ISS4E

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University of Waterloo
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ISS4E vision

To use information systems and science to increase the efficiency and reduce the carbon footprint of energy systems.

http://iss4e.ca

Team

- **Directors**

  Prof. S. Keshav (CS)

  Prof. Catherine Rosenberg (ECE)

- **Affiliated Faculty**

  Prof. Tim Brecht (CS)
  Prof. Lukasz Golab (Management Sciences)
  Prof. Alex Lopez-Ortiz (CS)
  Prof. Bernard Wong (CS)

- **Postdocs**

  Yashar Ghiassi
  Kirill Kogan

- **Ph.D. Students**

  Adedamola Adepetu
  Omid Ardakanian
  Tommy Carpenter

  Rayman Preet Singh Matharu

- **Masters Students**

  Peter Gao

  Xiang Gao
  Elnaz Rezaei

  Sahil Singla

- **Research Associates**

  Bo Hu
  Pirathayini Srikantha

  Hadi Zarkoob

Current and Recent Projects

Electric vehicles

- Car pools to reduce range anxiety (Carpenter)
- Optimal charging of vehicle fleets (Zarkoob)
- Distributed optimal charging (Ardakanian)
- Sentiment analysis of online EV reviews (Carpenter)

Smart homes and buildings

- Temperature setpoint market (Singla)
- Smart appliances (Srikantha)
- Home peak load prediction (Matharu/Gao)
- Analysis of home load seasonality (Rezaei/Adepetu)
- Clustering of home loads and computing consumption profiles for automated feedback (Matharu/Ardakanian/Koochakzadeh)
- Optimal scheduling of home storage (Carpenter/Singla)

Smart homes and buildings (contd.)

- Personal thermal comfort (Gao)
- Regression models for building loads (Case)
- Per-panel solar load monitoring and anomaly detection (Hu/Gao)
- Private storage and analysis of home meter data (Matharu)
- Optimal battery sizing to deal with outages (Singla/Ghiassi)

Distribution network

- Optimal storage location (Shpungin)
- Optimal load scheduling in microgrids (Kogan)

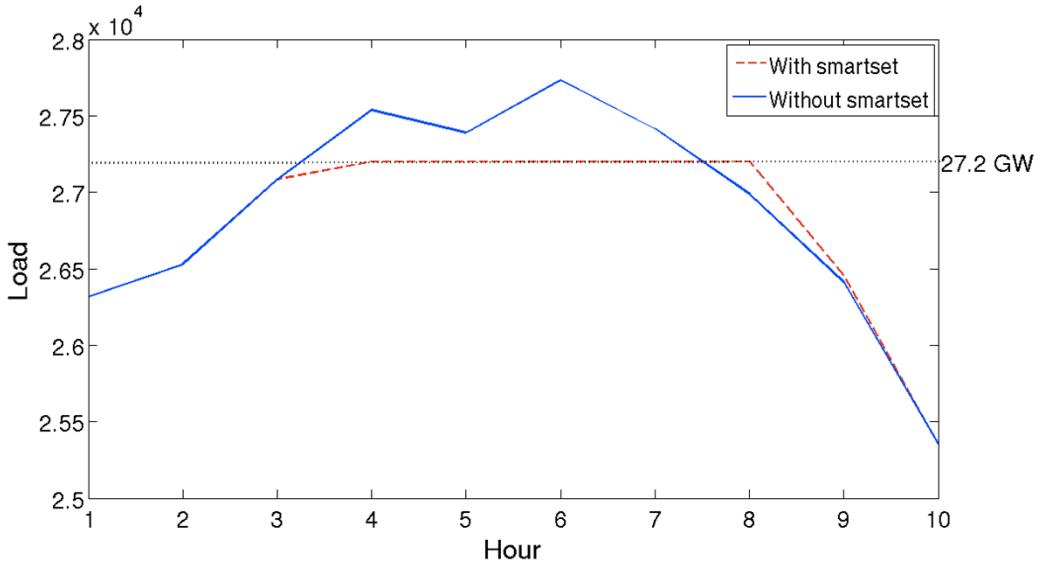
Generation

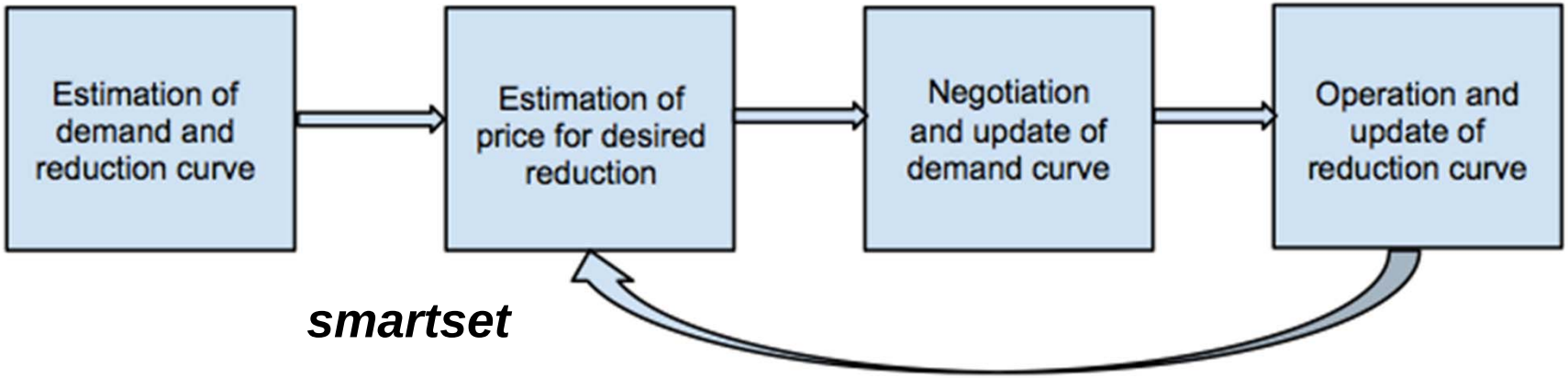
- Firming up solar power (Ghiassi)

