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Demand Management & Efficient Provisioning - An Imperative for Sustainable Growth

Urban Systems Collaborative, Berkeley, CA
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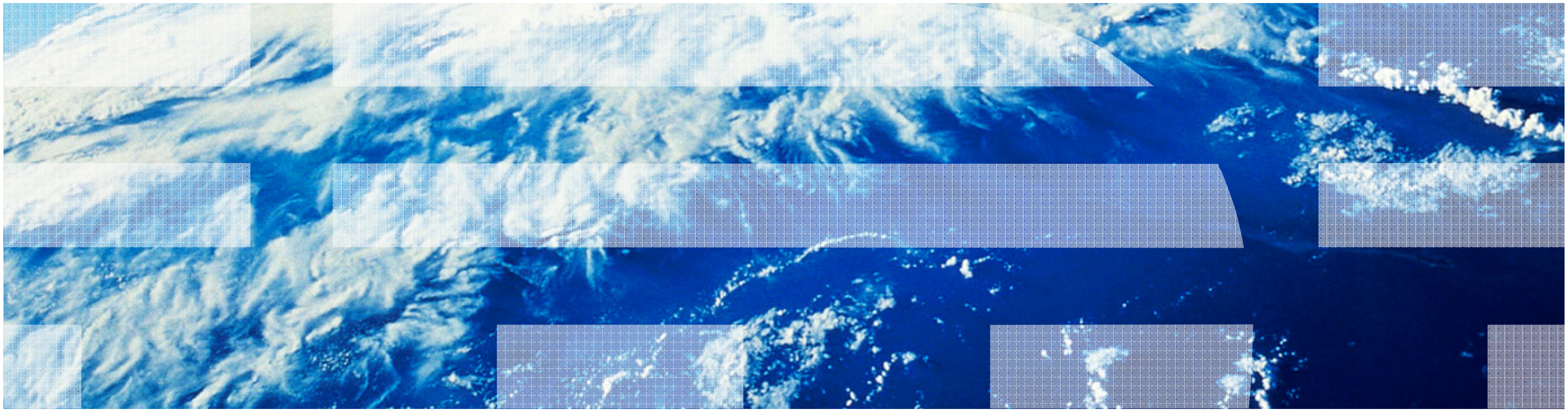


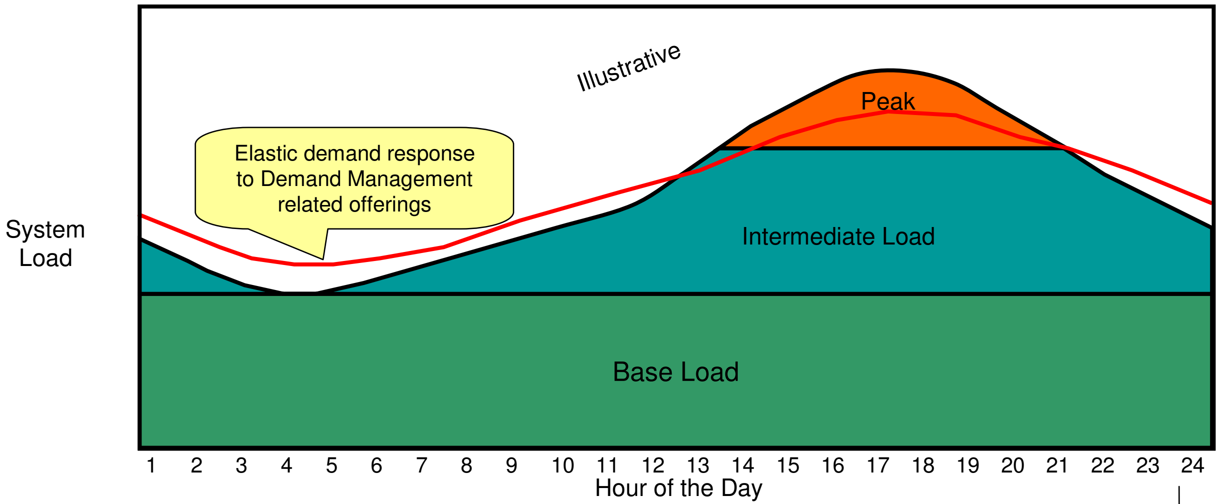
Urbanization – The challenge for Smarter Cities

