



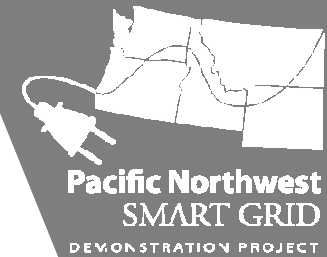
Transactive Control in the Pacific Northwest Smart Grid Demonstration Project

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Dr. Ronald B. Melton, Project Director
Battelle, Pacific Northwest Division

PNNL-SA-93659

Pacific Northwest Demonstration Project



What:

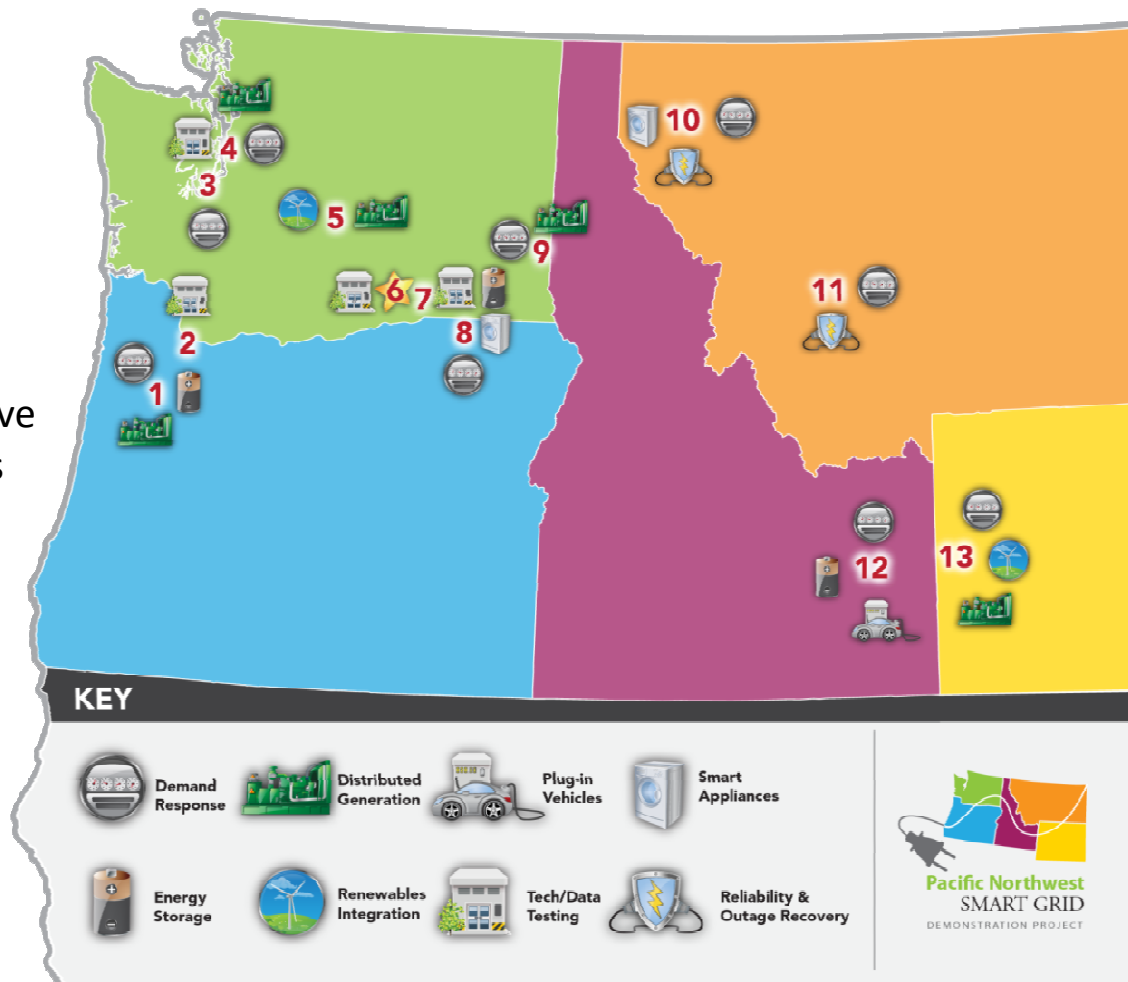
- \$178M, ARRA-funded, 5-year demonstration
- 60,000 metered customers in 5 states

Why:

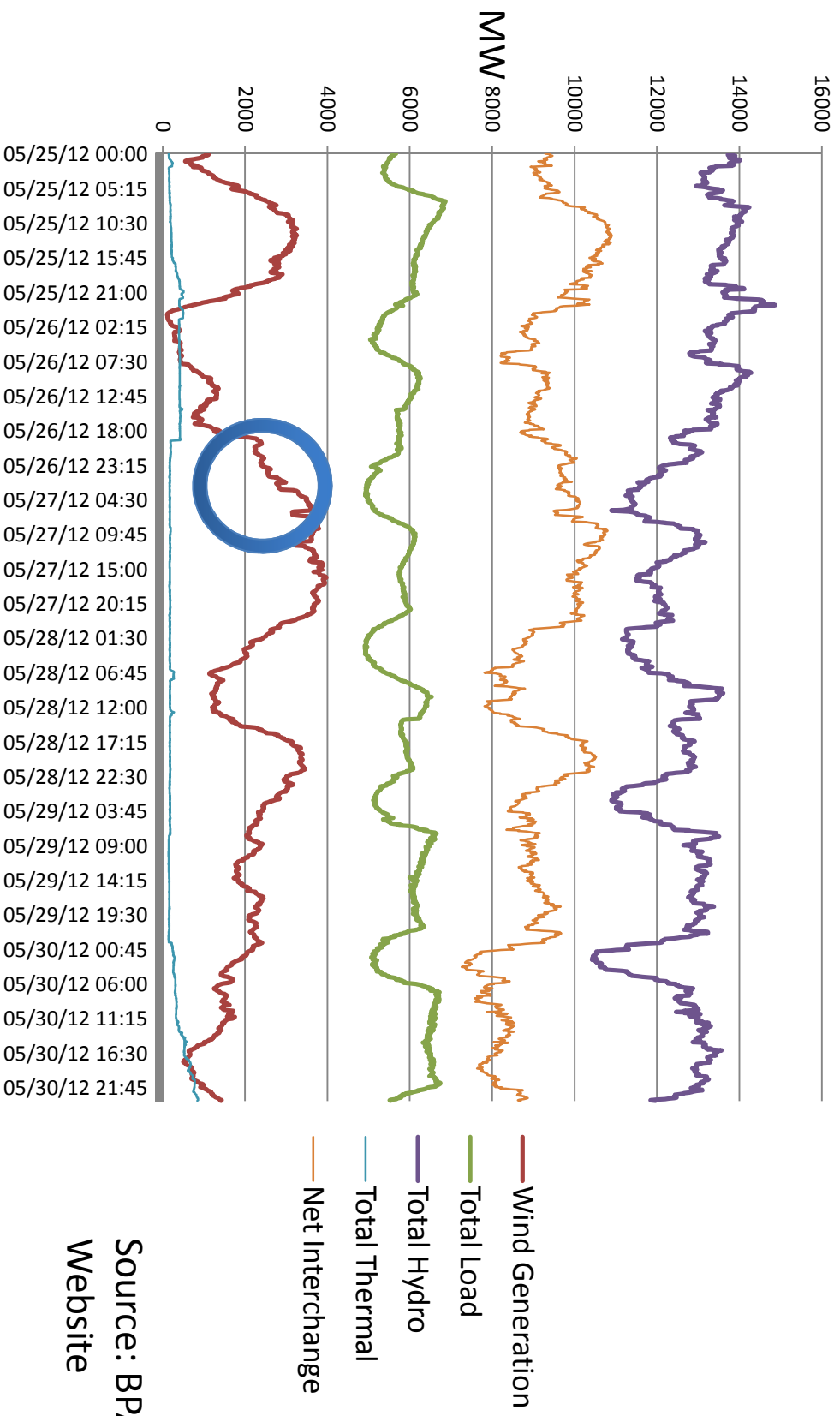
- Develop communications and control infrastructure using incentive signals to engage responsive assets
- Quantify costs and benefits
- Contribute to standards development
- Facilitate integration of wind and other renewables

Who:

Led by Battelle and partners including BPA, 11 utilities, 2 universities, and 5 vendors