SAMPLE PROJECTS

Demand Response through a Temperature Setpoint Market in Ontario

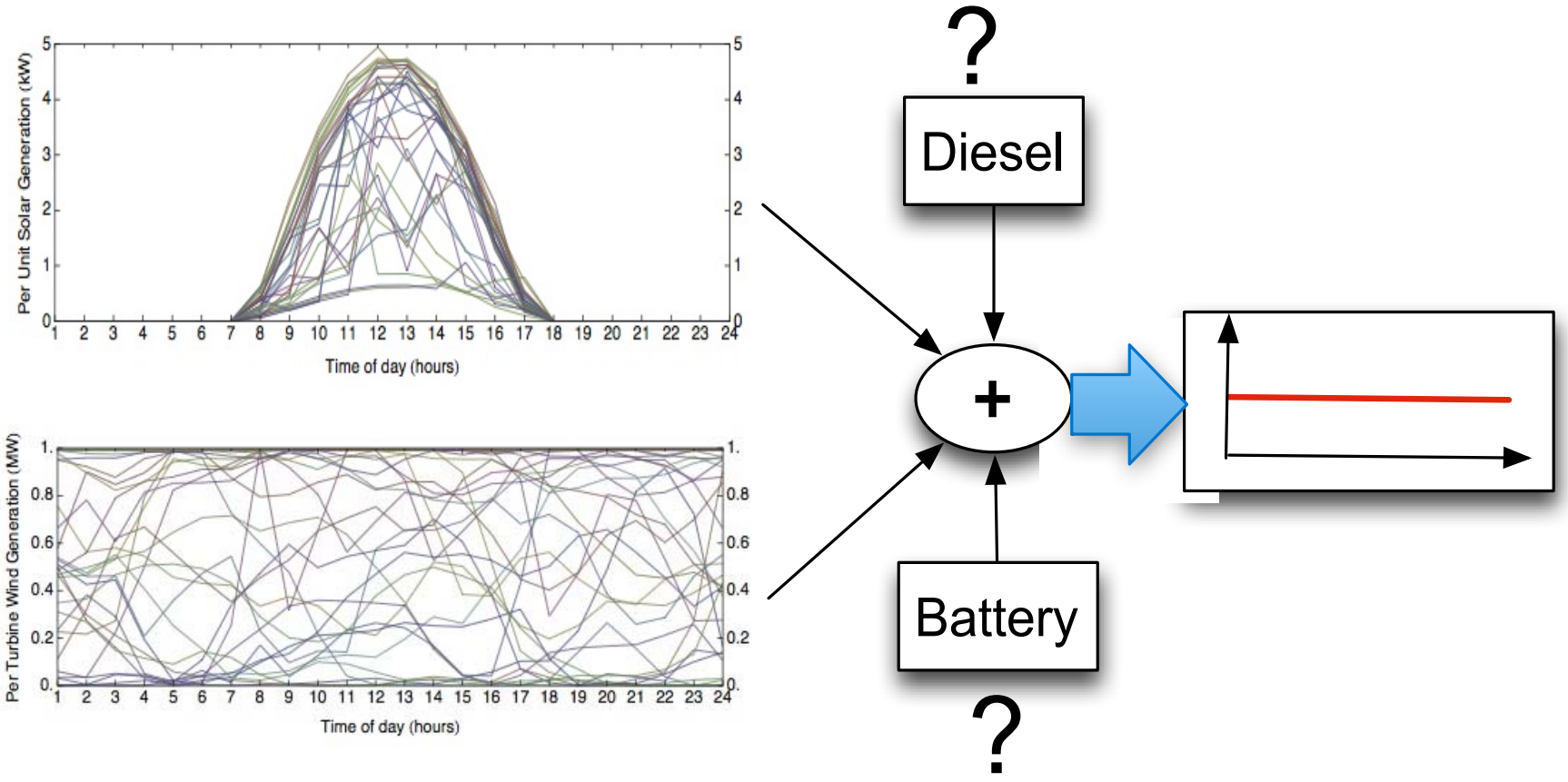
- Ontario has peak load for a few hours in summers
- Peak load reduction possible by increasing thermostat during peak hours
- Payment of $2 per hour of setback can reduce operating costs by $688 million over 20 years





Ref: S. Singla, S. Keshav*: Demand Response through a Temperature Setpoint Market in Ontario,* IEEE SmartGridComm, 2012

Firming up Intermittent Energy Sources

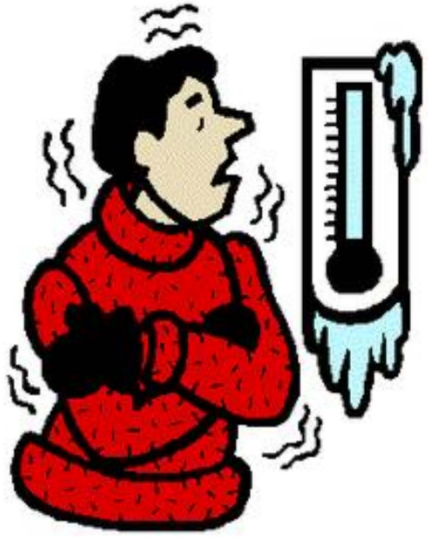


Personal Thermal Control System

Objectives:

- Measuring human thermal comfort automatically
- Saving electricity bill without affecting comfort

We use Kinect to detect activity and clothing



The system learns the user prefers warmer condition

- Senses environmental conditions
- Detects human activity and clothing
- Learns personal thermal preference

Personal Thermal Control System

The system can learn the insulation factor of a house, and hence make the optimal thermal control sequence accordingly

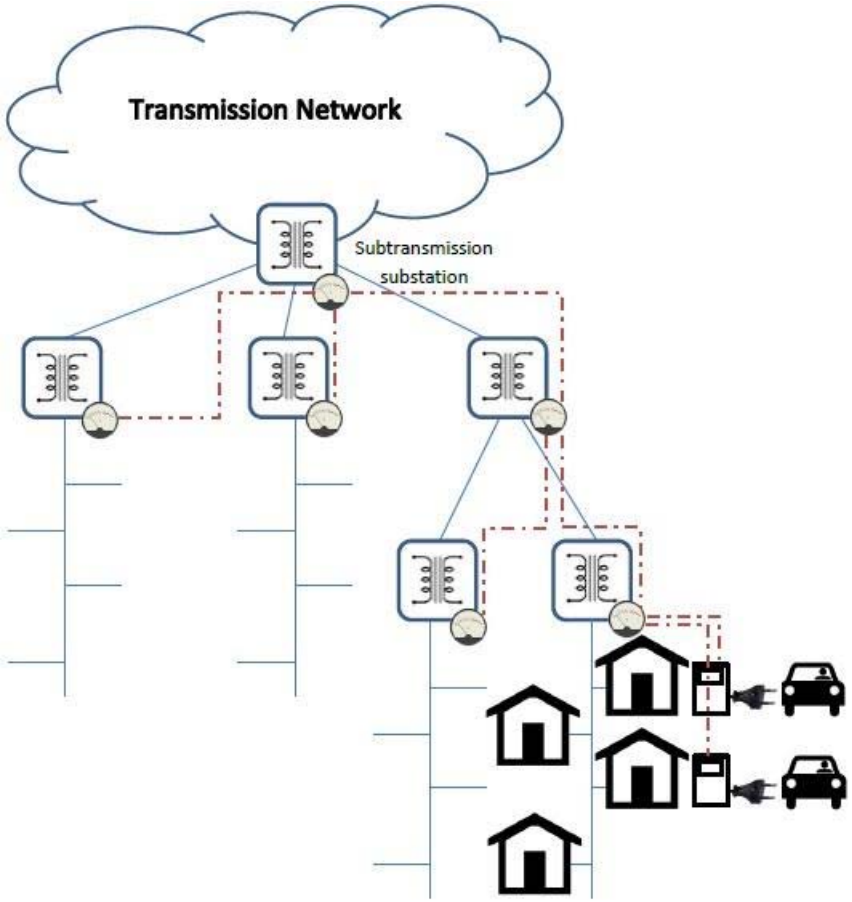
It gives energy saving tips to human:

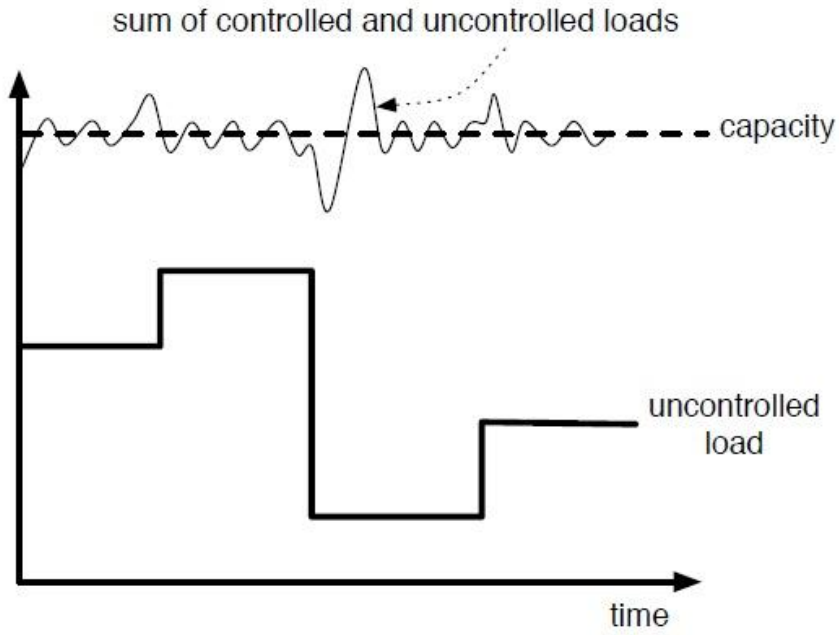
wear your coat to save $15 per month

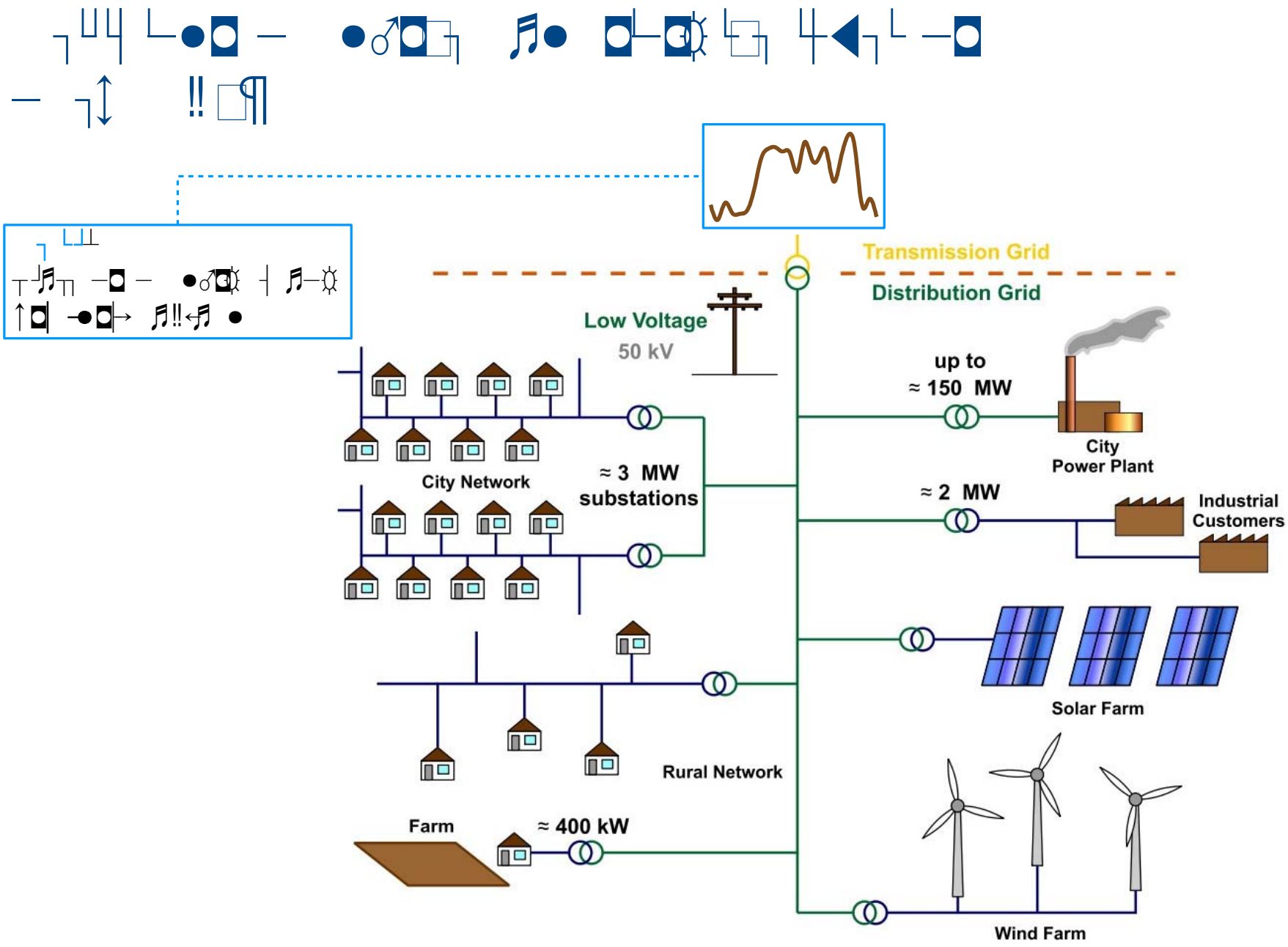
- Learning based home modeling
- Human in the loop control

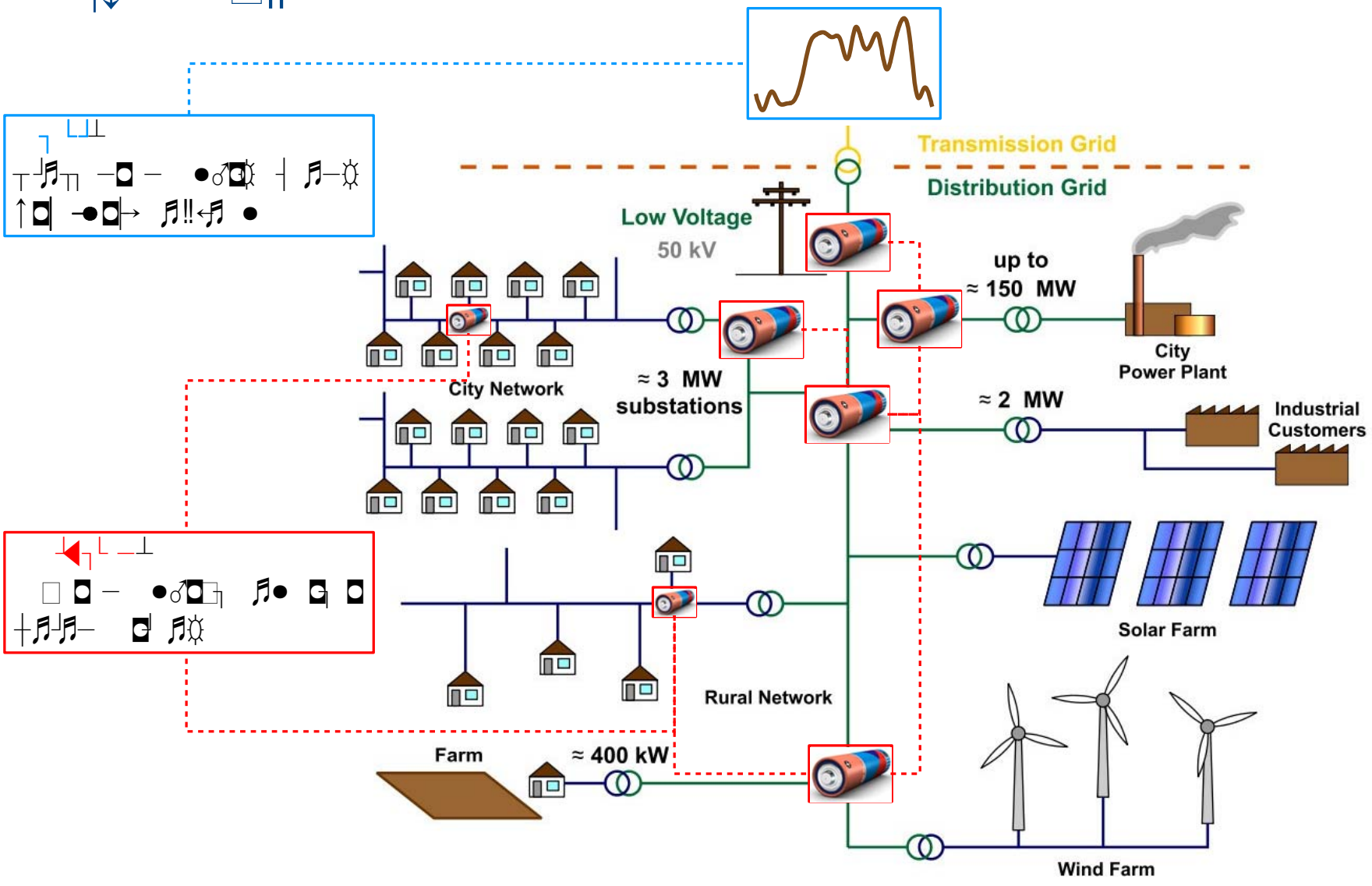
Real Time Distributed Congestion Control for Electrical Vehicle Charging