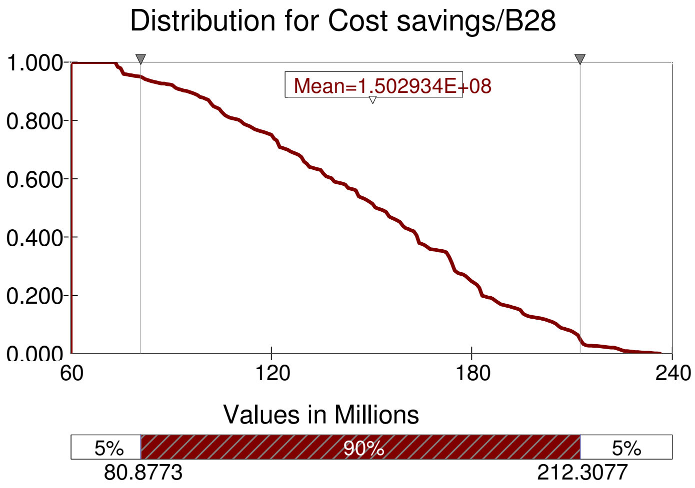
- Urban Population growing rapidly
  - 2010: 78% of developed, and 46 % of developing population
  - 2050: 86% of developed and 64% of world population
- Massive demand for Urban Services
  - Transport
  - Energy/Electricity
  - Water
- Cannot double the capacity of city infrastructure
  - Need to use resources very efficiently and provision for demand precisely

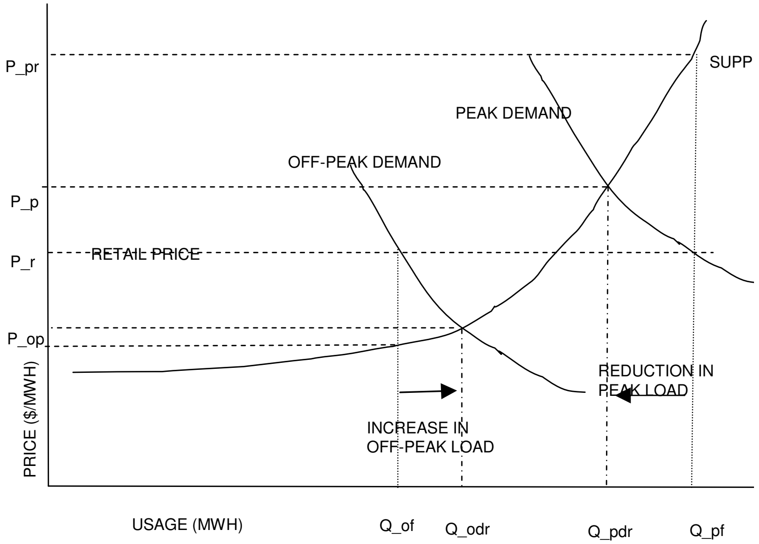
Three approaches

- Demand Management to level load on infrastructure
- Increase Availability of infrastructure
- Provision resources very efficiently (μ-Demand estimation)

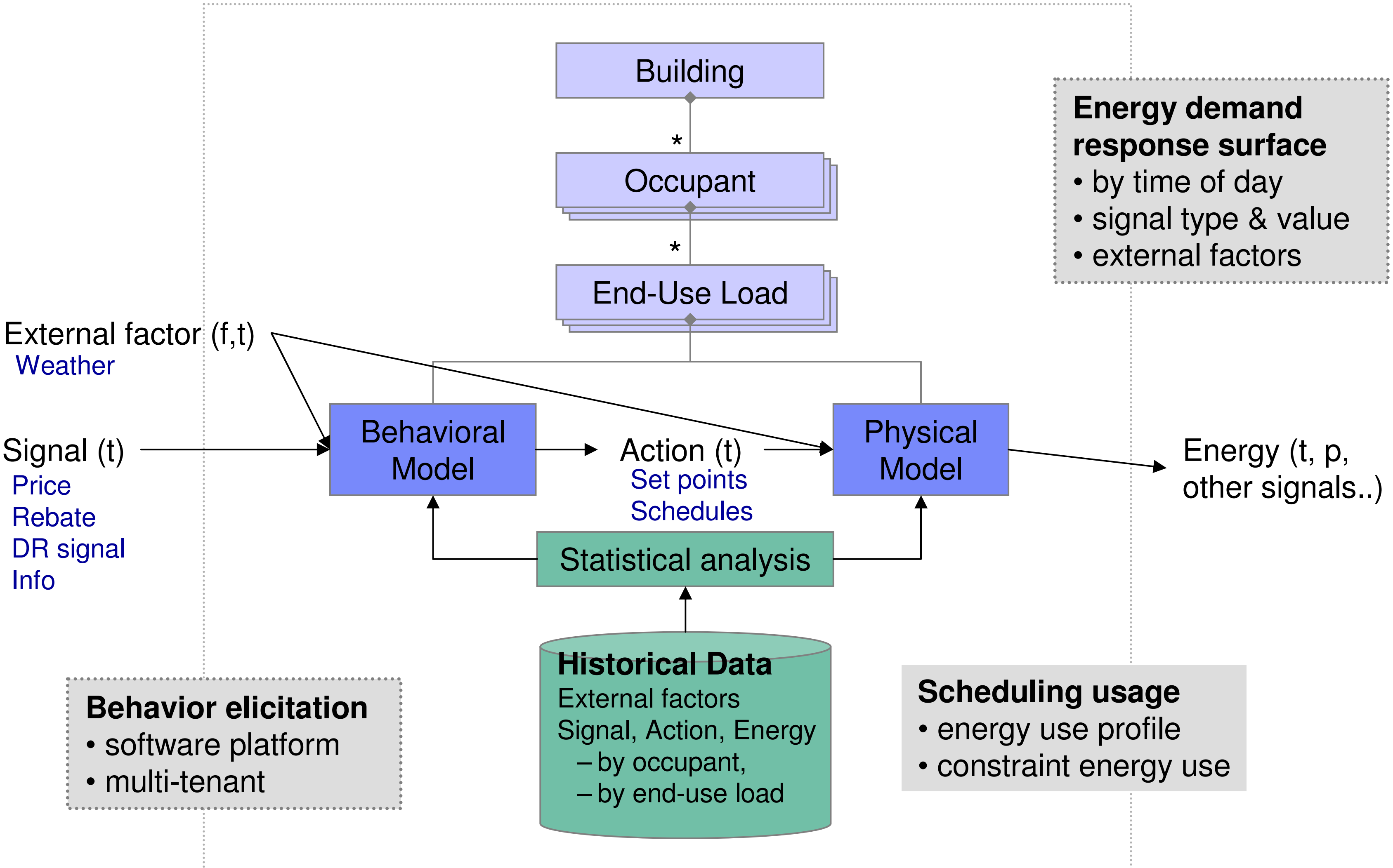
Demand Shaping and Shaving (Demand Response)