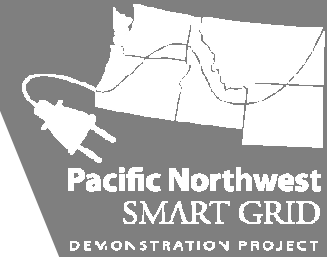


Typical BPA Control Area Generation

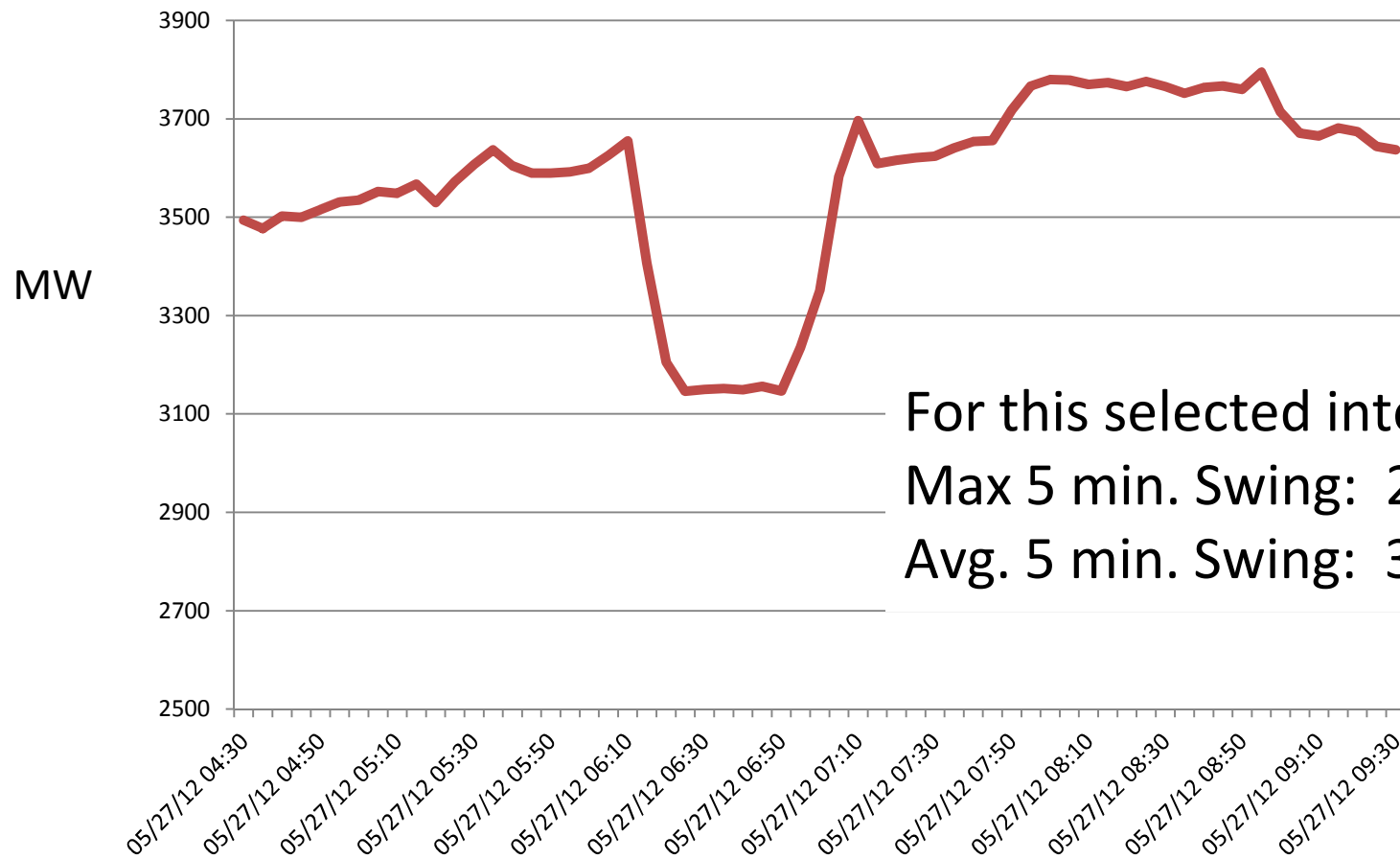


Source: BPA
Website

Zoom in on Wind



Wind Generation

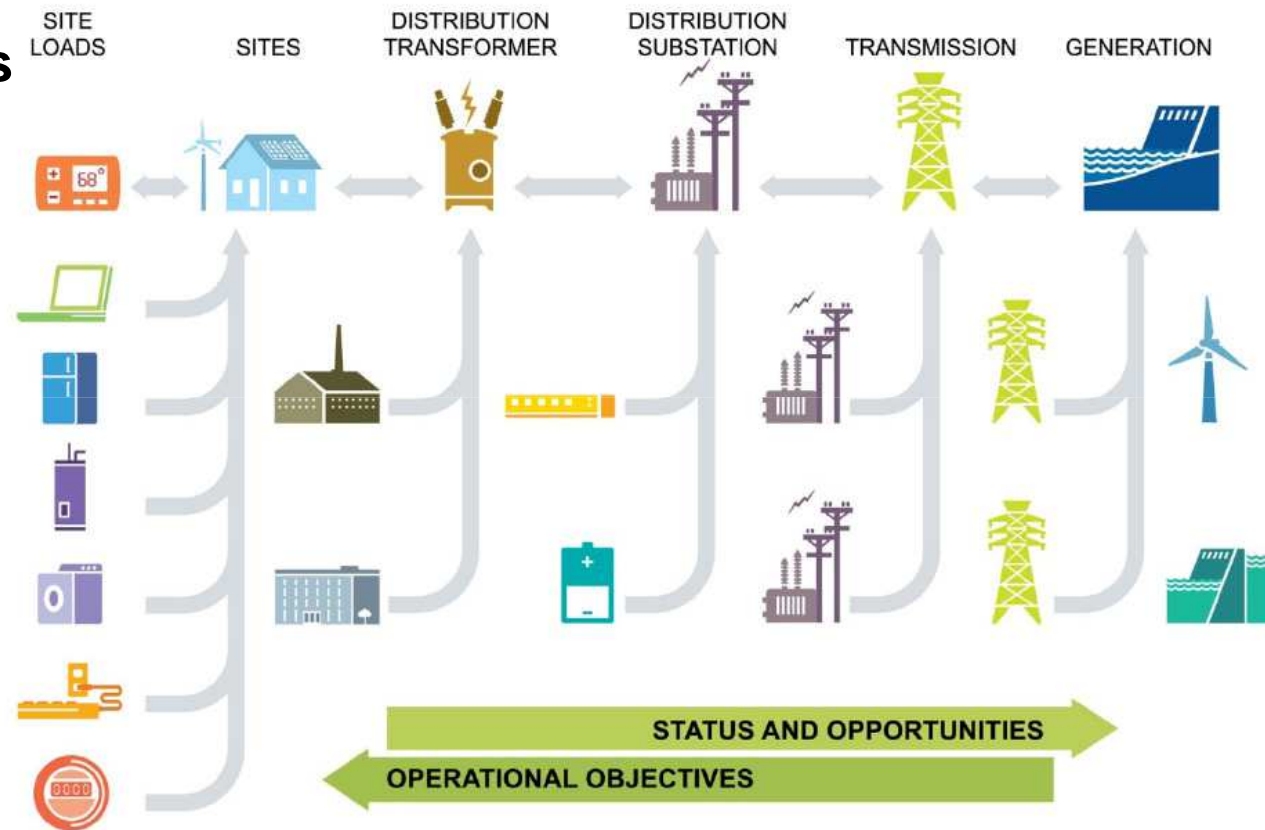


For this selected interval:
Max 5 min. Swing: 248 MW
Avg. 5 min. Swing: 33MW

Project Basics

Operational objectives

- Manage peak demand
- Facilitate renewable resources
- Address constrained resources
- Improve system reliability and efficiency
- Select economical resources (optimize the system)

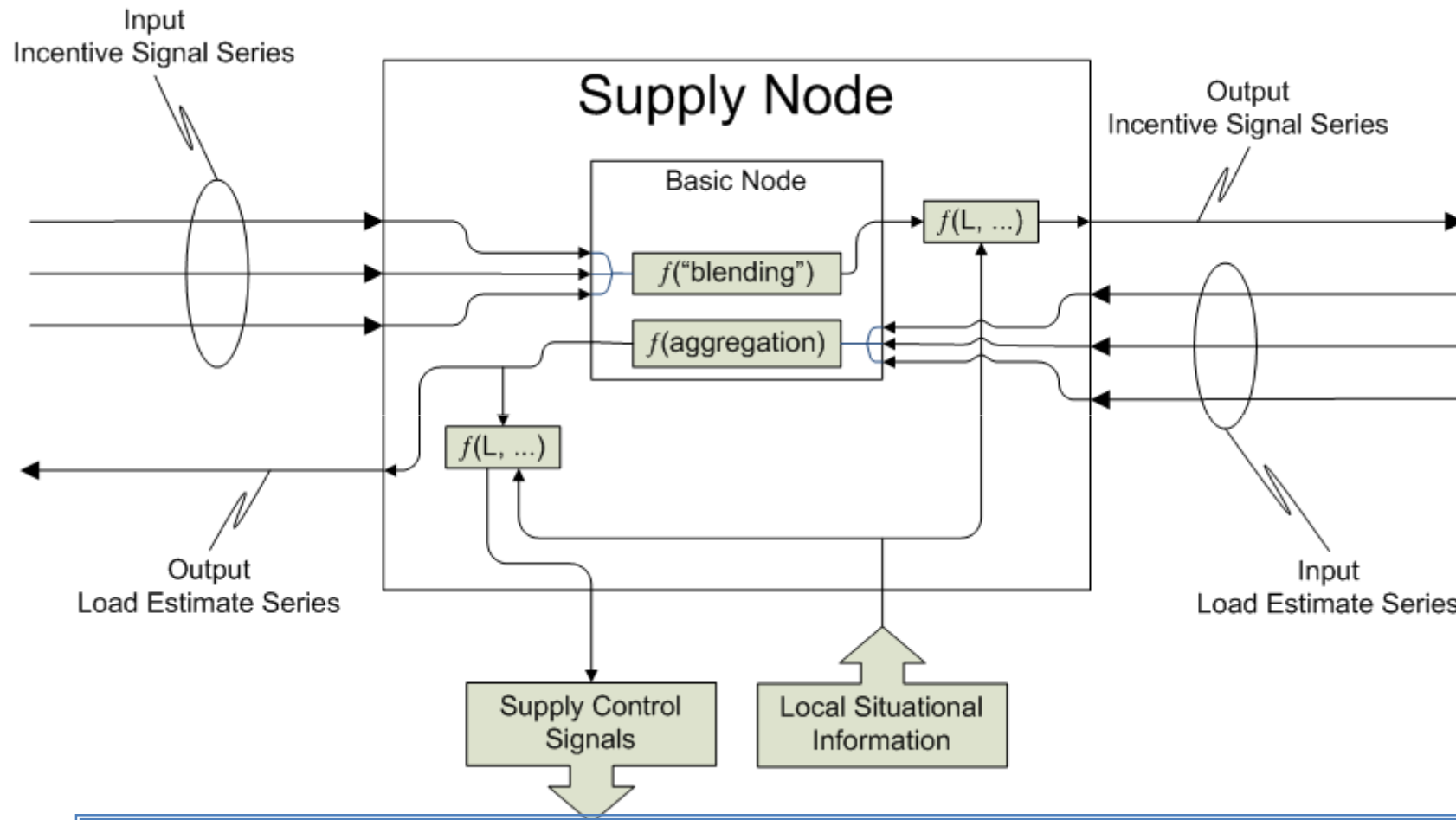


**Aggregation of Power and Signals Occurs
Through a Hierarchy of Interfaces**

Transactive Nodes

- A *transactive node* includes an agent of sorts (i.e., a computer and its software applications) that orchestrates each *transactive node's* responsibilities to
 - economically balance energy
 - incentivize energy consumption or generation
 - activate its own responsive generation and/or load resources
 - exchange both *transactive incentive signals (TIS)* and *transactive feedback signals (TFS)* with each of its neighboring *transactive nodes*.

Transactive Node Inputs & Outputs



The system is distributed, predictive, scalable, and its signals track the energy that it represents.

An Incentive Signal

Predict and share a dynamic, price-like signal—the unit cost of energy needed to supply demand at this node using the least costly local generation resources and imported energy. May include

- Fuel cost (consider wind vs. fossil vs. hydropower generation)
- Amortized infrastructure cost
- Cost impacts of capacity constraints
- Existing costs from rates, markets, demand charges, etc.
- Green preferences?
- Profit?
- Etc.

