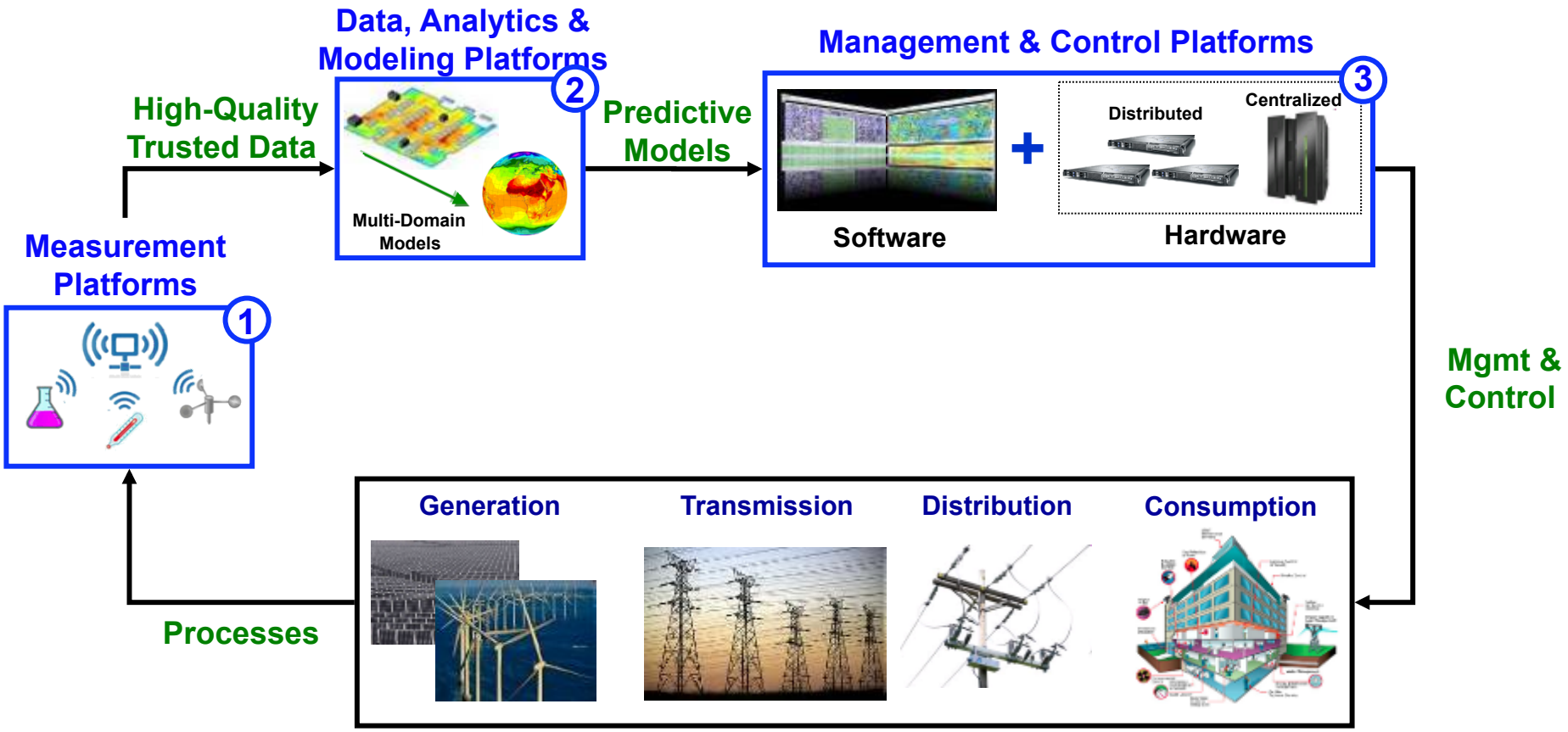
Three Topics to Share

- **On Feedback Loops**
  - Case Study: Renewable integration in Spain
- **Smart Grids as Coupled Earth and Human Systems**
- **Distributed Control Through Transactive Energy Management**