Building energy demand prediction & responsiveness



Building

*

Occupant

*

End-Use Load

External factor (f,t)
Weather

Signal (t)
Price
Rebate
DR signal
Info

Behavioral Model

Action (t)
Set points
Schedules

Physical Model

Energy (t, p, other signals..)

Statistical analysis

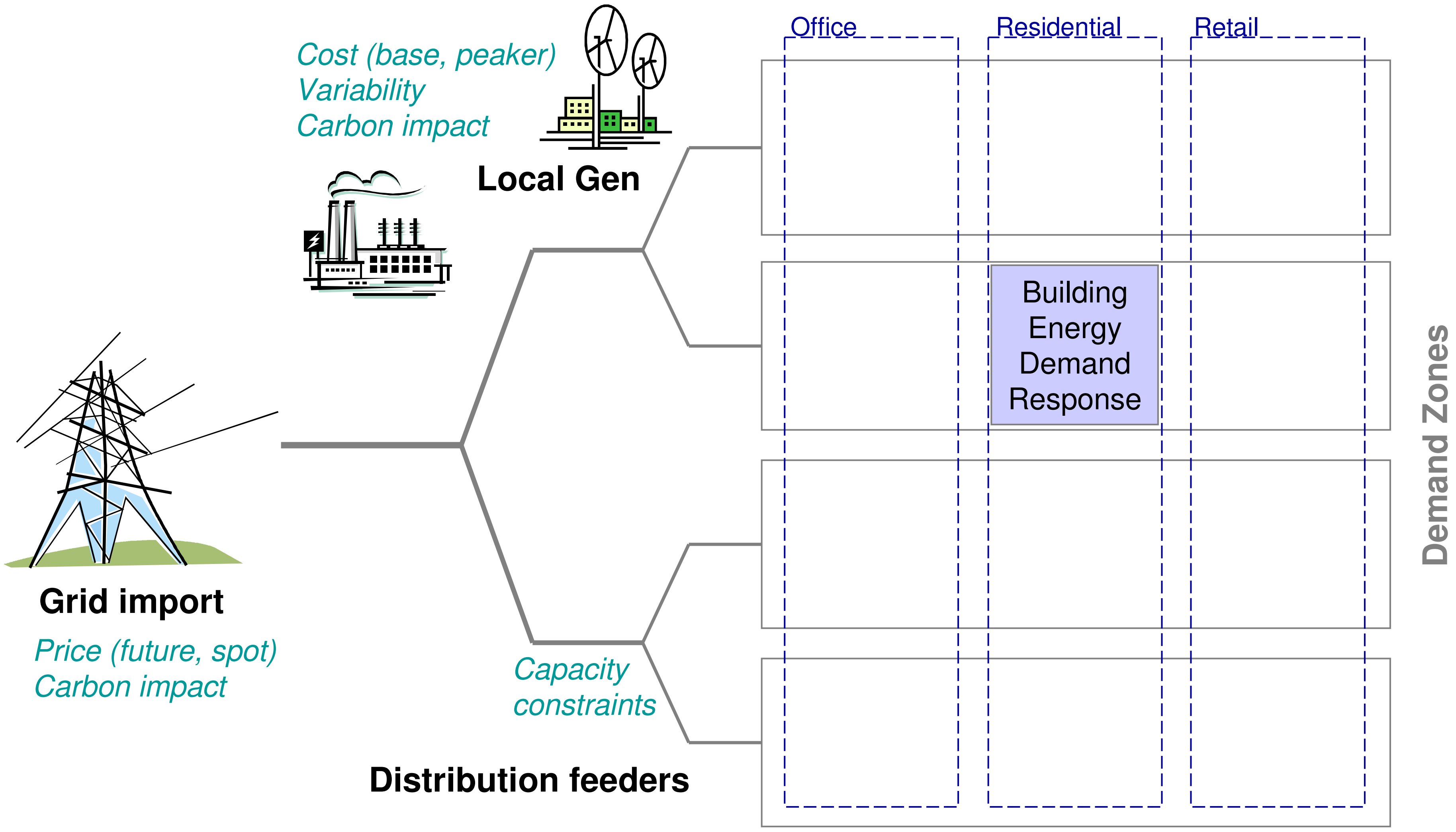
Historical Data
External factors
Signal, Action, Energy
- by occupant,
- by end-use load

