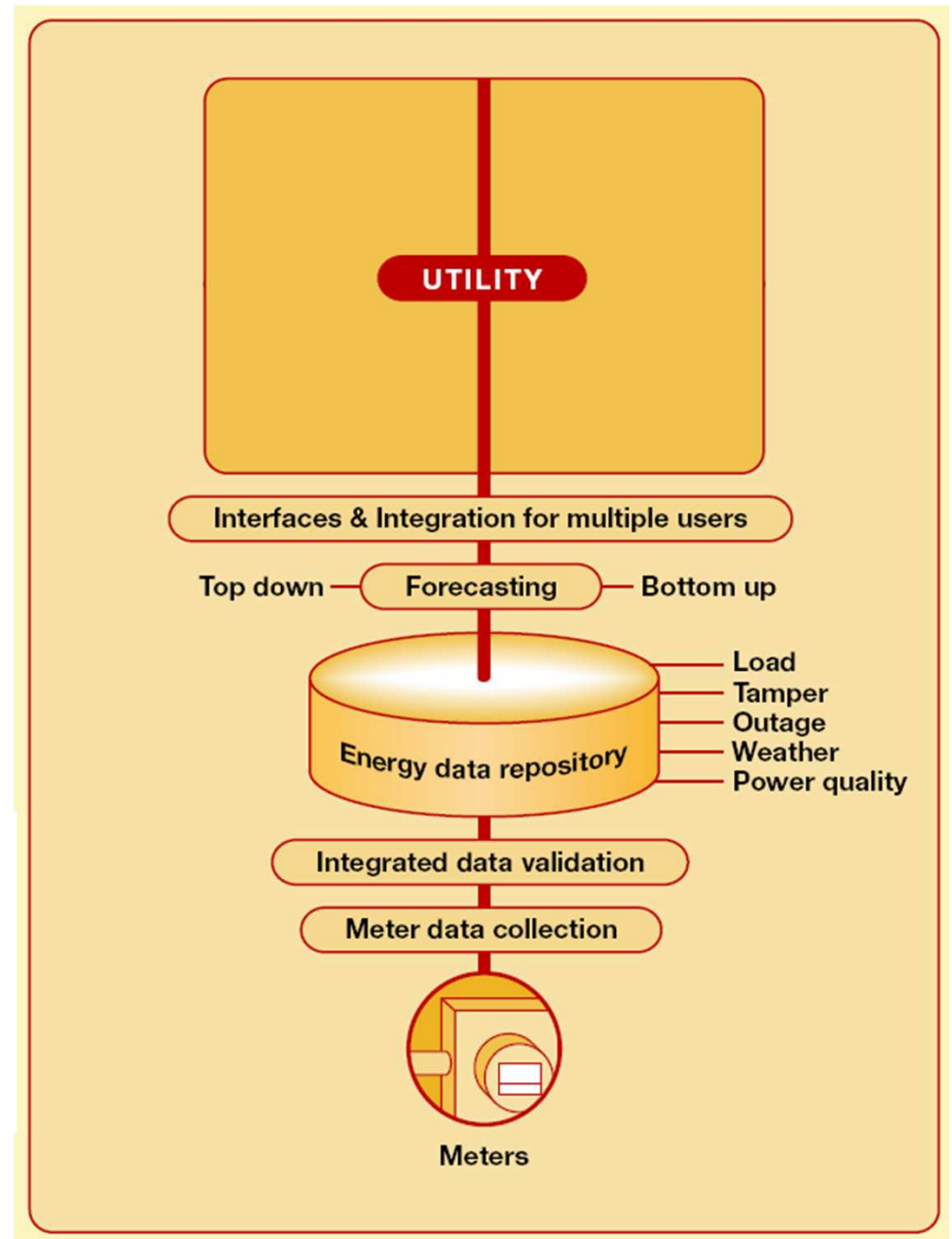
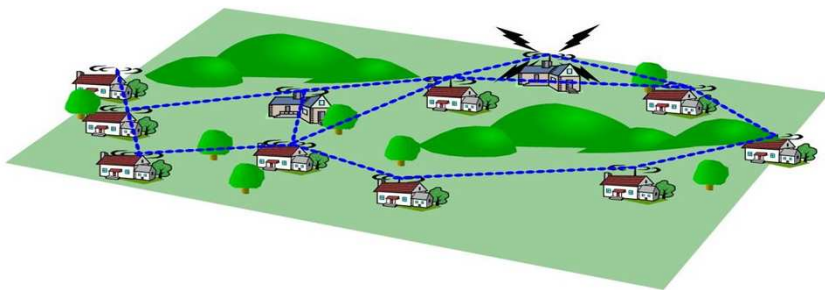
Mesh technology can be more effective than Star systems in hilly terrain but distance between meters is an issue





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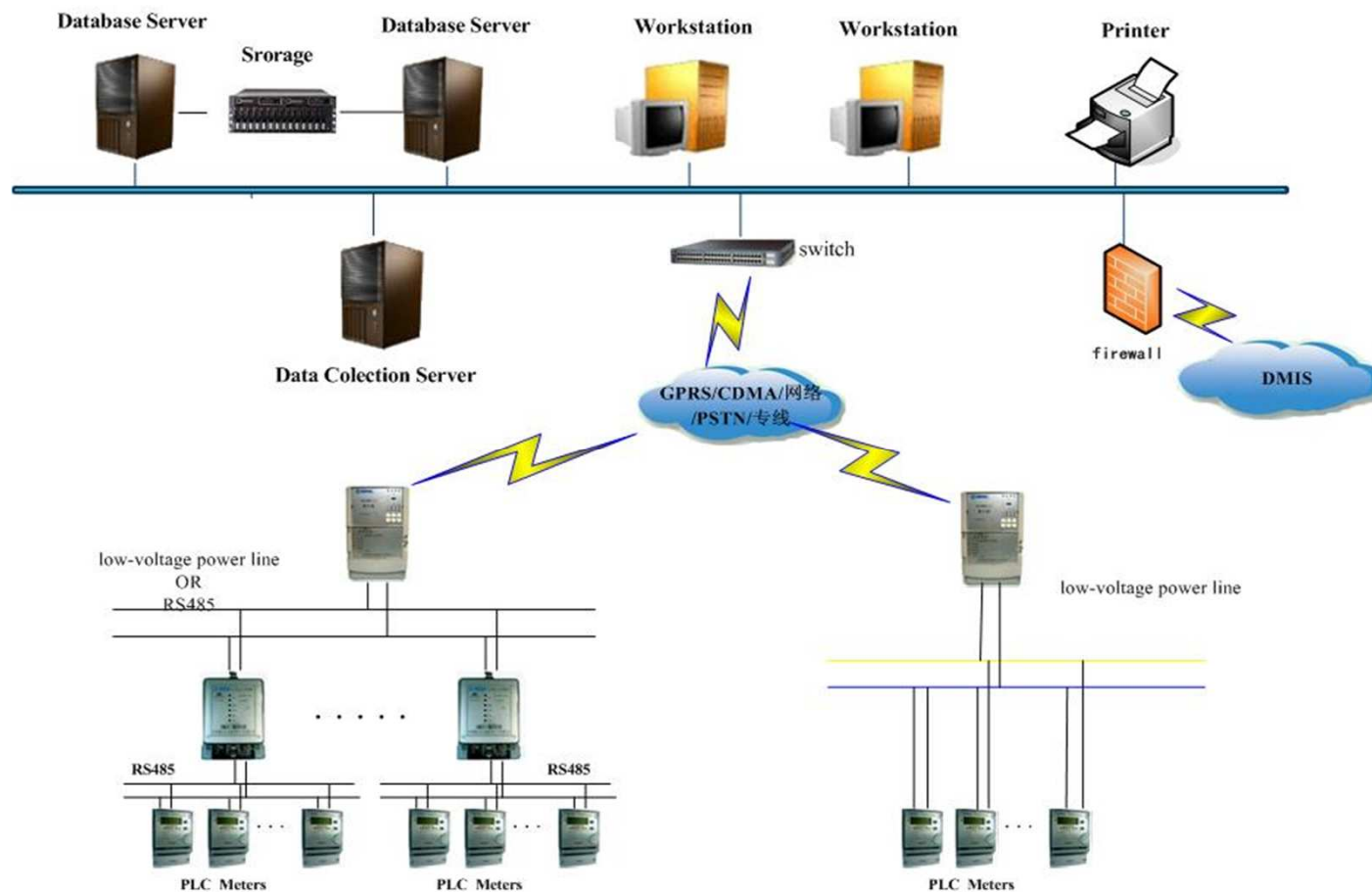
Optimize meter data collection