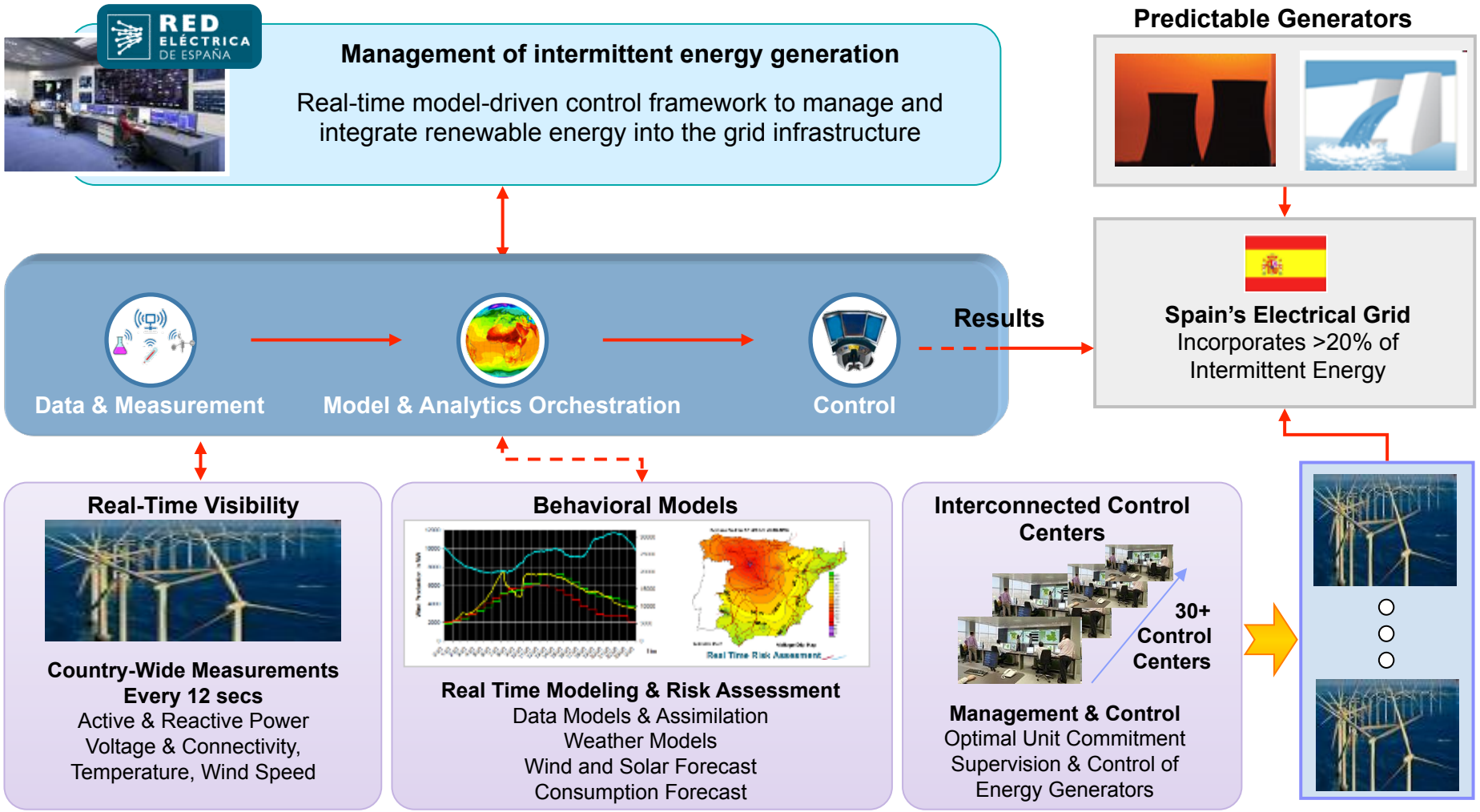
dgil@us.ibm.com

Measurement, Modeling & Control Platforms will Drive Smarter Energy Systems Through the Broad Implementation of Feedback Control

Value Transformations	Processes (1)	High-Quality Trusted Data	(2)	Predictive Models	(3)	Management & Control



Smarter Energy in Practice - Model-driven optimization enables substantial electricity (>20%) generated through renewable energy

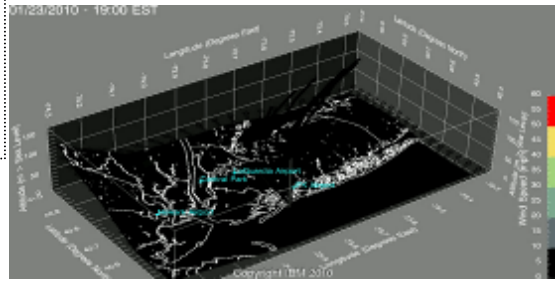


Smart Grid Research @ IBM: Coupled Earth and Human Systems

EARTH SYSTEM MODELING

- WEATHER MODELING
- GEOSPATIAL STATISTICS
- DATA ASSIMILATION

EARTH SYSTEMS



HUMAN SYSTEMS

BEHAVIORAL MODELING

- SOCIAL COMPUTING
- SIMULATION OF AGENTS
- PREFERENCE MODELING
- ENERGY USE SCHEDULING

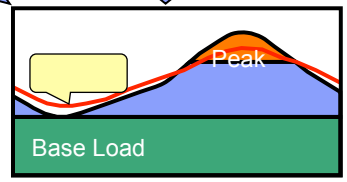
SUPPLY UNCERTAINTY

DEMAND UNCERTAINTY

RENEWABLES

PORTFOLIO PLANNING

- WIND/SOLAR FARM LAYOUT
- CONDITION BASED MNGT
- POWER FORECASTING



DEMAND MANAGEMENT

- DEMAND PLANNING & LOAD FORECASTING
- DEMAND RESPONSE
- TRANSACTIVE CONTROL

CONVENTIONAL GENERATION

RESOURCE/MARKET MGMT, OPERATIONS

- TRANSACTIVE CONTROL
- GENERATION PLANNING WITH UNCERTAINTY SUPPLY/DEMAND
- STOCHASTIC UNIT COMMITTMENT
- REAL TIME CONTINGENCY ANALYSIS

GRID OPERATIONS

- OUTAGE MANAGEMENT
- EV INTEGRATION
- TRANSACTIVE CONTROL
- REAL-TIME STATE ESTIMATION OF GRID (DATA ASSIMILATION)
- SIMULATION OF POWER FLOW
-CONDITION BASED MNGT