Energy demand response surface
- by time of day
- signal type & value
- external factors

Behavior elicitation
- software platform
- multi-tenant

Scheduling usage
- energy use profile
- constraint energy use

City energy demand model



Demand Classes

Building units
Variability
Correlation

Cost (base, peaker)
Variability
Carbon impact

Local Gen

Building Energy Demand Response

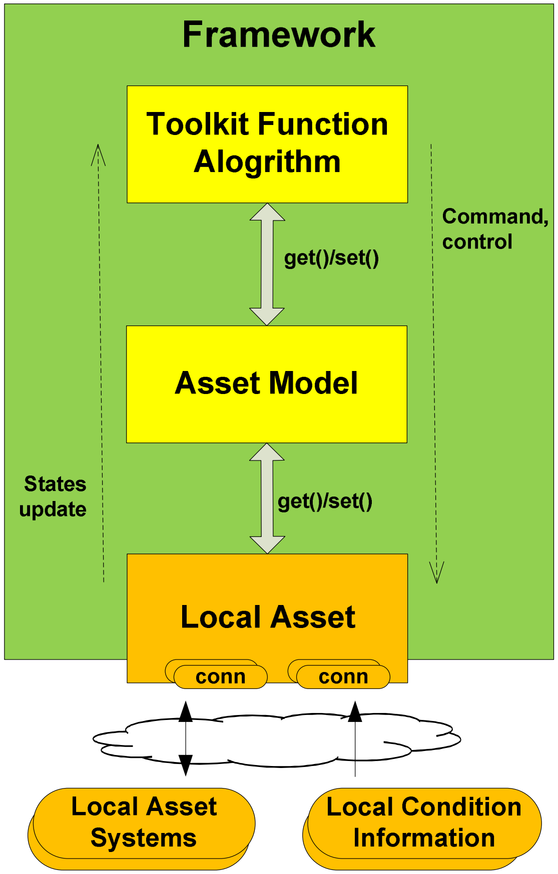
Grid import

Price (future, spot)
Carbon impact

Capacity constraints

Distribution feeders

Transactive Control of Distribution Grid (PNW DOE Project)



Framework

Toolkit Function Alogrithm

get()/set()

Command, control

Asset Model

States update

get()/set()