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AMI Network - PLC

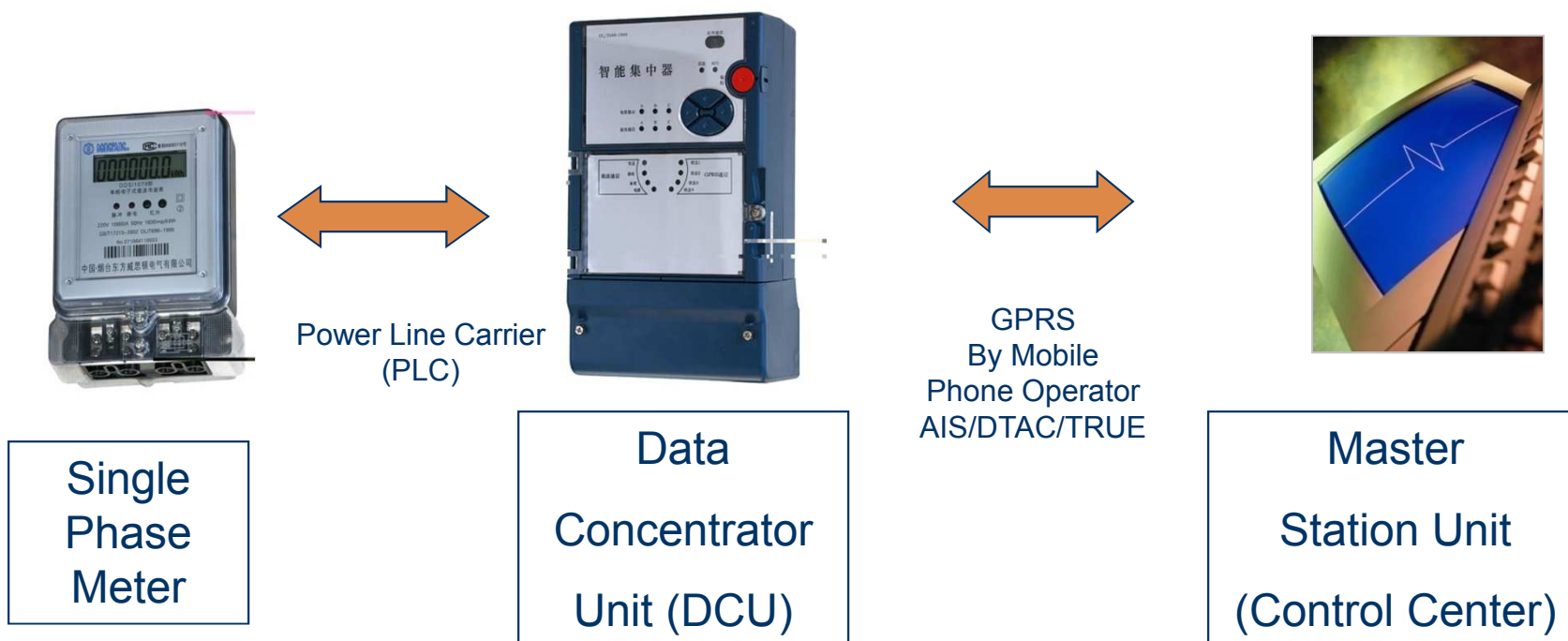


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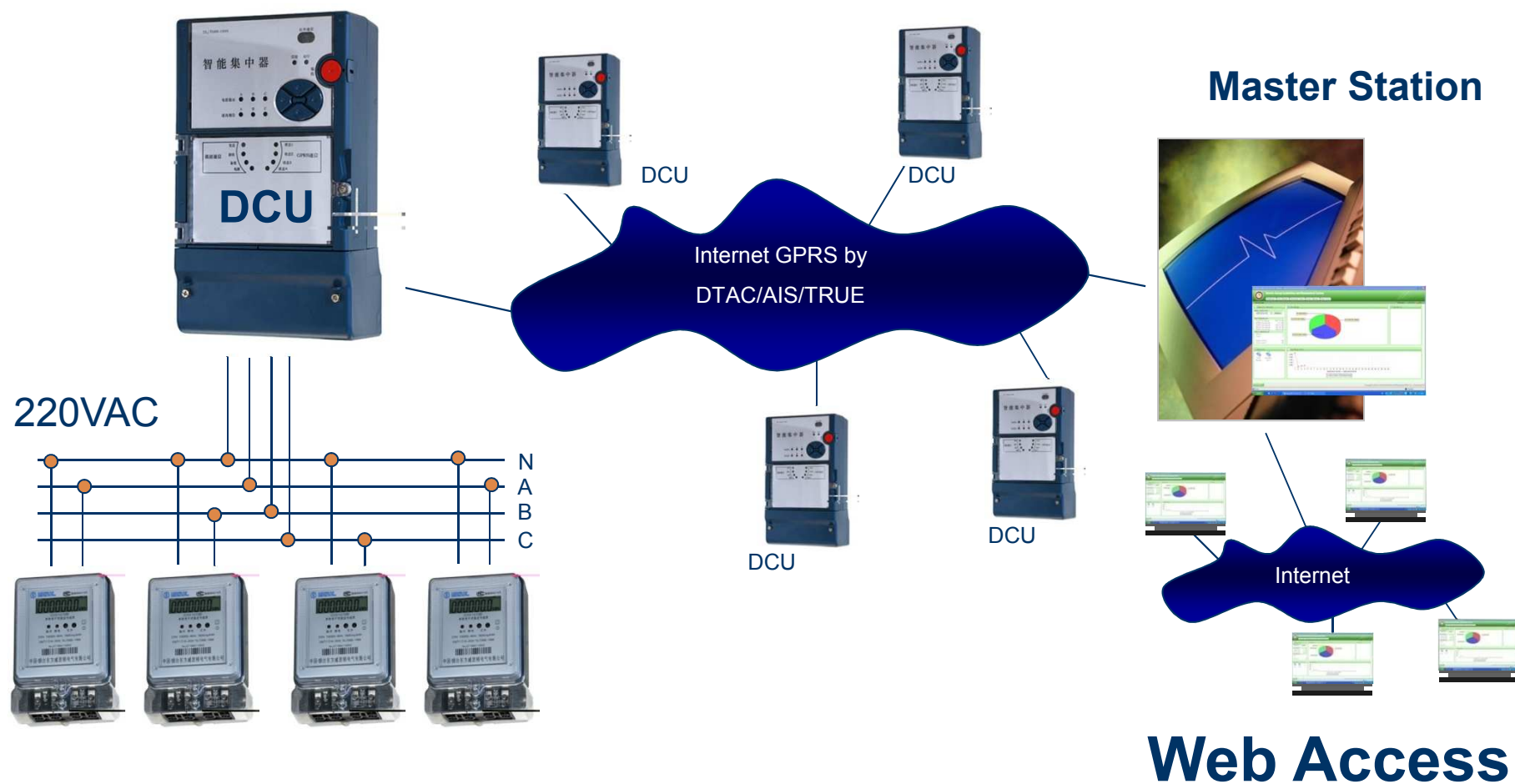
AMI Network - PLC





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AMI Network - PLC



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AMI Network - PLC



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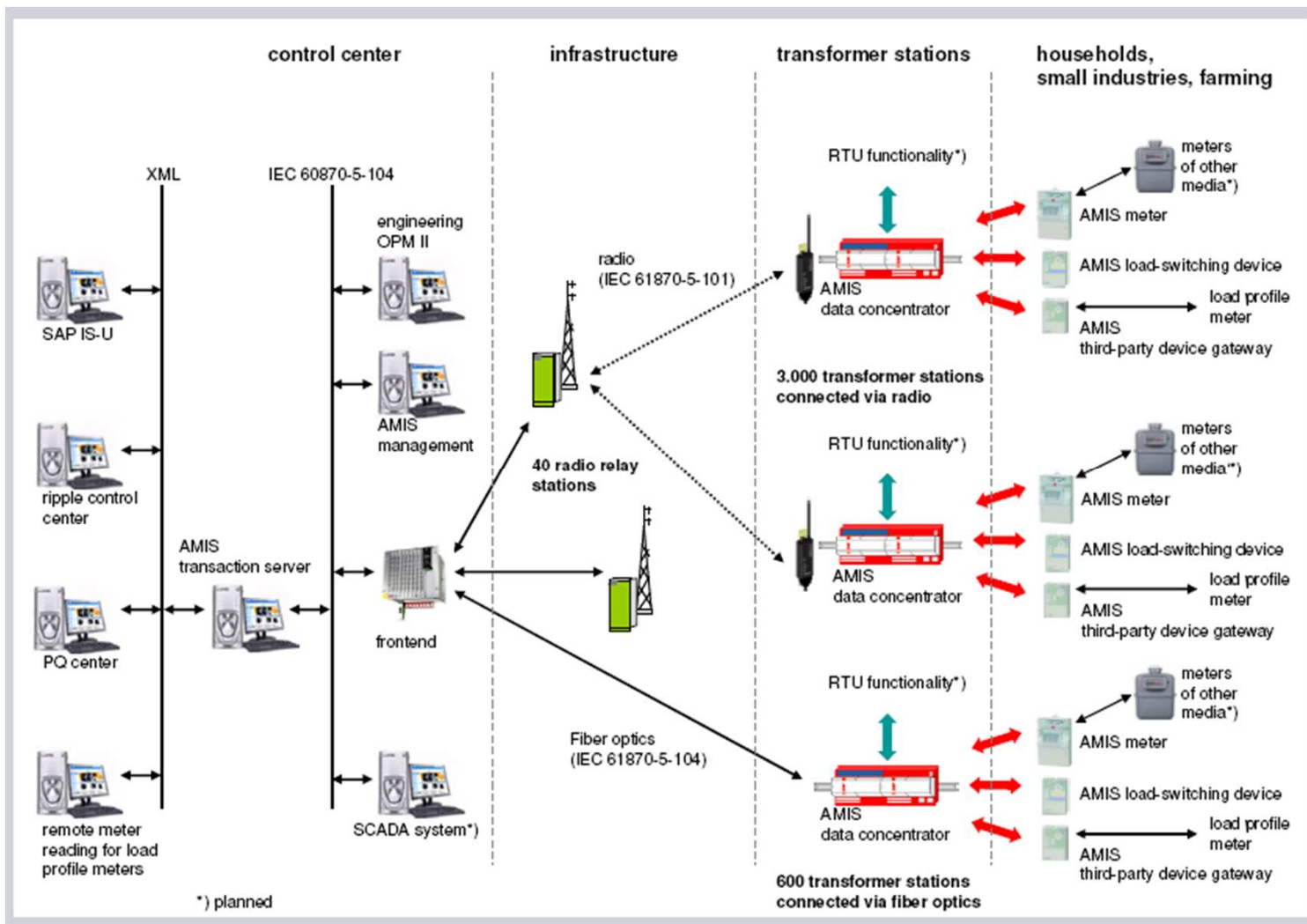
AMI Network - ZigBee





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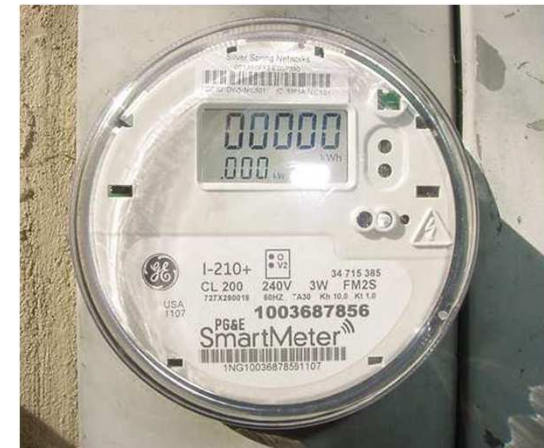
Example of AMI Project



Smart Grids Foundation: Largest US Smart Meter Deployment

- Ubiquitous automated meter reading
 - 10 million meter upgrades by 2012
 - 3.5 million deployed to date
- Frequent meter reads
 - daily for gas
 - hourly or 15 minute intervals for electric
- Embedded in-premise network gateway device unlocks new opportunities
 - Customer energy management
 - Demand-side management
 - SmartCharging for PEVs

PG&E
SmartMeter

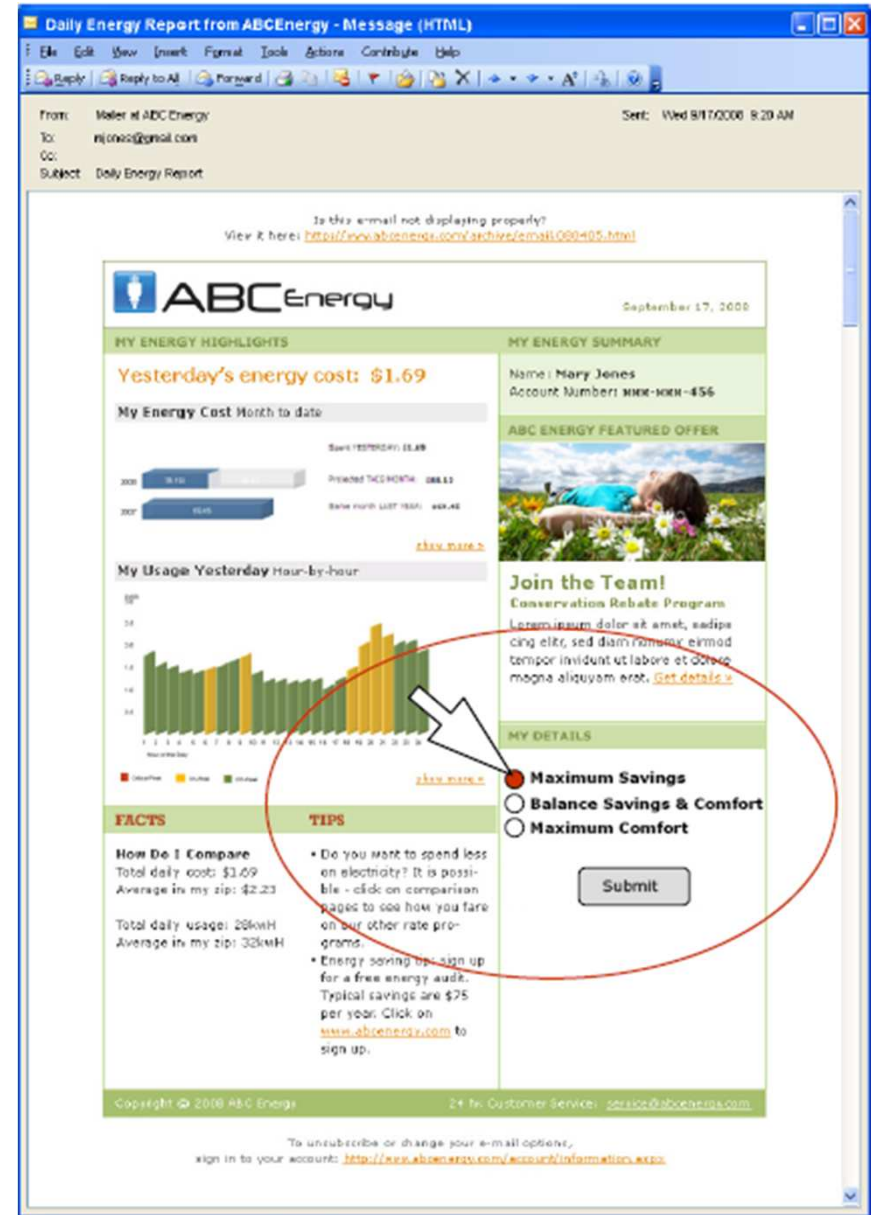




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Online Energy Use Information

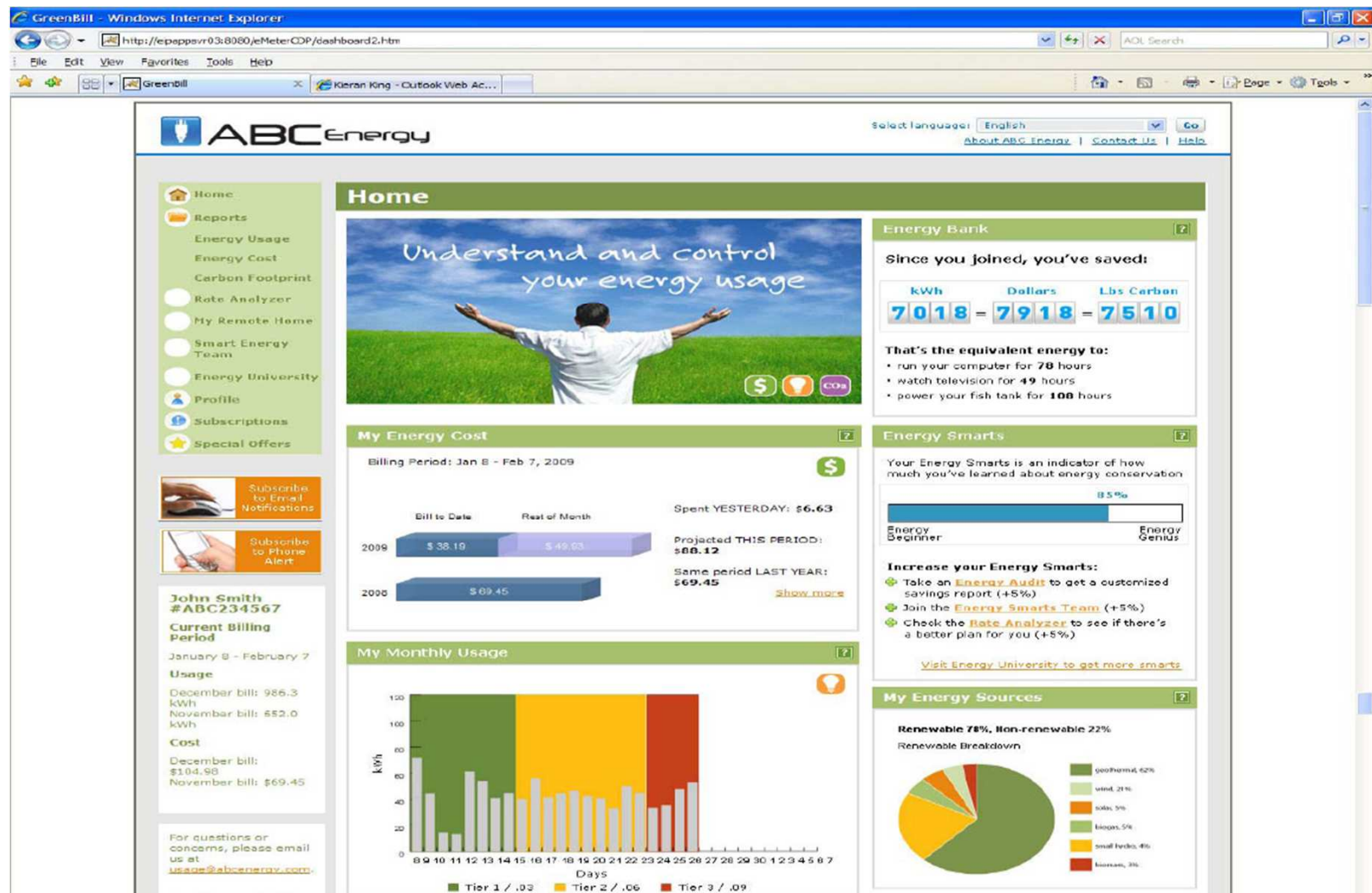
- Secure customer access
- Displays energy use by billing cycle, month, or week
- Displays daily hourly electric use
- Customer service reps able to view same graphs online





