DNV·GL

What lies below the curve

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About DNV GL

- Founded 1864
- Headquartered in Norway
- 10,000 employees

Strong position in:

- Tankers
- Offshore classification
- Power & transmission
- System certification

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- Founded 1867
- Headquartered in Germany
- 6,000 employees

Strong position in:

- Container ships
- Ship fuel efficiency
- Marine warranty
- Renewable energy

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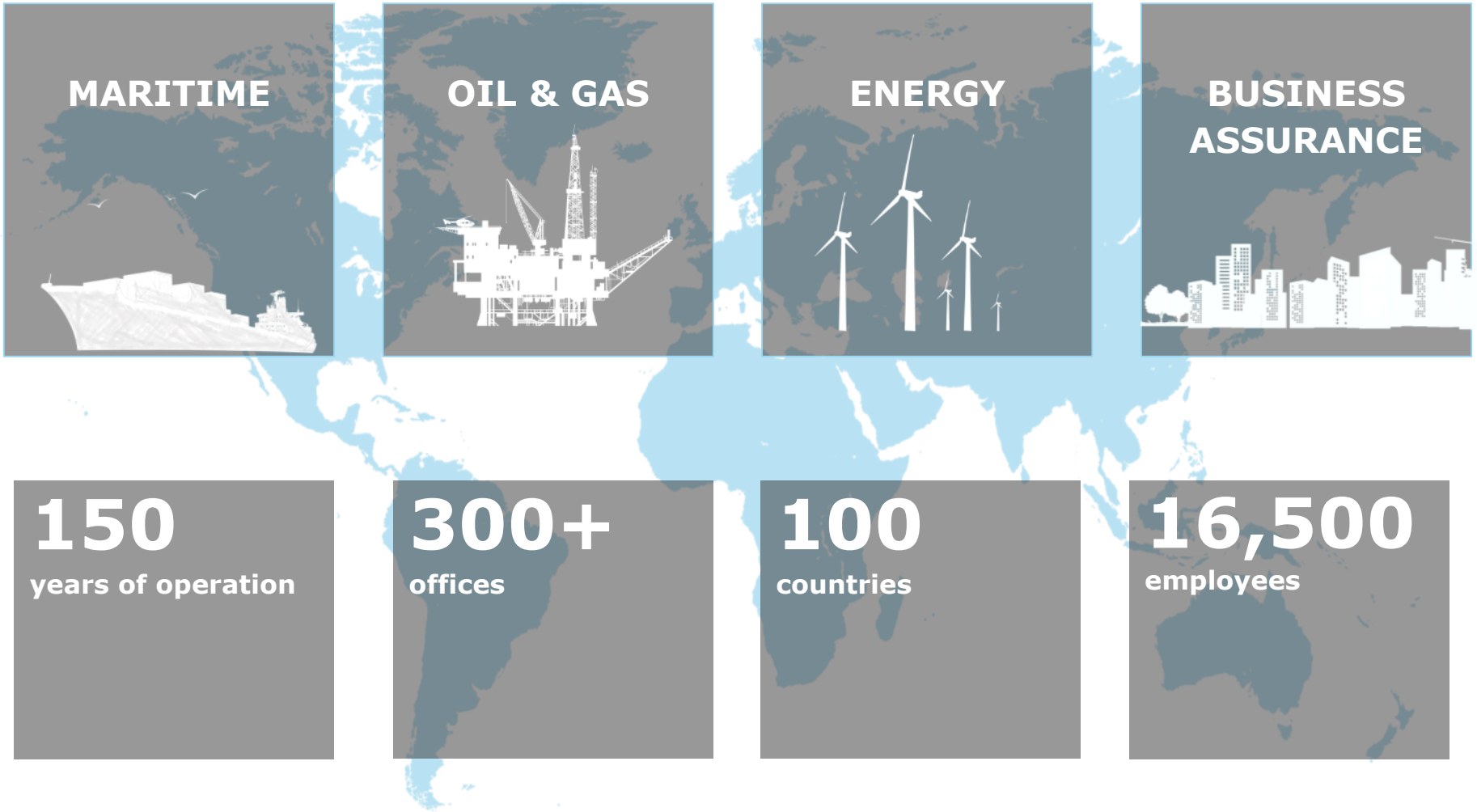
- **Created 2013**
- **Headquartered in Norway**
- **16,000 employees**

Leading company in:

- **Classification**
- **Oil & gas**
- **Energy**
- **Business assurance**

A global presence



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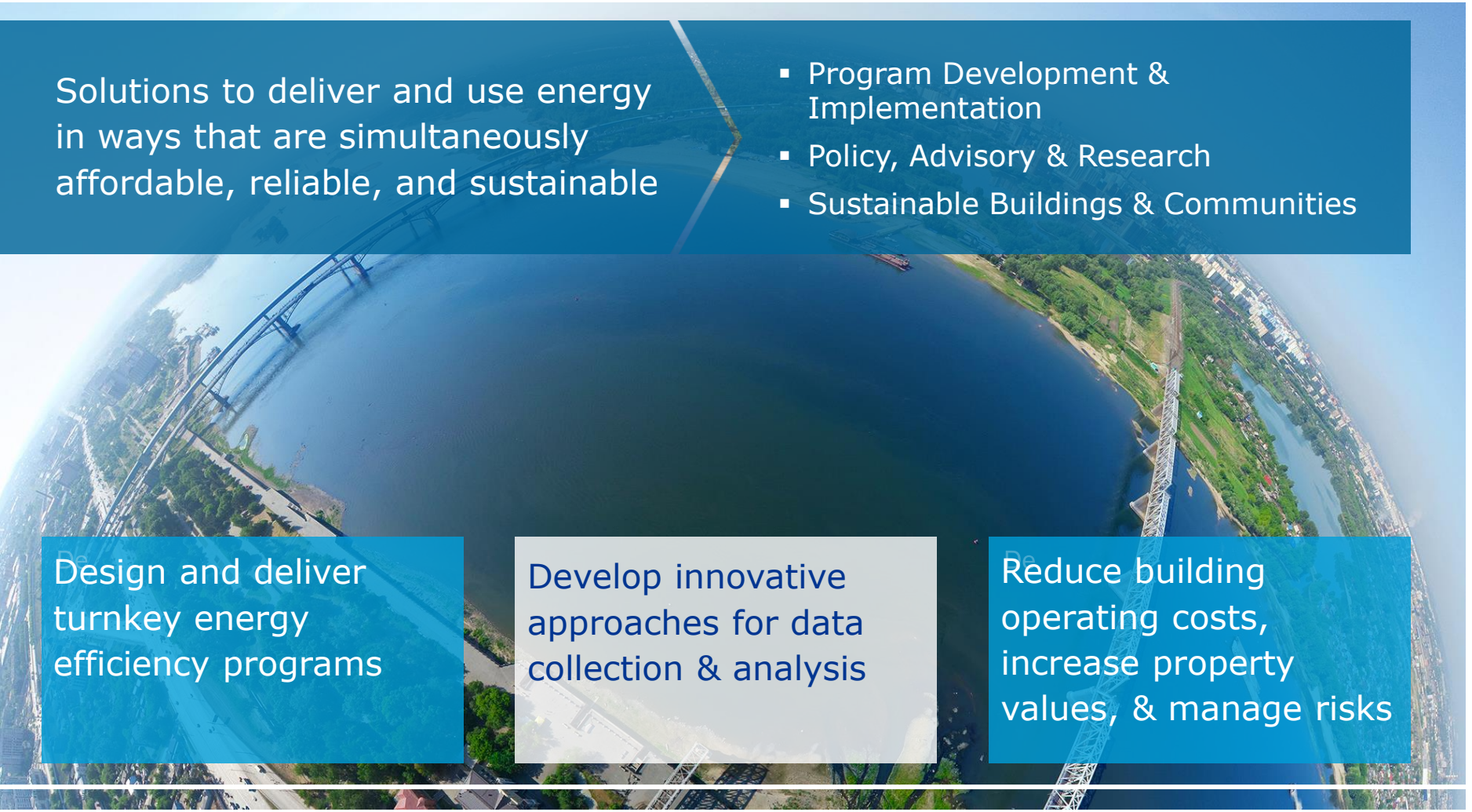
Sustainable Energy Use (SUS)



Solutions to deliver and use energy in ways that are simultaneously affordable, reliable, and sustainable

- Program Development & Implementation
- Policy, Advisory & Research
- Sustainable Buildings & Communities

Design and deliver turnkey energy efficiency programs

Develop innovative approaches for data collection & analysis

Reduce building operating costs, increase property values, & manage risks

Policy, Advisory & Research (PAR)