Local Asset

conn

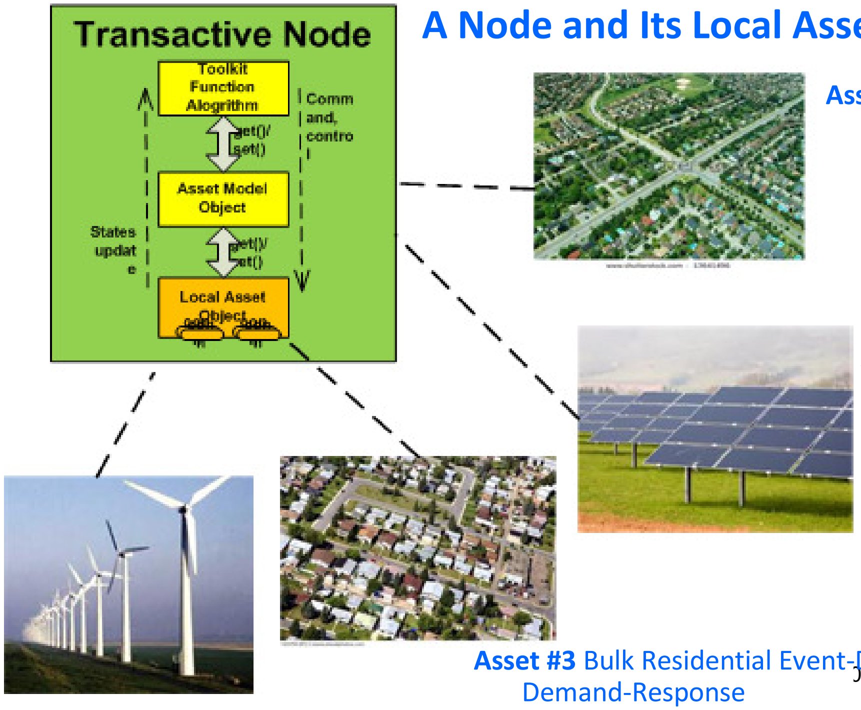
conn

Local Asset Systems

Local Condition Information

- **Toolkit Function**
  - A mathematic algorithm or control model that takes set of input data to compute output data needed for TIS/TFS calculation for a specific type of local asset or asset-system.
- **Asset Model**
  - A software object represents current states, local condition or static characteristics/configuration of a local asset of an asset-system.
- **Local Asset**
  - Represents one asset or asset-system associated with a Transactive Node

A Node and Its Local Assets



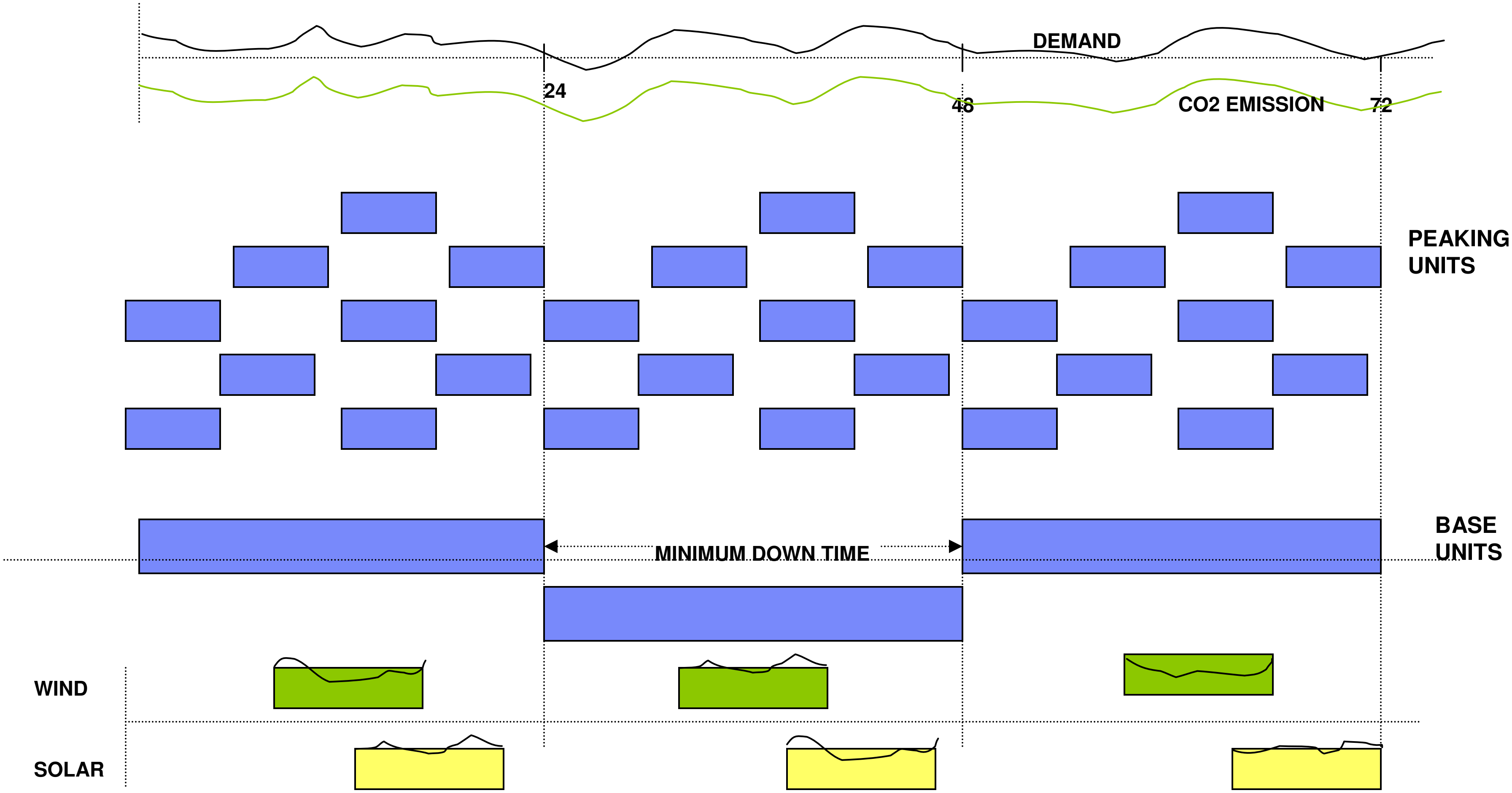
Asset #1 Bulk Inelastic Residential Loads

