FEMP Metering Training Course
Session 2: Metering Technologies, Communications, and Data Storage
March 14, 2007

Course Introduction – slide 3

- Help Federal agencies meet EPAct 2005 metering requirements
- Three-part program
  - Metering Overview (2/28/2007)
  - Metering Technologies, Communications, and Data Storage (3/14/2007)
  - Metering Planning, Financing, Data Usage, and Case Studies (4/4/2007)

Session #1 Presentation – slide 4

- Video available at http://eere.pnl.gov/femp/metering_webcast.stm

Session #2 Objectives – slide 5

- As related to EPAct 2005, a detailed overview of:
  - Electric metering technologies
    - Non-electric metering topics
  - Communication options
  - Data access and storage

Other FEMP Metering Support – slide 6

- FEMP metering website:
  http://www.eere.energy.gov/femp/technologies/om_advmetering.cfm
- Energy 2007 – August 5-8, 2007
  http://www.govenergy.com
- Metering Best Practices Guide – summer 2007:
  - Methods and approaches
  - Technologies and applications
  - Communications and data storage
  - Program planning
  - Data applications
  - Case studies

Session #2 Topics – slide 7

- ❑ Session #1 Highlights
- ❑ Metering Technologies
- ❑ Communications Options
- ❑ Data Access and Storage
- ❑ Session #3 Overview

Session #1 Highlights – slide 8

- EPAct 2005 metering "take-aways"
  - All buildings deemed "practicable" require metering
  - Practicable metric is "cost effectiveness"

Session #1 Highlights – Advanced Meters – slide 9

- Solid-state
- Interval data (at least hourly)
- Daily communications and retrieval (at least daily)
- Data use and analysis

Session #1 Highlights – Metering Approaches – slide 10

- Long-term
- Short-term
- Run-time
- One-time

Session #1 Highlights – Metering Hierarchies – slide 11

- Whole-building
- Panel/sub-panel
- Circuit
- End-use

Session #1 Highlights – System Development Considerations – slide 12

Metering system development pathways:
1. In-house
2. Combined in-house and contracted (hybrid)
3. Contracted/turn-key

Session #1 Highlights – EPAct 2005 Metering Requirements – slide 13

- All buildings deemed "practicable" require metering
- Practicable metric is "cost effectiveness"
- Federal cost effectiveness gauge: 10-year simple payback

Session #1 Highlights - Equation – slide 14

- Minimum electric bill for practicability:

$$\frac{\left[\left(\frac{\text{Installed Cost}}{\text{Desired Simple Payback}}\right)+\text{Annual Cost}\right]}{\%\ \text{Annual Savings}}=\text{Minimum Annual Electric Bill}$$

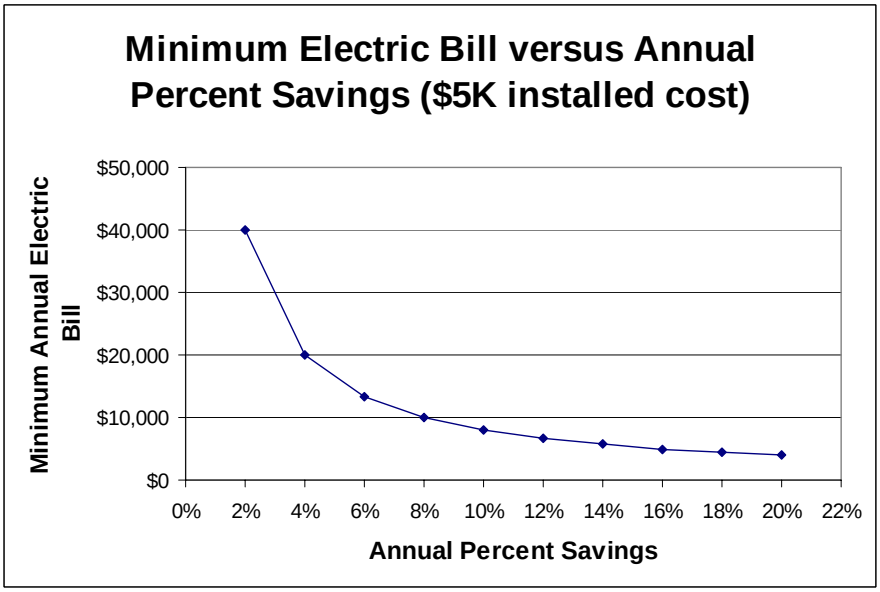
Session #1 Highlights - Sample – slide 15