Example “Resource Functions”: Wind farm, fossil generation, hydropower, demand charges, transmission constraint, infrastructure, transactive energy, imported energy

A Feedback Signal

Predict and send dynamic feedback signal—power predicted between this node and a neighbor node based on local price-like signal and other local conditions. May include

- Inelastic and elastic load components
- Weather impacts (e.g., ambient temperature, wind, insolation)
- Occupancy impacts
- Energy storage control
- Local practices, policies, and preferences
- Effects of demand response actions
- Customer preferences
- Predicted behavioral responses (e.g., to portals or in-home displays)
- Real-time, time-of-use, or event-driven demand responses alike
- Distributed generation

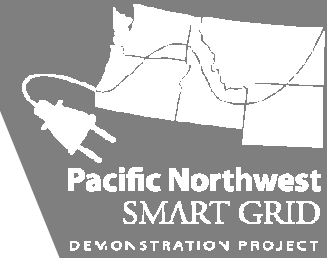
Example “Load Functions”:

Battery storage, bulk inelastic load, building thermostats, water heaters, dynamic voltage control, portals / in-home displays



Transactive Control – Electric Vehicle Charging Example

Simple Example – Local Electric Vehicle Charging

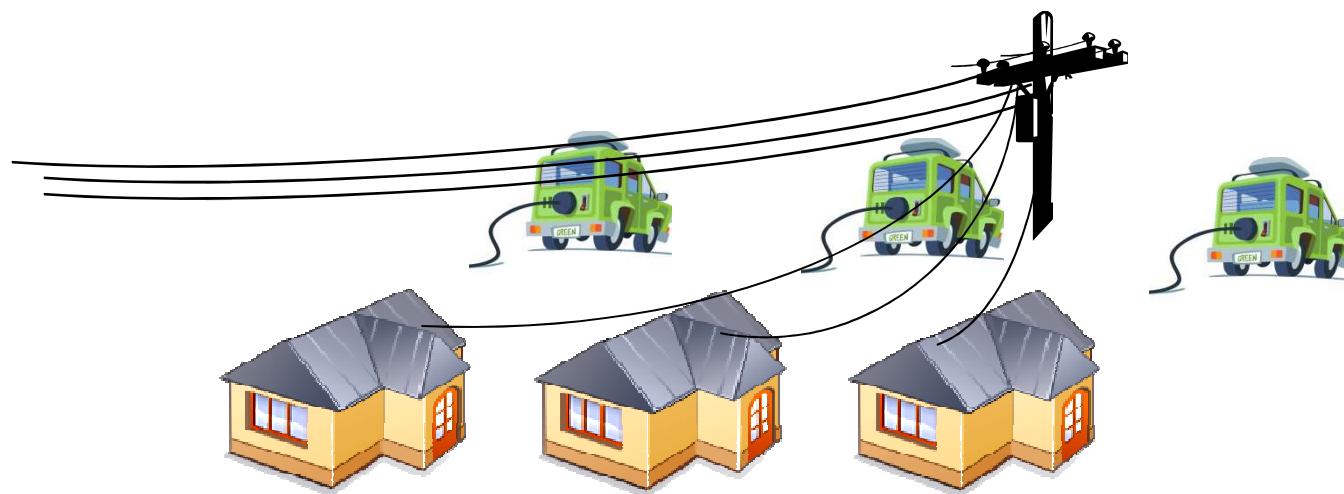


- Imagine the following situation:
 - Three neighbors with electric vehicles and different charging strategies
 - All three fed by same distribution transformer
 - All three come home and want to do a fast charge at the same time!
- Problem – transformer is overloaded if all three fast charge at the same time
- Transactive control solution –
 - Transformer sees in feedback signal that all three plan to fast charge
 - Transformer raises value of incentive signal during planned charging time to reflect decreased transformer life
 - Smart chargers and transformer “negotiate” through TIS and TFS until an acceptable solution is found

Our Example



**Pacific Northwest
SMART GRID**
DEMONSTRATION PROJECT

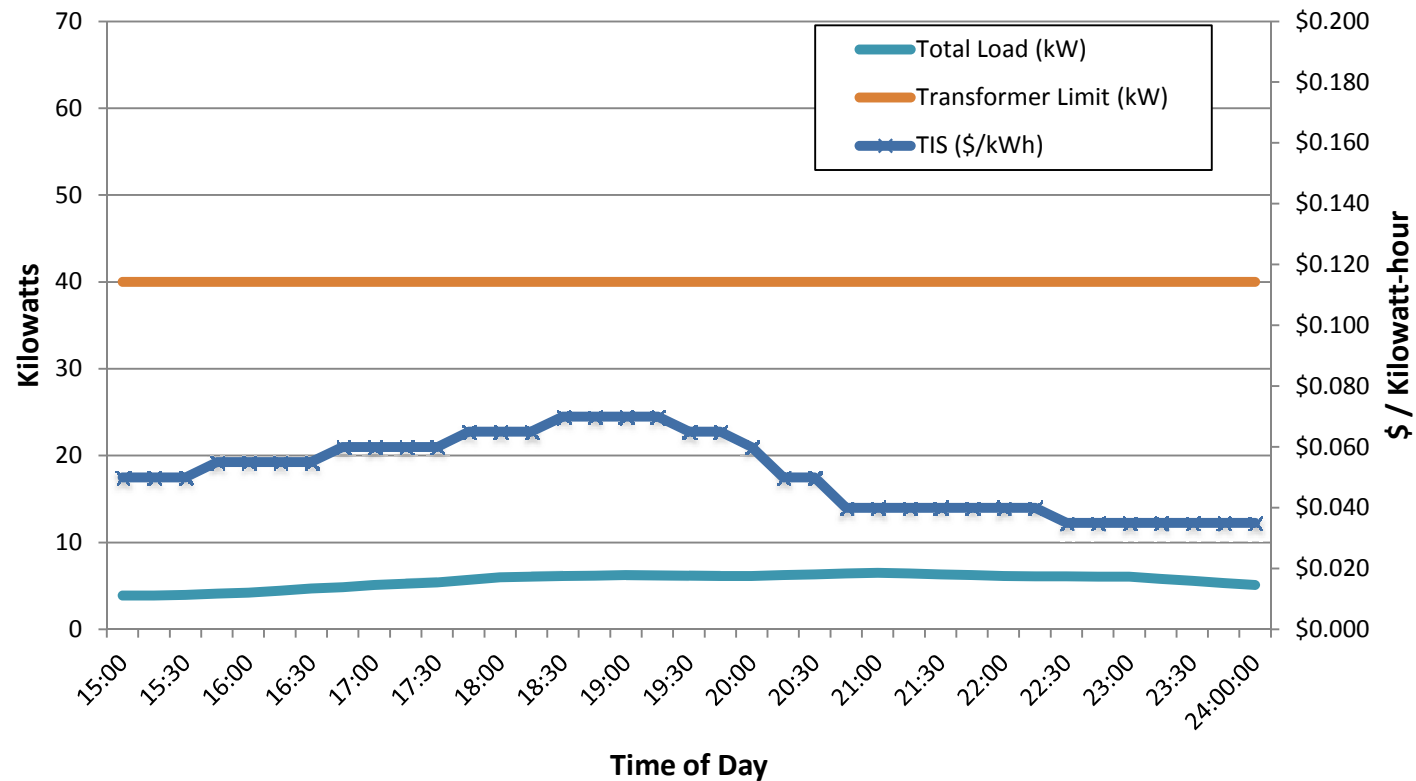
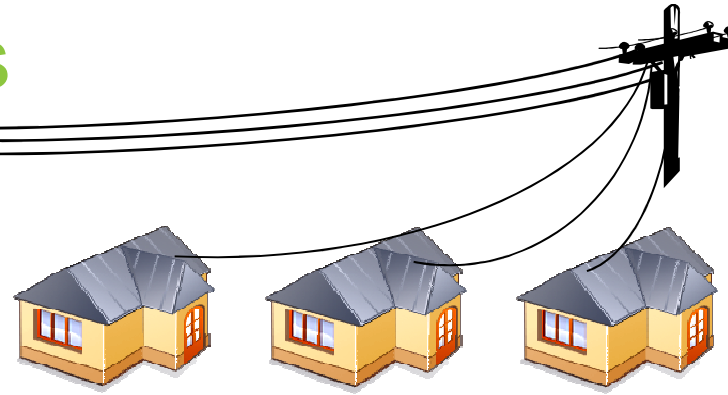
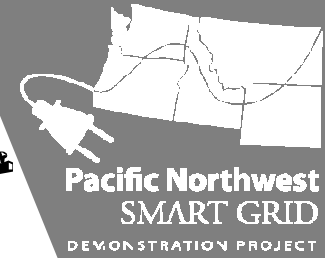


House 1:
I'm flexible

House 2:
I want it now!

