VTWAC Project: Demand Forecasting

IEEE PES Green Mountain Chapter
Rutland, Vermont, 23 June 2016

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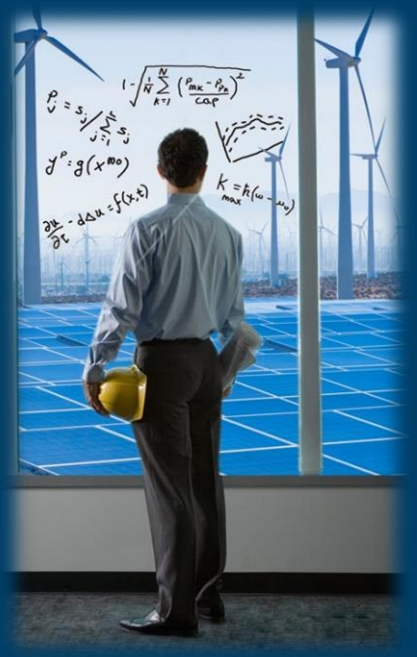
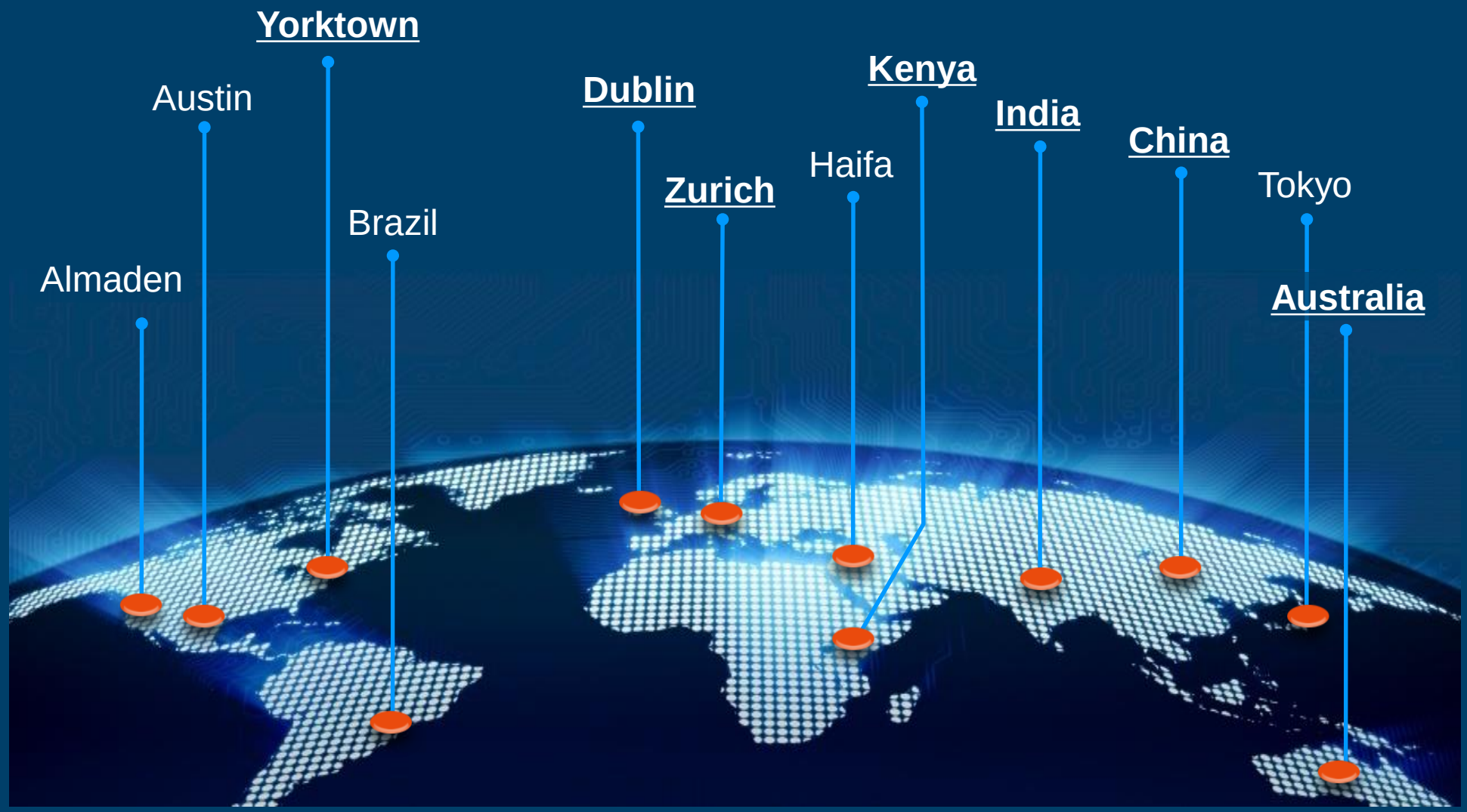
Outline

- Smarter Energy Research in IBM
- VTWAC Project
  - Background & demo
  - Data sources
  - Analytics models
  - Insights & use cases
- Outlook / discussion



IBM Journal of Research and Development:
Special issue on Smarter Energy
Jan-Feb 2016