Smart Grid Architecture






Transmission Grid
Distribution Grid
Low Voltage
50 kV
up to
≈ 150 MW
City
Power Plant
City Network
≈ 3 MW
substations
≈ 2 MW
Industrial
Customers
Solar Farm
Rural Network
Farm
≈ 400 kW
Wind Farm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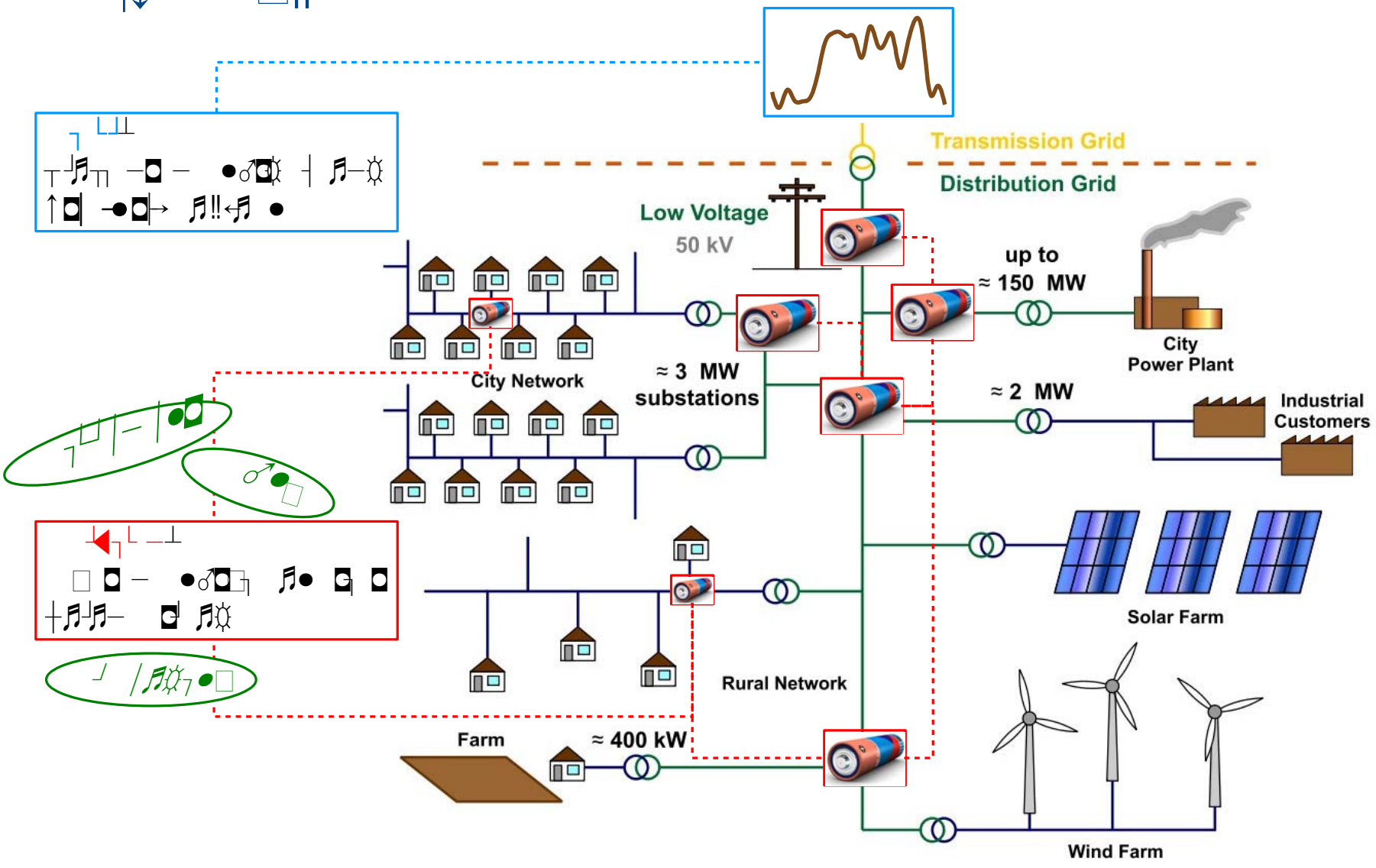
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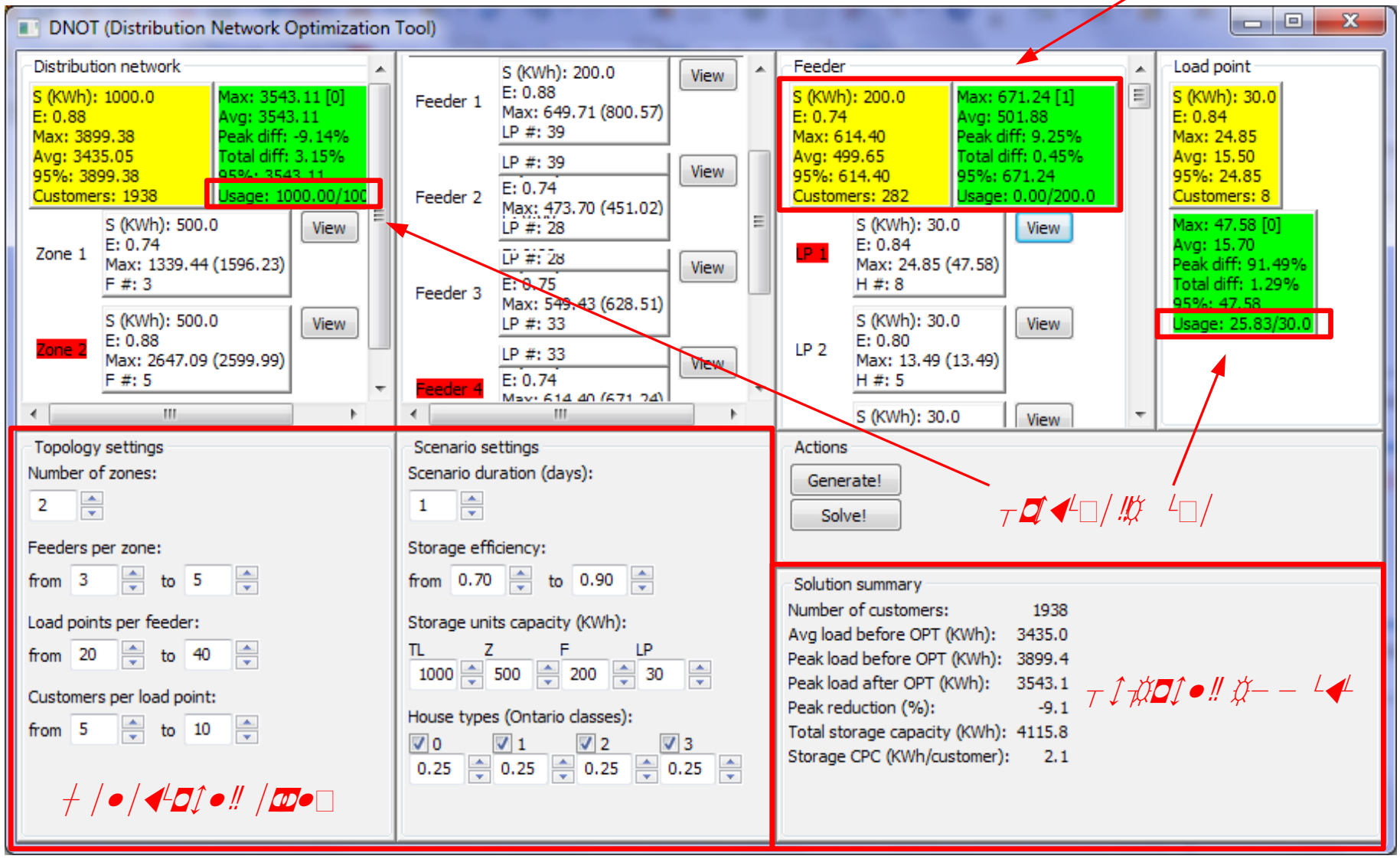