Asset #2 Solar Energy

Asset #3 Bulk Residential Event-Driven Demand-Response

Asset #4 Wind Energy

Generation Planning for Electricity Production & Availability



Integer programming problem with uncertain demand & supply
-> Stochastic optimization
The heat rate of a unit is a (nonlinear) function of load -> nonlinear optimization
- maintenance improves heat rate and hence CO2 emissions

Stochastic Modeling & Spinning reserves (Improving Availability)

- **Stochastic Unit commitment vs. Deterministic Spinning Reserve model**
  - An example of 10 units, 5 time periods and 10 scenarios.
  - Increasing spinning reserve levels in deterministic model result in less unmet demand but more cost. At 30% level, there is no unmet demand
  - Stochastic model has less implicit reserves than all explicit spinning reserve models, and hence less cost. It has no unmet demand.

Explicit (Spinning) Reserves (%)	*Implicit (System) Reserves(%)*					*Unmet Demand (MWH)*					*Cost ($)*
	1	2	3	4	5	1	2	3	4	5	
0	26.2	38.9	22.5	22.1	23.9	0	56.4	106.5	98.1	125.7	-
10	26.2	38.9	24.9	27.2	14.9	0	56.4	115.6	131.4	205.5	-
15-20	26.2	35.1	35.2	35.1	37.6	0	0	1.20	0	31.1	-
25	43.8	53.9	40	39.8	42.2	0	0	0	0	12.1	-
30	43.8	53.9	53.9	53.9	54.6	0	0	0	0	0	223,812
Stochastic	43.8	37.3	16.2	11.4	6.8	0	0	0	0	0	212,817

Improve Availability of a Water System (Case Study)

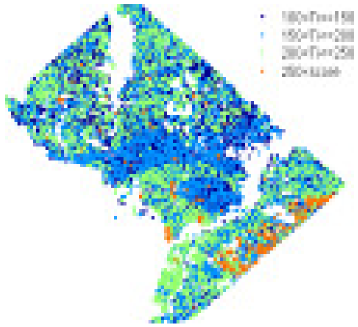
Failure Association

- How does environmental conditions impact failure?
- Does one brand hydrant fail more frequently than the other brand?
- How does aging process impact asset condition?

Failure Prediction

- Which hydrant will fail most likely in the next 6 months?
- What type of failure will most likely happen given the current condition?
- How likely is the pipe segment going to fail?

Asset Failure & Risk



PM Optimization

Replacement

- What is the state of the water delivery and sewage disposal?
- What is the best to allocate capital for infrastructure network upgrade?