Smarter Energy Research in IBM

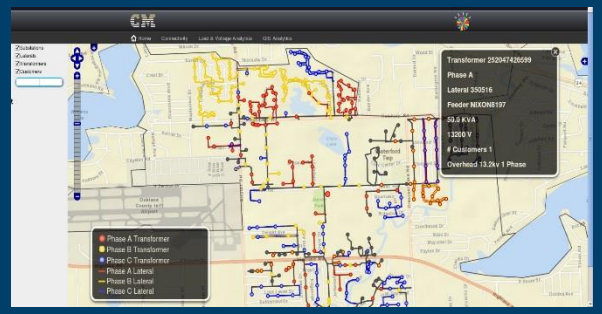


Smarter Energy Research in IBM

Vermont Renewable Energy Integration Project

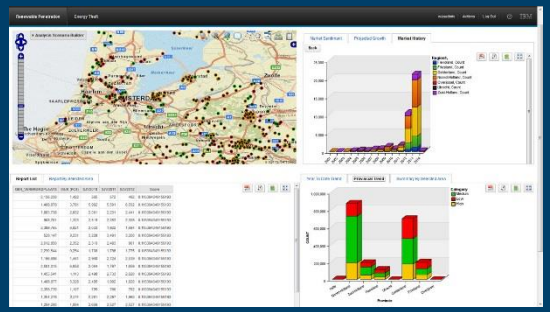
Transactive Energy Management

Outage Prediction & Response Optimization



Connectivity Model

Asset Risk Management & Optimized Repair-Rehab-Replace

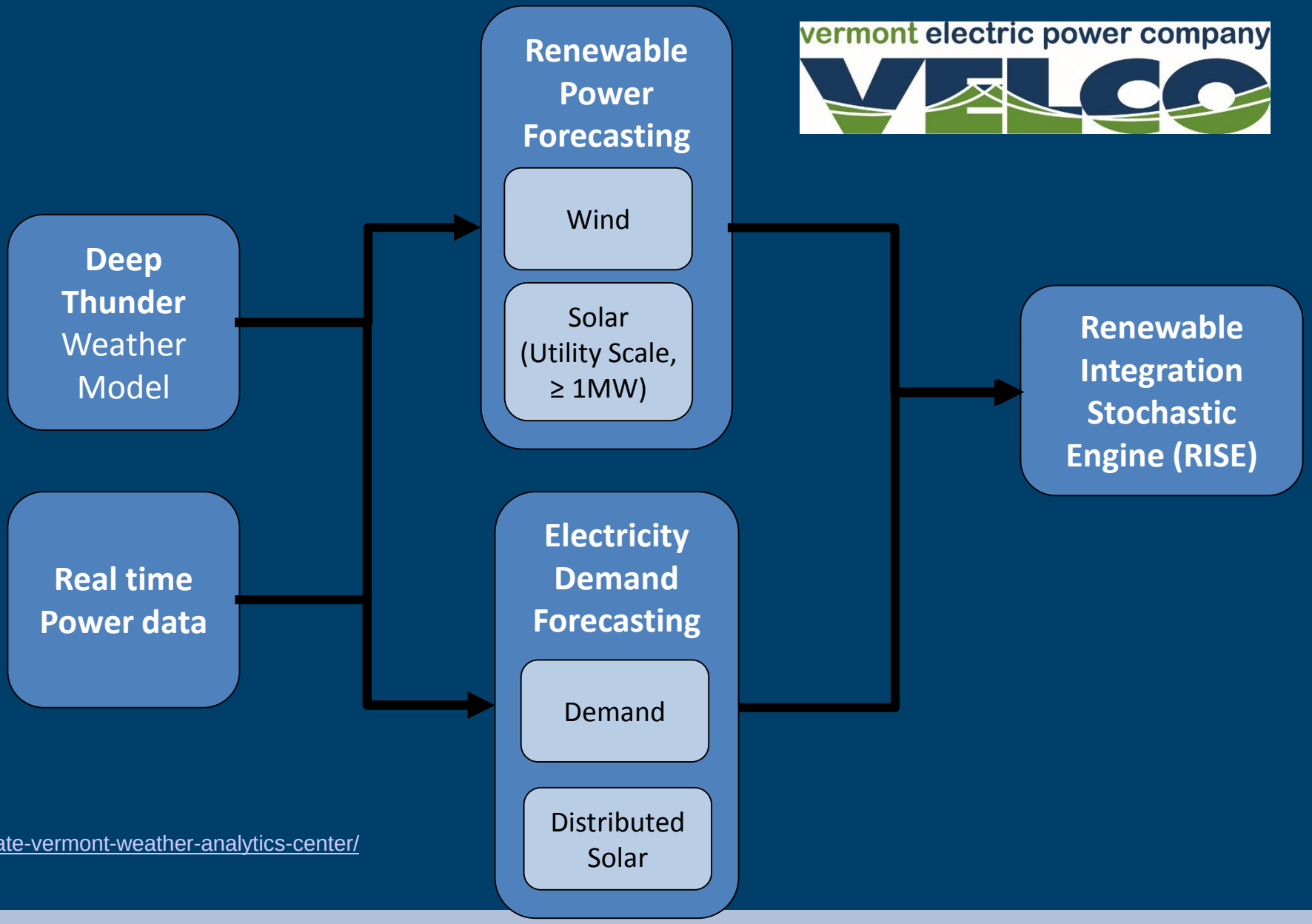


Customer Intelligence

http://www.research.ibm.com/client-programs/seri/applications.shtml

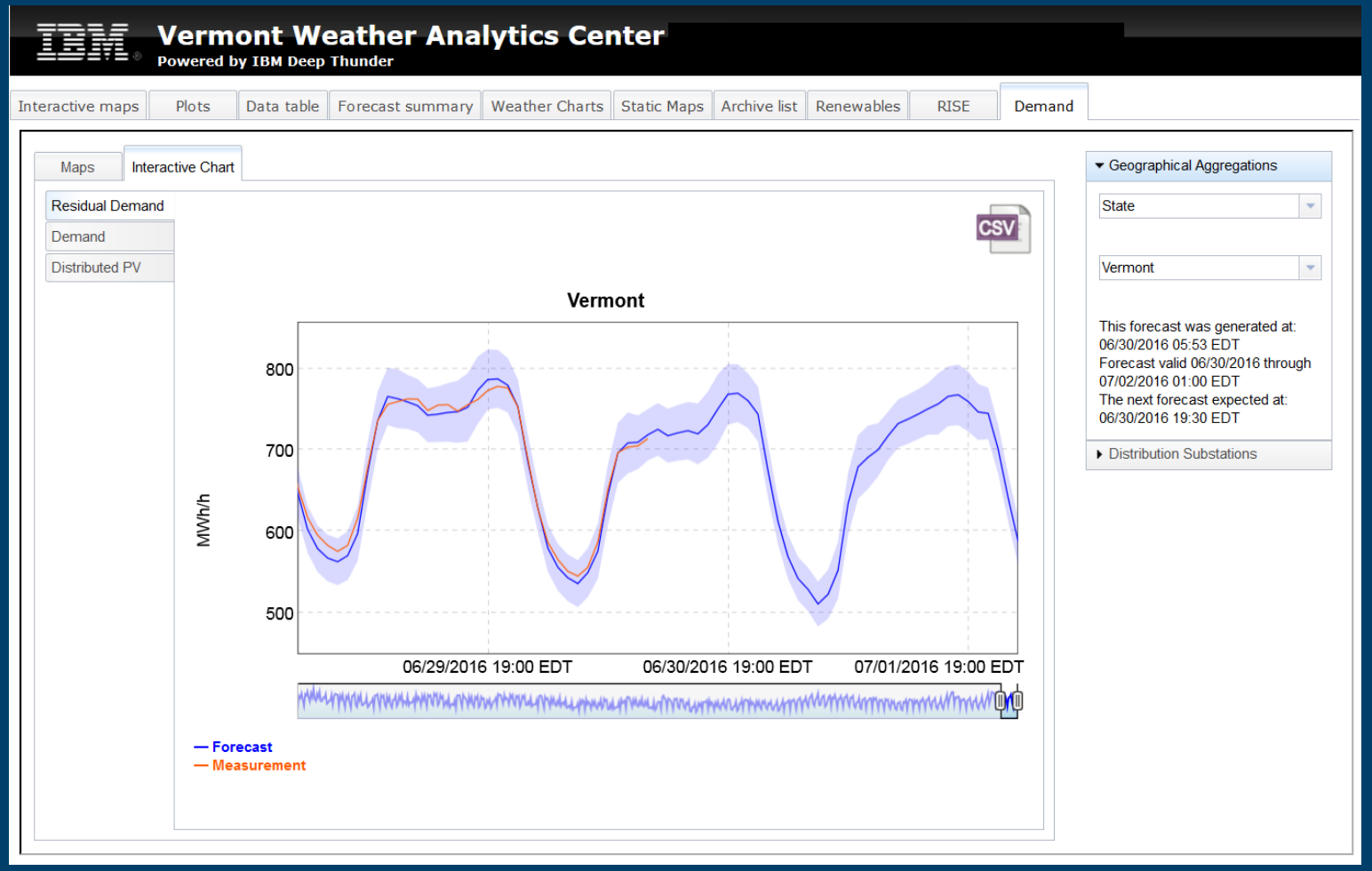
VTWAC Project *Background*

- Project started 2014
- Recently extended till 2018
- 2016 EEI Award finalists
- 2016 US-Ireland Research Innovation Award finalists
- Presented at top academic and industry events

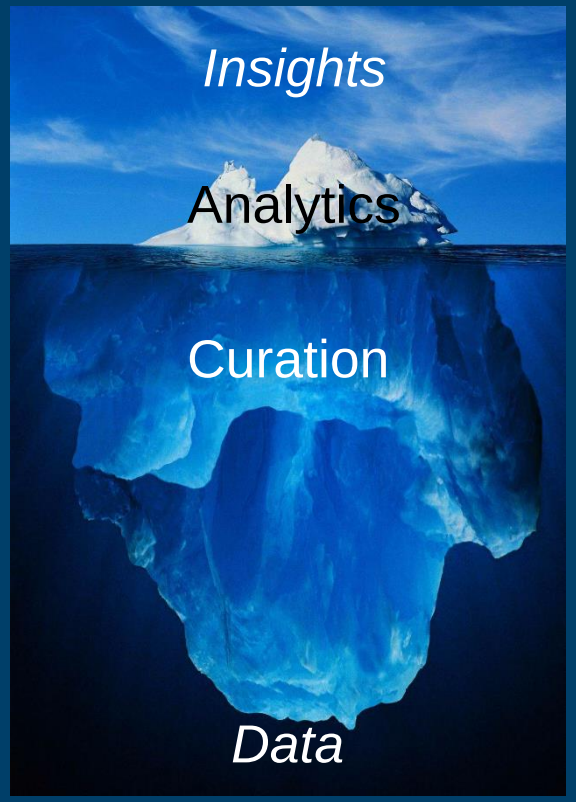


Press releases:
http://www.velco.com/news/velco-and-partners-to-create-vermont-weather-analytics-center/
http://www.velco.com/our-work/innovation/vtwac2