DNOT (Distribution Network Optimization Tool)
Distribution network
S (KWh): 1000.0
E: 0.88
Max: 3899.38
Avg: 3435.05
95%: 3899.38
Customers: 1938
Max: 3543.11 [0]
Avg: 3543.11
Peak diff: -9.14%
Total diff: 3.15%
Usage: 1000.00/100
Zone 1
S (KWh): 500.0
E: 0.74
Max: 1339.44 (1596.23)
F #: 3
View
Zone 2
S (KWh): 500.0
E: 0.88
Max: 2647.09 (2599.99)
F #: 5
View
Feeder 1
S (KWh): 200.0
E: 0.88
Max: 649.71 (800.57)
LP #: 39
View
Feeder 2
LP #: 39
E: 0.74
Max: 473.70 (451.02)
LP #: 28
View
Feeder 3
LP #: 28
E: 0.75
Max: 549.43 (628.51)
LP #: 33
View
Feeder 4
LP #: 33
E: 0.74
View
Feeder
S (KWh): 200.0
E: 0.74
Max: 614.40
Avg: 499.65
95%: 614.40
Customers: 282
Max: 671.24 [1]
Avg: 501.88
Peak diff: 9.25%
Total diff: 0.45%
95%: 671.24
Usage: 0.00/200.0
LP 1
S (KWh): 30.0
E: 0.84
Max: 24.85 (47.58)
H #: 8
View
LP 2
S (KWh): 30.0
E: 0.80
Max: 13.49 (13.49)
H #: 5
View
S (KWh): 30.0
View
Load point
S (KWh): 30.0
E: 0.84
Max: 24.85
Avg: 15.50
95%: 24.85
Customers: 8
Max: 47.58 [0]
Avg: 15.70
Peak diff: 91.49%
Total diff: 1.29%
95%: 47.58
Usage: 25.83/30.0
Topology settings
Number of zones:
2
Feeders per zone:
from 3 to 5
Load points per feeder:
from 20 to 40
Customers per load point:
from 5 to 10
Scenario settings
Scenario duration (days):
1
Storage efficiency:
from 0.70 to 0.90
Storage units capacity (KWh):
TL Z F LP
1000 500 200 30
House types (Ontario classes):
0 1 2 3
0.25 0.25 0.25 0.25
Actions
Generate!
Solve!
Solution summary
Number of customers: 1938
Avg load before OPT (KWh): 3435.0
Peak load before OPT (KWh): 3899.4
Peak load after OPT (KWh): 3543.1
Peak reduction (%): -9.1
Total storage capacity (KWh): 4115.8
Storage CPC (KWh/customer): 2.1

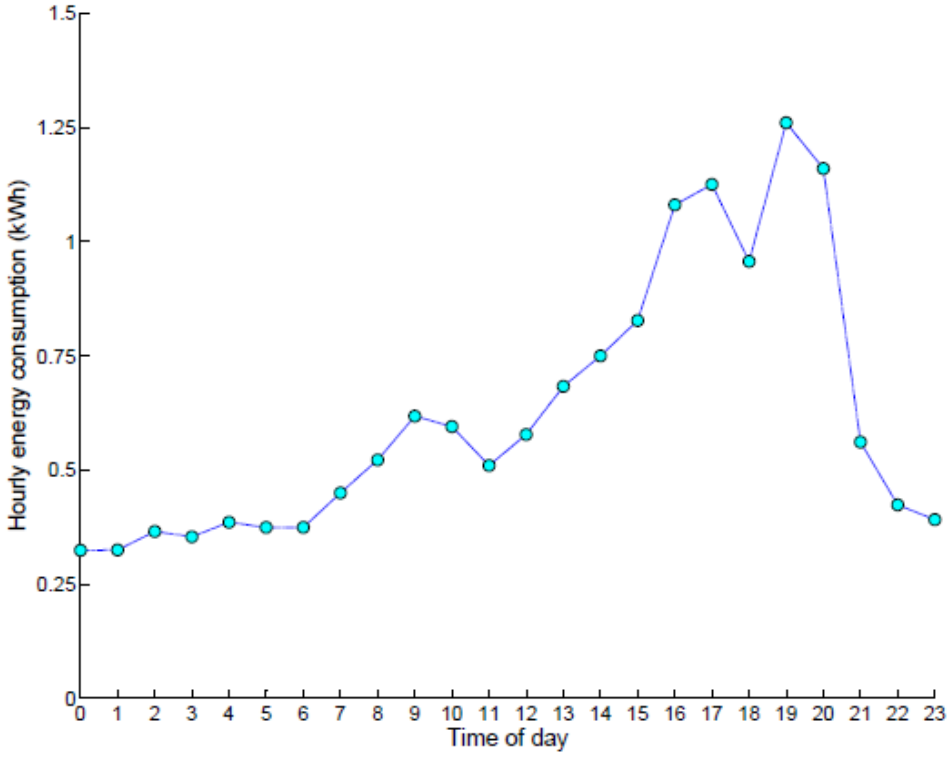
Automated feedback via consumption profiles and clustering