House 3:
I'm a bargain hunter

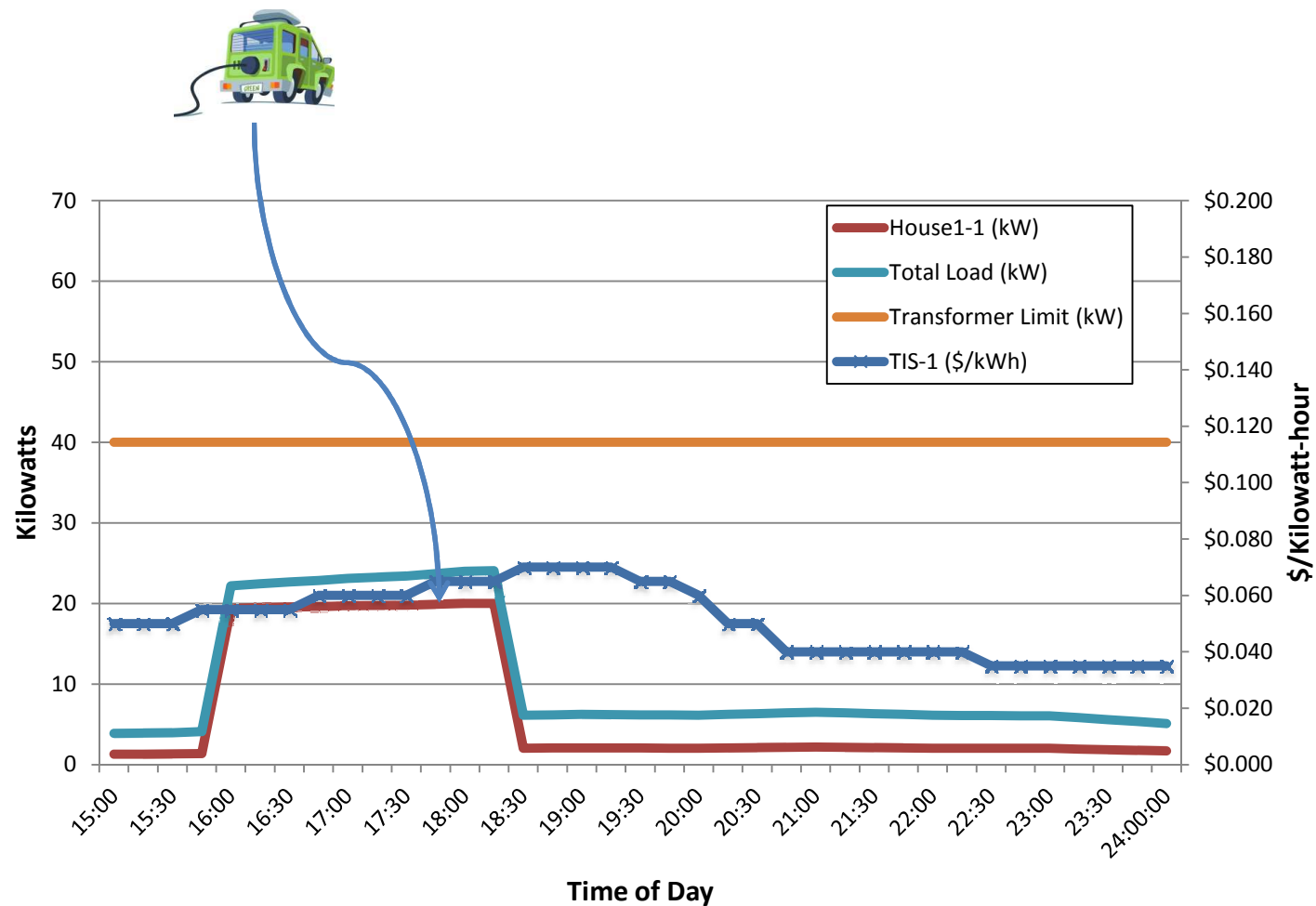
Start – house loads



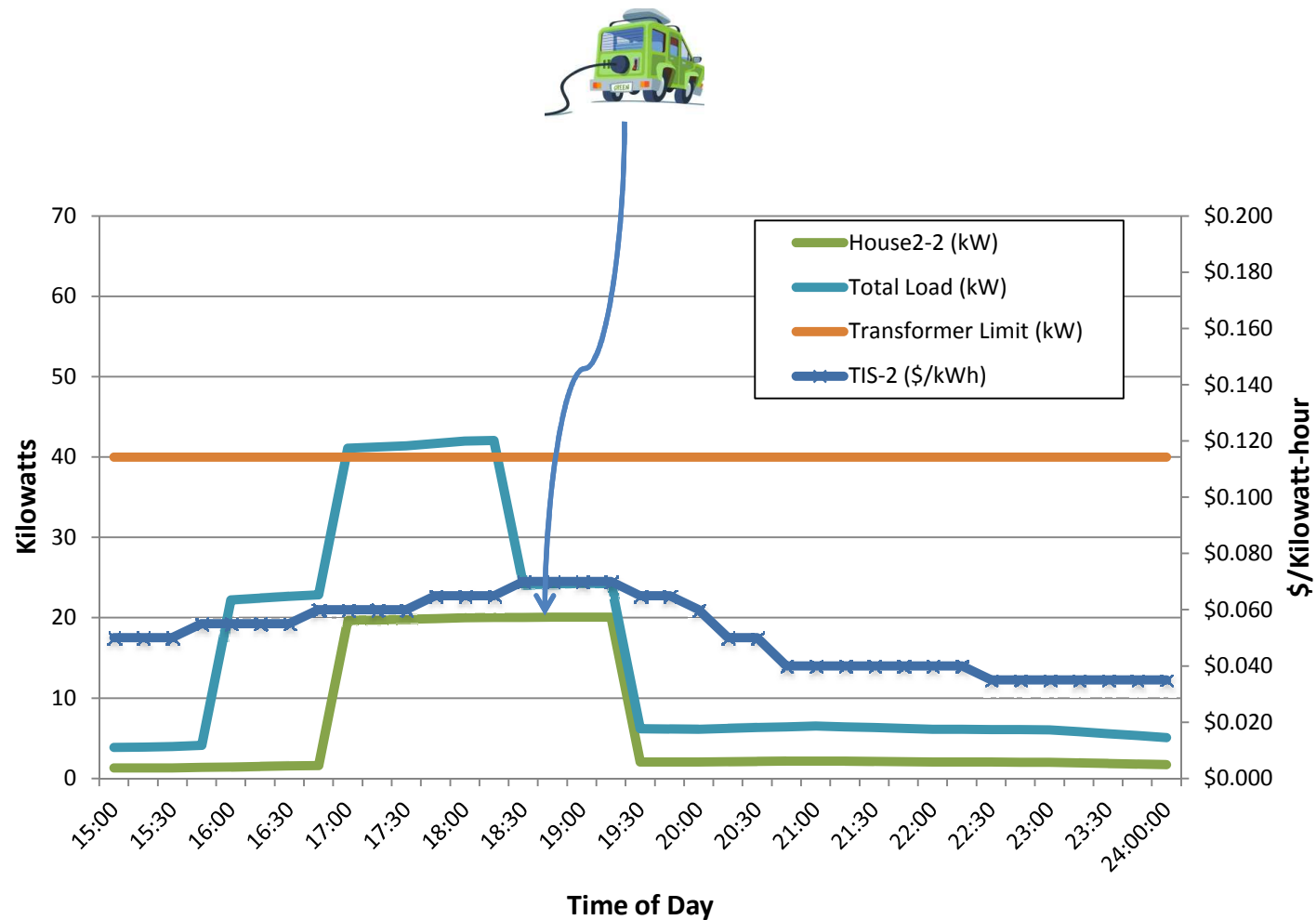
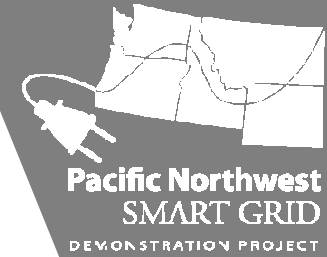
House 1 plan revealed



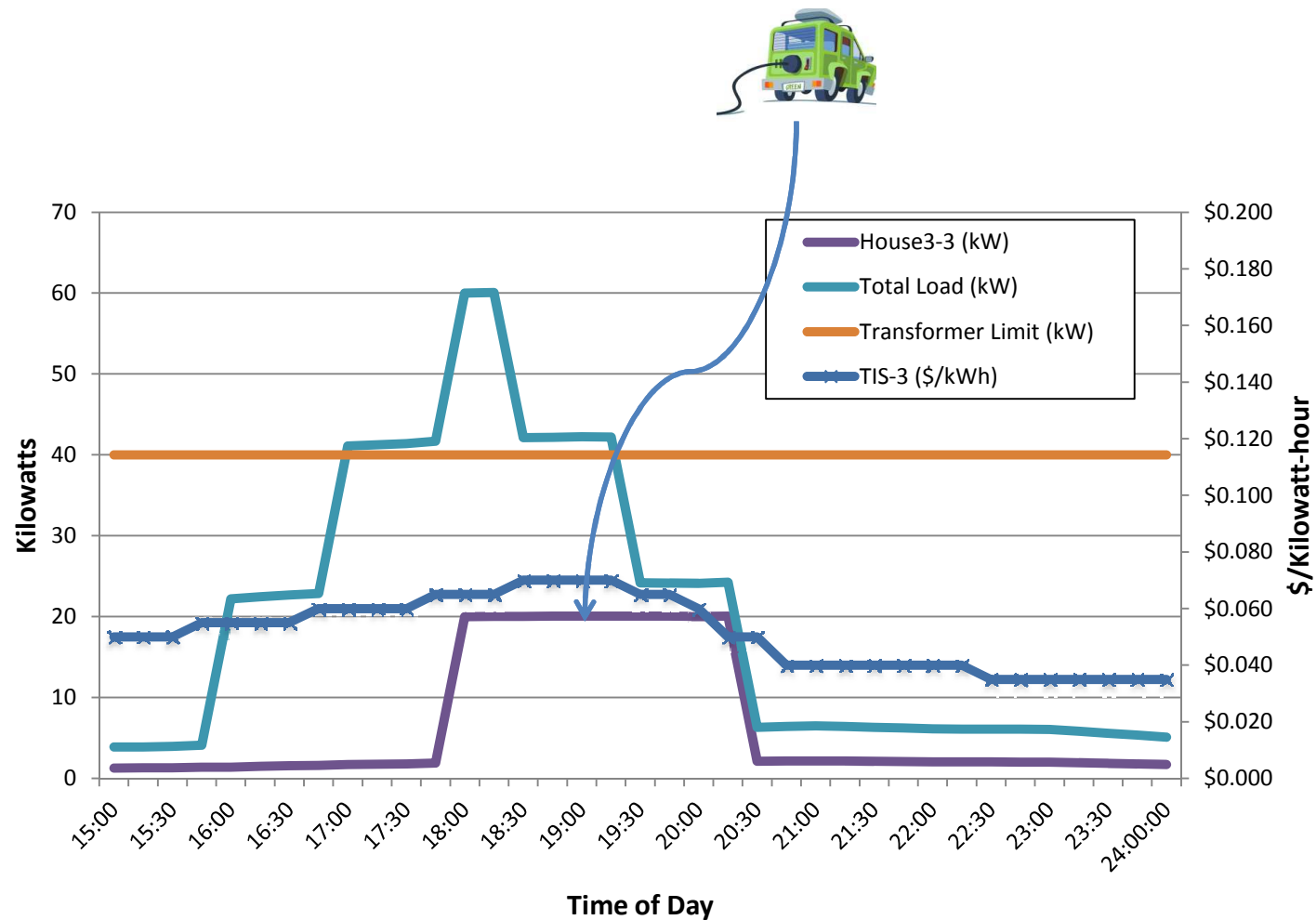
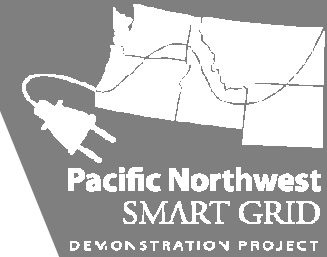
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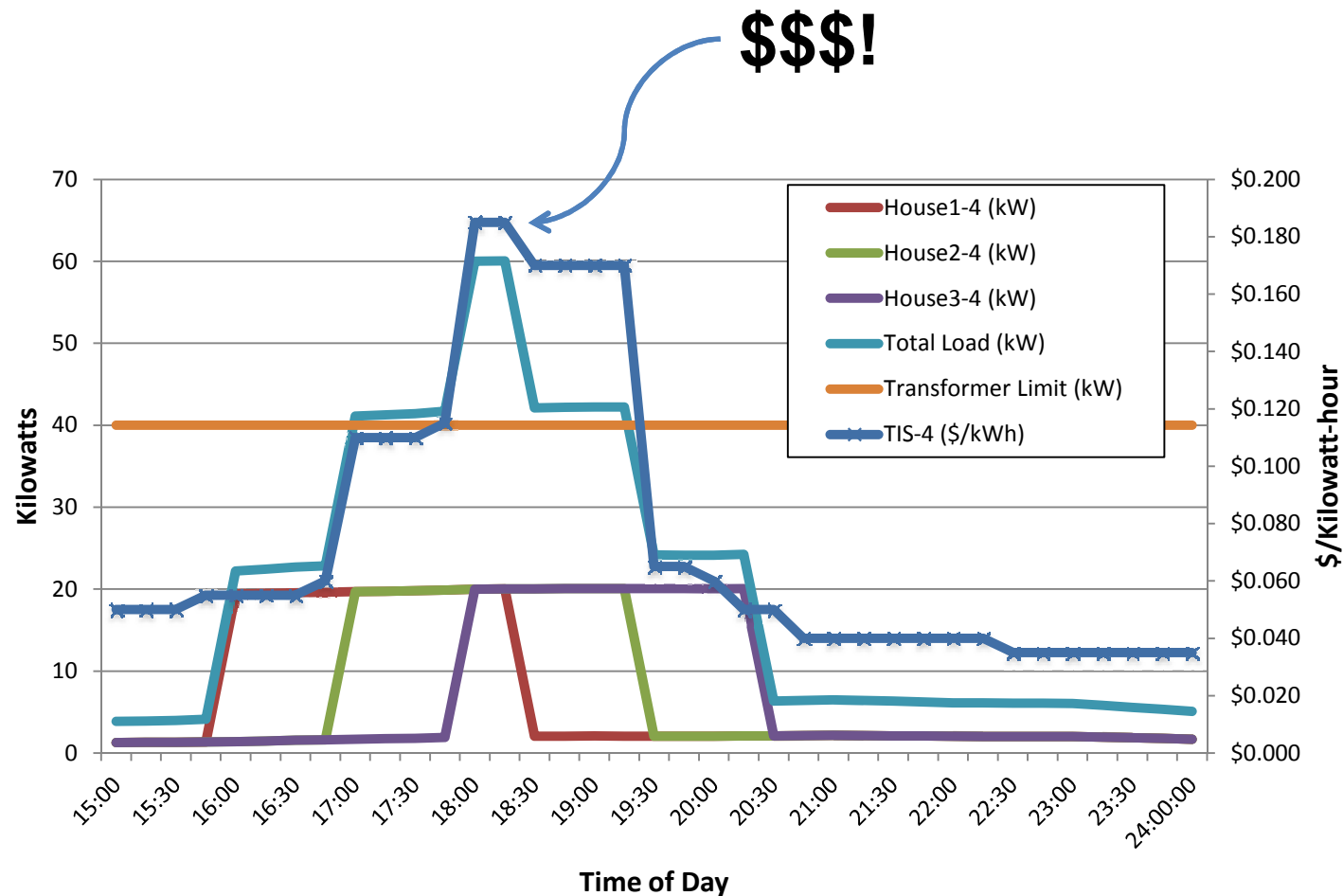
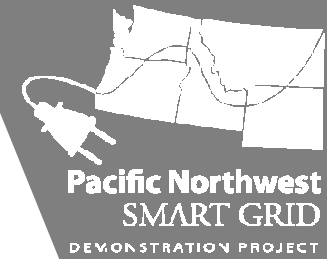
House 2 plan revealed