VTWAC Project
Demo



VTWAC Project
Data sources

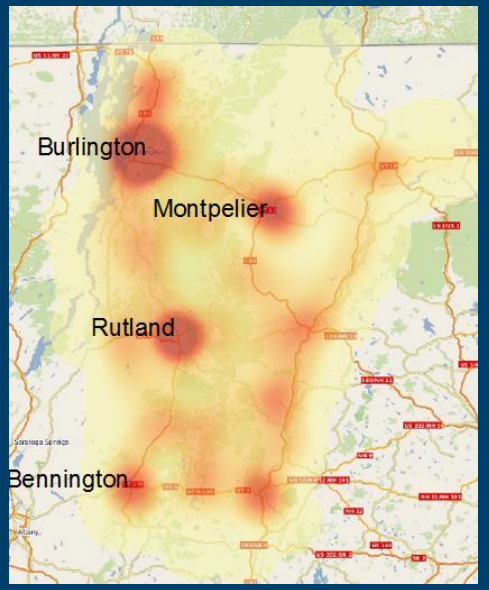


Challenges:

- Massive amounts of data (TBs)
- Sourced from heterogeneous systems
- Owned by different entities
- Largely unstructured
- Quality issues

VTWAC Project
Data sources

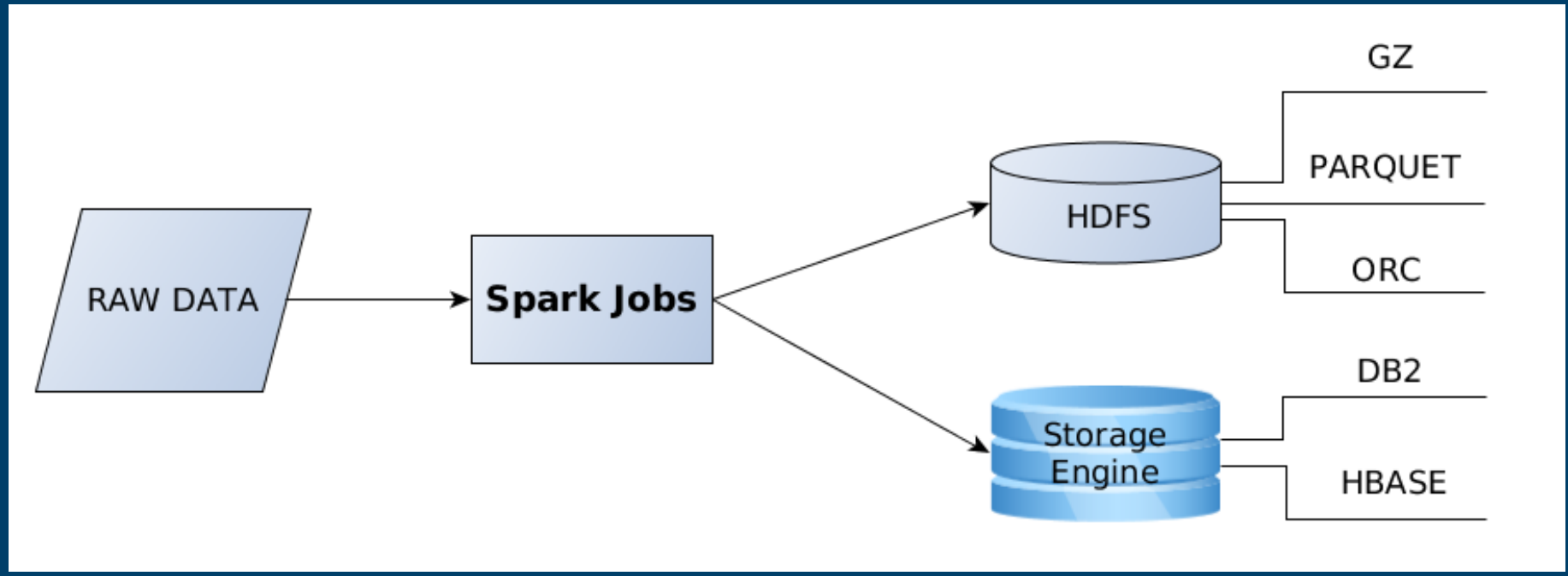
- Smart meter data:
  - ~280k service points
  - 15-minute usage / generation values (kWh)
  - Monthly batches Feb 2013 – Jun 2015
  - Daily batches Jul 2015 – present
  - Total: 25B rows, 2TB data
  - Metadata (updated weekly):
    - latitude/longitude (truncated)
    - zip code
    - feeder id
    - generation nameplate information
- VELCO MV90 data



Heat map of service points

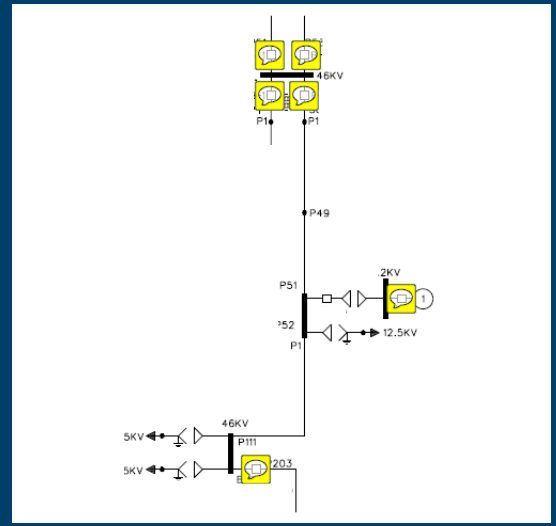
VTWAC Project
Data sources

- Spark as framework for data ingestion, filtering and aggregation:



VTWAC Project
Data sources

- SCADA data:
  - 479 tags from VELCO and Vermont DUs (through ICCP)
  - (Sub-)transmission transformers, buses, sectionalizers
  - Active powers (MW)
  - Some derived values (e.g., total service territory load)
  - 1-min to 15-min resolution historically (Jan 2012 – Jan 2015)
  - Since Feb 2015: ~5-min resolution close to “real-time”
- PSS/E network planning model:
  - Asset information and metadata
  - Network topology: connectivity, line impedances
- One-line diagrams:
  - Unstructured, schematic view of the (sub-)transmission network

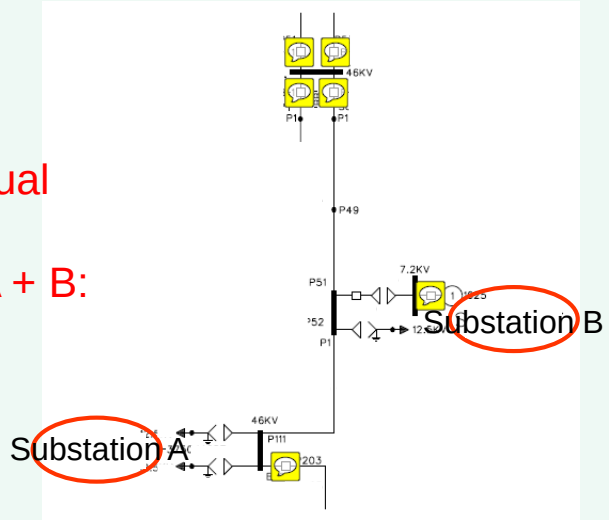


Snapshot from one-line diagram. The yellow sticky notes correspond to points where we have SCADA measurements.