Consumption Profile

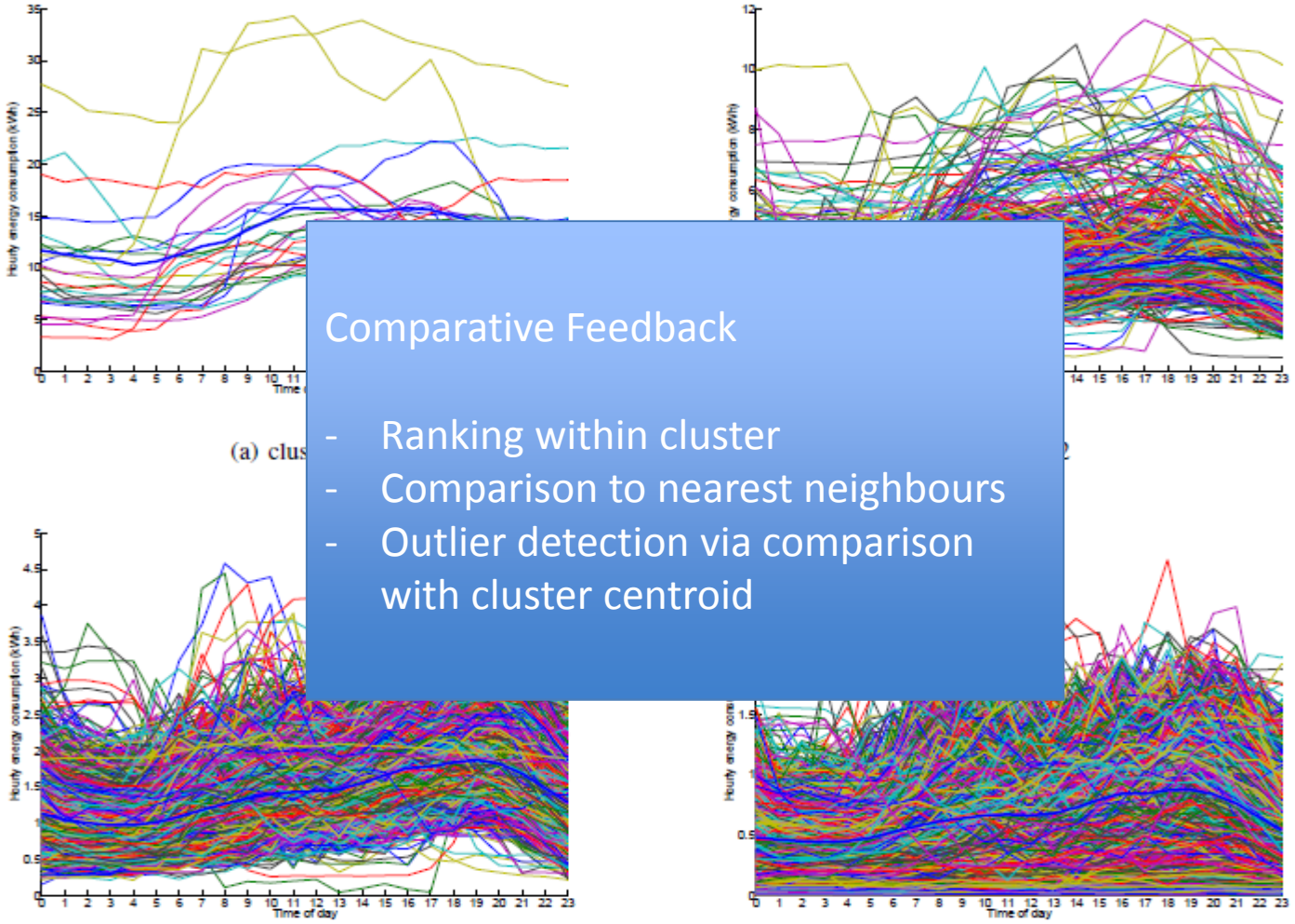
- Average hourly activity-based load (weekday/weekend)
- Hourly temperature dependence

Personalized Feedback

- Shift load to off-peak hours
- High nightly load -> replace appliances
- High temperature-dependent load when low activity-based load -> reprogram thermostat