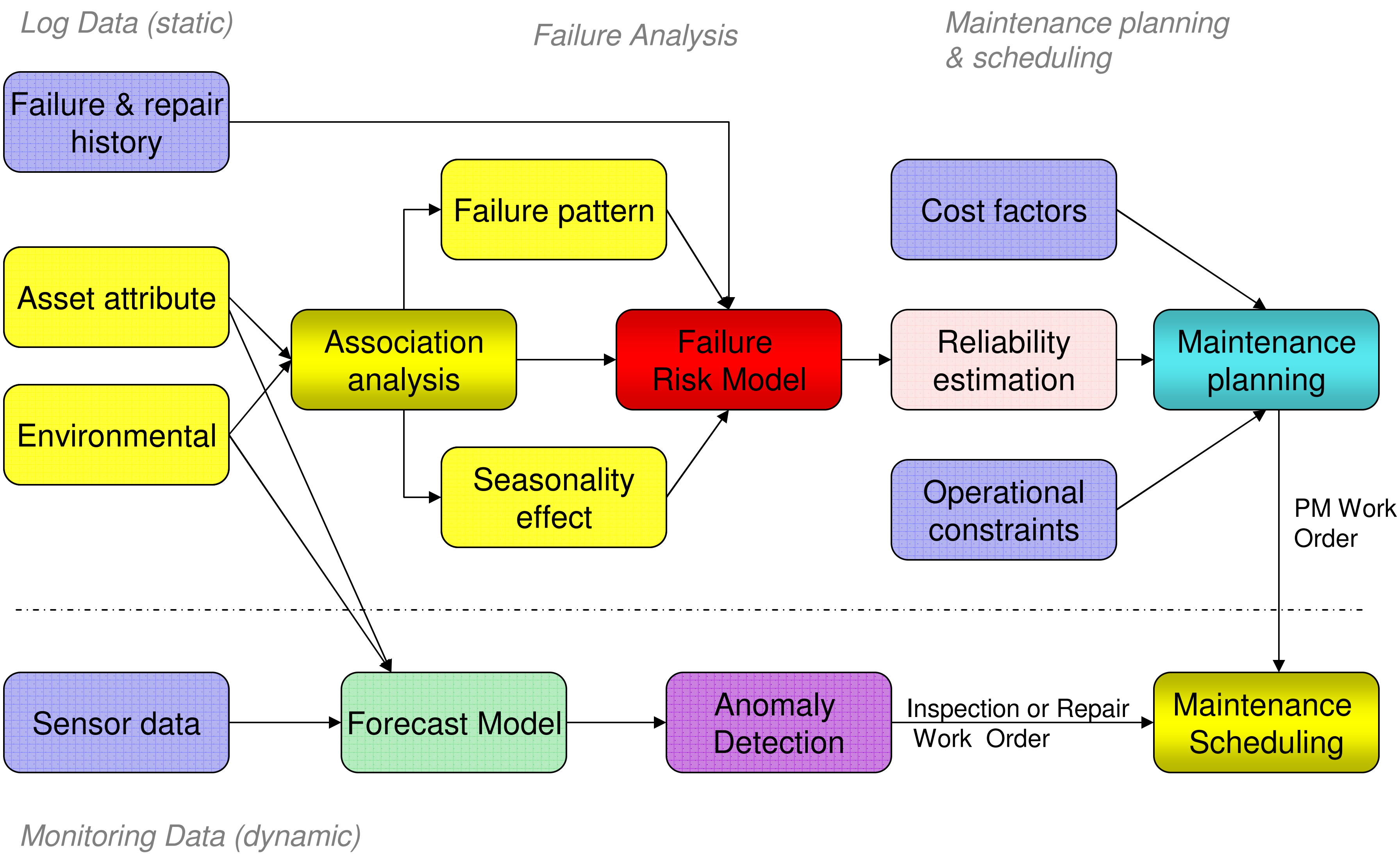
Preventive Maintenance

- Can I reduce PM cost?
- Which failures are driving my water mains repair costs?
- Which pipes should I replace to prevent challenges next winter?

Application of these techniques in an engagement with Washington D.C. Water and Sewer Authority resulted in

- 25% increase in maintenance crew utilization
- 30-50% cost savings on selected inspection and preventive maintenance
- significant revenue increase through loss prevention and differential pricing

Predictive asset management to Improve Availability



Log Data (static)

Failure Analysis

Maintenance planning & scheduling

Failure & repair history

Failure pattern

Cost factors

Asset attribute

Association analysis

Failure Risk Model

Reliability estimation

Maintenance planning

Environmental

Seasonality effect

Operational constraints

PM Work Order

Sensor data

Forecast Model

Anomaly Detection

Inspection or Repair Work Order

Maintenance Scheduling

Monitoring Data (dynamic)

Transportation Services – example of μ-Demand

- Mass Transit
  - Based on schedule
  - Occupancy is usually very low except for peak hours
  - Provisioning often based on coverage and hence leads to inefficiences

- μ-Demand for each person
  - Spatial trip demand (origin-destination requirements)
  - Time window for start and end time
  - Possible because of smart hand held devices