VTWAC Project
Data c

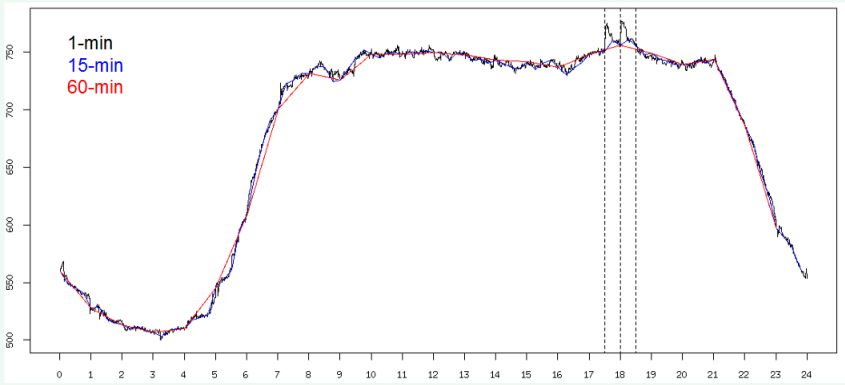
1st Challenge:
Obtain quantity of interest from SCADA

Obtain residual demand for Substation A + B:



Formula:
+ ICCP_X_46.0_B-01 ME_MWATT.MV
– ICCP_Y_46.0_B-02 ME_MWATT.MV
+ ICCP_Z_7.2_G-03 ME_MWATT.MV

2nd Challenge:
Approximate MWh by MW



State load (MW), June 10, 2014

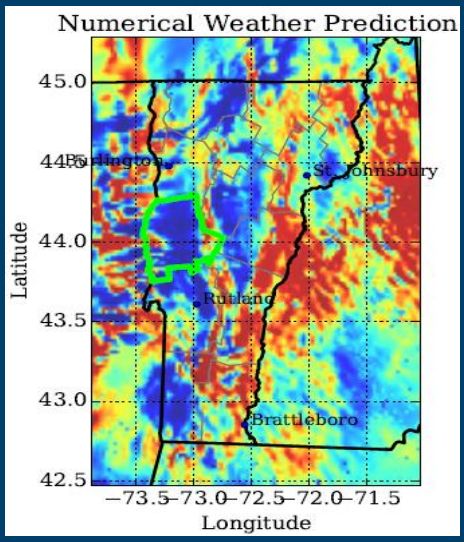
Challenge: How to approximate MWh by MW (e.g., to compare SCADA with AMI)?

Approach: Compute hourly integrals over high-frequency MW measurements.

Accuracy: Less than 0.3% difference.

VTWAC Project
Data sources

- Weather data
  - Deep Thunder
    - 1-km resolution
    - 72h-ahead forecasts at 0 and 12 UTC
    - Operational forecasts from Nov 2014 – present
    - Postprocessed output: 289 NetCDF files, total size 35GB
  - MADIS
    - Historical weather data for New England, Jan 2011 – present
- Statistical models
  - ~1,600 models (state, DU service territories, substations, counties, zip codes, demand/distributed PV, mean/uncertainty)
  - Stored in PMML format
  - May all require different inputs for scoring



Deep Thunder output

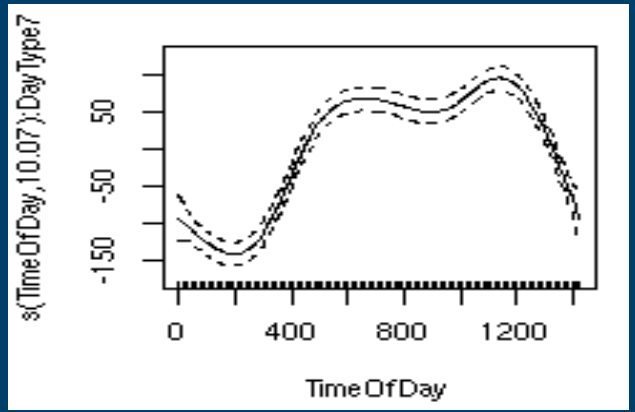
VTWAC Project
Analytics models

Non-Linear Additive Models:

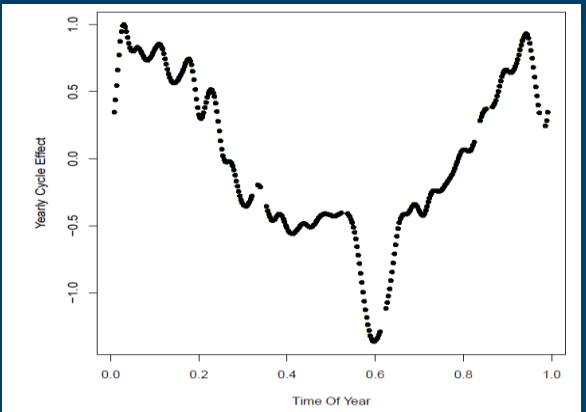
- Sum of 1D and 2D smoothing functions
- Flexibility and interpretability

Main inputs:

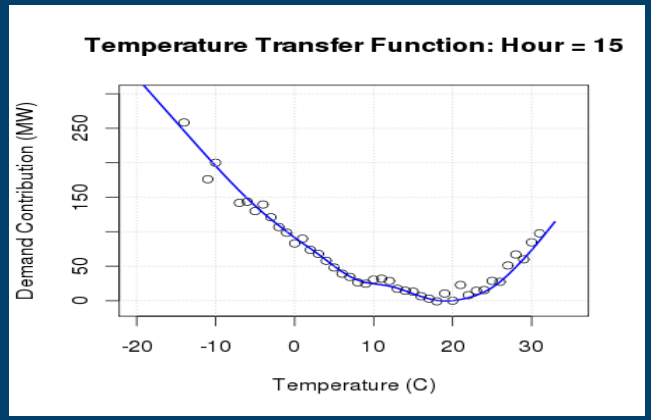
- Calendar: TimeOfDay, TimeOfYear, special days
- Temperature: Lagged, Integrated, Min/Max
- Irradiance
- Dew point
- PV generation: Data-driven physical models
- Real-time measurements:
  - 1-16h ahead: DailyMinimum
  - 17-24h ahead: Lag 24h
  - 25-40h ahead: Lag 48h
  - Data anomalies: Fallback models



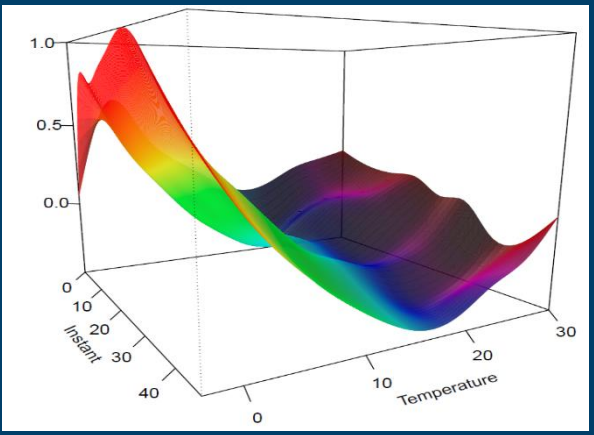
TimeOfDay



TimeOfYear



Temperature



TimeOfDay / Temperature

VTWAC Project
Analytics models

Residual demand forecasting accuracy:

Entity	Jul 1-31	Aug 1-31	Sep 1-30	Oct 1-31	Nov 1-30	Dec 1-31	Jan 1-31	Feb 1-29
State*	1-16h: 2.1% 17-24h: 2.1% 25-40h: 2.5%	1-16h: 1.6% 17-24h: 1.4% 25-40h: 2.0%	1-16h: 1.6% 17-24h: 1.8% 25-40h: 1.7%	1-16h: NA 17-24h: NA 25-40h: NA	1-16h: 2.3% 17-24h: 2.0% 25-40h: 3.0%	1-16h: 2.8% 17-24h: 3.4% 25-40h: 3.6%	1-16h: 2.2% 17-24h: 2.0% 25-40h: 2.5%	1-16h: 2.7% 17-24h: 2.8% 25-40h: 3.3%
BED	1-16h: 2.6% 17-24h: 3.0% 25-40h: 3.1%	1-16h: 2.2% 17-24h: 2.8% 25-40h: 3.1%	1-16h: 2.1% 17-24h: 3.3% 25-40h: 3.1%	1-16h: 1.4% 17-24h: 1.3% 25-40h: 1.4%	1-16h: 2.0% 17-24h: 1.4% 25-40h: 2.4%	1-16h: 2.3% 17-24h: 1.7% 25-40h: 2.9%	1-16h: 2.2% 17-24h: 2.4% 25-40h: 2.6%	1-16h: 1.7% 17-24h: 2.0% 25-40h: 1.7%
GMP	1-16h: 2.1% 17-24h: 2.0% 25-40h: 2.8%	1-16h: 1.7% 17-24h: 1.6% 25-40h: 2.1%	1-16h: 1.9% 17-24h: 2.4% 25-40h: 2.8%	1-16h: 2.4% 17-24h: 2.9% 25-40h: 2.8%	1-16h: 2.7% 17-24h: 1.8% 25-40h: 2.6%	1-16h: 3.0% 17-24h: 2.7% 25-40h: 3.0%	1-16h: 3.2% 17-24h: 2.6% 25-40h: 3.5%	1-16h: 3.3% 17-24h: 4.1% 25-40h: 4.9%
VEC	1-16h: 2.1% 17-24h: 2.4% 25-40h: 2.7%	1-16h: 2.4% 17-24h: 2.5% 25-40h: 3.4%	1-16h: 2.4% 17-24h: 2.2% 25-40h: 2.8%	1-16h: 2.1% 17-24h: 3.1% 25-40h: 2.6%	1-16h: 2.9% 17-24h: 2.2% 25-40h: 3.2%	1-16h: 2.6% 17-24h: 3.4% 25-40h: 3.6%	1-16h: 2.8% 17-24h: 3.4% 25-40h: 3.6%	1-16h: 3.1% 17-24h: 3.2% 25-40h: 3.6%
VPPSA**	1-40h: 2.2%	1-40h: 2.6%	1-40h: 2.4%	1-40h: NA	1-40h: NA	1-40h: NA	1-40h: NA	1-40h: NA

VTWAC Project
Analytics models

Modeling uncertainty:

- Quantify uncertainty, manage risks, reduce safety margins

Main constituents:

- Randomness when / how long (industrial) appliances are used
- Uncertainty of model inputs (e.g., weather)
- Model bias and variance

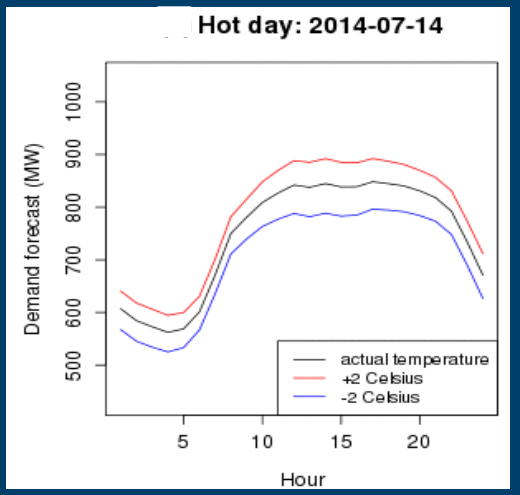
Formulation:

- $y = g(x) + s(x)\,\varepsilon$

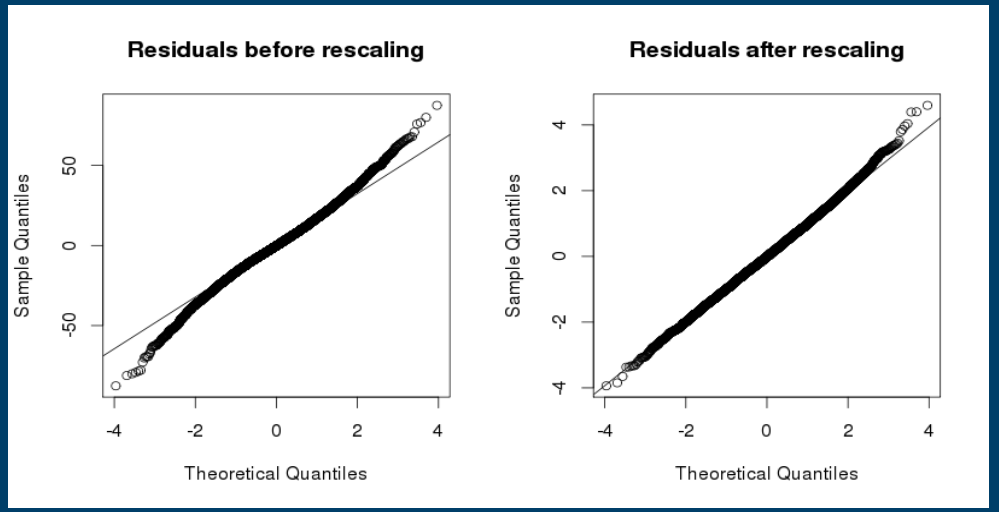
  Demand; Mean; Standard error; "Noise"

Intuition:

- For certain model inputs x, conditional variance $s^2(x)$ is higher
- E.g., extreme weather conditions, peak demand hours