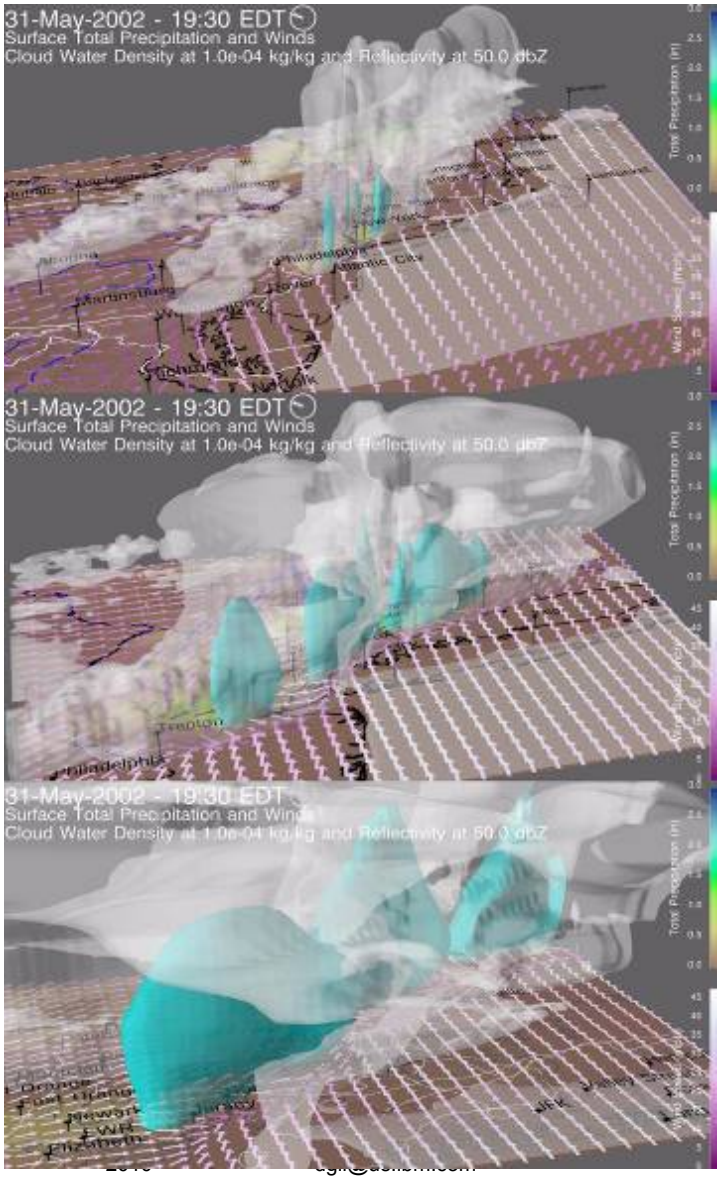
PHYSICAL CONSTRAINTS

-NETWORK TOPOLOGY & CAPACITY
-POWER FLOW

dgil@us.ibm.com

Coupled Systems: Example #1

Deep Thunder



- Capture the geographic characteristics that affect weather (horizontally, vertically, temporally)
- Ensure that the weather forecasts address the features that matter to the business

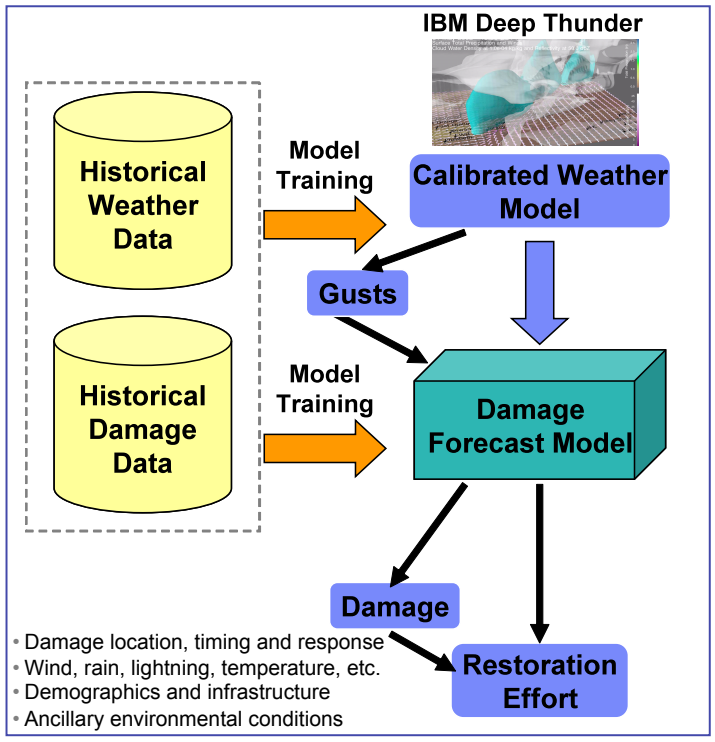
Coupled Systems: Example #1

The Business of Weather

***Deep Thunder*: a service for local, high-resolution weather predictions customized to business applications for weather-sensitive operations up to three days ahead**