- Minimum electric bill for practicability:
  - Installed cost: $5,000
  - Minimum payback: 10 years
  - Recurring costs: @$25/month
  - Annual savings: 2%

Sample Calculation

$$\frac{\left[\left(\frac{\$5{,}000}{10\text{ years}}\right)+\$25/\text{month}*12\text{ months}\right]}{2\,\%\text{ Annual Savings}}=\$40{,}000$$

Session #1 Highlights - Sample – slide 16



Session #1 Highlights – Estimate Energy Use – slide 17

- Need to know energy use to determine which to meter… BUT need a meter to know energy use…
- Four methods:
  - Square footage
  - Energy-use intensity
  - Calibrated software
  - Short-term metering

Session #1 Highlights – Square Footage – slide 18

- Estimate building energy use based on ft^2
  - Buildings greater-than/equal to cut-off ***are metered***
  - Buildings less than cut-off ***are not metered***

Benefits: quick, simple
Challenges: largely inaccurate

Session #1 Highlights – Energy-Use Intensity – slide 19

- kWh/ft^2/yr by facility type and climatic region
    - Commercial Buildings Energy Consumption Survey (CBECS) data
        - http://www.eia.doe.gov/emeu/cbecs/contents.html
    - DOE Buildings Energy Data Book
        - http://buildingsdatabook.eren.doe.gov/

Benefits: with EUI data, fairly quick and more accurate
Challenges: Site-specific EUI data available?

Session #1 Highlights – Calibrated Software – slide 20

- Single building (EnergyPlus, DOE-2, BLAST, etc.)
- Multiple building/site [Facility Energy Decision System (FEDS)] analysis
    - Site-wide analysis for energy efficiency opportunities AND metering practicability

Benefits: With site data, good accuracy
Challenges: Populating with site data

*DOE energy tools available at: http://www.eere.energy.gov/buildings/tools_directory/

Session #1 Highlights – Short-Term Metering – slide 21

- Temporary metering exercise
- Calculate annual energy use based on subset of annual energy data

Benefits: Done properly, very accurate
Challenges: Equipment and time

Session #1 Highlights – slide 22

- Guidance for Electric Metering in Federal Buildings (2/3/06): http://www1.eere.energy.gov/femp/pdfs/adv_metering.pdf
- Agency metering plans
    - Meet EPAct requirements
    - Designate primary personnel
    - Documentation of impracticability

Session #2 Topics –slide 23

- ✓ Session #1 Highlights
- ❑ Metering Technologies
  - ❑ Advanced Electrical Metering
  - ❑ Natural Gas
  - ❑ Water
  - ❑ Steam/Hot Water
- ❑ Communications Options
- ❑ Data Access and Storage
- ❑ Session #3 Overview

Metering Technologies – slide 24

- The basics:
  - Measure of current: ***amperage (amps)***
  - Measure of voltage: ***volts***
  - Current (amps) times Voltage (volts) = **Power** (Watts or Kilowatts)
  - Power over time (kilowatt-hours) = **Energy**
- Advanced metering goes beyond these!

Metering Fundamentals – Current – slide 25

- Current measurements
  - Current (amps) measured with ammeter or current transformer (CT)
    - Current draw proportional to magnetic field developed
    - CT detects field and develops output in proportion to field/current
    - CTs need to be sized for circuit, output current sized, and installed properly

Metering Fundamentals – Basic Meter Functions – slide 26

- Voltage measurements
  - Voltage (volts) measured with voltmeter as "potential" referenced to known voltage/ground
    - Voltage measured in parallel with circuit using potential transformer (PT)
    - Challenging part of installation – installed on "hot" line
    - PTs need to be sized/installed properly