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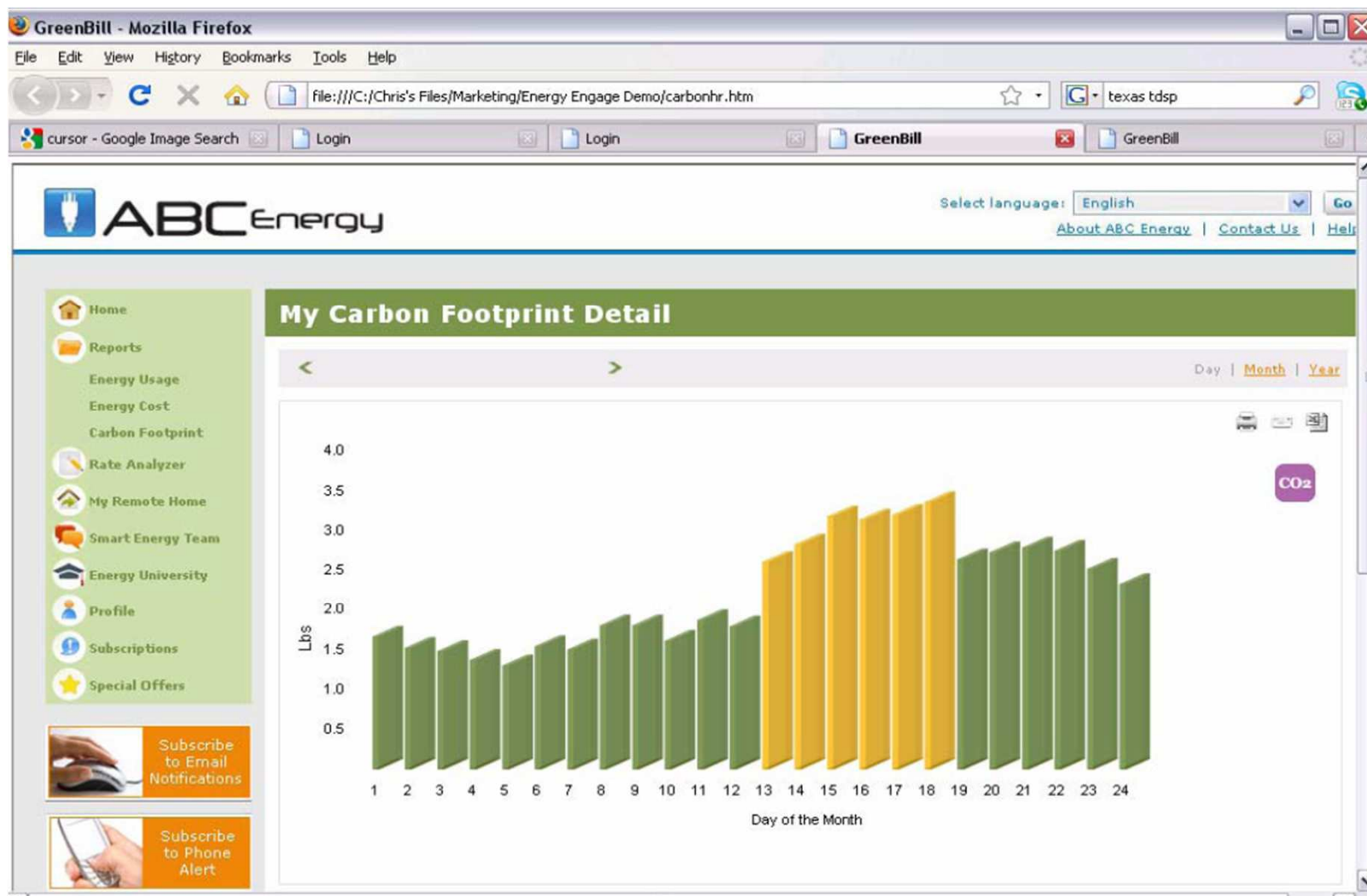
Energy Dashboard





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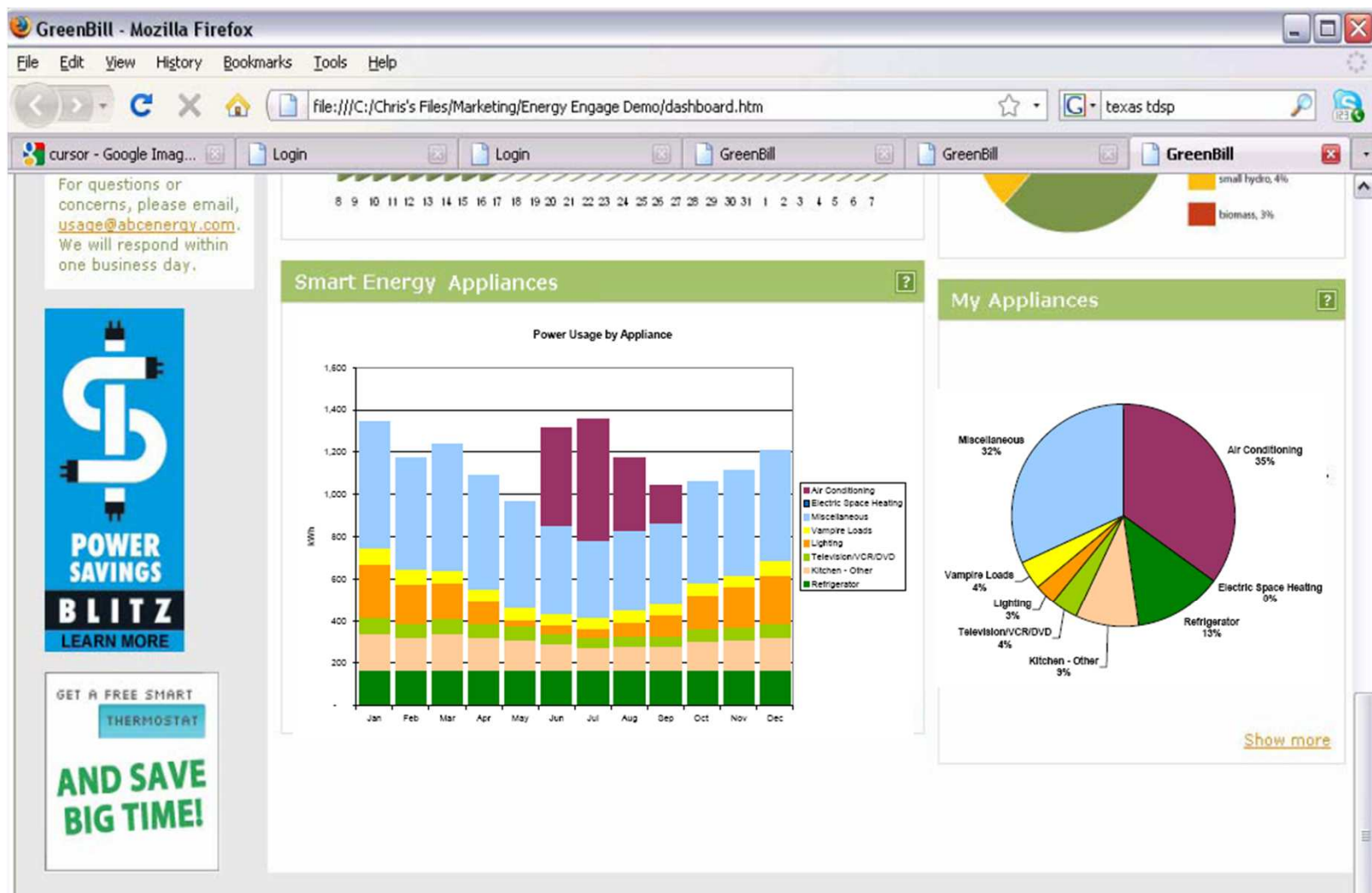
Carbon Footprint





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Usage by Appliance





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User Alarm and Alert

GreenBill - Mozilla Firefox

file:///C:/Chris's Files/Marketing/Energy Engage Demo/profile.htm

cursor - Google Image Search | Login | Login | GreenBill | GreenBill

ABC Energy Select language: English Go

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Personal Data	My Subscriptions																																							
Name Mary Jones Energy Account ABC123456 Address 123 Main St. Anytown, ST 94707 User ID email or unique ID Password 	<table><thead><tr><th></th><th>Text Message</th><th>Email</th></tr></thead><tbody><tr><td colspan="3">Regular Notifications</td></tr><tr><td>My Energy Cost and Usage - Daily</td><td>☐</td><td>☐</td></tr><tr><td>My Energy Cost and Usage - Weekly</td><td>☐</td><td>☐</td></tr><tr><td>My Energy Cost and Usage - Monthly</td><td>☐</td><td>☐</td></tr><tr><td colspan="3">Triggered Alerts</td></tr><tr><td>Power Outage Alerts</td><td>☐</td><td>☐</td></tr><tr><td>Budget Threshold Alerts</td><td>☐</td><td>☐</td></tr><tr><td colspan="3">Set my monthly energy budget to: \$ </td></tr><tr><td colspan="3">Alert me with a Budget Threshold Alert when:</td></tr><tr><td colspan="3">☐ I move into the next price tier. (For tiered rate customers only.)</td></tr><tr><td colspan="3">☐ My actual energy cost is % of my energy budget.</td></tr><tr><td colspan="3">☐ My projected monthly energy cost is \$ over</td></tr></tbody></table>		Text Message	Email	Regular Notifications			My Energy Cost and Usage - Daily	☐	☐	My Energy Cost and Usage - Weekly	☐	☐	My Energy Cost and Usage - Monthly	☐	☐	Triggered Alerts			Power Outage Alerts	☐	☐	Budget Threshold Alerts	☐	☐	Set my monthly energy budget to: \$			Alert me with a Budget Threshold Alert when:			☐ I move into the next price tier. (For tiered rate customers only.)			☐ My actual energy cost is % of my energy budget.			☐ My projected monthly energy cost is \$ over		
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PREPAYMENT USING AMI



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Hardware vs. Software

- What's common in all of the standard prepayment solutions is they are hardware based



- With smart meters we can move to software based solution





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Typical AMI Business Case

☐ Business that an AMI solution supports:

☐ Peak demand management / critical peak pricing

☐ Energy conservation

☐ Lower meter reading costs

☐ Improve customer service / shorten customer call times

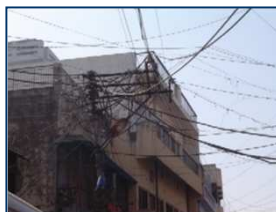
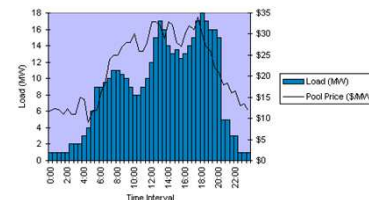
☐ Offer advanced product options and billing capabilities

☐ Remote detection – outage and network management

☐ Theft discovery

☐ *Prepayment*

☐ Asset management (predictive maintenance of distribution equipment)