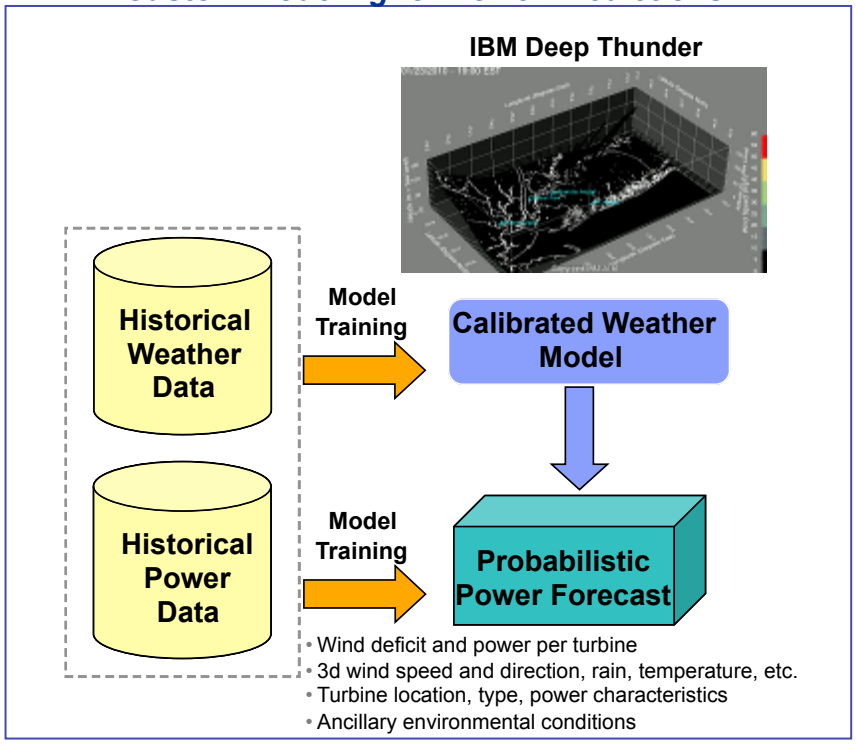
Coupled Weather and Impact Modeling

Custom Modeling for Predictions of Outages



Coupled Weather and Renewable Power Forecasting

Custom Modeling for Power Predictions



dgil@us.ibm.com

Coupled Systems: Example #2

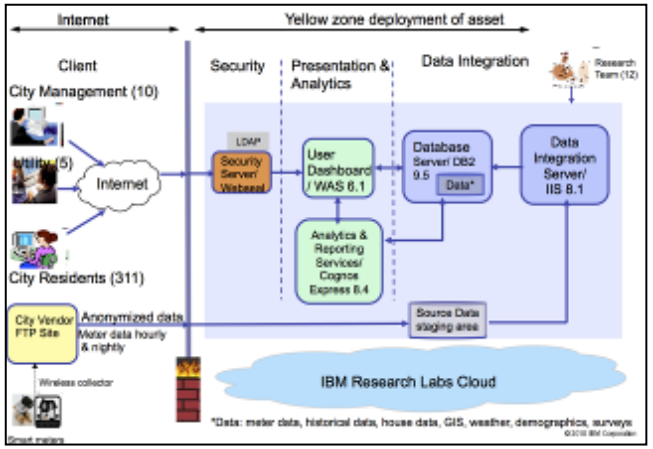
Smart Grid and Social Computing

- **The social computing perspective**
  - The “smartness” of smart systems comes from **technology AND people**, not just technology alone
  - People **actively participate** in smart systems, **supplying local knowledge** about where they work and live that complements sensor-derived data;
- **Social computing research issues**
  - **Social Intelligence**. How do we design systems that tap human knowledge to support more sustainable energy use?
  - **Crowdshifting**. How can our systems support the widespread behavioral change required by smart grid applications?
  - **Legitimacy**. How to design systems (and policies) that mitigate the fears of ‘Big Brother’ provoked by use of sensors and monitoring of energy use?

The Dubuque Experiment

Goal: Deliver timely information and insights through cloud-based service to increase awareness, modify usage and reduce waste

- Provide information to the City of Dubuque, Iowa
- Provide feedback to citizens to support understanding and management of resources



Today's Paradigm: Centralized

Tomorrow's Paradigm: Distributed Control

Meters

.....

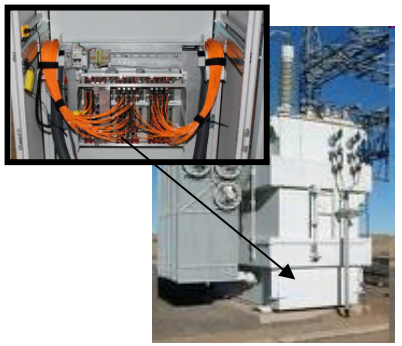
Synchrophasors

Legacy Operational Processes

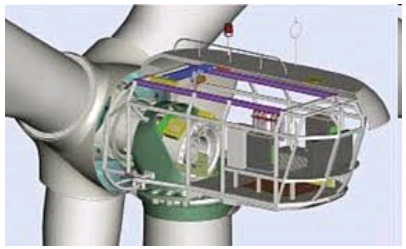
- Outage Management System (OMS)
- Workforce Management
- …