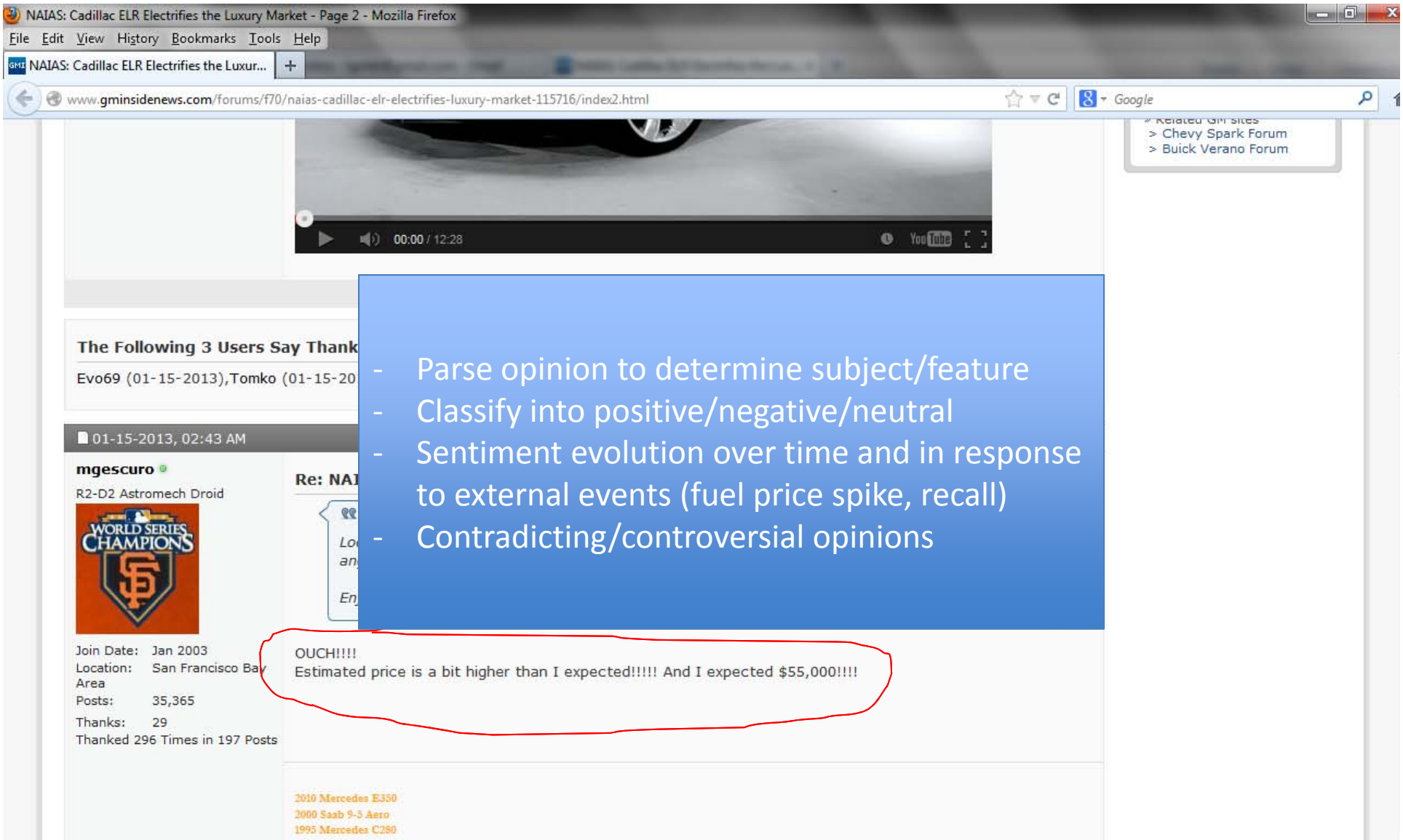
Feedback via clustering



Comparative Feedback

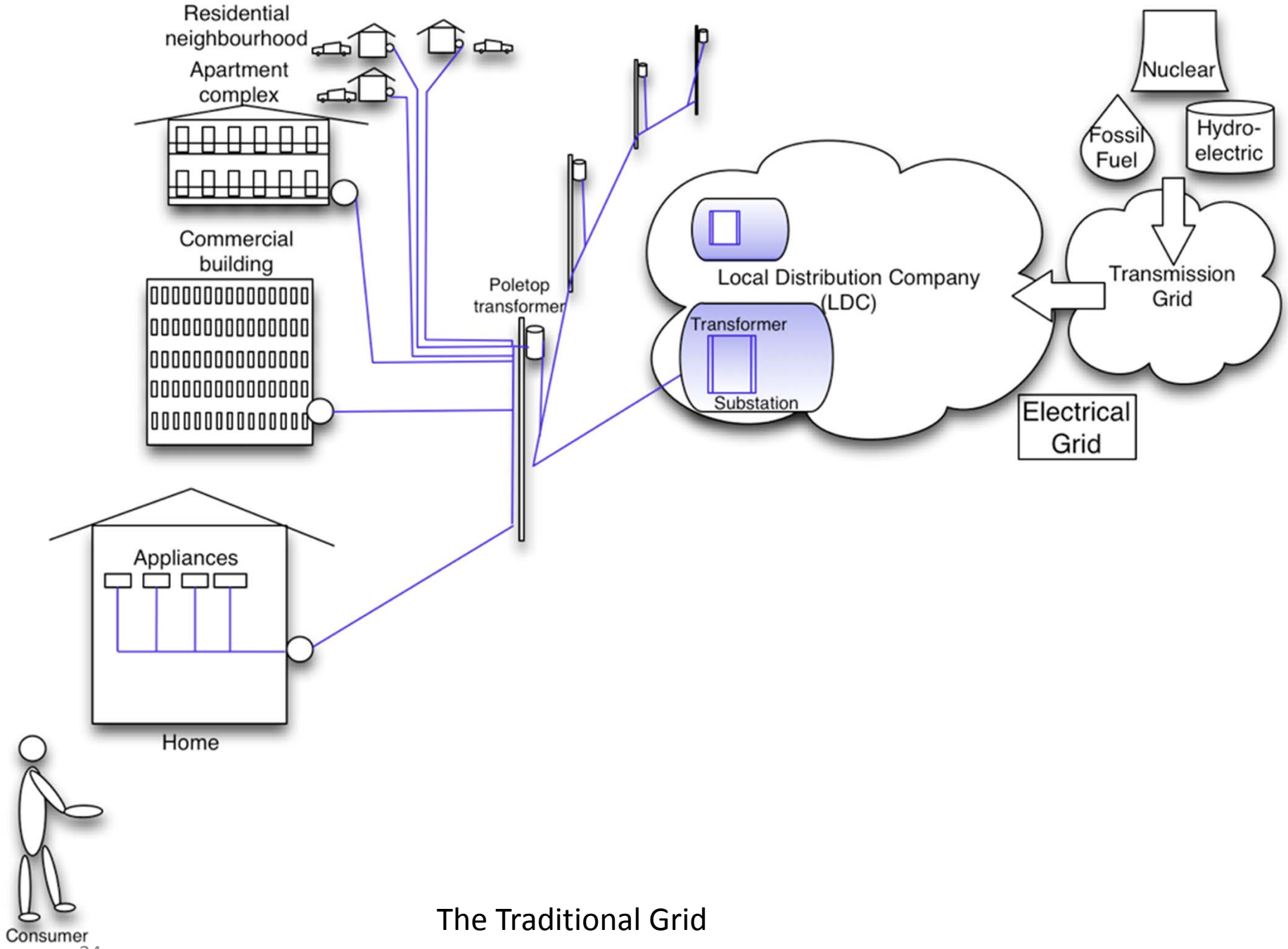
- Ranking within cluster
- Comparison to nearest neighbours
- Outlier detection via comparison with cluster centroid

Sentiment analysis of online EV reviews



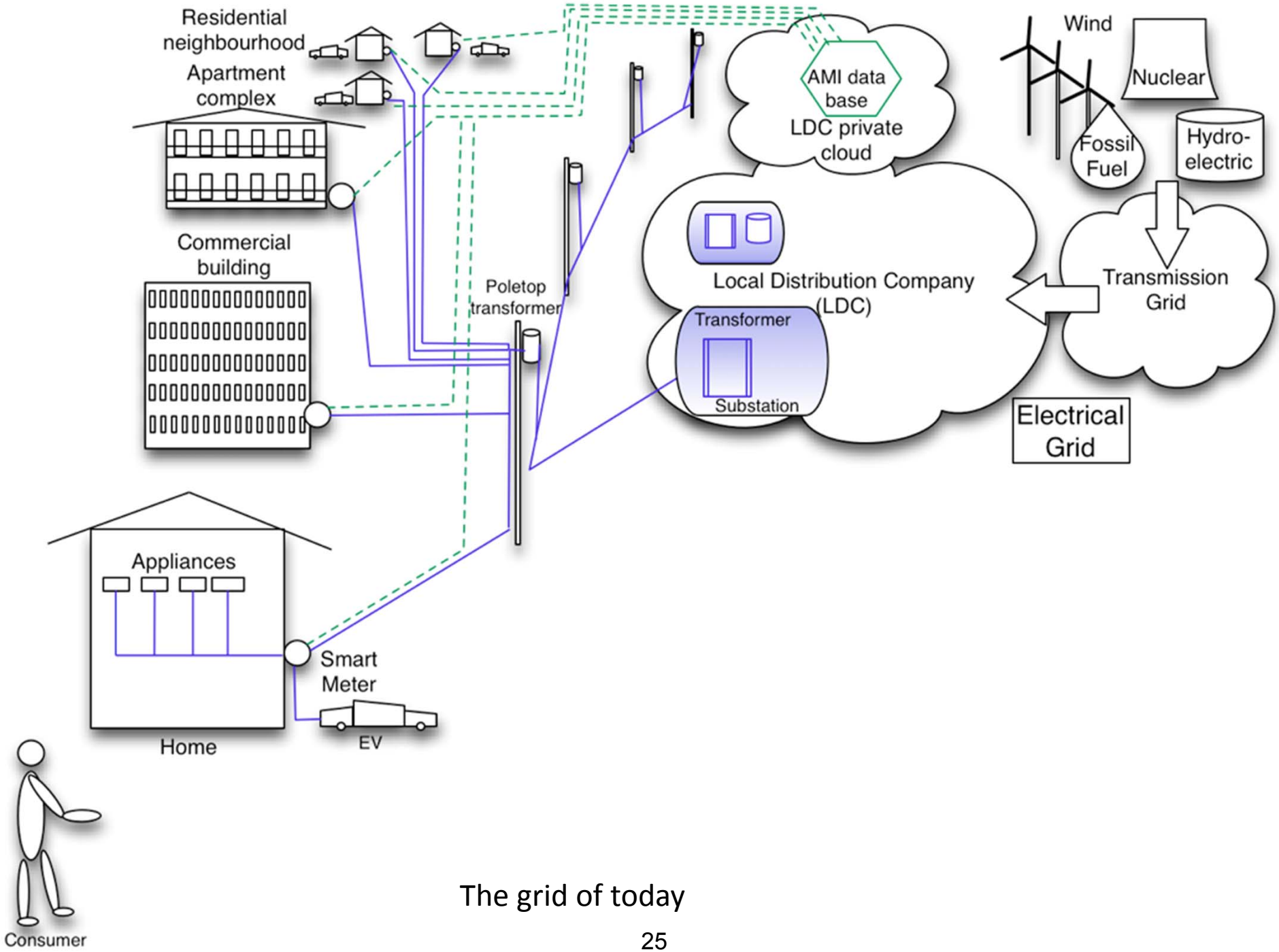
- Parse opinion to determine subject/feature
- Classify into positive/negative/neutral
- Sentiment evolution over time and in response to external events (fuel price spike, recall)
- Contradicting/controversial opinions