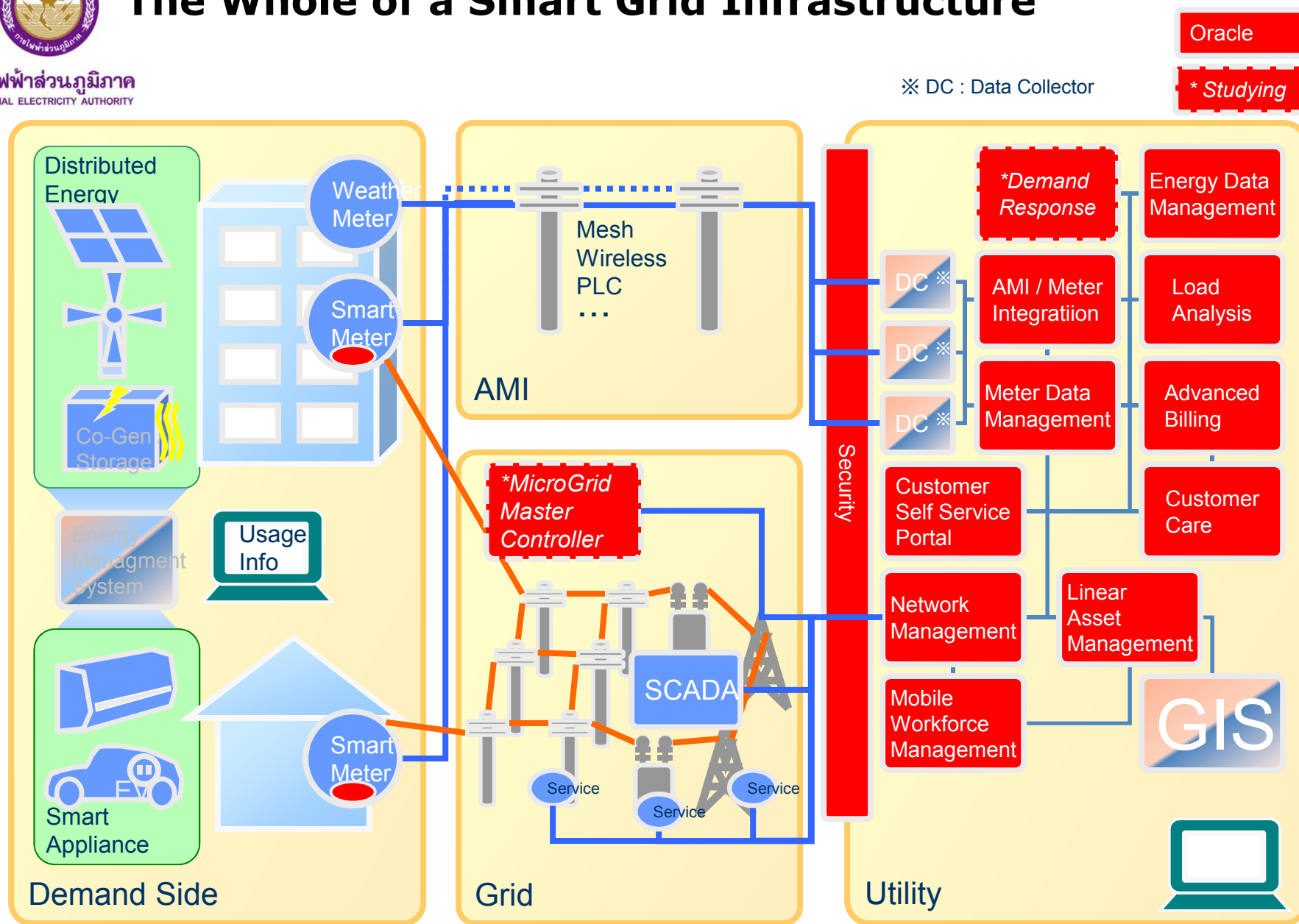
Benefits of the Software-based Solution

- ☐ Use existing or planned AMI infrastructure
 - ☐ AMI is being implemented globally for many business reasons
 - i.e. - prepayment is just another benefit of AMI
- ☐ Extend the program to all interested parties
- ☐ One billing system
- ☐ Use existing payment infrastructure
- ☐ Health and safety issues can be more easily addressed



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The Whole of a Smart Grid Infrastructure



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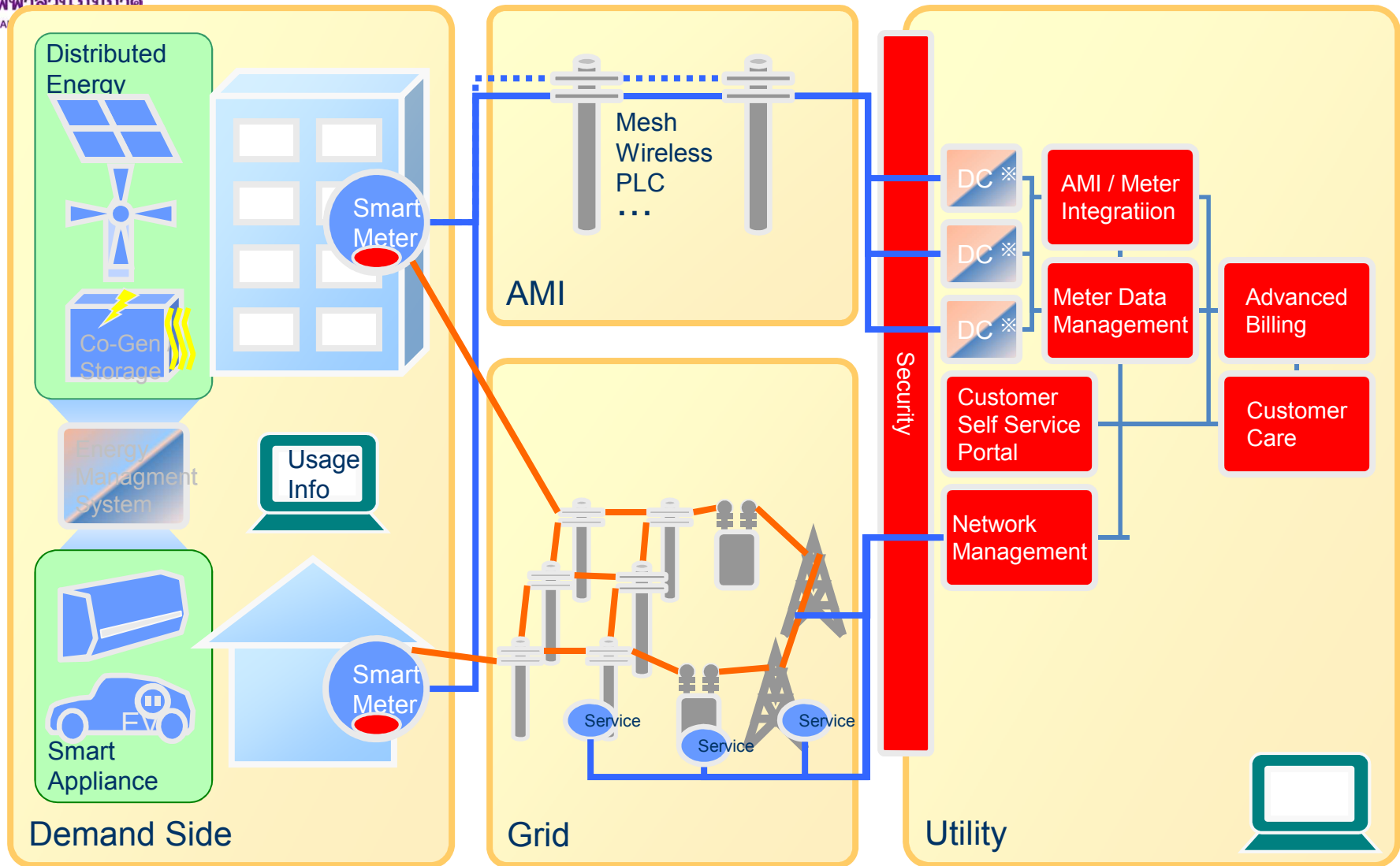


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Prepayment Within The Smart Grid

※ DC : Data Collector

Oracle

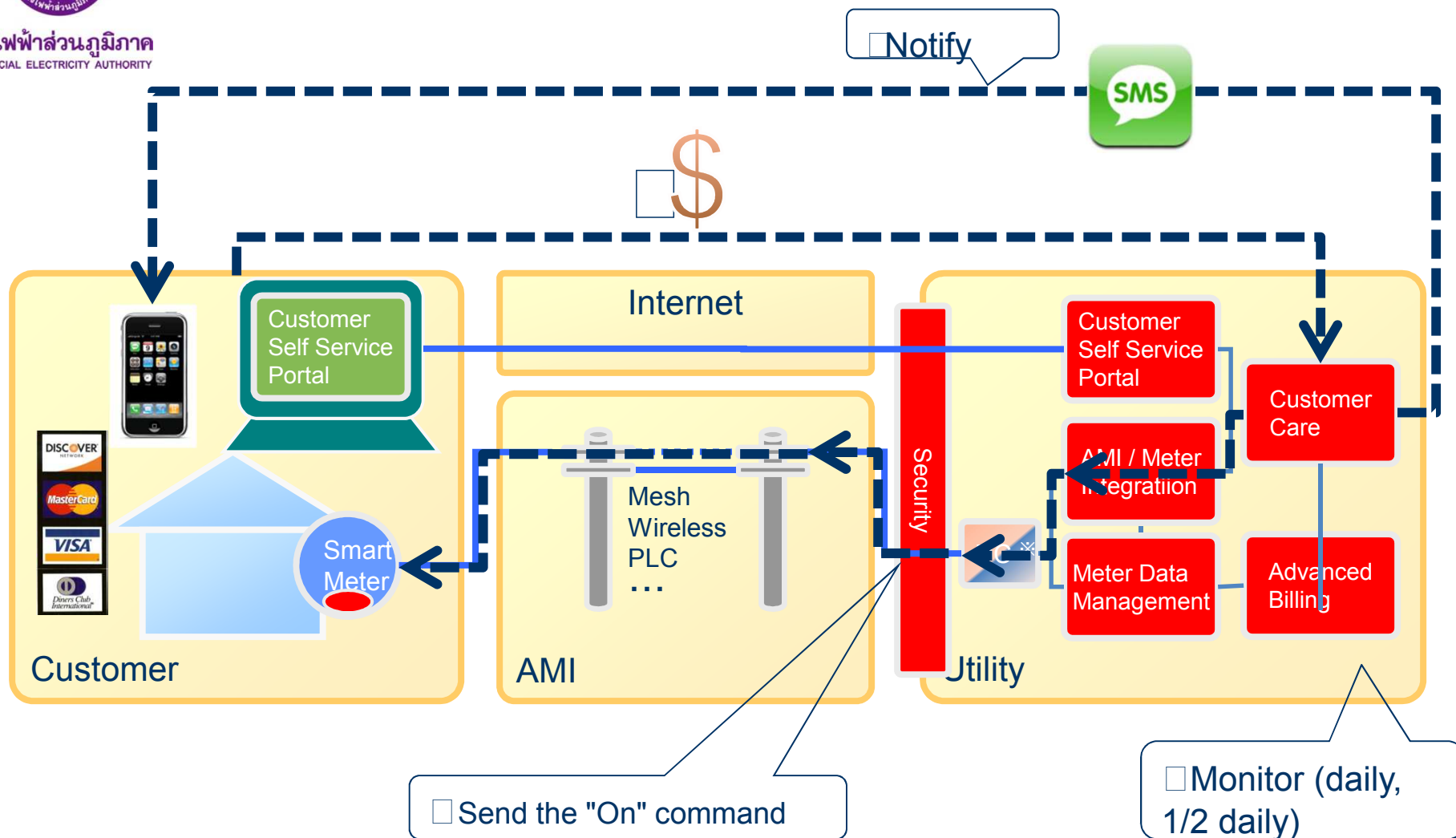


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Prepayment Within The Smart Grid



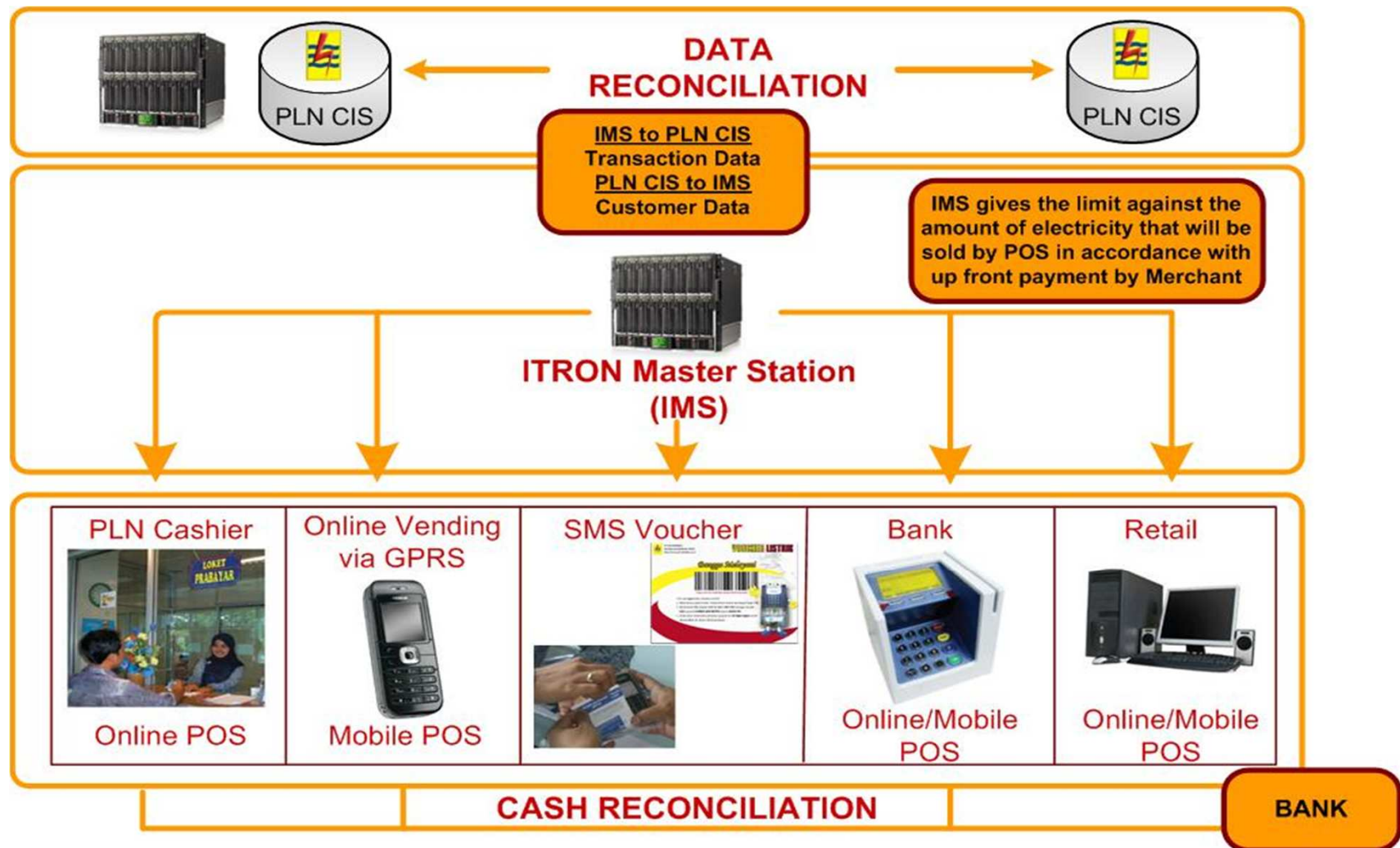
※ DC : Data Collector

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Itron Prepayment Infrastructure





