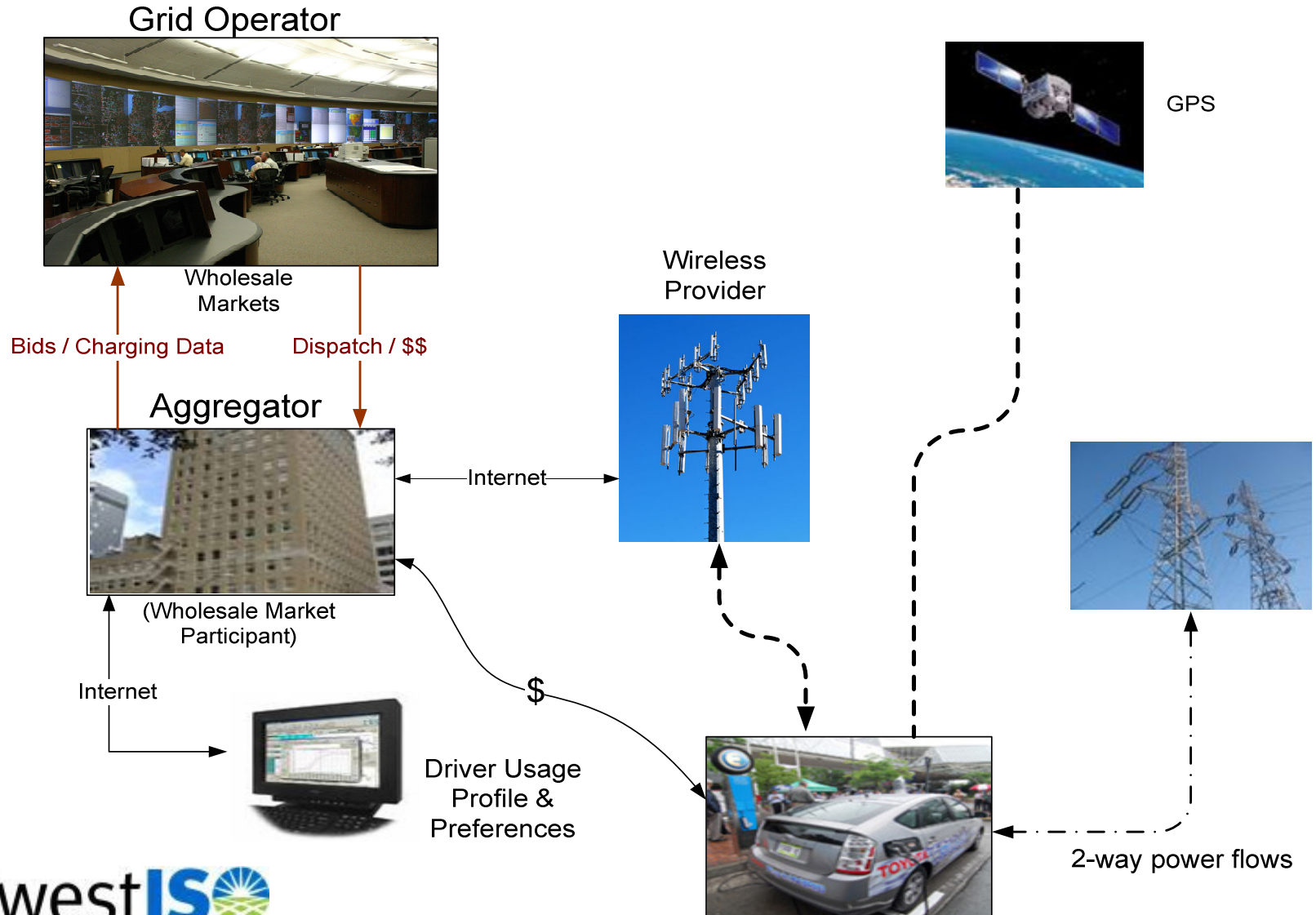


Grid Architecture & V2G

Rich Kalisch
November 2009

V2G Overview



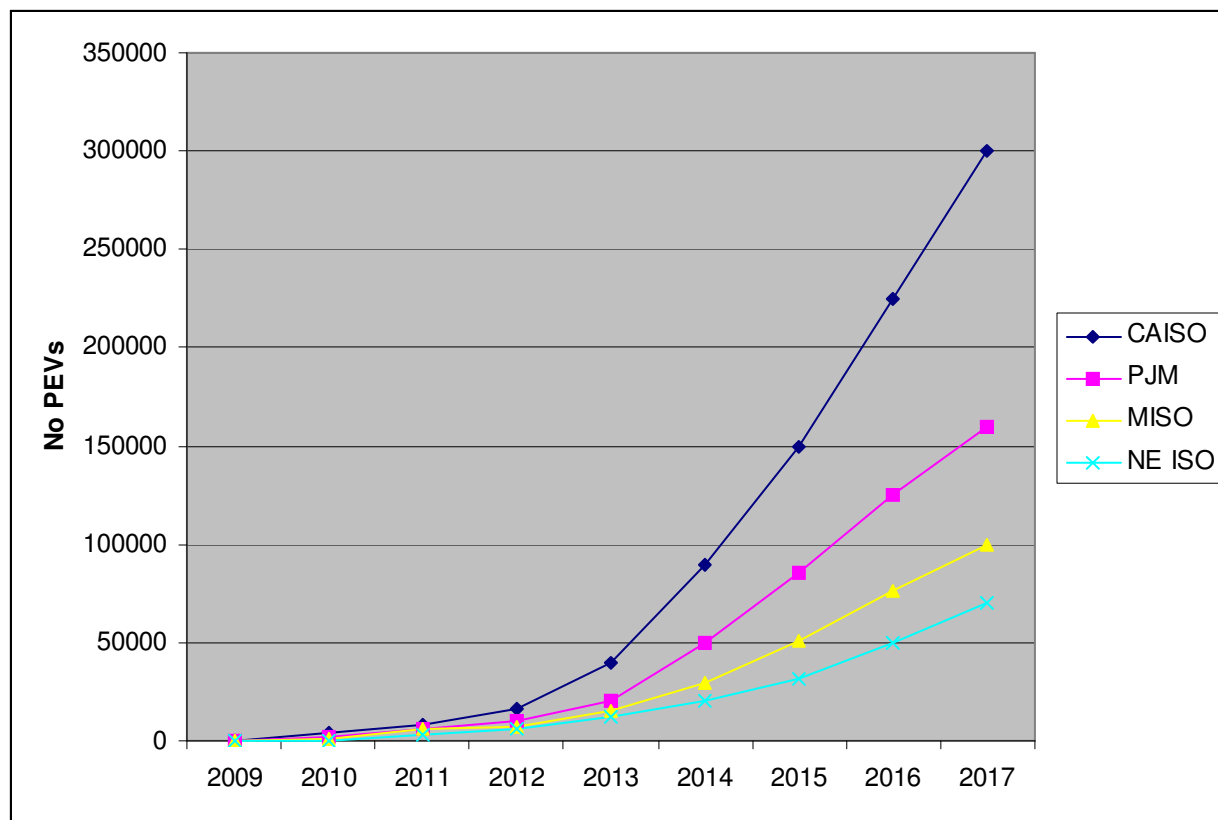
ISO/RTO Council

- PEV Study Underway to assess impact on
 - Market products
 - Reliability operations