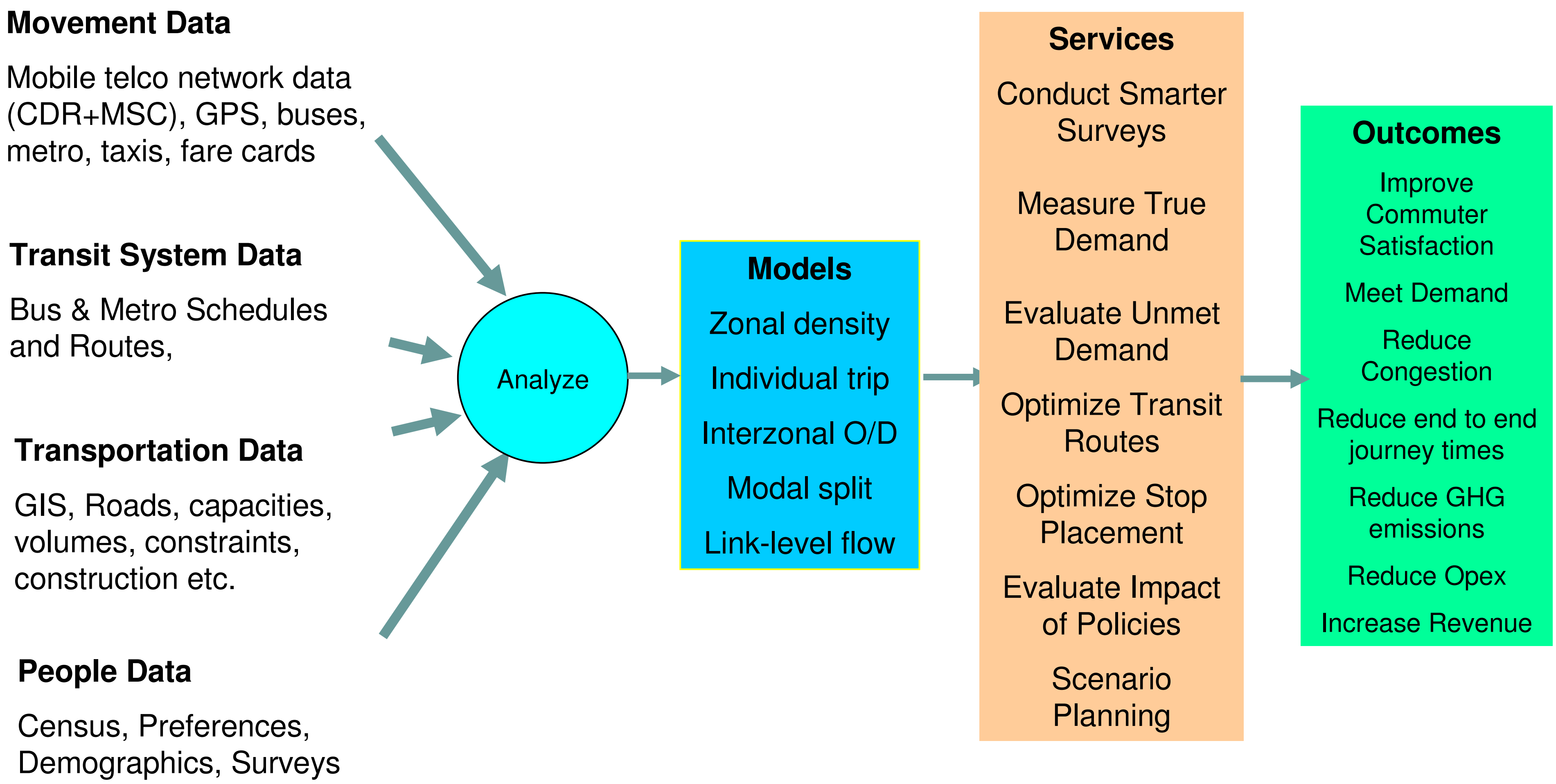
- Provisioning can be done efficiently
  - Use a fleet of smaller vehicles
  - Route cars/vans based on demand to pickup and drop off people on common routes
  - Matching of demand to vans/cars can be done optimally in near real time to allow high occupancy and hence low cost

Vehicle Routing for μ-Demand Aggregation

- O-D trip demand
- Aggregate multiple trips
- Route vehicles to pick and drop multiple people
- Objective
  - Maximize occupancy
  - Minimize wait time
  - Minimize CO2

- Mobile devices can provide apps for O-D trip demand

Understanding People Movement to Optimize Transportation



Movement Data

Mobile telco network data (CDR+MSC), GPS, buses, metro, taxis, fare cards

Transit System Data

Bus & Metro Schedules and Routes,

Transportation Data

GIS, Roads, capacities, volumes, constraints, construction etc.

People Data

Census, Preferences, Demographics, Surveys

Models

- Zonal density
- Individual trip
- Interzonal O/D
- Modal split
- Link-level flow

Services

- Conduct Smarter Surveys
- Measure True Demand
- Evaluate Unmet Demand
- Optimize Transit Routes
- Optimize Stop Placement
- Evaluate Impact of Policies
- Scenario Planning

Outcomes

- Improve Commuter Satisfaction
- Meet Demand
- Reduce Congestion
- Reduce end to end journey times
- Reduce GHG emissions
- Reduce Opex
- Increase Revenue