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Additional Benefits

- ☐ Central tracking of critical needs customers
- ☐ Easy to manage a small credit balance to avoid loss of power
- ☐ Less costly to change / modify the program over time
- ☐ Future possibilities
 - ☐ Charging PHEVs - pay as you go



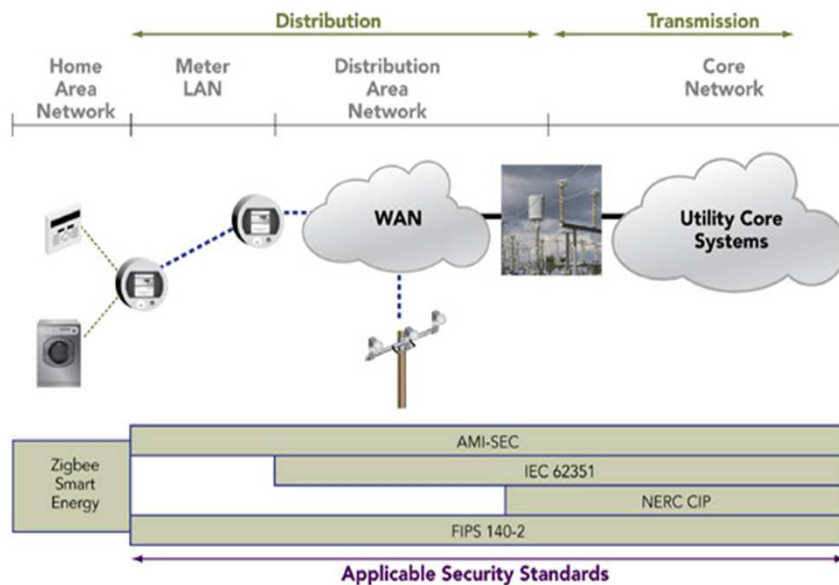
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Security Considerations

□ Nothing new here

□ AMI security must already be in place

□ Payment security systems must already be in place



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1 Meter energizes, self-authenticates

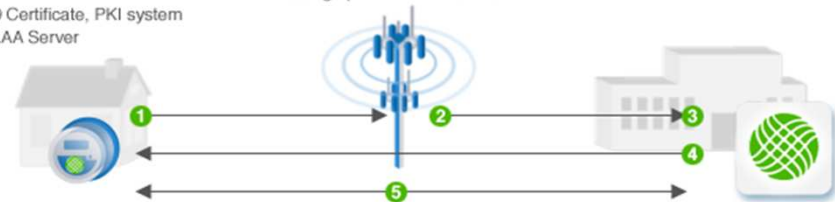
- Device security via EAP/TLS, IPSec, IKE, unique digital signature and hardware-enforced code signing
- WiMAX PKMv2 (EAP/TLS over RADIUS)
- X.509 Certificate, PKI system and AAA Server

2 Meter authenticated, authorized by 4G broadband network

- EAP-based authentication
- AES-CCM-based authenticated encryption
- CMAC and HMAC based control message protection schemes

3 Meter authenticated, authorized by PolicyNet

- Identity & AAA Services (ITU, IETF)
- Certificate Authority w PKI
- AAA Server (RADIUS; EAP/TLS)



4 Secure Smart Grid system connection established

5 End-to-end data encryption and transmission

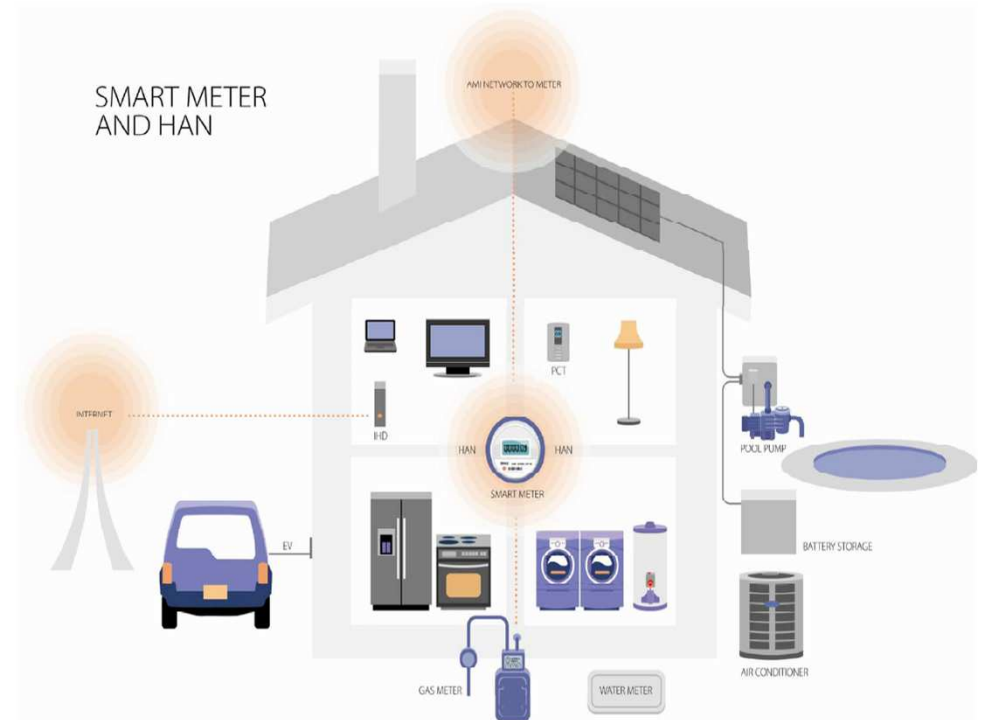
- Cipher Block Chaining Message Authentication Code Protocol (CCMP)
- IPSEC / GRE, TLS, GMPLS
- Traffic Engineering: DiffServ, RSVP

© 2006 – 2010 Grid Net.

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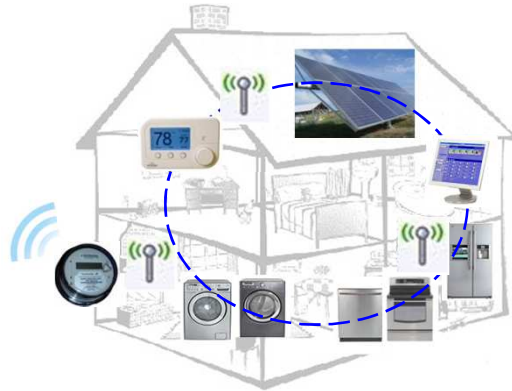


HOME AREA NETWORK (HAN)



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In-premise Network: Increasing Levels of Sophistication



Basic



- Simple high-low indicator

Enhanced



- More comprehensive in-home displays (usage, cost, time)
- Programmable Communicating Thermostat (PCT)

Advanced

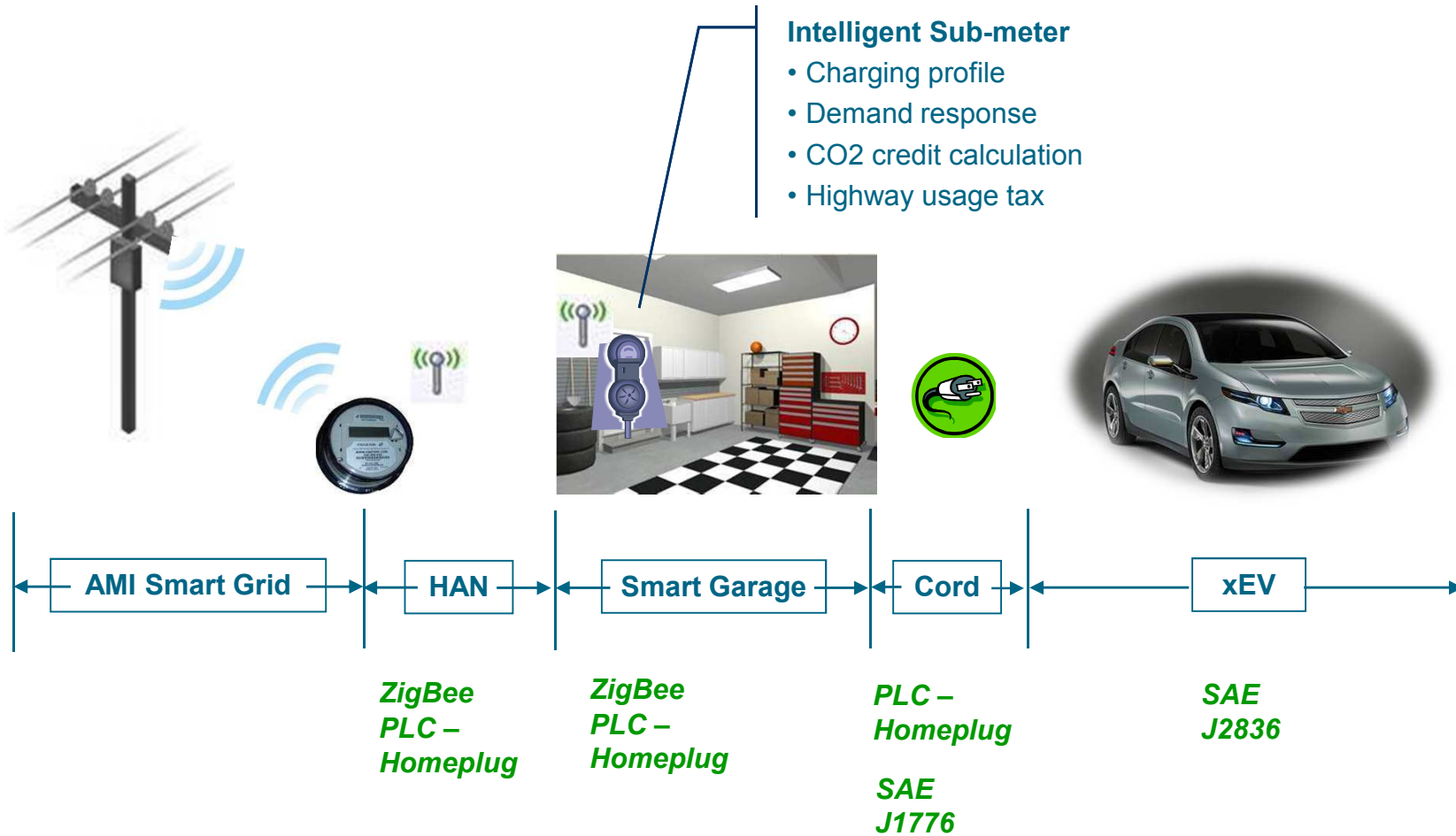


- Fully automated intelligent energy management system
- Other automated/programmable appliances
- Electric vehicle charging / storage
- Distributed generation and storage