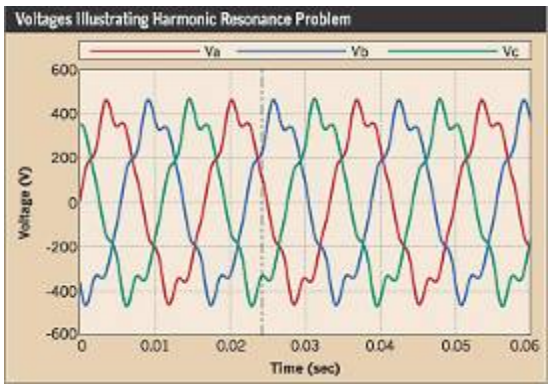
Safety First – slide 27

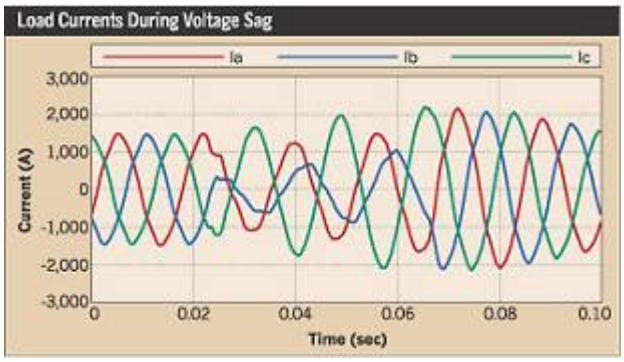
- Only trained and certified personnel should interact with electrical components
- All safety rules should be observed and reinforced regularly
- All actions need to comply with the National Electric Code (NFPA 70)
- Personal Protective Equipment (PPE) - NFPA 70E
- Even split-core CTs should not be installed in live 480-volt panels!

Advanced Electronic "Smart" Meters – slide 28

- Advanced features relating to power quality:
  - True root-mean-squared (RMS)
  - Power factor
  - Harmonics (THD)
  - Form factor
  - Peak form
  - Transient disturbance

Examples of Power Quality Problems – slide 29





http://bg.ecmweb.com/ar/electric_learning_read_waveform
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Advanced Electronic "Smart" Meters – slide 30

- Other advanced metering features:
  - Statistics: min, max, average
  - Multiple billing periods
  - Accept external inputs
  - Two-way communication
  - On-board storage capability (data logging)
  - Multiple channels of data

Getting Data from Advanced Meters – slide 31

- Single variable signal output types:
  - Switch closure
  - Digital pulses
  - Analog output
    - Current, 4-20 mA
    - Voltage, 0-5 Vdc
- Download data in table or file format via communications mechanism (more on this later)
- Some advanced features may require viewing through meter software interface

How to Select Advanced Electric Meters – slide 32

- Determine service voltage
- Estimate maximum amperage or power
- Physical installation requirements
- Determine accuracy requirements
- How will meter be read? What communications are required?
- What functionality is required and what is negotiable?

Tips for Using Advanced Meters – slide 33

- Don't over-buy
- Get a flexible system
- Make sure the system will communicate with other meters or data acquisition systems
- Develop formal specifications to ensure future compatibility
- Don't overlook the effort it will take to create a process to collect, store, and archive the data
- Make sure someone is tasked to <u>use</u> these data

Session #2 Topics – slide 34

- ✓ Session #1 Highlights
- ✓ Metering Technologies
  - ✓ Advanced Electrical Metering

- ✓ Natural Gas
- ✓ Water
- ✓ Steam/Hot Water

- ❑ Communications Options
- ❑ Data Access and Storage
- ❑ Session #3 Overview

Natural Gas Meters – slide 35

- Common gas meters measure a volume of gas and are normally installed downstream of a pressure regulator and then calibrated to be accurate at that pressure
- The utility will provide estimated or actual (by month) energy content (BTU) of gas
- Types of natural gas meters:
  - Diaphragm (bellows)
  - Rotary
  - Turbine

Gas Meter: Diaphragm – slide 36

- Mechanism: Two or more chambers with movable diaphragms fill and empty creating mechanical motion that drives the counter mechanism
- Application: Small to medium (3/4" to 2" line sizes)
- Accuracy: 90% of meters accurate within 1% for 20 years
- Cost: $150 - $400