 - Information technology and interoperability standards



IRC PEV Penetration by ISO

1 million PEVs deployed in U.S. between 2015 and 2019



Other ISOs
under 50,000

- ERCOT
- NY ISO
- SPP

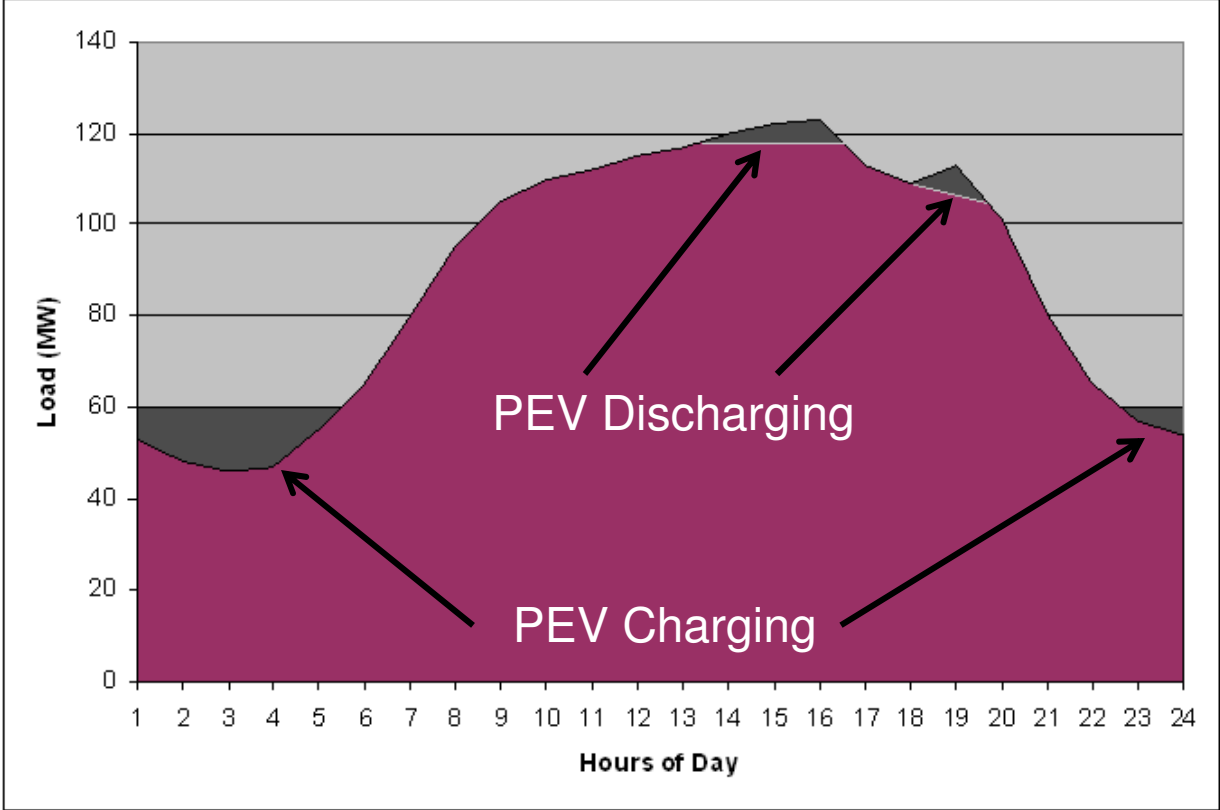
Timing & Stages of V2G Capabilities?