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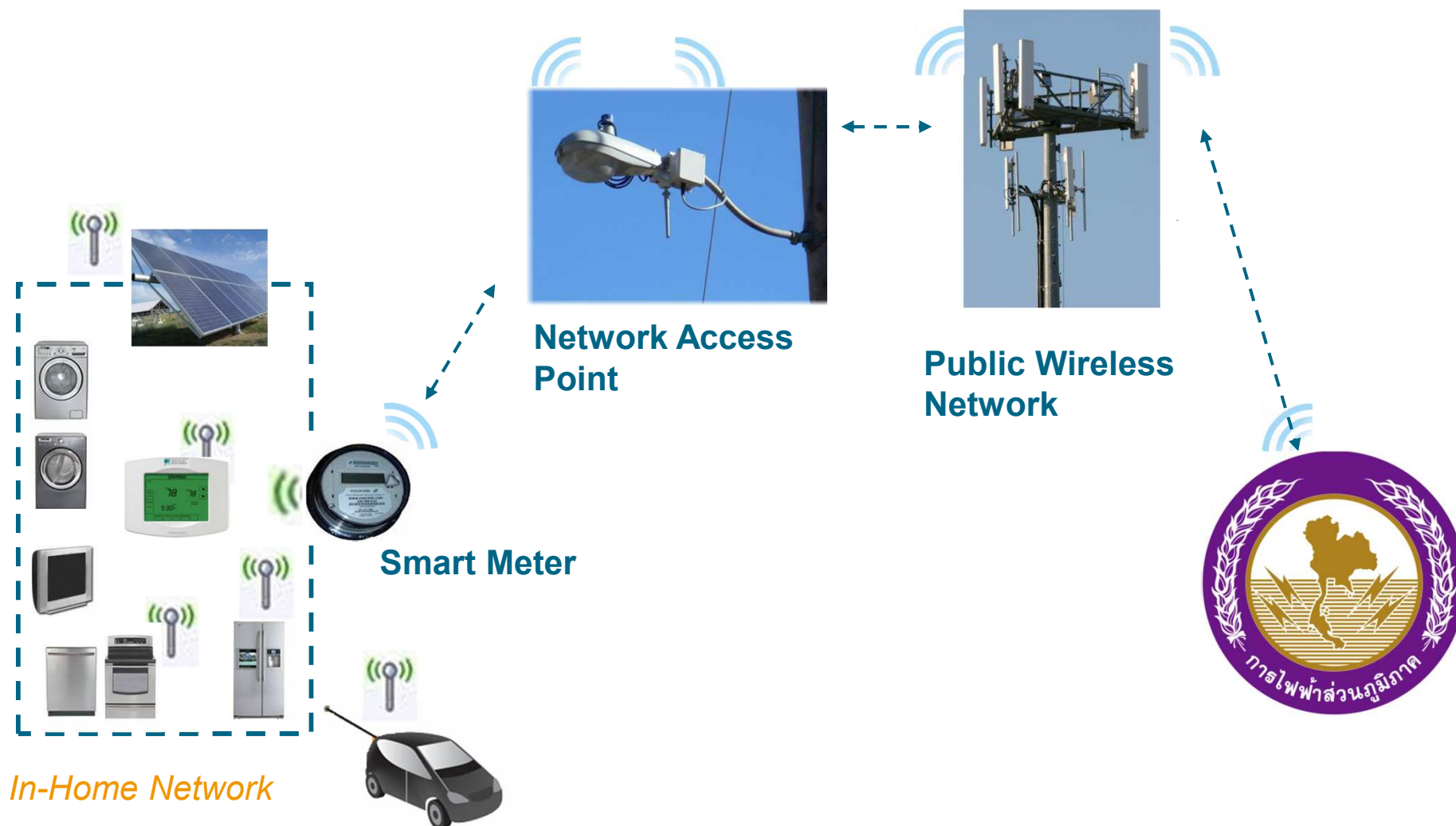
SmartPort Network Architecture





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Smart Grids Expands Sensing and Control into Customer Premise





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Smart House – Xcel Energy

Added green
power sources

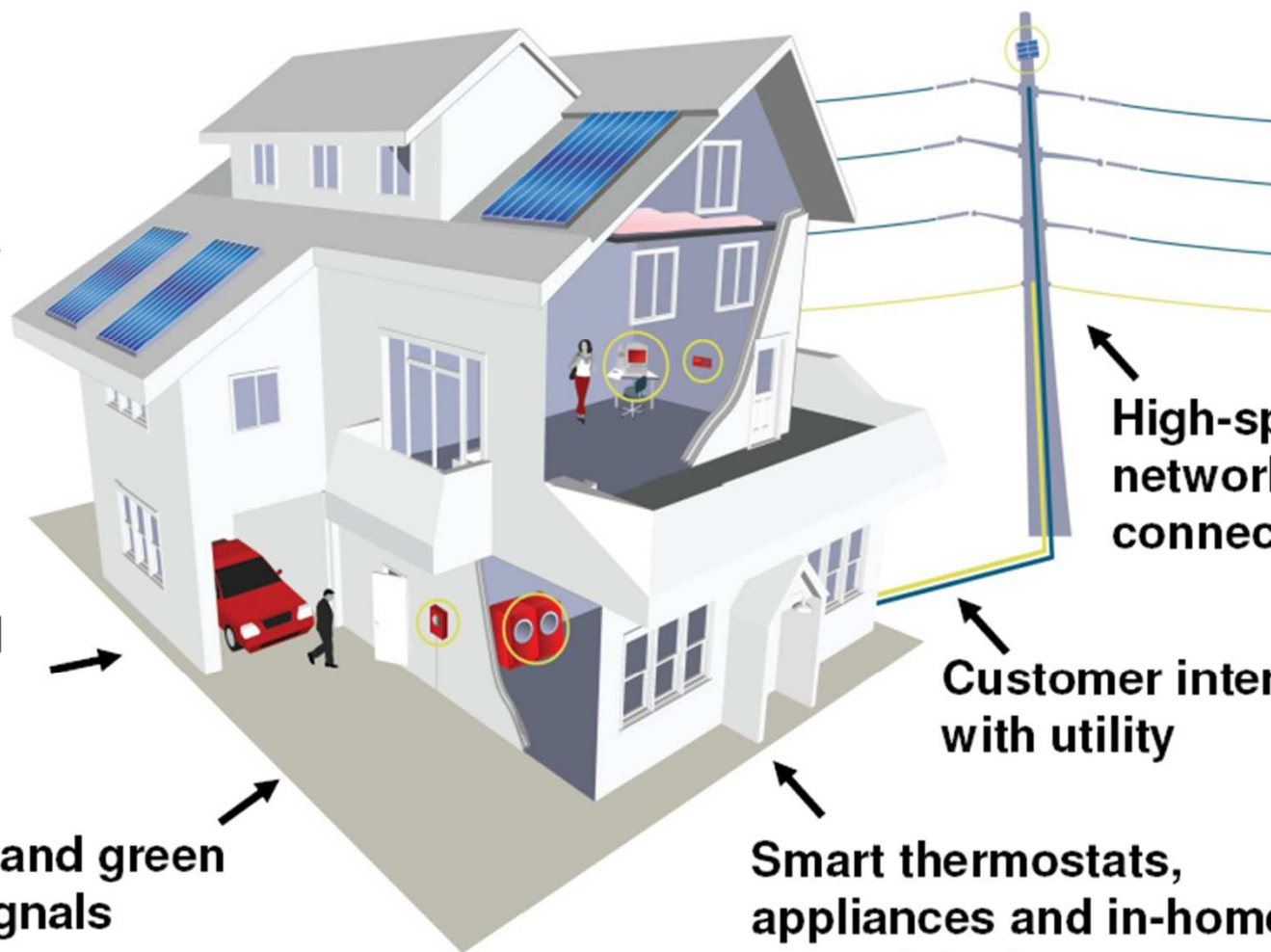
Plug-in hybrid
electric cars

Real-time and green
pricing Signals

High-speed,
networked
connections

Customer interaction
with utility

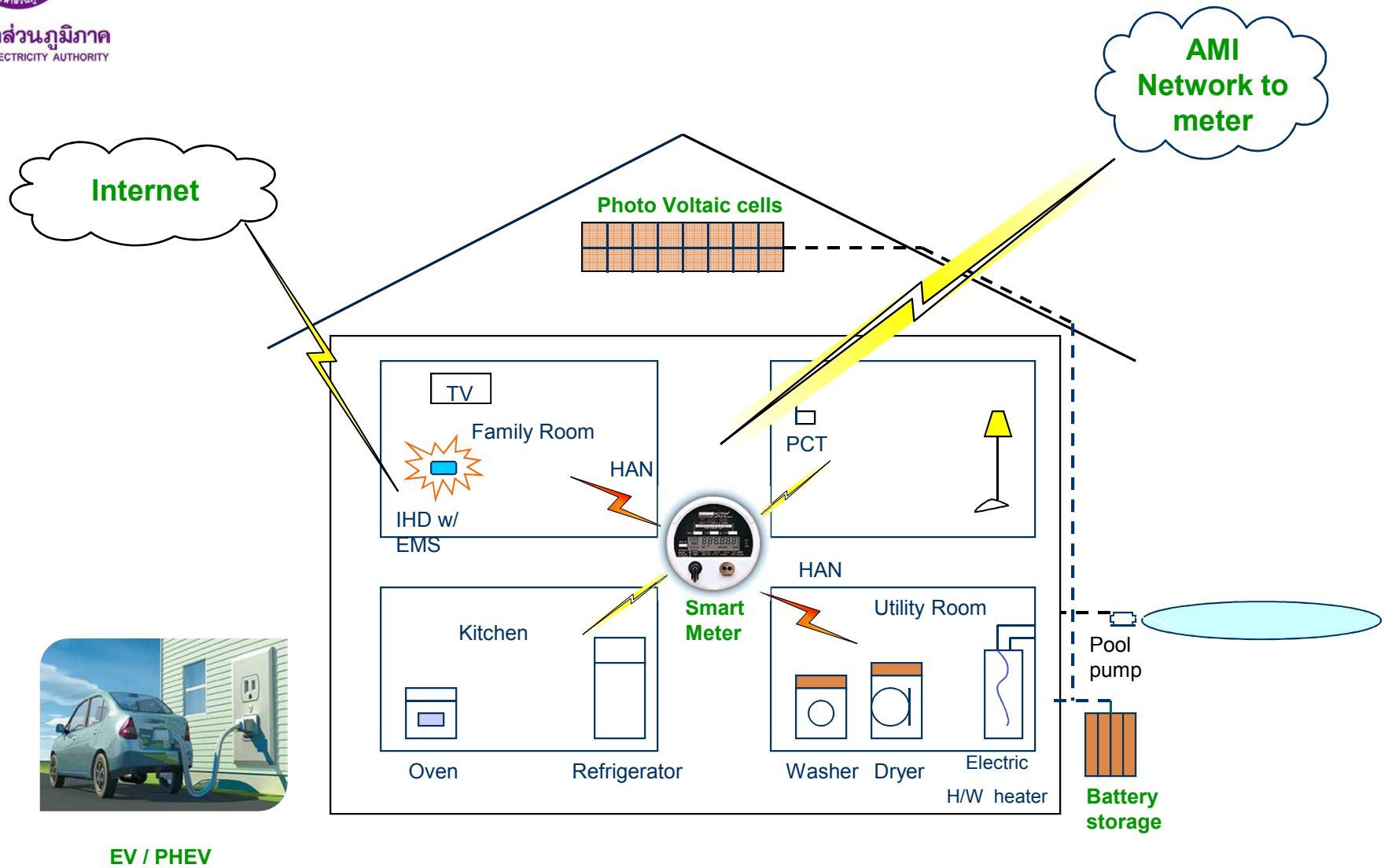
Smart thermostats,
appliances and in-home
control devices





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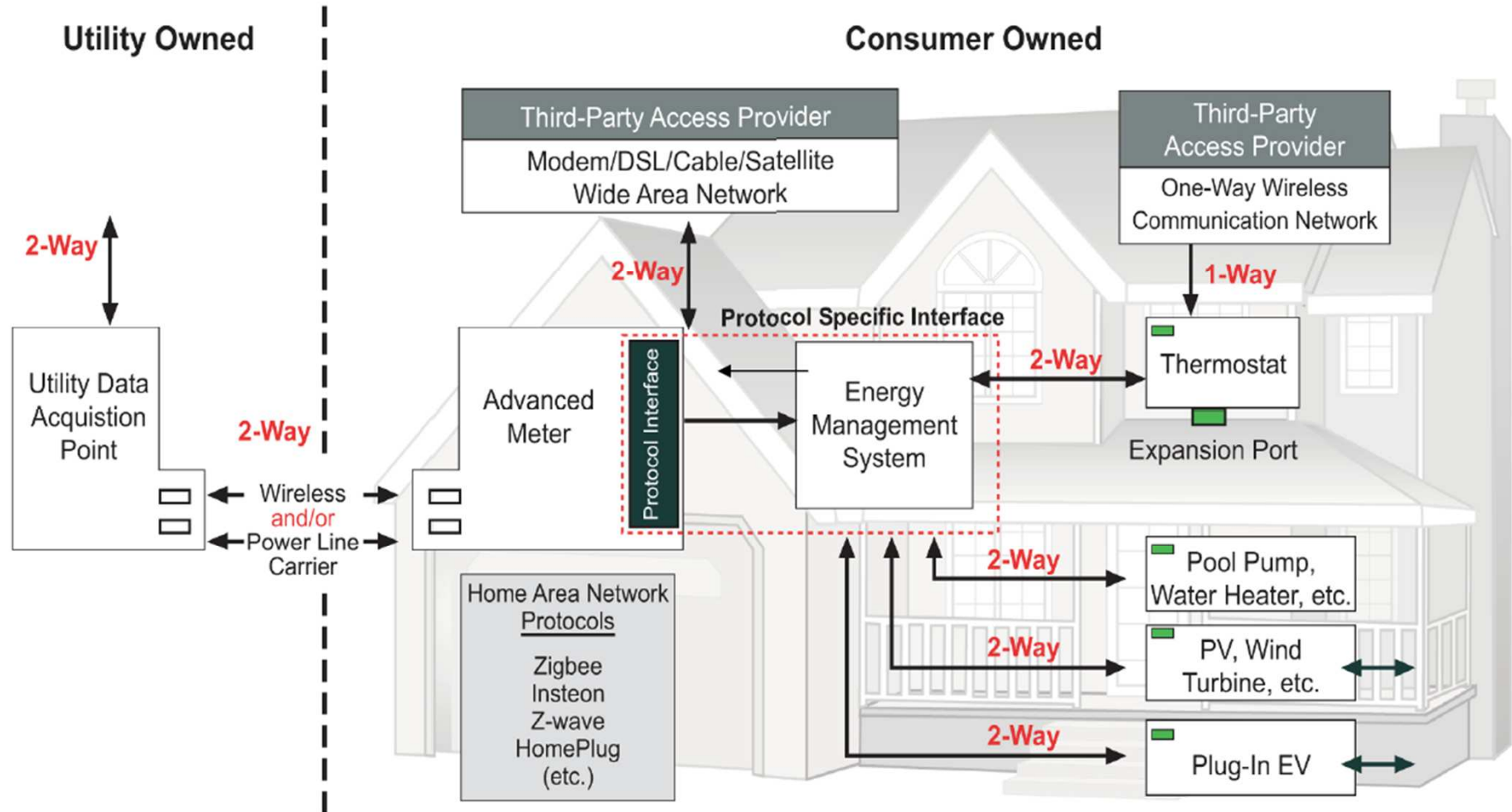
Smart Meter and HAN