Home & Building Controls

Embedded Control



Substation



Wind Turbines with embedded intelligence

Command Center

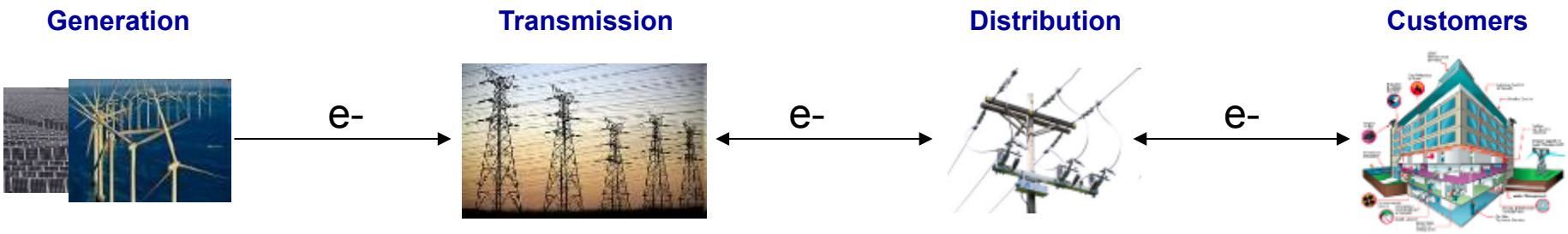
A loosely-coupled network of responsive assets – How do we manage it?

Transactive Energy Management

dgil@us.ibm.com

Transactive Energy Management Defined

Transactive Incentive Signal: reflects true cost of electricity at any given point

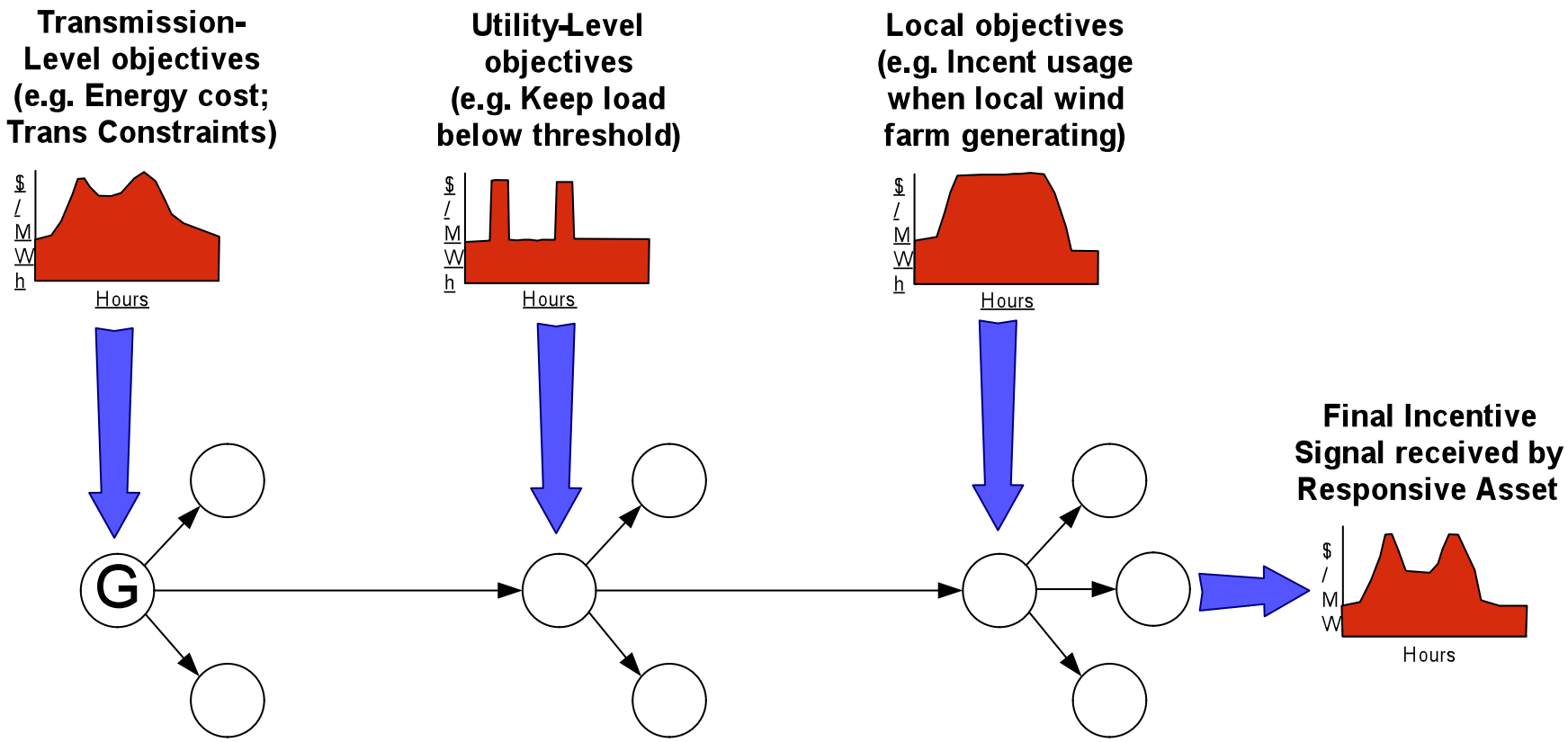


Transactive Feedback Signal: reflects anticipated consumption in time

The Transactive Energy Management system is a distributed software and communications environment that logically overlays the electricity grid. It deploys thousands (even millions) of software control agents to manage all responsive assets in the system. Agents communicate with each other through the incentive and feedback signals.