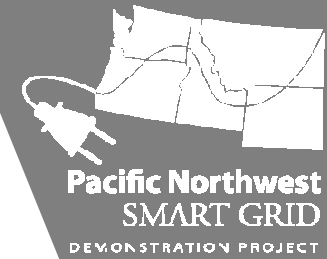
House 3 plan revealed



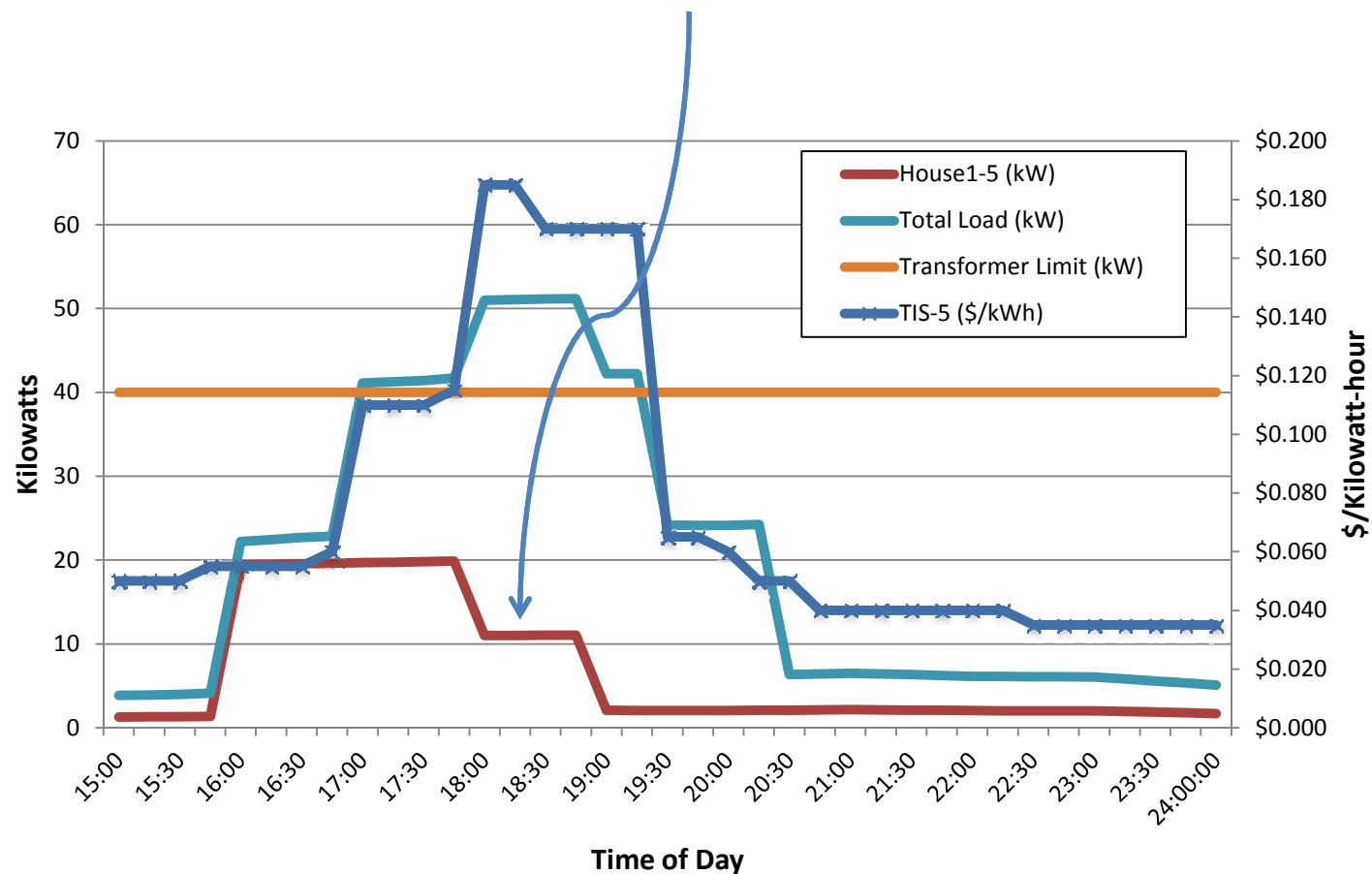
TIS changed in response to charging plans