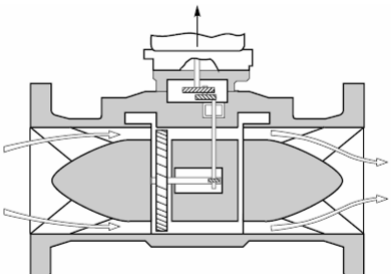
Gas Meter: Rotary – slide 37

- Mechanism: Incoming gas spins 2 "lobes" or rotors that record a volume of gas per rotation
  - Can handle higher volumes and pressures than diaphragm meters
- Application: medium size (1.5" to 4" typical)
- Accuracy: 0.25% to 0.5%
- Cost: $300 - $500
- Other: Can be temperature compensating

Gas Meter: Compact Orifice – slide 38

- Mechanism: Obstruction in flow creates pressure difference proportional to flow
- Application: ½" to 4" gas lines
- Accuracy: 0.5% to 2%
- Cost: $2,000 to $5,000
- Other: temperature and/or pressure compensated

Gas Meters: Turbine Meter – slide 39



- Mechanism: Small fan-like turbine is inserted into the flow
  - Will be pressure and temperature compensated
- Application: For large industrial-size gas applications
- Size: Available in 2” – 20” (2.5-gpm to 19,000-gpm)
- Accuracy: 0.5% to 1%
- Cost: $500 to $4,000 depending on size

Gas Meter Retrofit – slide 40

- Pulse initiator can be installed on existing dials
- Pulses are low resolution
- Ownership issues are the major challenge on gas meters

How to Select Gas Meters – slide 41

- Determine service size and expected peak demand
- Physical installation requirements
- Determine accuracy requirements
- How will meter be read? What communications are required?

Session #2 Topics – slide 42

- ✓ Session #1 Highlights
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Water Meters – slide 43

- Positive Displacement
  - Oscillating piston
  - Nutating disk
- Velocity Water Meters
  - Single-jet/multi-jet
  - Turbine meters
  - Paddle wheels
- Microprocessor
  - Electromagnetic
  - Ultrasonic

Water Meters: Positive Displacement – slide 44

- Mechanism: entering water pushes on a disk fixed to a rotating shaft
  - Rotation energy is transferred by a small magnet to the register head mounted on top
- Application: Residential and small commercial buildings (1/2” to 3”)
- Accuracy: 0.5% to 1.0%
- Costs: $50 to $400 depending on size
- Other: pressure loss increases with flow proportionally to the recording inaccuracies

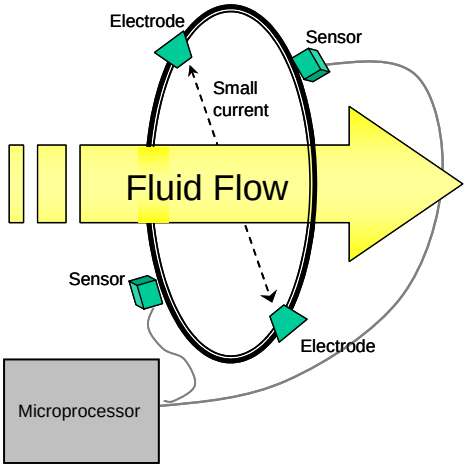
Water Meters: Turbine – slide 45

- Mechanism: Small fan-like turbine is inserted into the flow
  - Magnetic pick-up records rotation proportional to flow
- Application: Large commercial or industrial with high usage and high flow rates
- Size: Available in 2” – 20” (2.5-gpm to 19,000-gpm)
- Accuracy: 0.5% to 1%
- Cost: $500 to $4,000 depending on size

Insertion Turbine Flow Meter – slide 46

- Turbine used in sub-metering application
- Pulse output read by data loggers or EMCS systems
- Sensor can be changed without shutting down or draining the system
- High accuracy
- Meter cost $500 + data logger cost + installation