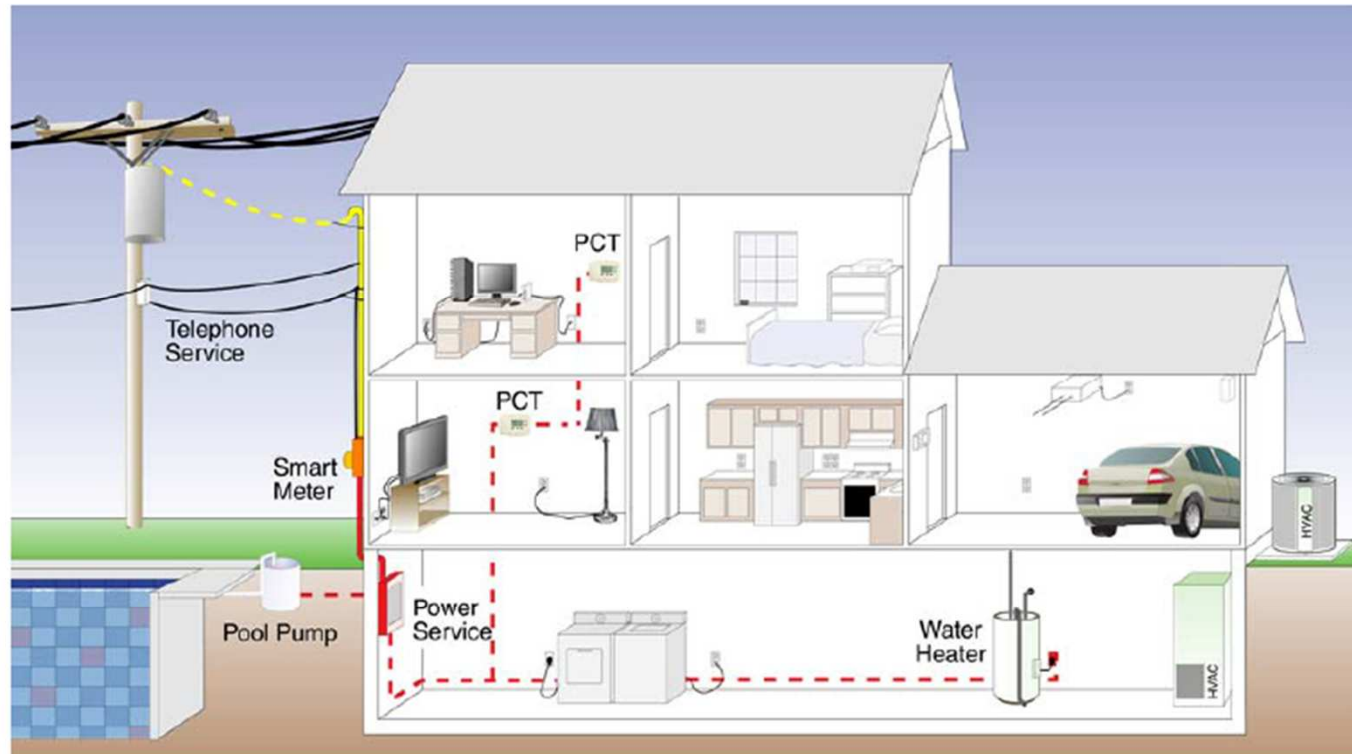
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General HAN Communication Network Architecture





- HomePlug
- Insteon
- WiFi
- ZigBee
- Z-Wave



- Air Conditioner
- Pool Pump
- Water Heater



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In-Home Display Devices



- Provide consumers with usage information, price notification, total bill values



- Can place in most obvious location in home to maximize impact





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Controllable Thermostats



Controllable thermostats enable the utility to remote transmit signals to raise or lower temperature set points.

- A few degree change can result in significant demand reduction when aggregated together
- Operation does not significantly impact customer comfort
- Customer retains over-ride control

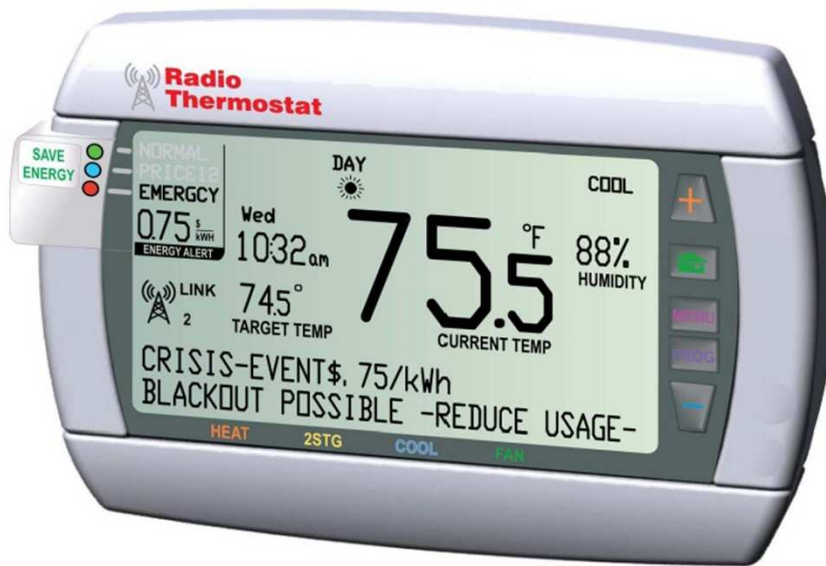




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PCT = programmable communicating thermostat