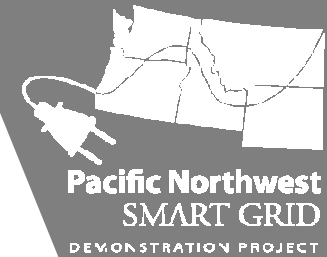
House 1 responds to TIS change



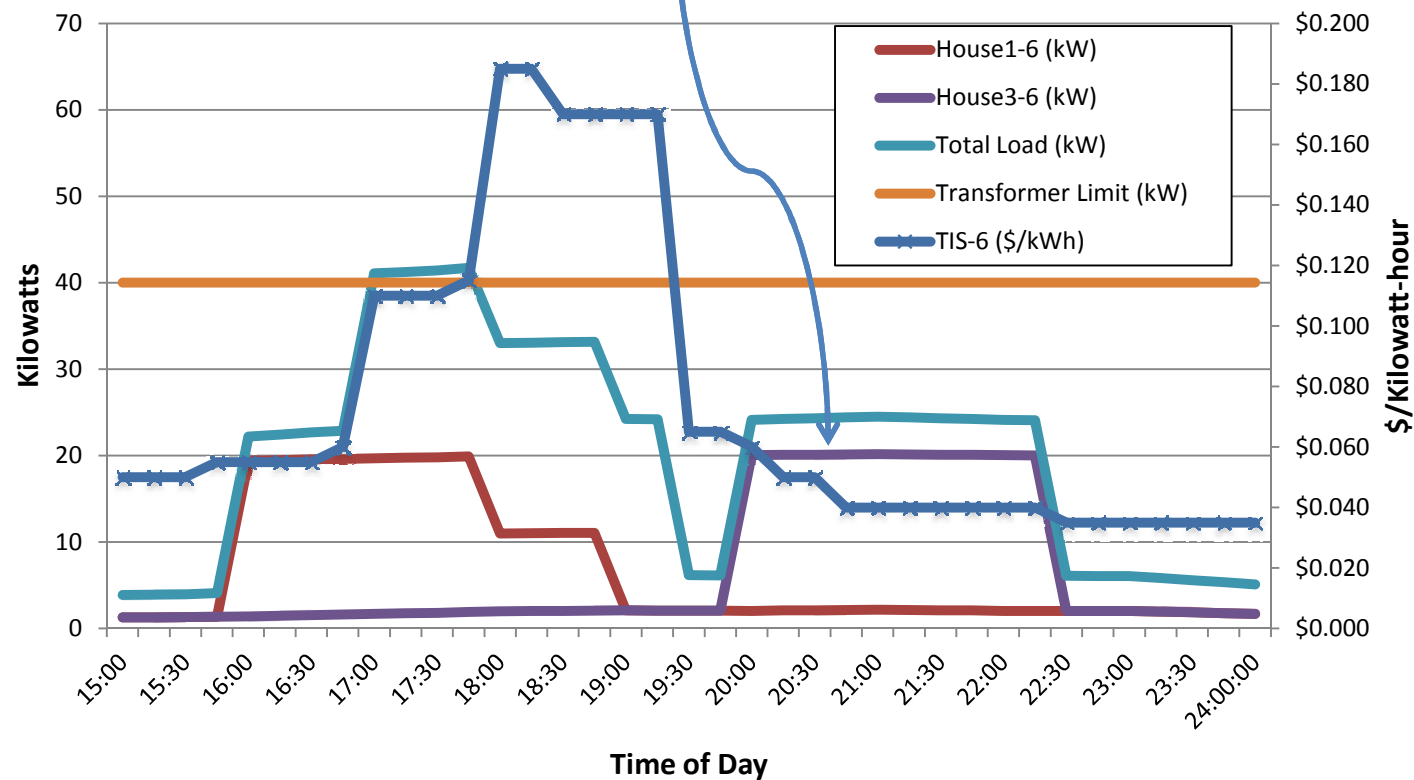
House 1:
I'm flexible



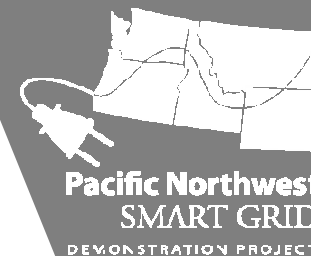
House 3 responds to TIS change - shift



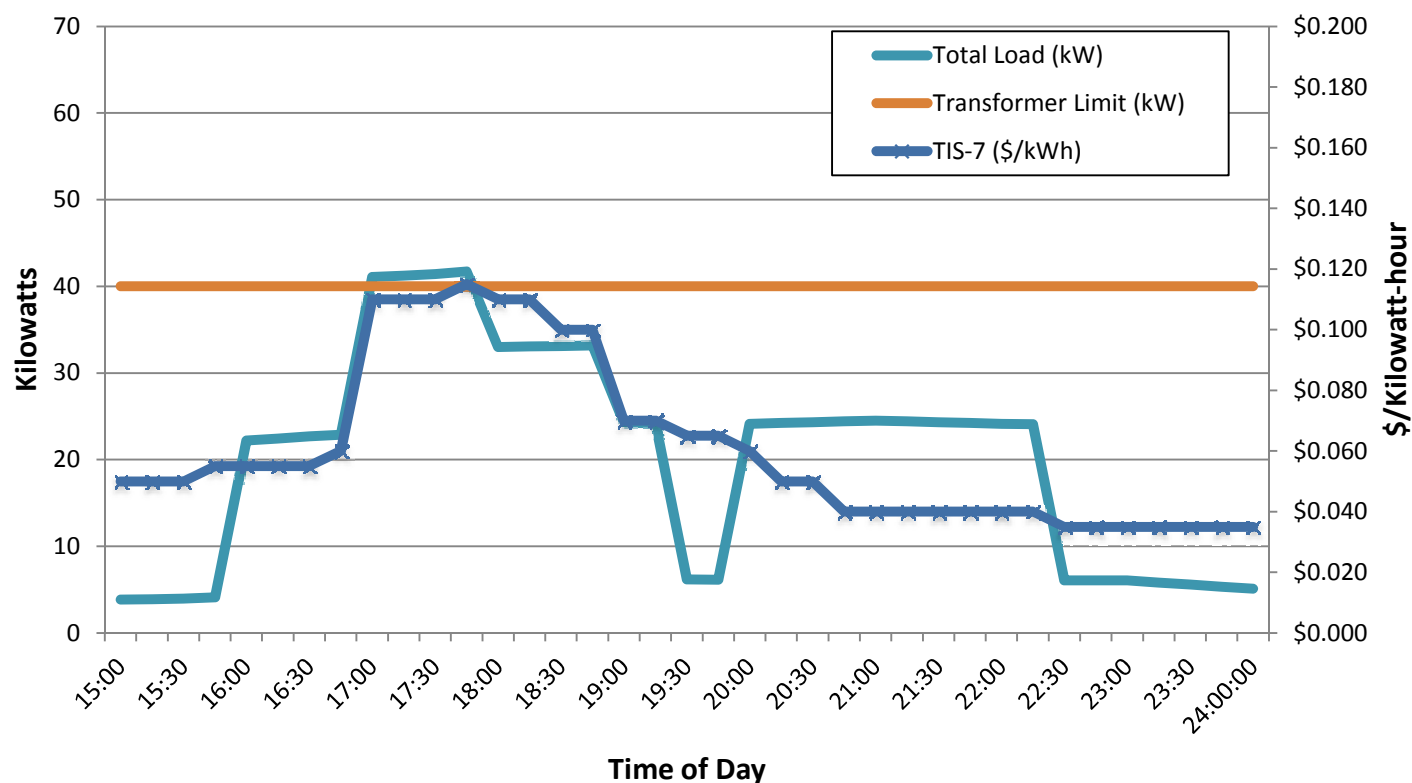
House 3:
I'm a bargain hunter



TIS responds to new plans – agreement



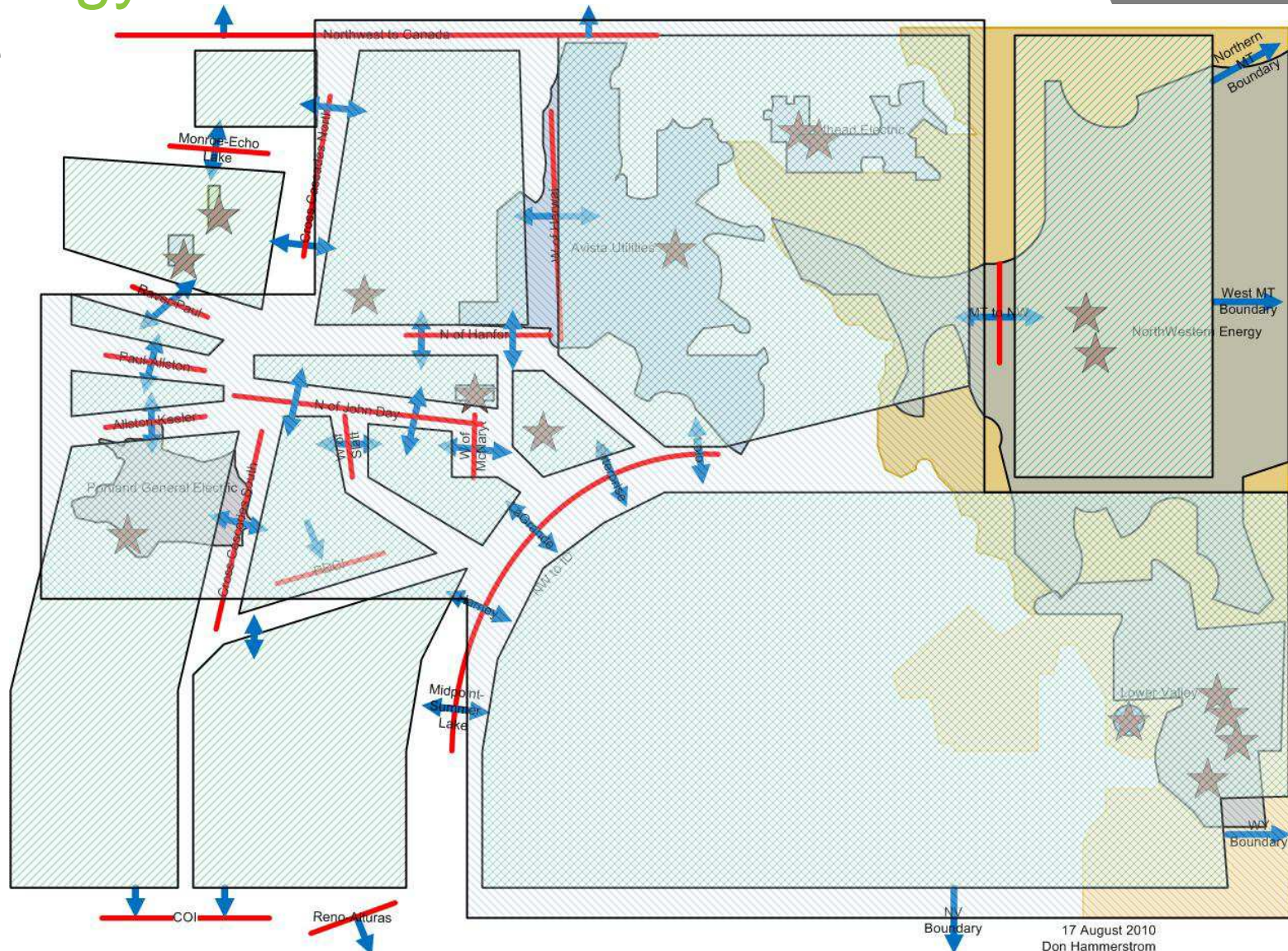
House 2:
I want it now!
I didn't make any change.
I will pay the higher price.