Water Meters: Electromagnetic – slide 47

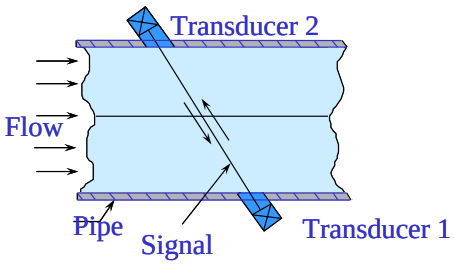


- Fluid flow calculated based on strength of magnetic field generated by small current introduced to the fluid (Faraday's Principle of Induction)
- High accuracy, approximately +/- 0.15%
- Available in 2" to 12" with 4-20 mA output
- Cost: $3,000 to $7,000

Water Meters: Compound Meters – slide 48

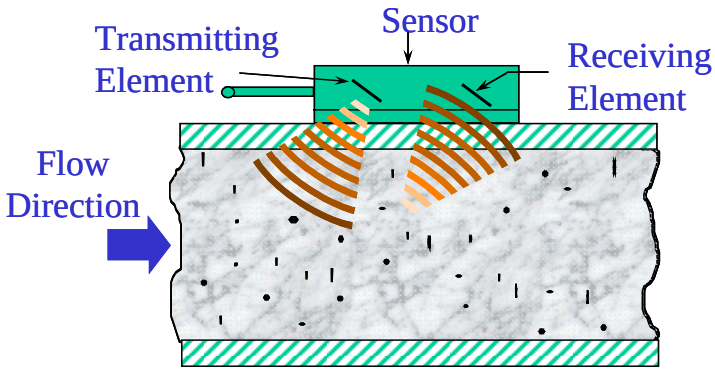
- Meters have a pressure sensitive valve and 2 registers – one for low flow conditions and one for high flow conditions. Water volume is the sum of the two registers.
- Application: Commercial, institutional, and other places with fluctuating usage and flow rates
- Notes: Available in sizes 2" to 6" (1/4-gpm to 1,200-gpm peak flow)
- Cost: $2,500 to $5,000

Water Meters: Transit Time Ultrasonic – slide 49



- Mechanism: Uses transfer time of ultrasonic wave from transducer to receiver. Transit time is proportional to flow.
- Application: Medium to large size pipes. Can be permanent or non-invasive (clamp-on).
- Accuracy: 1% to 4%
- Cost: $2,500 to $5,000

Water Meters: Doppler Ultrasonic – slide 50



- Mechanism: Uses frequency shift of moving fluid to measure flow. Prefers fluids with suspended particles.
- Application: Medium to large size pipes. Can be permanent or non-invasive (clamp-on).

Meter Installation Tips – slide 51

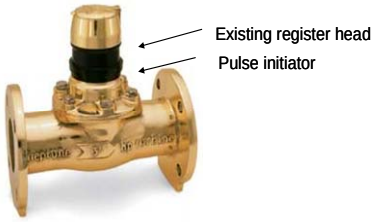
- Proper sized meters
- Accessibility
- Straight pipe before and after meter
- Strainers for protection
- Install bypass and test ports

- Calibration: Use AWWA Manual M6

http://www.awwa.org/bookstore/product.cfm?id=30006

Retrofit for Water Meters – slide 52

- Technologies exist to adapt existing meters to automatic data collection without needing a meter with built-in pulse output
  - For example: Add-on module produces switch closure, digital pulse output, or 4-20 mA signal proportional to flow
  - Retrofit existing meter, while preserving existing register head
  - Cost: $300



How to Select Water Meters – slide 53

- Determine expected flow rates
- Physical installation requirements
- Determine accuracy requirements
- How will meter be read? What communications are required?

Session #2 Topics – slide 54

- ✓ Session #1 Highlights
- ✓ Metering Technologies
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- ❑ Communications Options
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- ❑ Session #3 Overview

Steam/Hot Water Metering– slide 55

- Steam comes in three varieties:
  - Wet steam contains both steam and some condensate
  - Saturated steam contains no water and exists at one temperature and pressure

    - Superheated steam has been raised above the saturation point
- Hot water
    - High temperature
    - Medium temperature

Steam Metering – slide 58

- Requires both flow measurement and fluid properties (temperature and/or pressure)
- Output can be steam quantity (lbs/hr) or even better energy content (Btu/hr)
- Common meter types:
    - Turbine meters
    - Vortex shedding
    - Annubar
    - Orifice