Creation and modification of incentive signals

Below is an example of a signal being modified as it flows from supply towards consumption through the transactive network

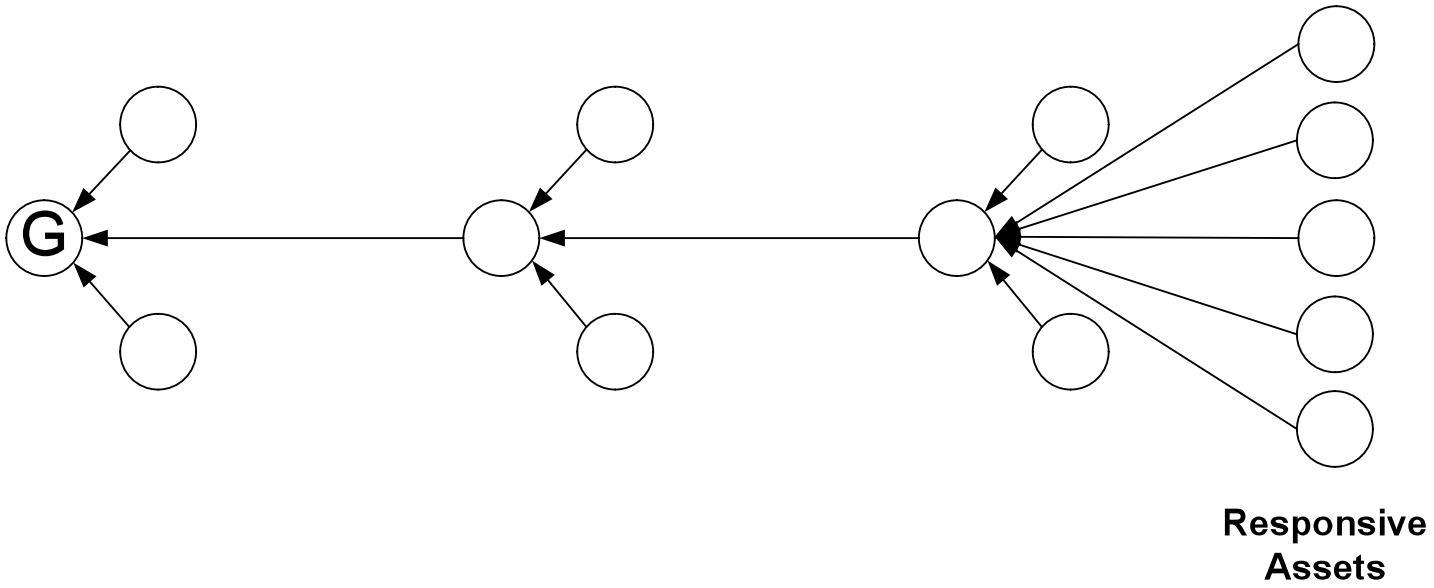


dgil@us.ibm.com

The Transactive Feedback Signal (TFS)

At each node, a local consumption plan is generated.

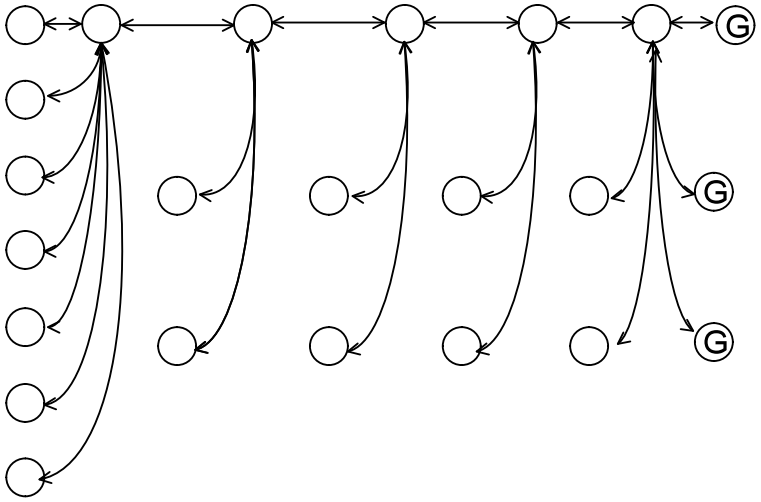
This plan is added to the planned load from all the nodes “below” this node and passed up to Generation.