- **Stage 1** – Simple charging control **(1-5 years)**
 - Off peak charging
 - No V2G capability
- **Stage 2** – Smart charging based on pricing signals **(3-10 years)**
 - Demand response (DR) – variable charging
 - Participation in ISO ancillary services market as DR
 - No V2G capability

Timing & Stages of V2G Capabilities? (continued)

- **Stage 3** – V2G Participation in Ancillary Services Market **(5-12 years)**
- **Stage 4** – V2G Participation in Energy Market **(10-20 years)**
- **Timing** of above dependent on...
 - PEV volumes
 - Battery technology and warranties

Smart Charging with V2G Capabilities



Potential ISO Market Participation

- **Regulation**

- Automatic Generation Control (frequency)
- Response within 5 min.
- Market limited to approximately 1% peak load

- **Contingency Reserve**

- Reserves to cover loss of transmission or generation facilities
- Response within 10 min.
- Market typically limited to size of largest online facility

- **Energy**

- Scheduled in day-ahead market
- Unlimited market potential



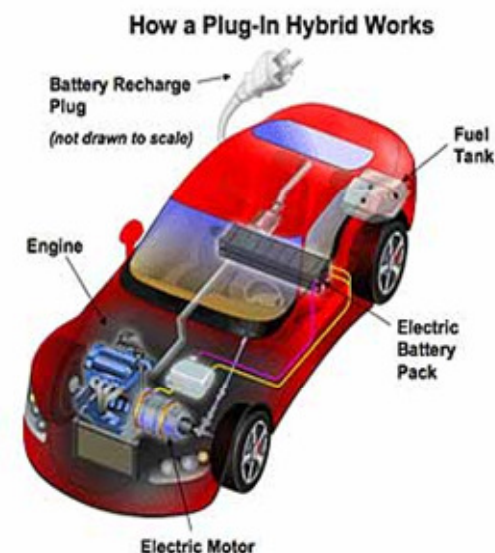
Necessary Changes to Grid Structure to Support V2G?

- **Policy**
 - Net metering retail rates
 - Time of use/ hourly retail rates
- **Business model**
 - Aggregator role
- **Operations**
 - Smart Charging infrastructure
- **Grid Infrastructure**
 - Distribution feeders



Challenges for V2G?

- **Smart charging infrastructure**
- **Battery charging cycles**
- **Distribution grid**
 - Transformer loads (capacity)
 - Two-way power flows (reliability, quality)
- **Aggregator capabilities**
 - Communications to vehicle
 - Charging/discharging management
- **Interoperability**
 - Communications standards incorporating security



Sample PEV Activities Midwest ISO Region

- **DTE Energy / GM / Univ. of Michigan**
PEV 2009 conference in Detroit
- **IUPUI (IN Univ. Purdue Univ.) & IPL**
Plug-in-Electric Vehicle Study
- **Madison Gas & Electric**
Vehicle charging network demonstration project
- **Michigan PSC**
Pilot to integrate PEVs into the grid

Electric Car History



- Detroit Electric
- Range 65-100 miles
- 100 years old