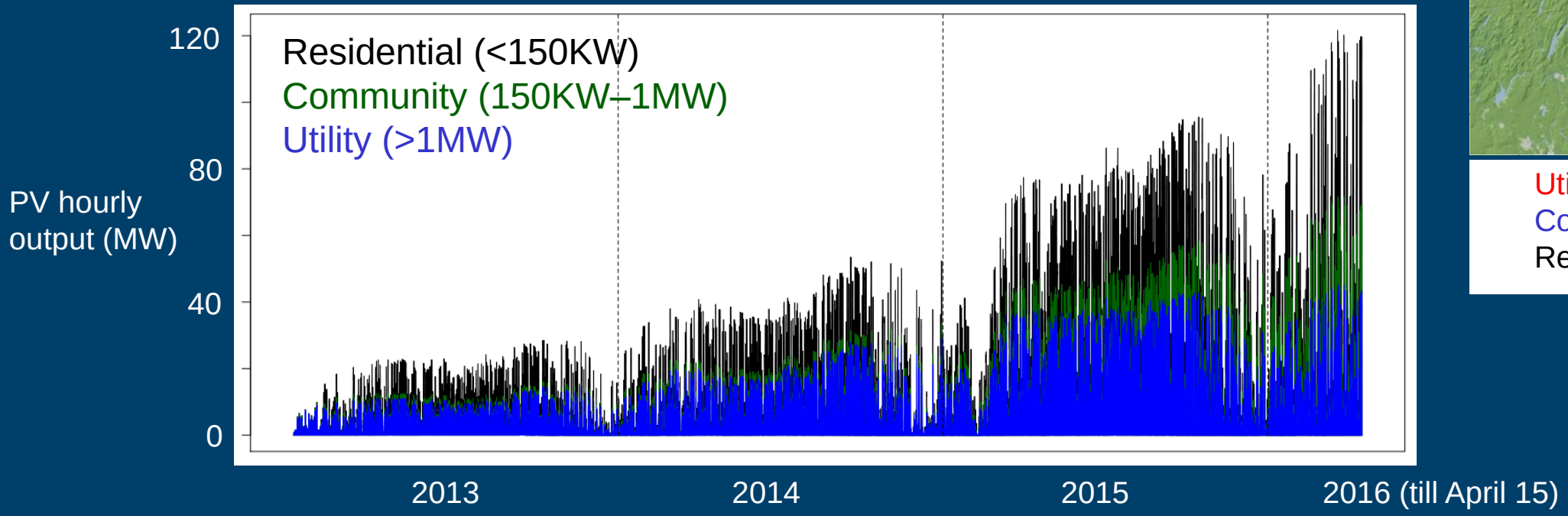
Effect of temperature uncertainty



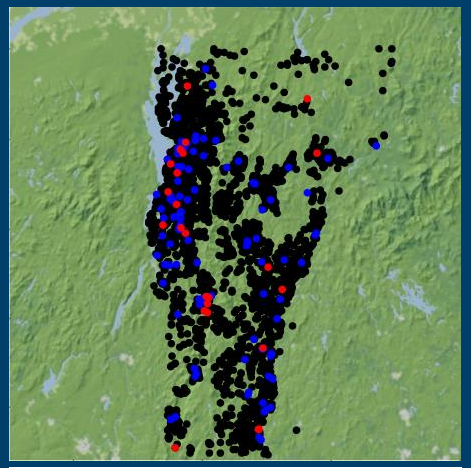
"Normalization" of residuals

VTWAC Project
Insights and use cases

- Vermont PV output*:



PV system locations

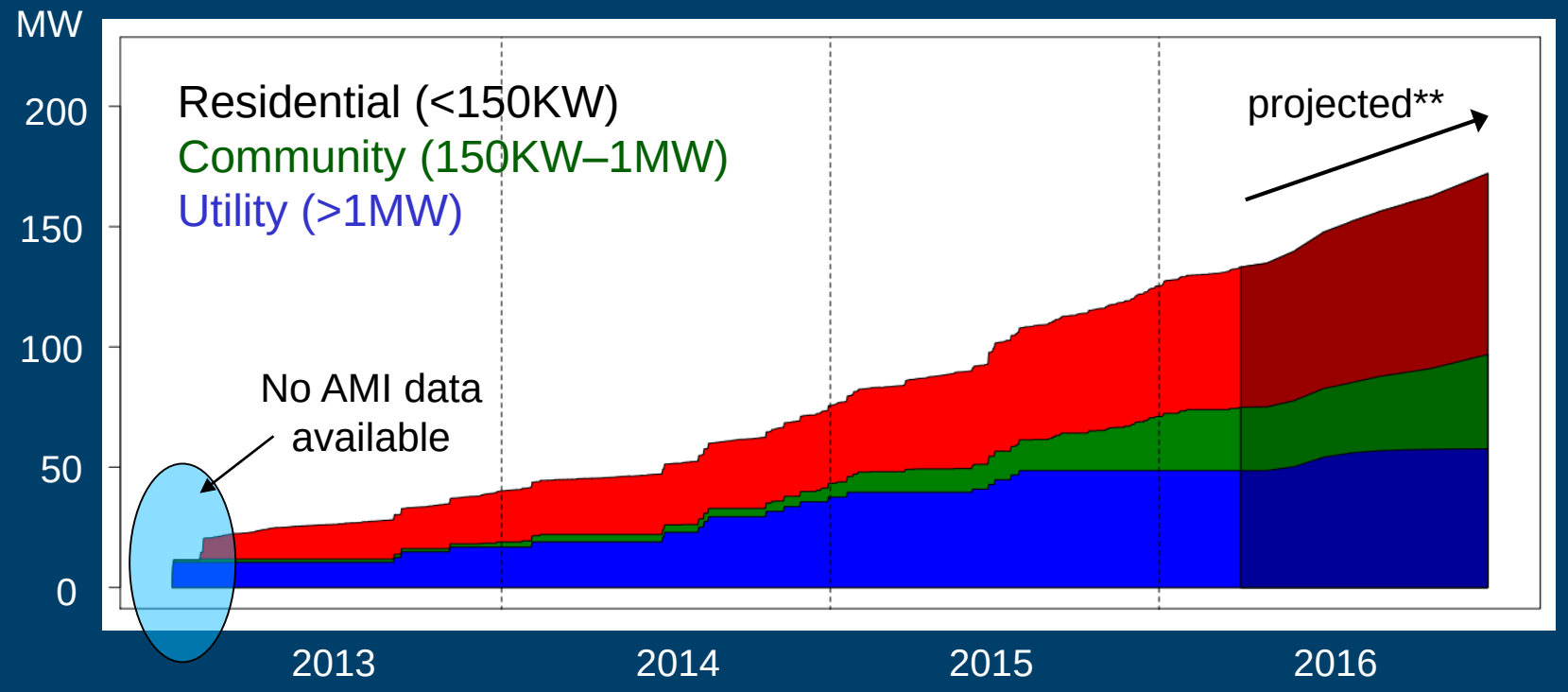


Utility-scale
Community-scale
Residential-scale

*based on VELCO and GMP revenue metering data

VTWAC Project
Insights and use cases

- Vermont installed PV capacity*:



Projected growth

May 2016 → Dec 2016

63MW → 77MW
(45%) (45%)

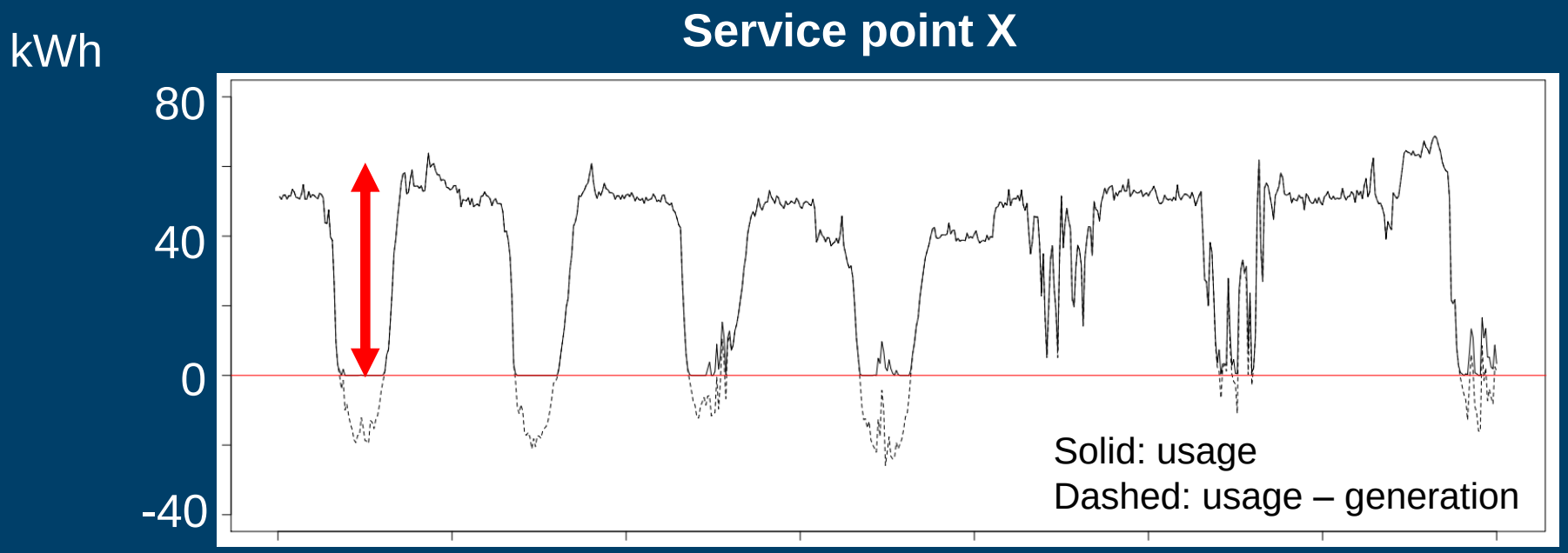
28MW → 40MW
(20%) (23%)