Steam Meter: Vortex – slide 57

- Mechanism: measures vibration of the vortices behind an obstruction in the flow
    - Should be pressure and temperature compensating
- Application: medium to large (1" to 12" lines)
- Accuracy: 1% to 2%
- Cost: $4,000 to $6,000

Annubar Flow Meter – slide 58

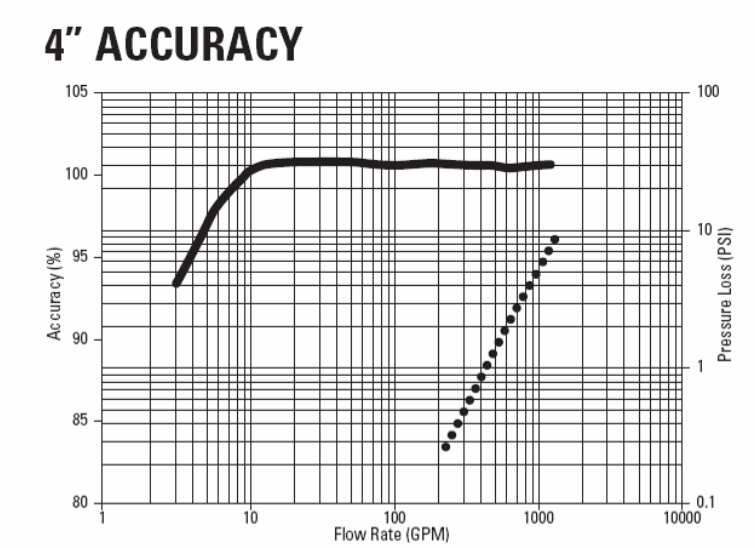
- Mechanism: Uses pitot tubes (or even array of pitot tubes) to measure the difference between static pressure and the flowing pressure of steam. Volumetric flow is calculated using Bernoulli's Principle.
- Application: 2" to 96"
- Accuracy: 2%

Steps to Selecting the Right Meter – slide 59

- Specify fluid characteristics
- Determine expected range
- How will meter be read?
- Determine environmental requirements
- Determine accuracy requirements over range of flow
- Determine installation physical requirements

Meter Calibration Curve – slide 60

- Check meter accuracy and pressure loss over the full range of flows to ensure it matches your application



Meter Summary by Type – slide 61

Flow Meter	Recommended Service	Range-ability	Typical Pressure Loss	Typical Accuracy	Required Upstream Diameters	Typical Cost
Turbine	Clean, viscous liquids	20:1	High	0.25%	5 to 10	High
Positive Displacement	Clean, viscous liquids, smaller size	10:1	High	0.5%	None	Med
Etc.						

www.seilenterprise.co.kr/English/Technology/meterselectionguide.htm

Session #2 Topics – slide 62

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Metering Communications - Considerations – slide 63

- Existing infrastructure
- Non-proprietary protocols
- Need for multiple solutions

Metering Communications - Options – slide 64

- Phone lines
  - Cellular options
- Ethernet/LAN
- Wireless/Radio Frequency (RF)
- Building Automation System (BAS)
- Power-line Carrier

Metering Communications – Phone Lines – slide 65

Advantages:
Usually available
Proven technology

Challenges:
Can be expensive
Wired installation – except cellular
Can be difficult to view real time data

Metering Communications – Ethernet/LAN Connection – slide 66

Advantages:
Increasing availability
Proven technology
Always connected
Data sharing

Challenges:
Network/IT concerns
Wired installation

Metering Communications – BAS/EMCS System – slide 67

Advantages:
Usually available
Fast communication
Always connected

Challenges:

Potential system compatibility issues
Potential data availability issues

Metering Communications – Wireless Network – slide 68

Advantages:

No wiring
Fast communication
Always connected

Challenges:

System cost
Perceived RF interference issues
New system/infrastructure

Metering Communications – Power-Line Carrier – slide 69

Advantages:

Makes use of existing infrastructure
Always connected

Challenges:

System cost
Speed of communication
Technical issues with transformers

Session #2 Topics – slide 70

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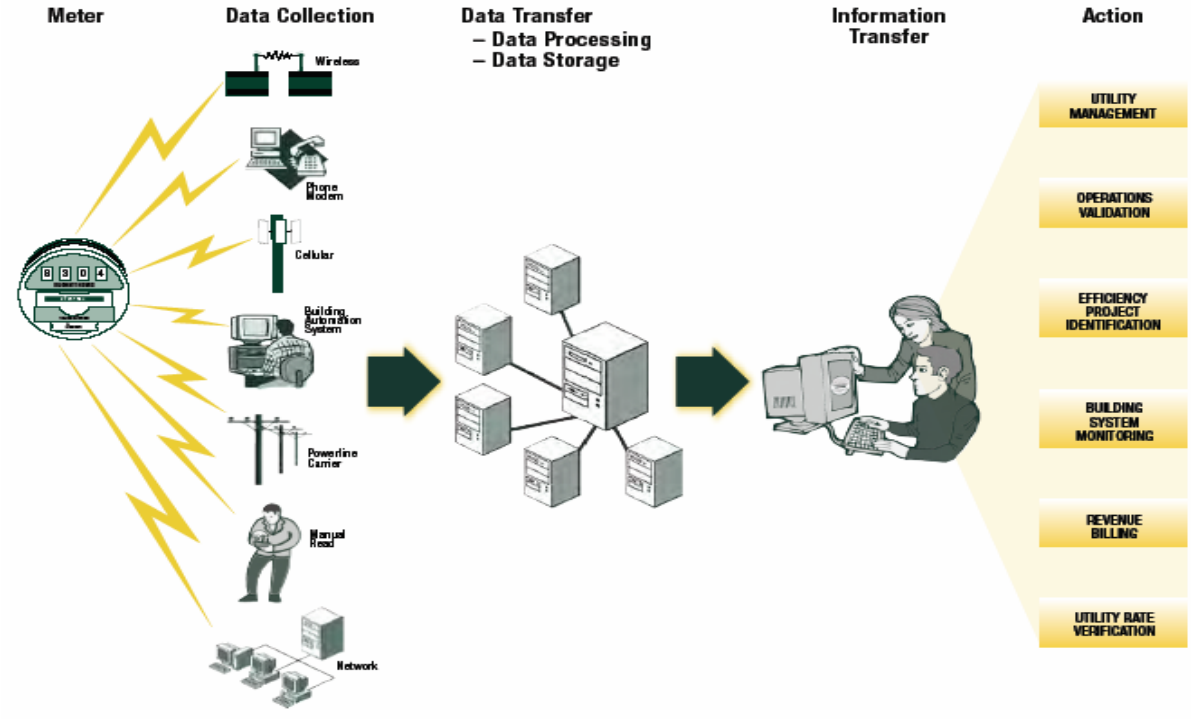
Metering System Path to Action – slide 71



Data Acquisition – slide 72

- Data collection mechanism(s)
  - Avoid too many different systems
  - Must automate the process
  - Plan on some repair cost for meters that lose communication or fail
- Metering system software
  - Use dedicated computer
  - Plan for periodic upgrades
  - Check for successful downloads daily to avoid lost data

Data Storage – slide 73

- In-house:
  - Need a dedicated central system for metered data
  - Should have regular backups and archives
  - More than a single individual should be involved
  - Need to account for cost to “house” data
- Applications Service Provider (ASP) is an alternative solution

Data Processing – slide 74

- Routine reporting should be automated
- Customizing reports is easier to do on an in-house system
- Data validation flags:
  - Missed download
  - Downloaded but missing data
  - Data out of norm
- If using an ASP, define requirements for how soon data and reports are available

Data Viewer/Reporting – slide 75

- More on this in Session 3
- Have prepared reports
- Make it easy for users to access the data
- Have existing reports available at a mouse-click
- Make it easy to get data and encourage use

Session #2 Topics – slide 76

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Session #3 Preview – slide 77

- Topics:
  - Metering planning
  - Financing
  - Uses for data
  - Federal sector case study

Live Q&A

Our Next Session – slide 79

- Metering Planning, Financing, Uses for Data and Case Studies
- Wednesday April 4, 2007 at 1:00 ET/ 10:00 PT