Consumer-centric Smart Grid

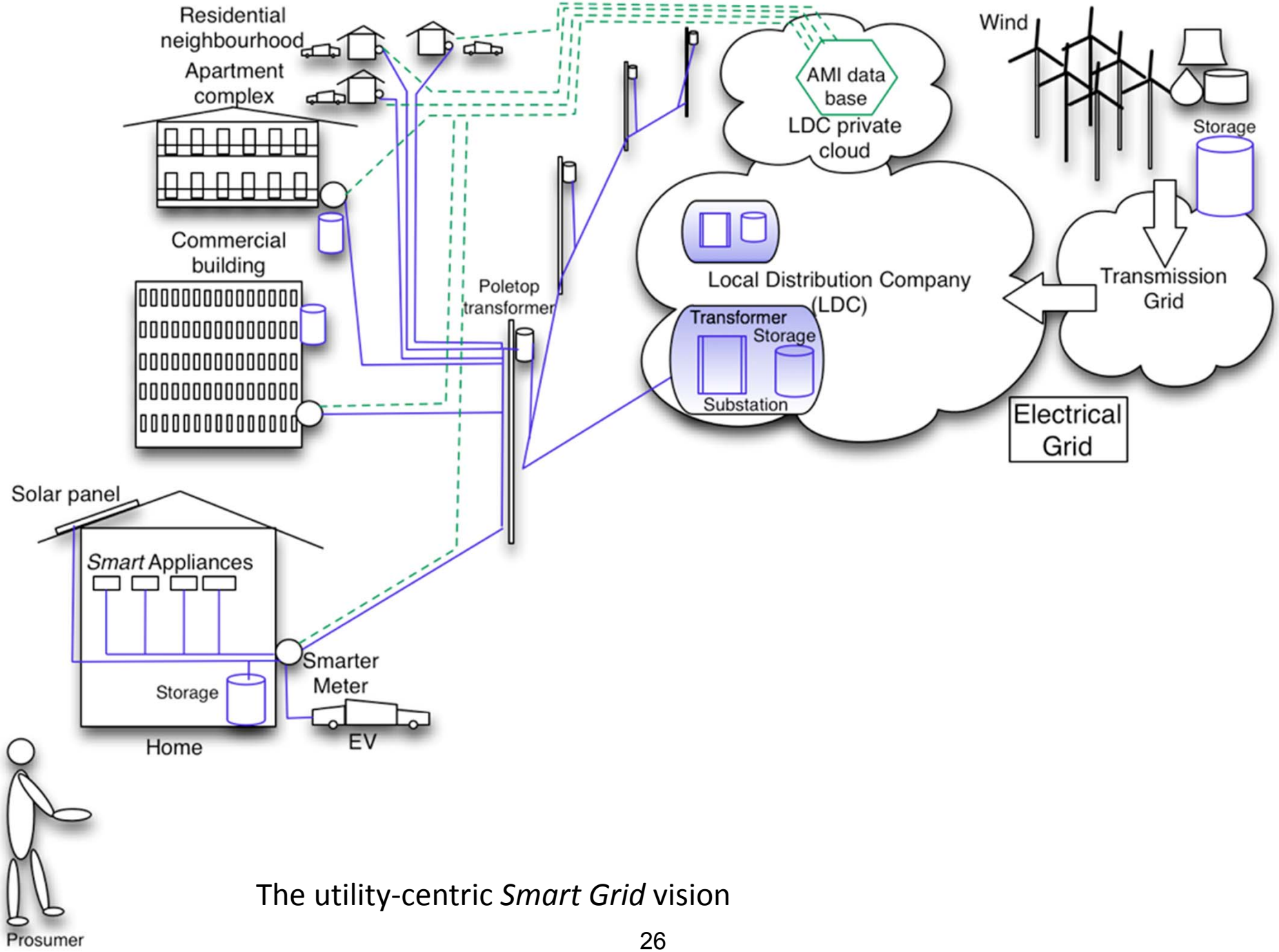


The Traditional Grid

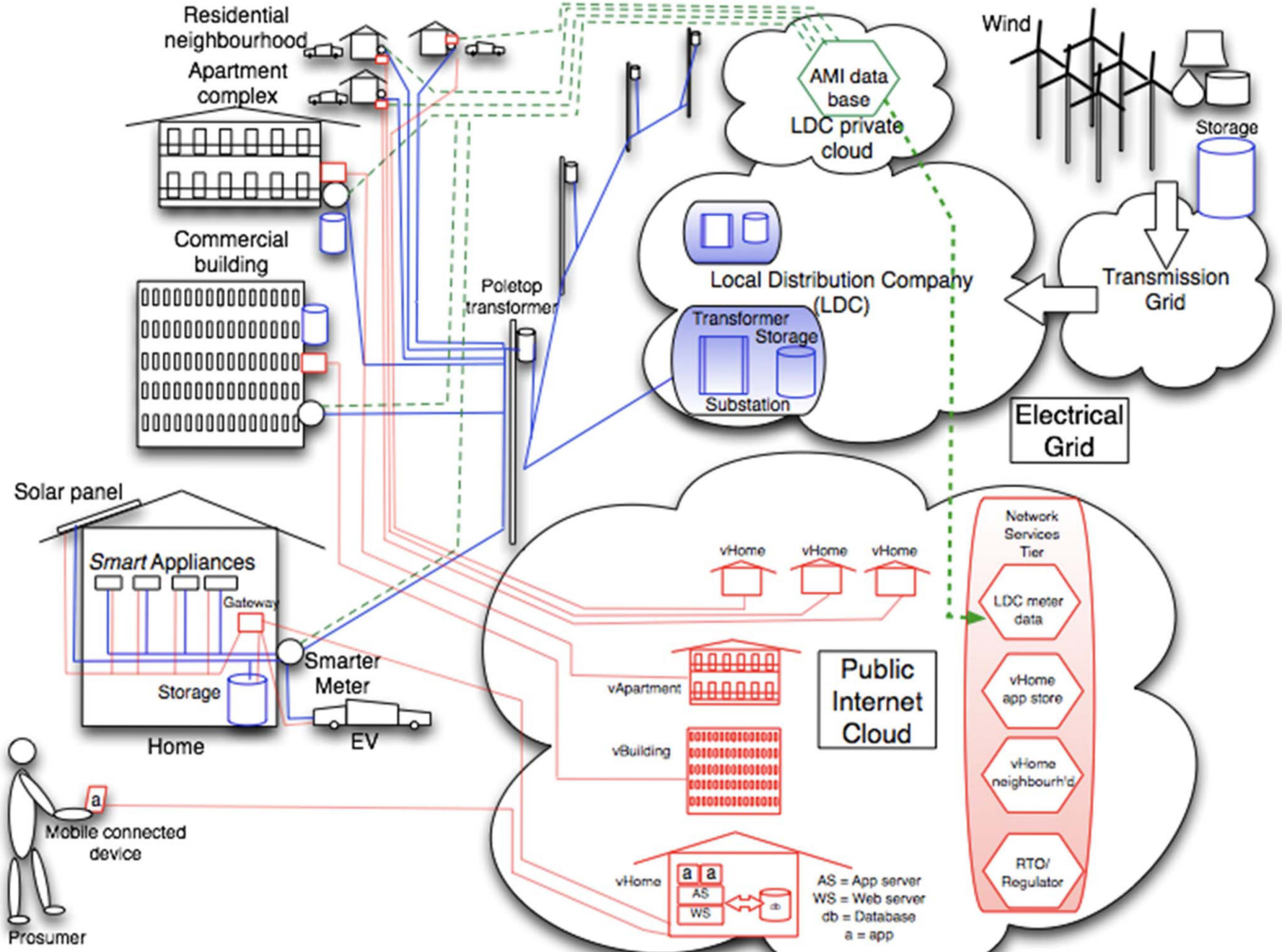
24



The grid of today



The utility-centric *Smart Grid* vision


Residential neighbourhood
Apartment complex
Commercial building
Poletop transformer
AMI data base
LDC private cloud
Wind
Storage
Local Distribution Company (LDC)
Transformer
Storage
Substation
Transmission Grid
Electrical Grid
Solar panel
Smart Appliances
Gateway
Storage
Home
Smarter Meter
EV
Mobile connected device
Prosumer
vHome
vHome
vHome
vApartment
vBuilding
vHome
AS
WS
db
AS = App server
WS = Web server
db = Database
a = app
Public Internet Cloud
Network Services Tier
LDC meter data
vHome app store
vHome neighbourh'd
RTO/ Regulator