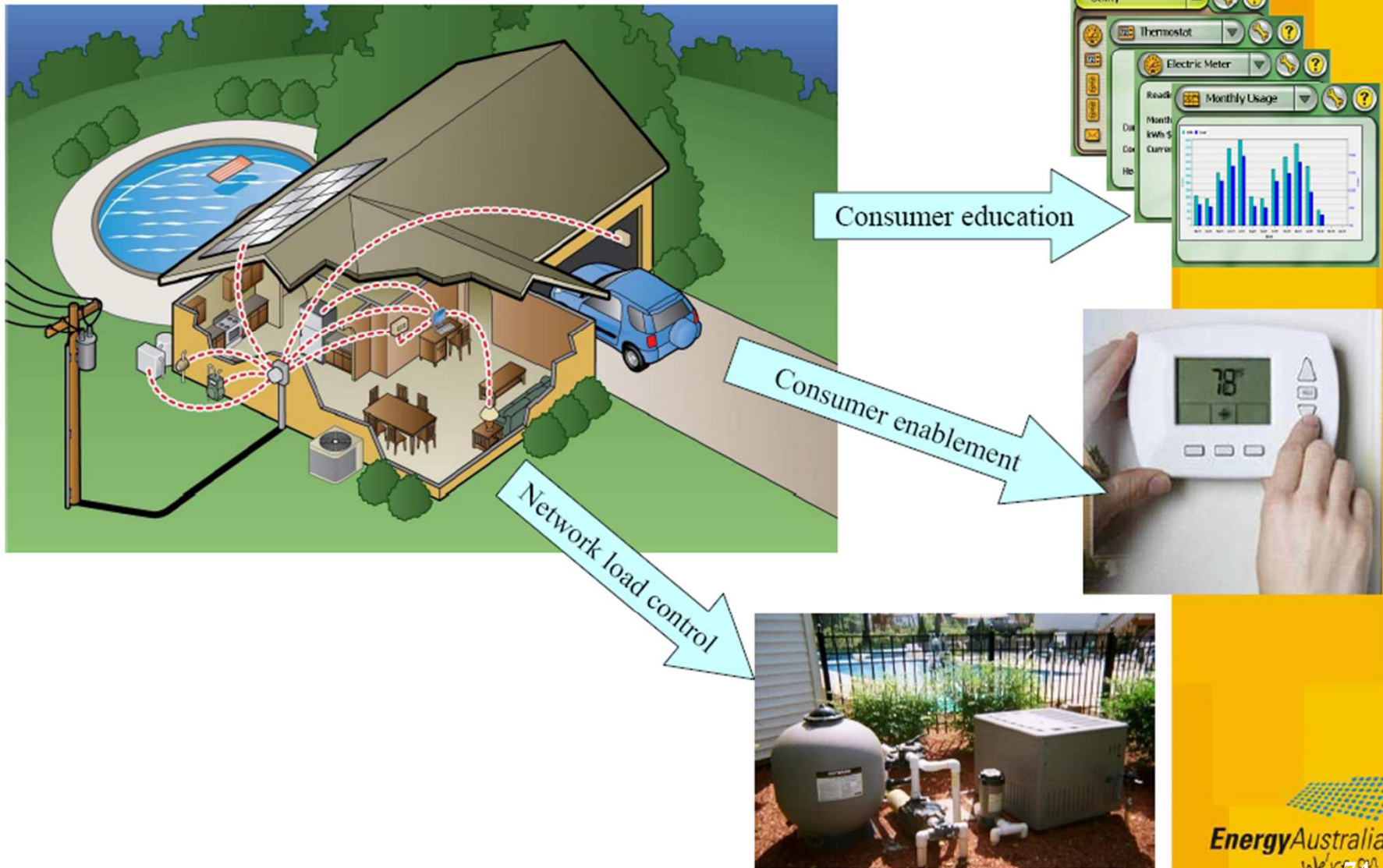
Front View



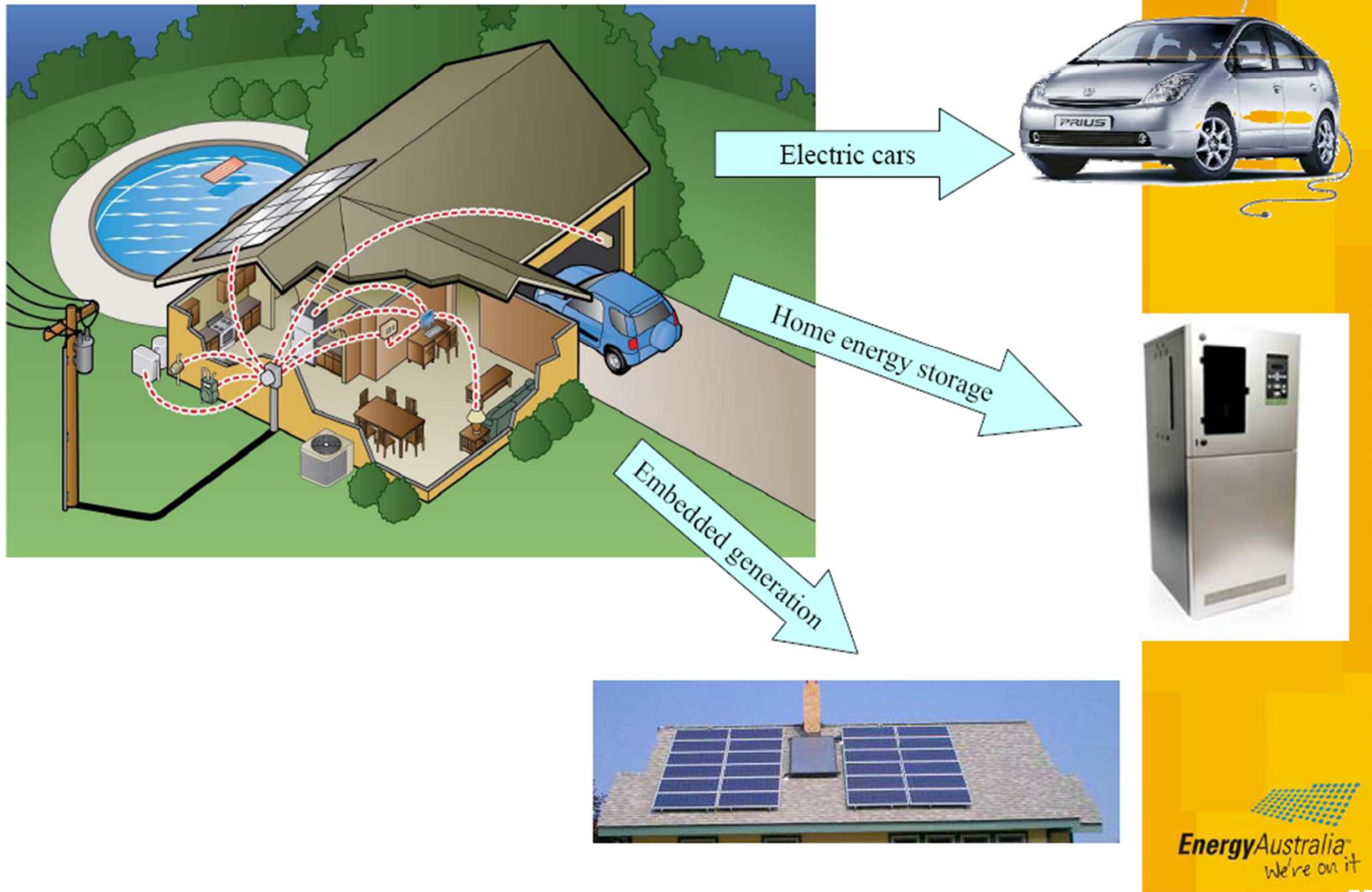
Rear View



HAN communications – a challenge



HAN functionality – longer term





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Web-based Customer Accesses

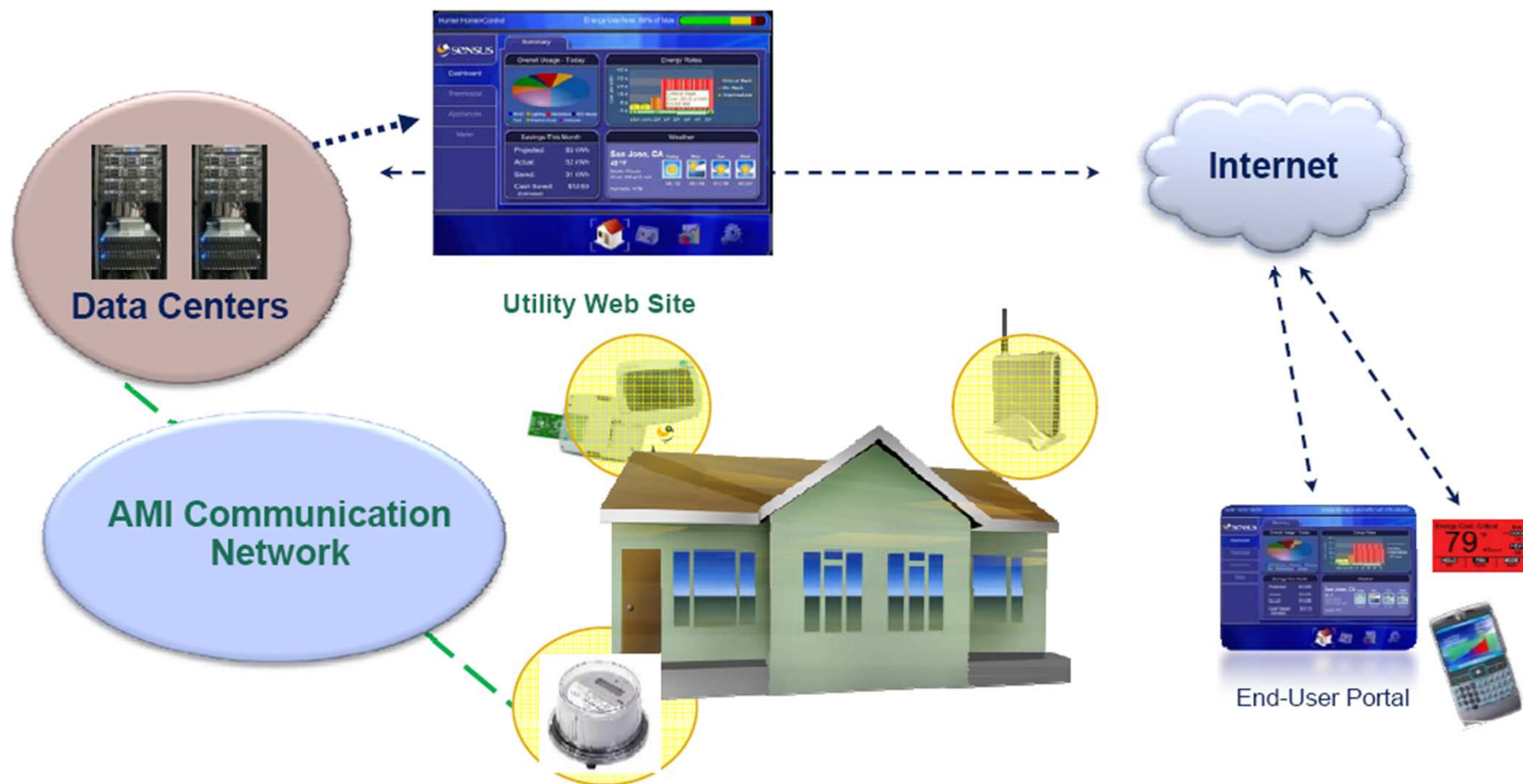
Sensus FlexServer™
provides customer access
via the web or other
devices ...





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Alternatives for provision of customer information ...

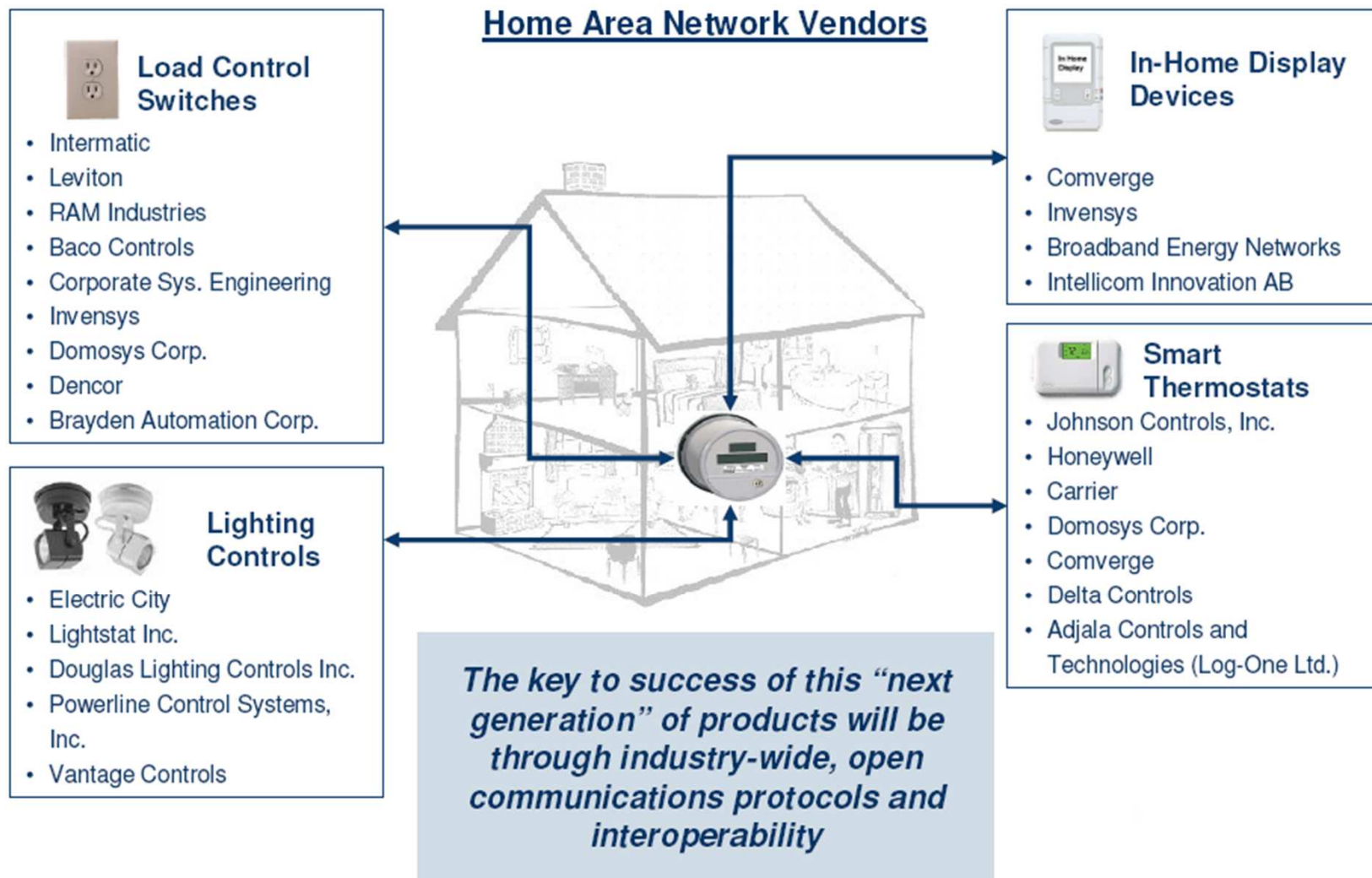


Meter, Thermostat, or In-Home Gateway Bridge



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The number of vendors seeking the Home Area Networking market is significant – many expect to follow the AMI path to commercialization.

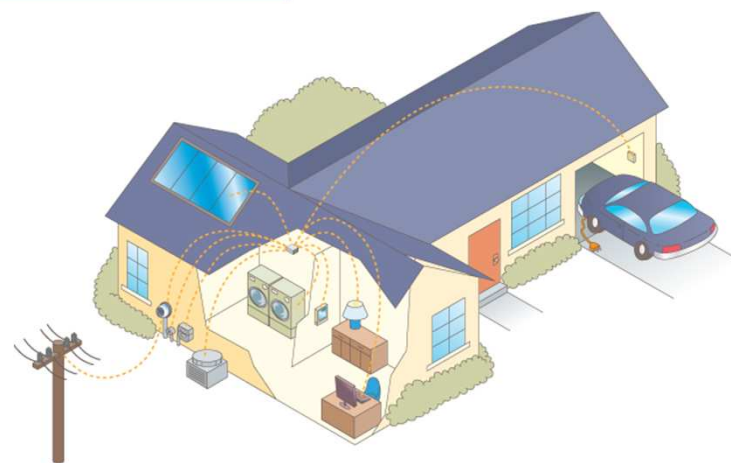




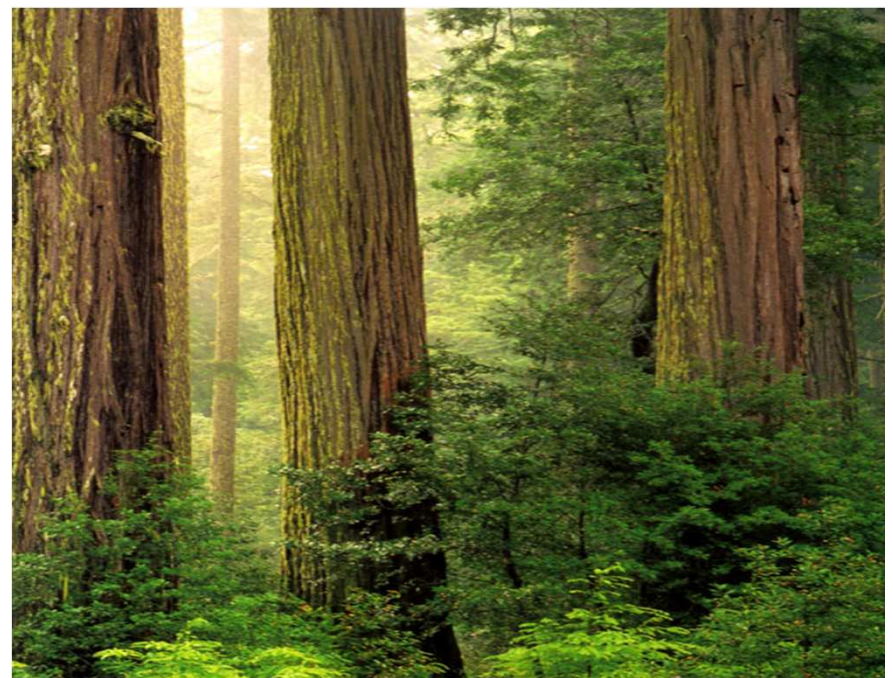
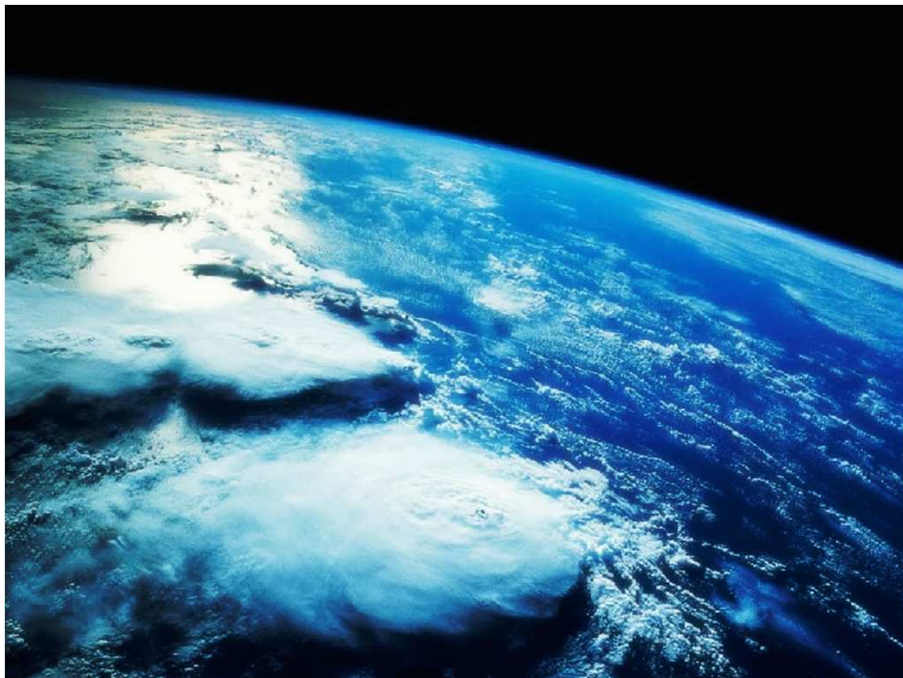
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Costs for in-premise equipment...

Device	Today's approx. cost in Volume 10k
▪ Programmable controllable thermostat (PCT) with radio	\$200 - \$250
▪ In home display	\$125
▪ Load control module (control water heaters, pool pumps, etc.)	\$100 - \$120



At PEA, We are Committed to Sustainability





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**Thank you
for your attention!**

Any Question?

Dr.Pradit Fuangfoo

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pradit_fu@pea.co.th**