Distribution System
Efficiency Potential & Conservation
Voltage Reduction

Power Committee

April 2009
Energy & Capacity Savings

From Here → To Here → And In Here

Residential Grid Connected PV System:
- Solar Panels
- Inverter
- Home Power/Appliances
- Utility Service
Key Points

1. New measure for 6th Plan
2. Large savings potential
   - 2% of load or 400-500 MWa by 2029
   - Low cost
   - Half of it less than $30/MWh
3. Solid cost & savings estimate
4. Savings both sides of the customer meter
   - End User Savings & Reduced Utility Losses
5. Many non-energy benefits
6. Barriers to adoption are addressable
The Standards

Figure 1-1
ANSI C84.1 Voltage Ranges
Optimize System Voltage

- Improve end-use equipment efficiencies
- Reduce losses along the way
- Improve effective capacity (kW) & reactive (kvar)
Tools

- System Optimization
- Line Drop Compensation
- End of Line Voltage Feedback
- Home Voltage Regulation
Source of Estimates

- NEEA Study completed January 2008
- Day-On / Day-Off testing
- Four years & about $1 million
- R.W. Beck
- Pilot tests in 13 utilities in PNW
Translation to 6P Supply Curve

- Four measures only (no house level regulators)
  - LDC voltage control, light system improvements, major system improvements, end-of-line control
- CVR factors by feeder type from NEEA study
  - CVR factors depend on character of feeder loads
- Count of regional feeders by type
- Estimate of regional load by feeder type
- Derived load shape
Achievable Utility Distribution System Efficiency

Savings Potential by Levelized Cost

Achievable Potential by 2030 (average megawatts)

Levelized Cost (2006$/MWh)
The Oracle

potential for "virtually free" (less than 0.1 cent/kWh) savings: from 92 - 145 AMW for the PNW; from 35 - 60 AMW for the publicly owned utilities. The resources available up to 1.0 cent/kWh was 142 - 230 AMW for the PNW; 51 - 95 AMW for the publicly owned utilities. An additional amount (from 170 - 268 and 65 - 112 AMW, respectively) is available at 5.04 cents/kWh, the figure specified by the Northwest Power Planning Council (NWPPC) as the cost-effectiveness threshold for conservation measures, compared to other generating resources. The total investor-owned utility portion of the resource available was estimated to range from 105 to 156 AMW.
Barriers to Adoption

- **Working Between Departments in Utility**
  - Business Practices between EE & Engineering

- **Regulatory Issues**
  - Utility losses are a pass-thru cost
  - Lost revenues
The following slides are from a presentation made to the Regional Technical Forum by R.W. Beck
DISTRIBUTION EFFICIENCY INITIATIVE (DEI)
Benefits on Both Sides of the Meter

RTF MEETING February 5, 2008
Overview

Key Project Elements

• Research Studies
  – Residential Homes (395 homes) Including In-Home assessments
  – Pilot Feeder Demonstration Projects
• Report of Findings
• Potential Northwest Region Savings
• Guidebook
• Software Tools

# Overview

## Participating Utilities

<table>
<thead>
<tr>
<th>Utility</th>
<th>DEI Participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avista Corp</td>
<td>Pilot Demonstration</td>
</tr>
<tr>
<td>Clark Public Utilities</td>
<td>Pilot Demonstration</td>
</tr>
<tr>
<td>Douglas PUD</td>
<td>Load Research</td>
</tr>
<tr>
<td></td>
<td>Pilot Demonstration</td>
</tr>
<tr>
<td>Eugene W &amp; EB</td>
<td>Load Research</td>
</tr>
<tr>
<td>Franklin PUD</td>
<td>Load Research</td>
</tr>
<tr>
<td>Hood River</td>
<td>Load Research</td>
</tr>
<tr>
<td>Idaho Falls Power</td>
<td>Load Research</td>
</tr>
<tr>
<td>Idaho Power</td>
<td>Load Research</td>
</tr>
<tr>
<td></td>
<td>Pilot Demonstration</td>
</tr>
<tr>
<td>PacifiCorp</td>
<td>Load Research</td>
</tr>
<tr>
<td>Portland General Electric</td>
<td>Load Research</td>
</tr>
<tr>
<td>Puget Sound Energy</td>
<td>Load Research</td>
</tr>
<tr>
<td></td>
<td>Pilot Demonstration</td>
</tr>
<tr>
<td>Skamania PUD</td>
<td>Load Research</td>
</tr>
<tr>
<td>Snohomish PUD</td>
<td>Load Research</td>
</tr>
<tr>
<td></td>
<td>Pilot Demonstration</td>
</tr>
</tbody>
</table>
Overview