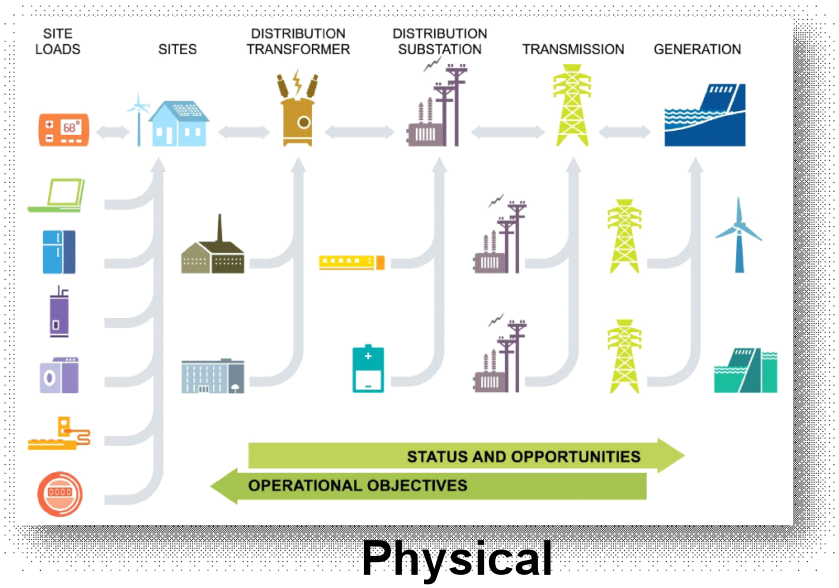
dgil@us.ibm.com

Propagation of the incentive and feedback signals

Incentive signals and feedback signals propagate through an information network (the transactive control system) that overlays the electrical network



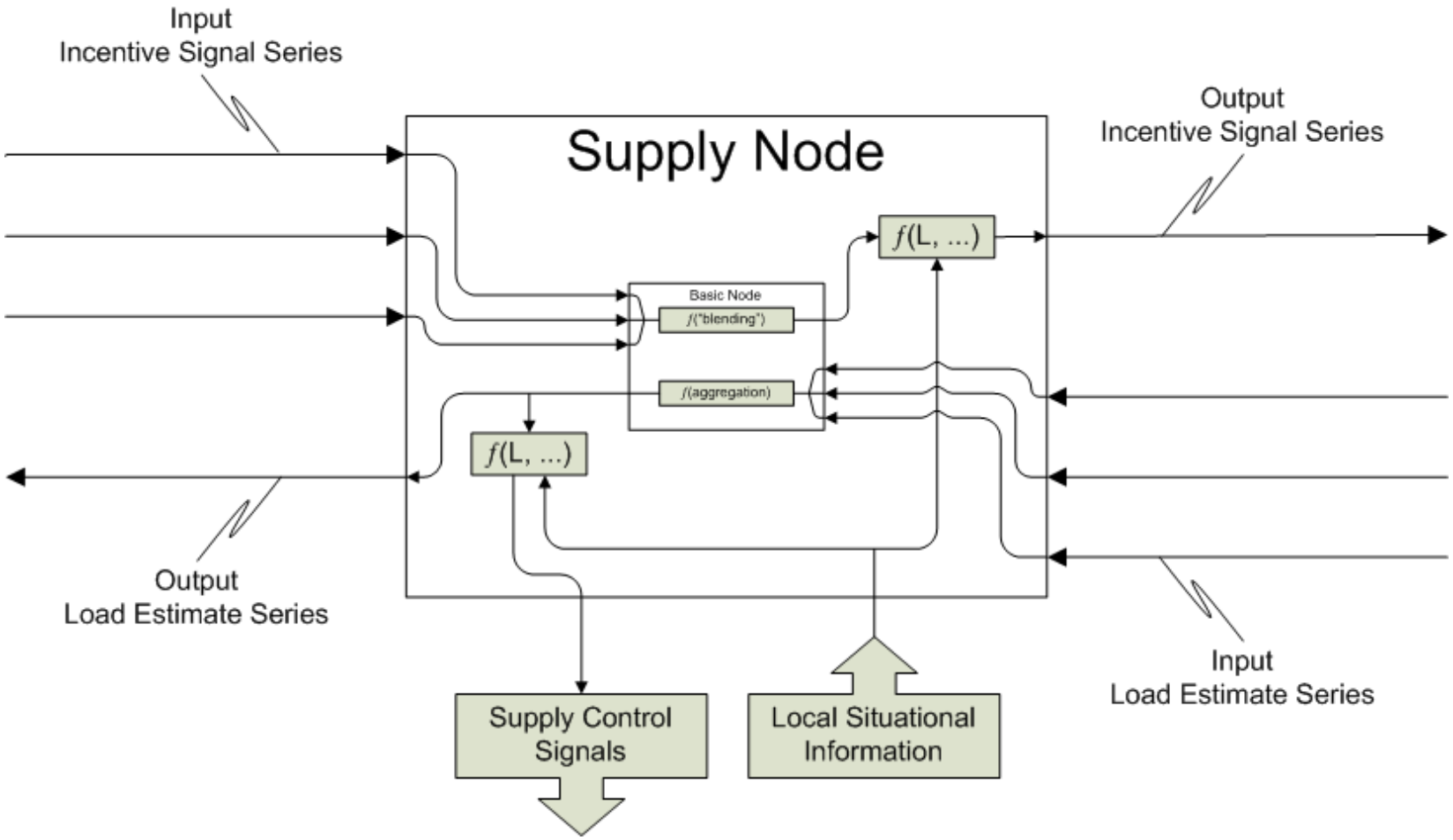
Information Network



Physical Network

dgil@us.ibm.com

Transactive Control Node example



dgil@us.ibm.com

Transactive Energy Management – What is inside?