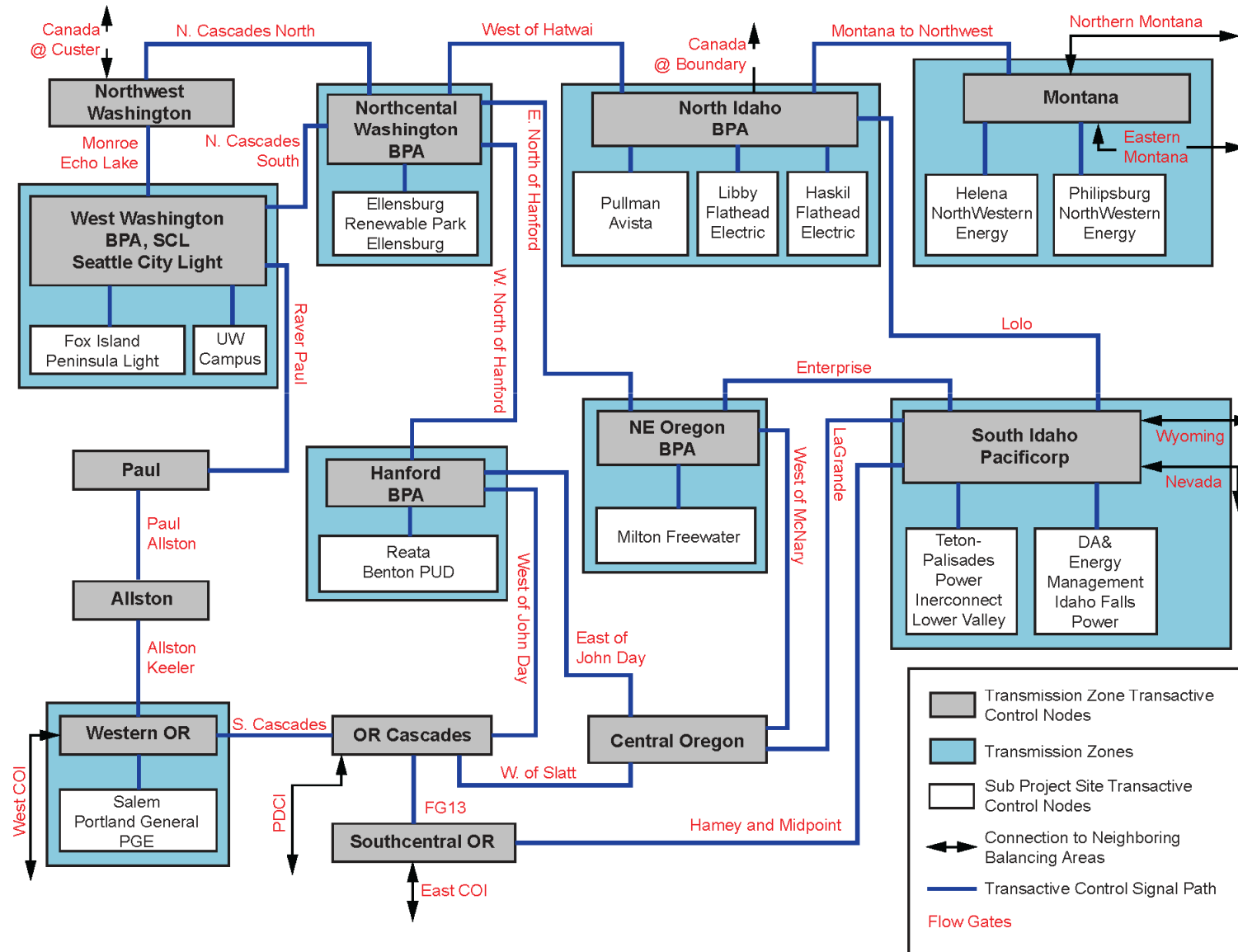


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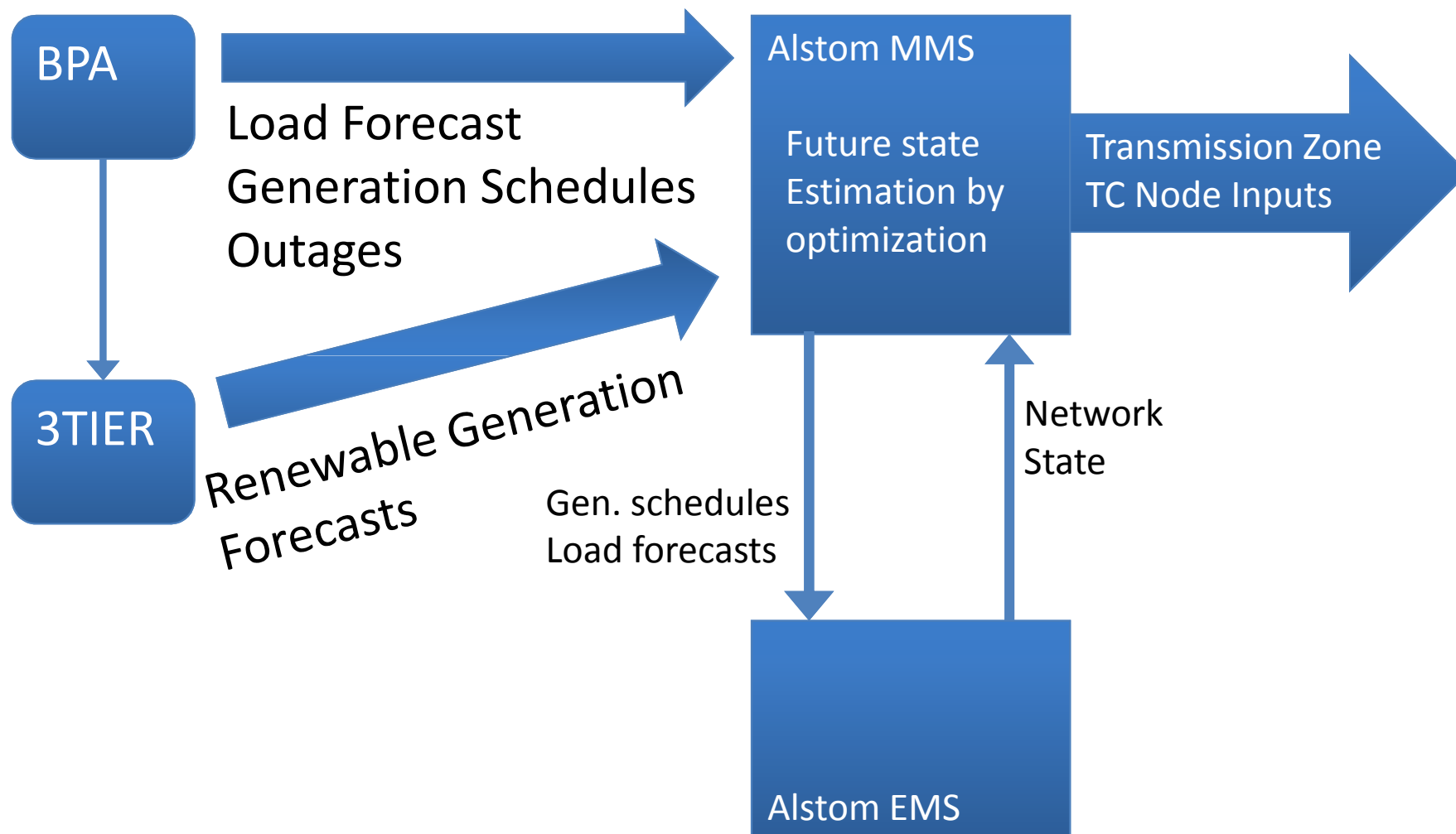
Flowgate



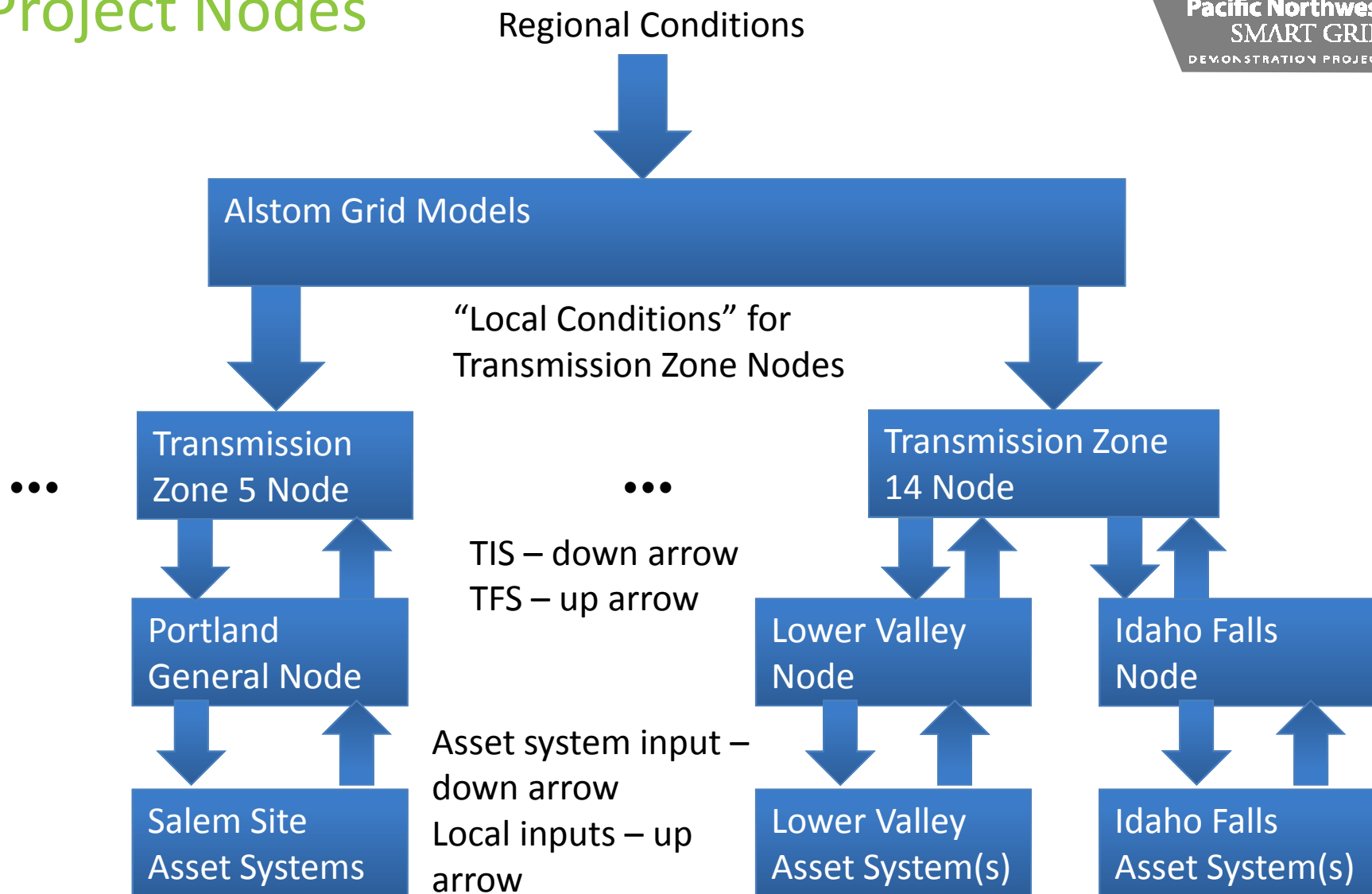
Regional and Subproject Transactive Control Nodes and Network Topology