49MW → 55MW
(35%) (32%)

*based on VELCO and GMP data **assuming same growth as May-Dec 2015

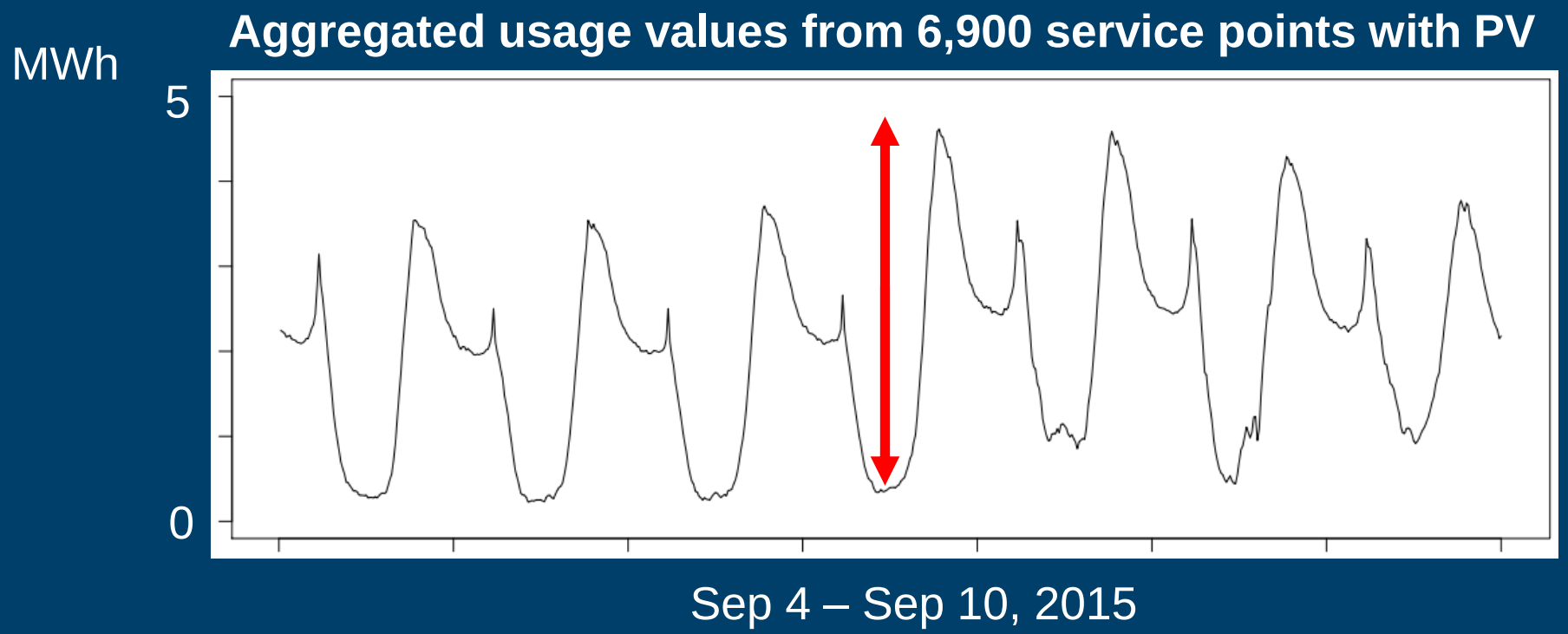
VTWAC Project
Insights and use cases

- Load reduction effect of net metering:



VTWAC Project
Insights and use cases

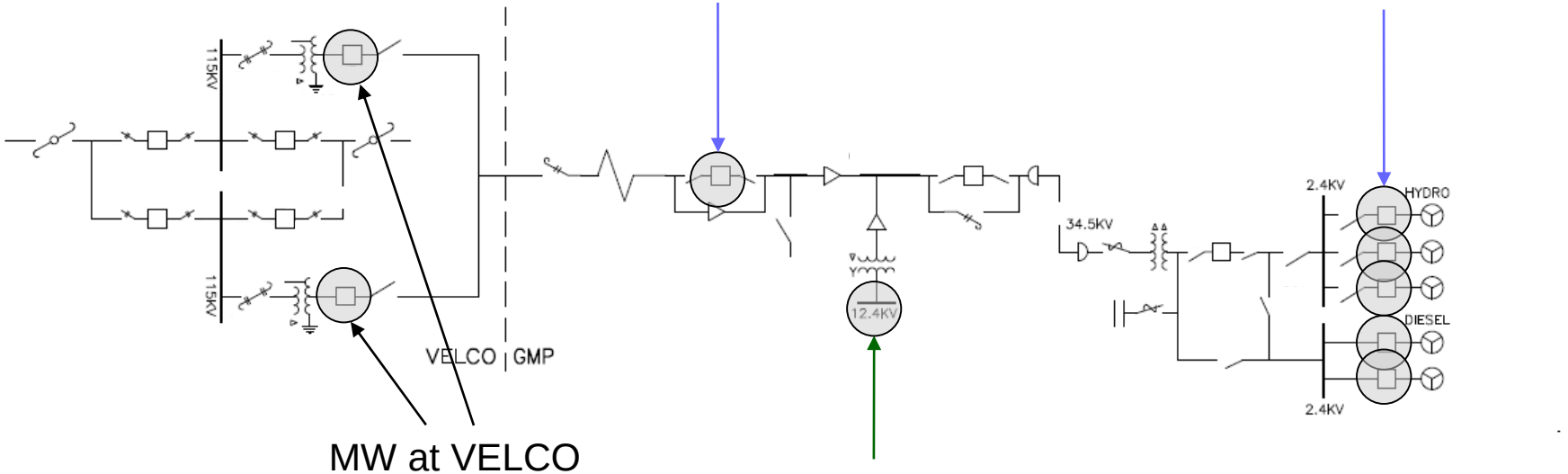
- Load reduction effect of net metering:



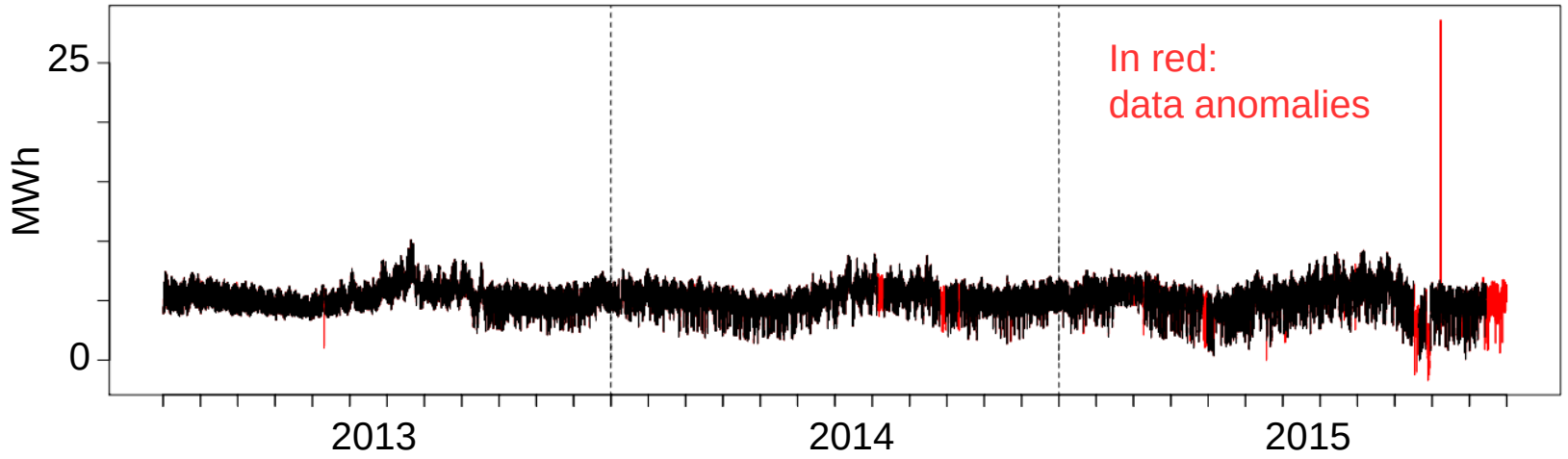
→ approximately 4-5MW load reduction in addition to the metered PV output