- **The software agents (supporting multiple languages: Java, C and C++)**
  - Communications are “event based”
  - Are scalable (from heavy duty at enterprise premises to lightweight embedded)
  - Provide security (certificate-based authentication system; full event provenance)
- **Distributed runtime environment in which the agents operate**
  - Internet-scale Control Systems (iCS is the reference implementation of ISO-IEC 18012)
    - Interoperability framework and primary distributed programming environment
  - Real-time analytics of data-in-motion
  - Data warehousing and data mining
- **System Management and Services**
  - Identity management and access control
  - Alerting and dashboards
  - Provisioning and deployment

dgil@us.ibm.com

Pacific Northwest Smart Grid Regional Demonstration Overview

- $178M 5-year project spanning Idaho, Montana, Oregon, Washington, & Wyoming
- Five technology companies, eleven utilities, and two universities are participating

>90,000 responsive assets to be deployed; 95 smart grid use cases





- **Primary objectives**:
  - Measure and validate smart grid costs and benefits
  - Refine & validate Transactive Energy Management
  - Integration of renewable resources
  - Contribute to the advancement of standards
- **Operational objectives:**
  - Manage peak demand
  - Address constrained resources
  - Facilitate renewables integration
  - Select economical resources
  - Improve system reliability
  - Improve system efficiency

dgil@us.ibm.com

PNW Plug-fest, April 2011

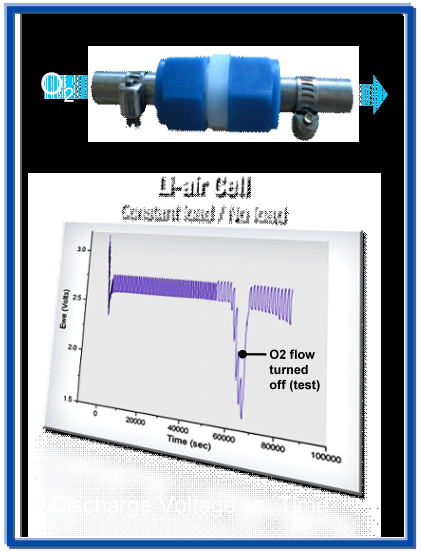
Battelle Lab, Pasco, Washington




dgil@us.ibm.com

Energy Grand Challenges @ IBM Research

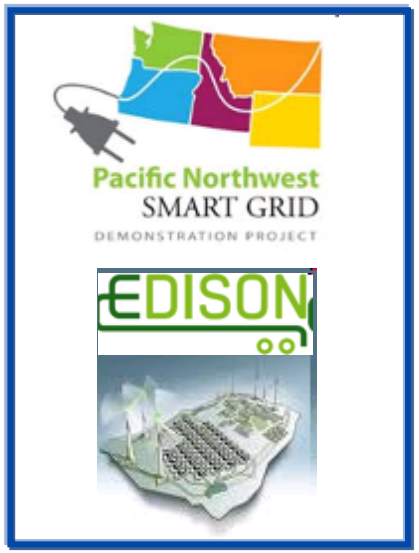
Li-Air Batteries with 500 miles range



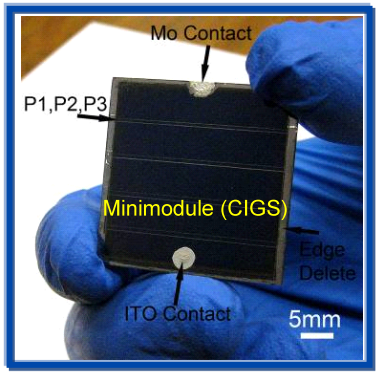
Zero-Emissions DC

Supercomputing & Grid Simulation

Smart Grids



Earth-Abundant Soln-Processed PV

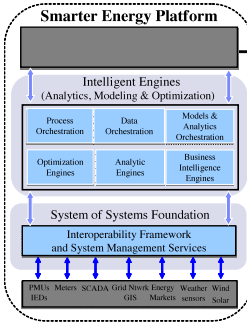


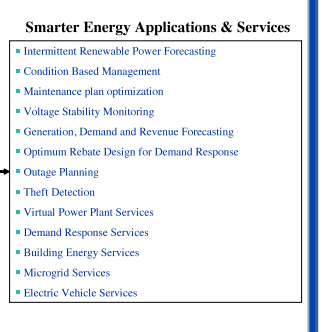
Concentrator PV

Smart Buildings

Energy Innovation Hub

Smarter Energy Platform





The Need for Global Collaboration in the E&U Industry

- **The Electric Power industry is in the midst of a massive, disruptive transformation**
- **The industry will see more change over the next 10 years than in the past 50-100**
- **The industry collectively under-invests in R&D**
  - Particularly in exploring new ways to benefit from the latest advances in information technology
- **The industry is in need of unconventional collaboration models and partnerships**
  - A key new value frontier is extracting value from information

dgil@us.ibm.com

Reference

dgil@us.ibm.com