Project Savings

Summary of Voltage and Energy Results

<table>
<thead>
<tr>
<th>Project</th>
<th>Voltage Reduction (ΔV)</th>
<th>CVR&lt;sub&gt;f&lt;/sub&gt; (%ΔE/%ΔV)</th>
<th>Project Energy Savings (MWh)&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Percent Energy Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Research</td>
<td>5.2 V (4.3%)</td>
<td>0.569&lt;sup&gt;2&lt;/sup&gt;</td>
<td>87</td>
<td>2.15%</td>
</tr>
<tr>
<td>Pilot Demonstration</td>
<td>3.03 V (2.5%)</td>
<td>0.69</td>
<td>8,476</td>
<td>2.07%</td>
</tr>
</tbody>
</table>

- Project Savings 8,563 MWhr (1.88 aMW annually)
- 345 kWhr per residential home (Load Research project)
- Cost of less than 5 Mills ($0.001/kWhr)
Summary
Pilot Demonstration Project

- Controlled voltage at substation (day ON day OFF)
  - Used Line Drop Compensation
  - Used End of Line voltage feedback loop
- 6 Utilities, 10 Substations, 31 feeders
- Performed system improvements
  - Installed feeder meters
  - Phase balancing
  - Voltage regulators
  - Capacitors
## Results of DEI Study

### Savings

| Overall Load Research CVR factor Estimate<sup>1</sup> |
|------------------|------------------|------------------|
| CVRf        | RP<sup>2</sup> | +/- |
| Energy (kWh)  | 0.569           | 10.1%           | 0.057           |

**Notes:**

1. This number is **not** the simple average of the by-utility or by-meter estimates. The method used to calculate this figure is discussed in Appendix A – Calculations Used in the Analysis, and will produce different results for an overall sample of sites than would be calculated taking a simple or weighted average of subsets of that sample.

2. Relative precision is a measure of the precision of an estimate. It is expressed as the ratio of the error bound of an estimate to the estimate itself. Thus, for an estimate x, a relative precision of 15% at the 90% level of confidence means that there is a 90% probability that the true value lies between 0.85x and 1.15x.
Results of DEI Study
CVR Factors

House-Level – CVR factor Energy

Feeder Level – CVR Factor Energy
Results of DEI Study
CVR Factors

CVR factor Distribution of Sample Homes
Results of DEI Study
CVR Factors

Load Research CVR Factor by Season w/ 90% Error Bounds
Results of DEI Study
CVR Factors

Load Research CVR Factor by Weekday by Season
w/ 90% Error Bounds
Results of DEI Study
Project Conclusions

• Existing technologies can be used to achieve the majority of the potential energy savings economically
• New technologies are commercially available to help utilities optimize the performance of the distribution system and regulating the voltage
• Utilities could benefit from pooling resources from their energy efficiency group and distribution planning, engineering and operation groups
• Utilities need to develop long-term plans to optimize the efficiency of the existing electrical infrastructure
• New facilities being installed today should be designed to achieve the lowest life cycle cost
• Policies should be established to provide incentives for utilities to reduce electric system losses
• Policies should be established to provide a mechanism to reimburse utilities for lost revenue
Distribution Efficiency Guidebook

Northwest Energy Efficiency Alliance

January 2008
DEI Study
Software Tools

LOAD FLOW

LOAD FLOW DIAGRAM 1
LINE: EXISTING
LOAD CASE: CASE 2--AT AVERAGE LOAD
BALANCED I^2*R LOSS (kW) = 62.2

V_{REG1}=126.7

\[ \begin{align*}
V_1 &= 125.7 \\
I_{S1} &= 168.4 \\
I_{L1} &= 60.3 \\
V_2 &= 124 \\
I_{S2} &= 108.3 \\
I_{L2} &= 34.6 \\
V_3 &= 122.1 \\
I_{S3} &= 73.9 \\
I_{L3} &= 43.6 \\
V_4 &= 121.2 \\
I_{S4} &= 31.8 \\
I_{L4} &= 26.2 \\
V_5 &= 121 \\
I_{S5} &= 8.7 \\
I_{L5} &= 8.7
\end{align*} \]

LOAD FLOW DIAGRAM 2
LINE: IMPROVED 3
LOAD CASE: CASE 2--AT AVERAGE LOAD
BALANCED I^2*R LOSS (kW) = 56.2

V_{REG1}=123

\[ \begin{align*}
V_1 &= 122.3 \\
I_{S1} &= 163.1 \\
I_{L1} &= 61 \\
V_2 &= 121.1 \\
I_{S2} &= 104.5 \\
I_{L2} &= 35 \\
V_3 &= 119.8 \\
I_{S3} &= 72.8 \\
I_{L3} &= 44 \\
V_4 &= 119.6 \\
I_{S4} &= 41.9 \\
I_{L4} &= 26.4 \\
V_5 &= 119.3 \\
I_{S5} &= 8.8 \\
I_{L5} &= 8.8
\end{align*} \]