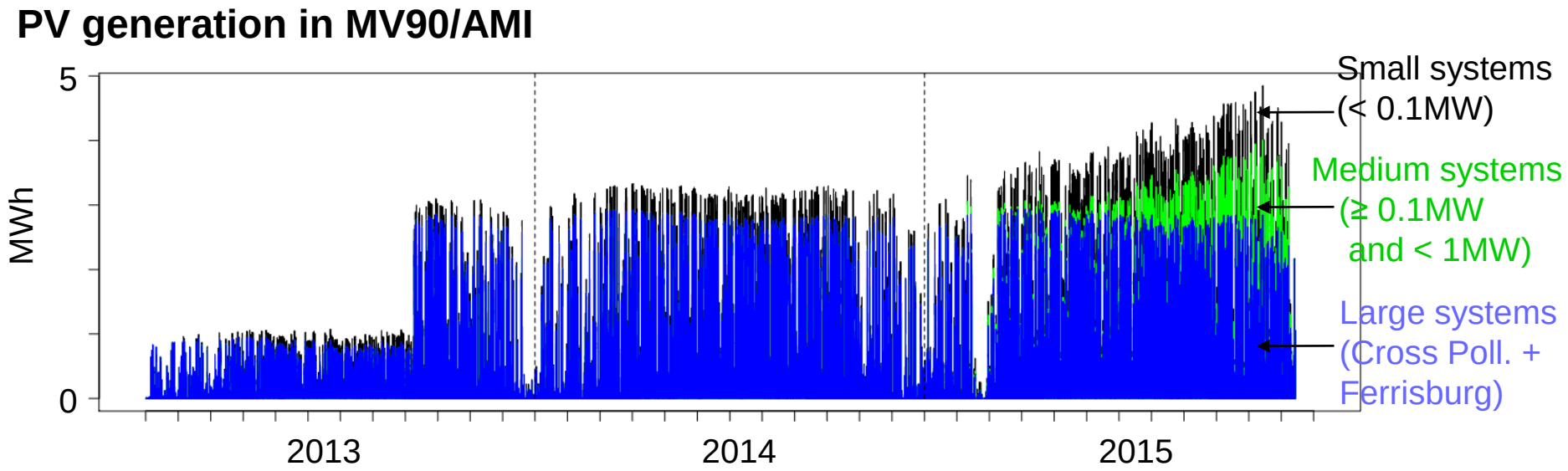
VTWAC Project
Insights and use cases

VELCO SCADA
GMP SCADA/ICCP
VELCO MV90, GMP AMI



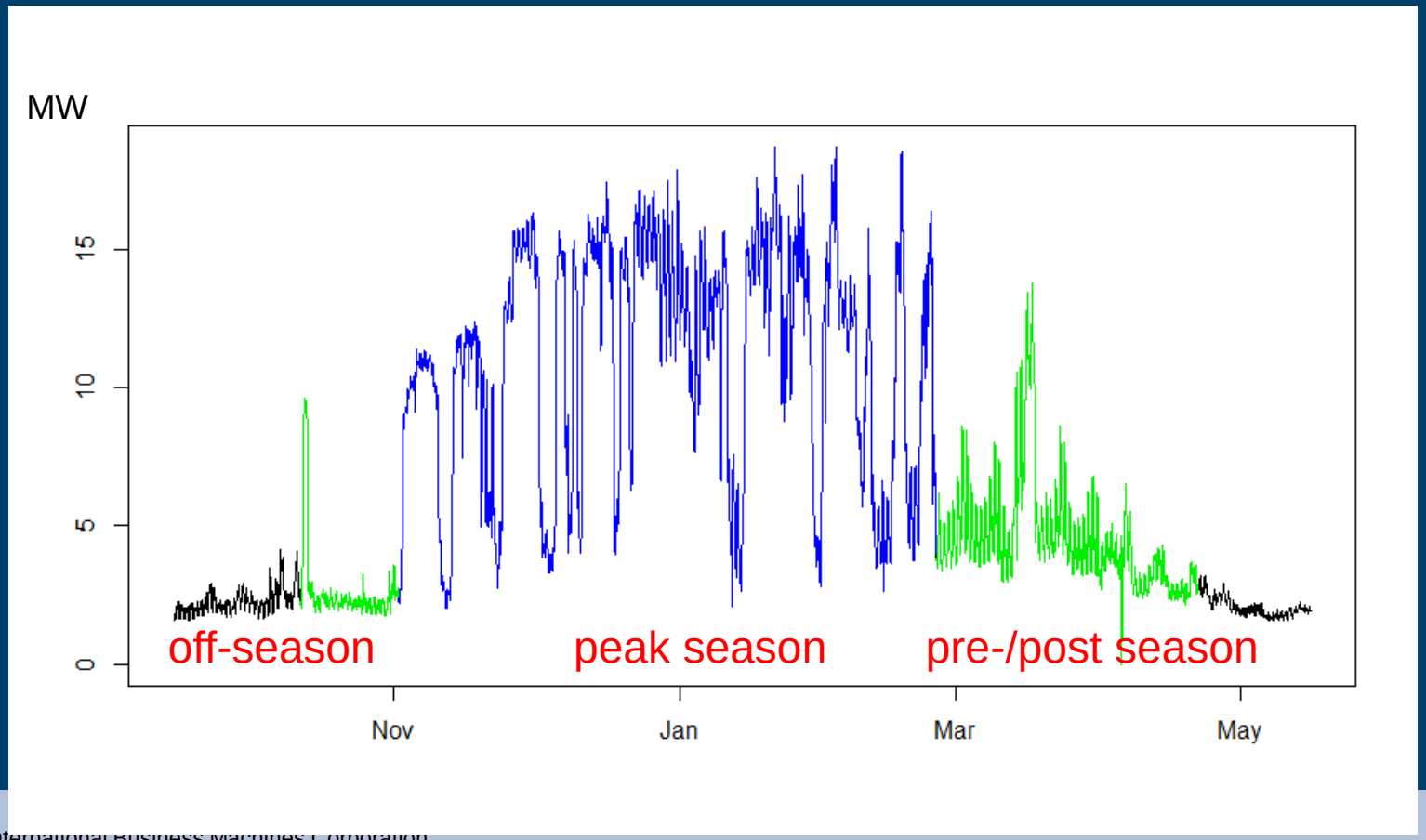
VTWAC Project





VTWAC Project
Insights and use cases

- Snowmaking:



List of substations:

- GMP Dover (10MW)
- GMP Madbush (13MW)
- GMP Stockbridge (5MW)
- GMP Snowshed (12MW)
- GMP Stratton (20MW)
- VEC Madonna (4MW)
- Lyndonville Burke (3MW)
- Stowe Lodge (12MW)

VTWAC Project
Insights and use cases

- Long-term planning:
  - Data and analytics services
  - Analysis of bulk and subsystem issues
  - Analysis of non-transmission alternatives
- Short-term planning / operations:
  - Renewable integration
  - Contingency analysis
  - Outage planning
- Peak energy management:
  - Reduction of regional network charges
  - Mitigation of congestion events

VTWAC Project
Outlook / discussion

- Prioritization of use cases
- Definition of economical / technical / societal metrics for success
- Offering of data and analytics services through platform
- Integration with operational tools
- Close collaboration with VELCO stakeholders and partners