Regional Modeling



Project Nodes



Example of “Good” Comparison

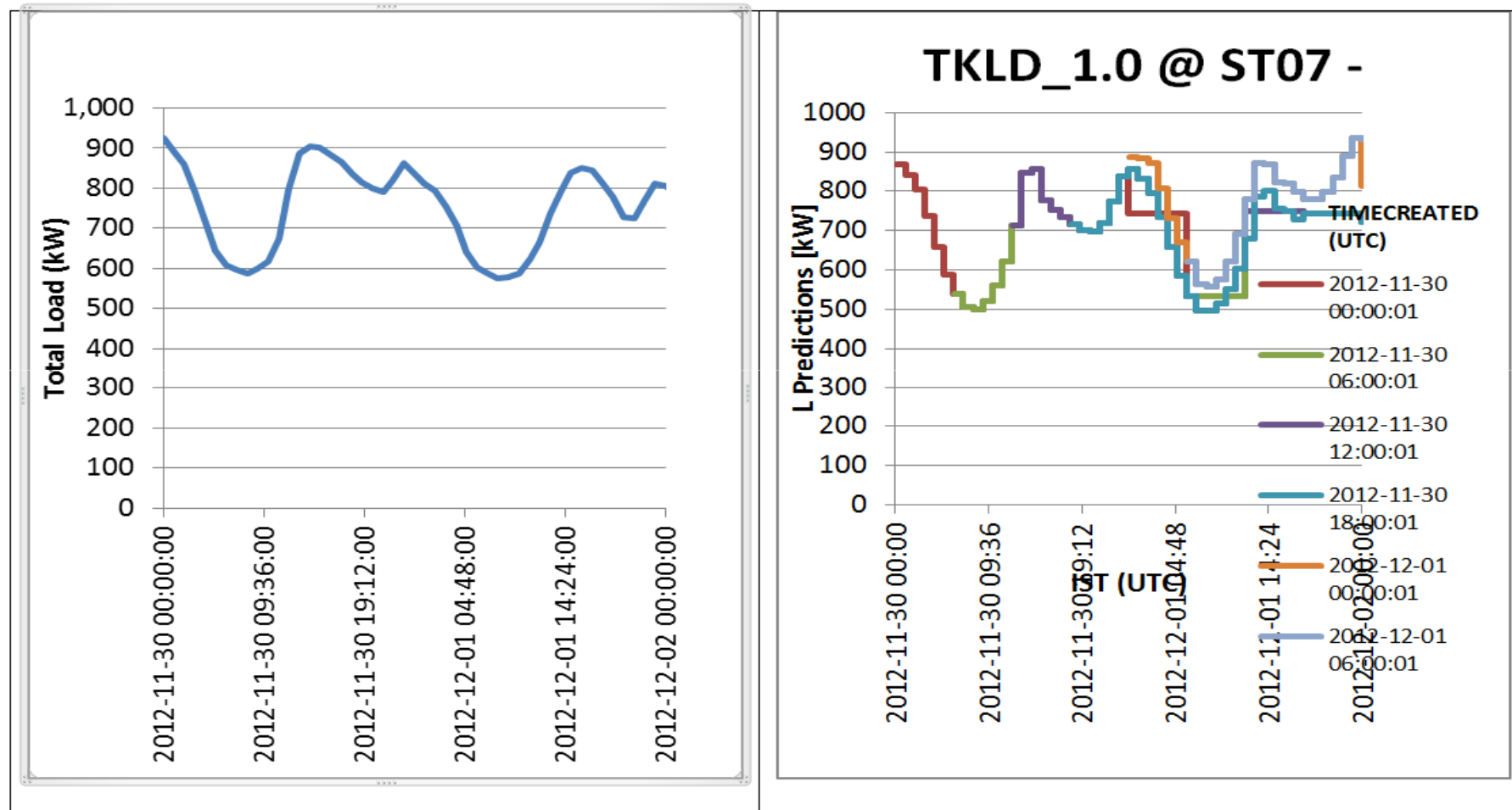
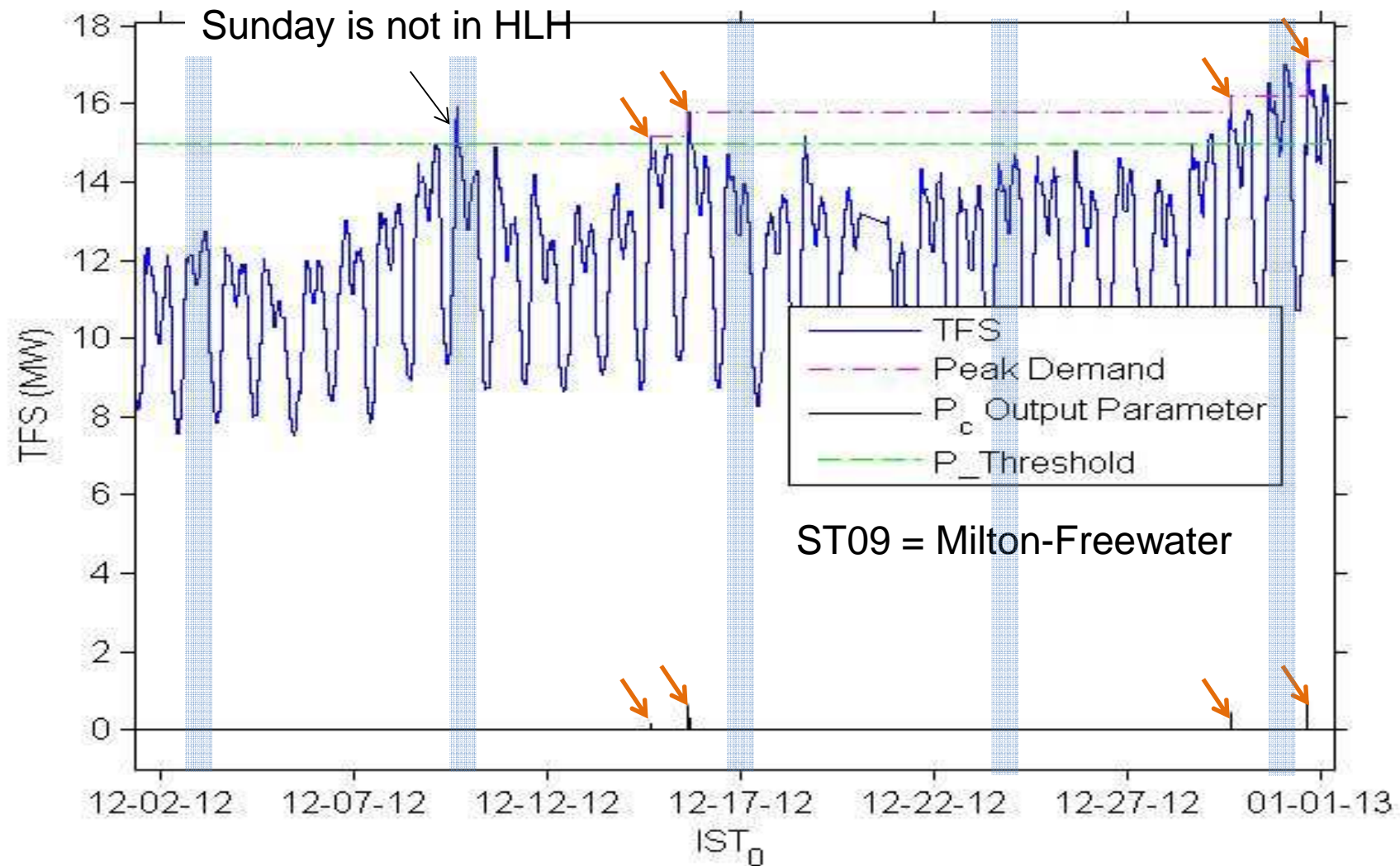
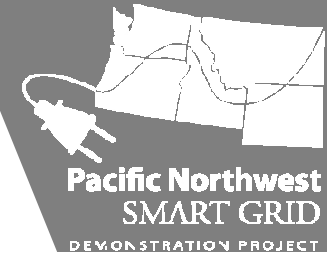
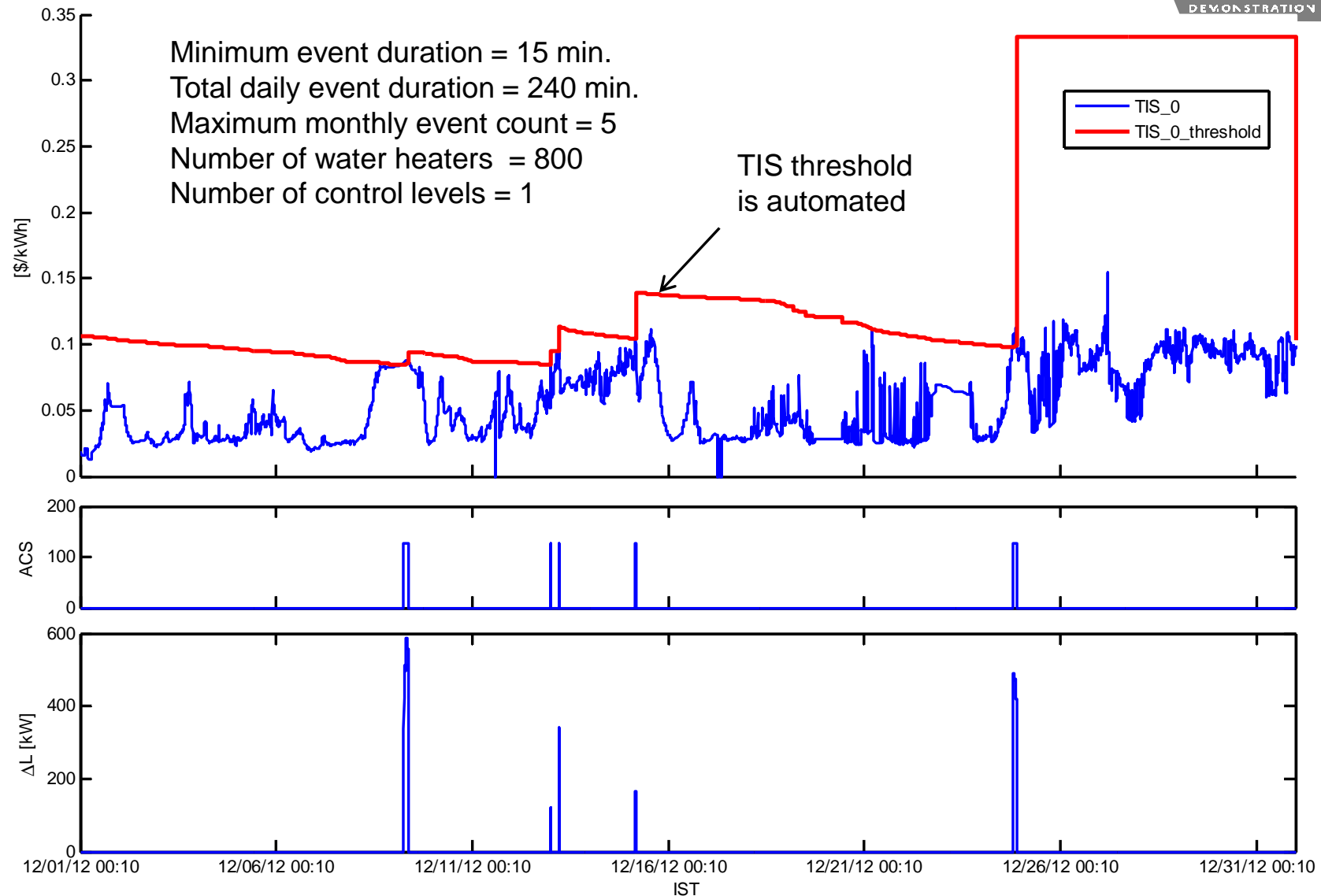
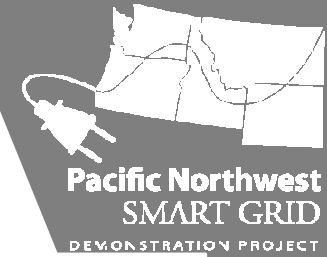


Figure 5. Side-by-side comparison of load at ST07 (Libby) from non-transactive data (FH-IM-41-1, on left) and TKLD_1.X output for ST07 (Libby). Plotted values exhibit similar magnitudes and patterns and therefore pass E2E test TKLD_1.0-2.

TKRS_7.1.1 Recommended Algorithm for BPA Demand Charges



TKLD_2.4: Simulation Results for ST09 (Milton-Freewater)



For further information

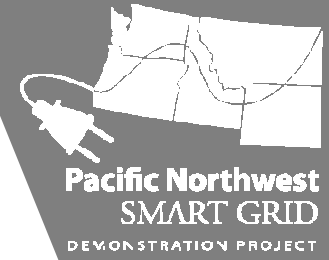
Dr. Ron Melton

ron.melton@battelle.org

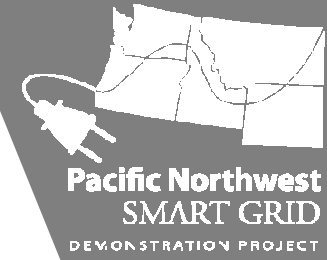
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- “Annual Report”
- Quarterly newsletters
- Participant summaries
- Background on technology



Acknowledgement & Disclaimer



- Acknowledgment: This material is based upon work supported by the U.S. Department of Energy under Award Number DE-OE0000190.
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