Advice, analysis, and evaluation assistance for energy efficiency programs and measures

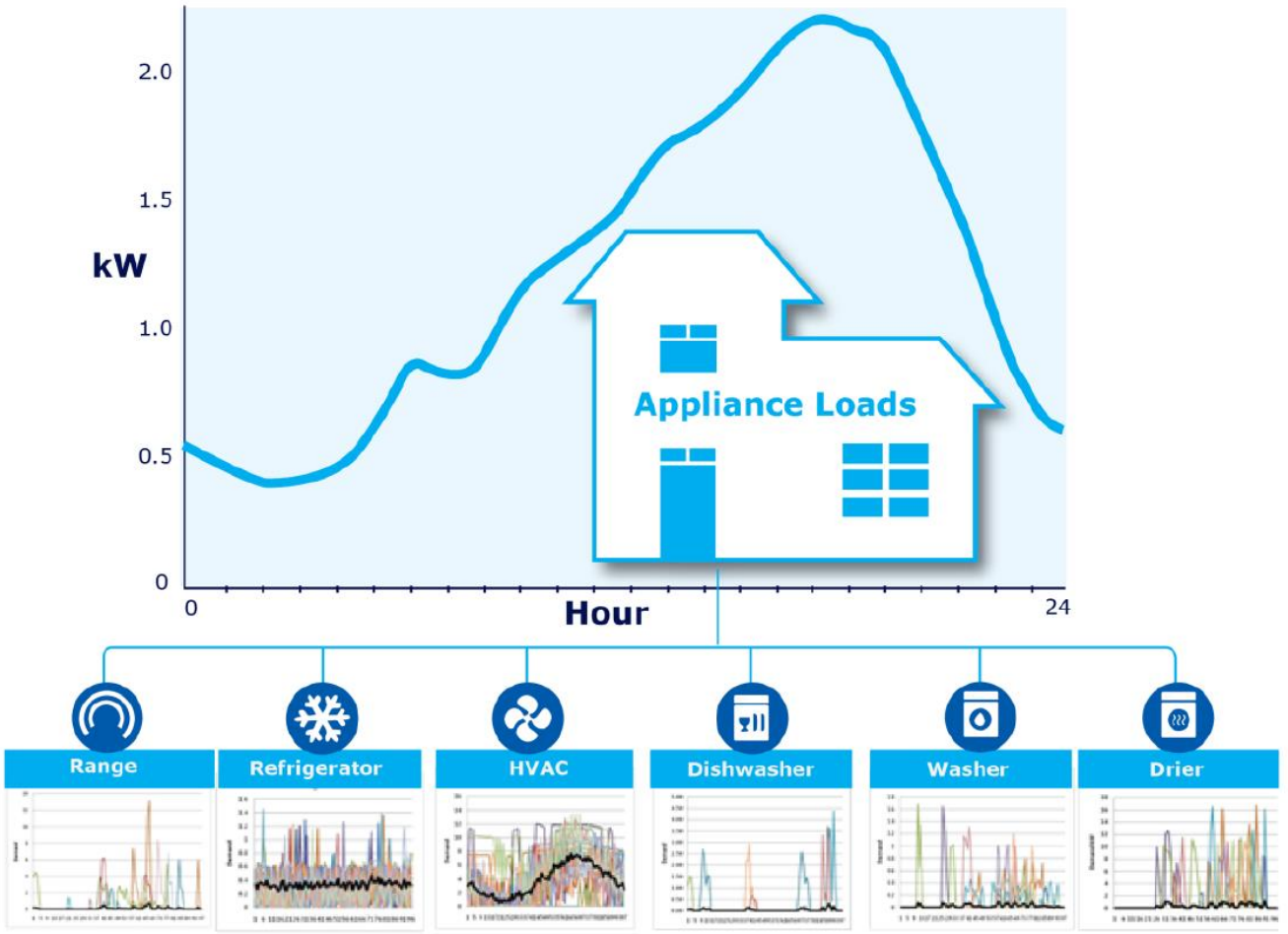
- Demand-side resource assessments
- Load research – profiling trends and customer behavior
- Market research and program evaluation
- Energy data analysis – customer and grid analysis

Expert statisticians, engineers, and social scientists

Evaluate and improve energy efficiency programs through rigorous, ground-breaking research

Develop innovative approaches for data collection, forecasting, end-use estimation, and data visualization

What lies below the curve



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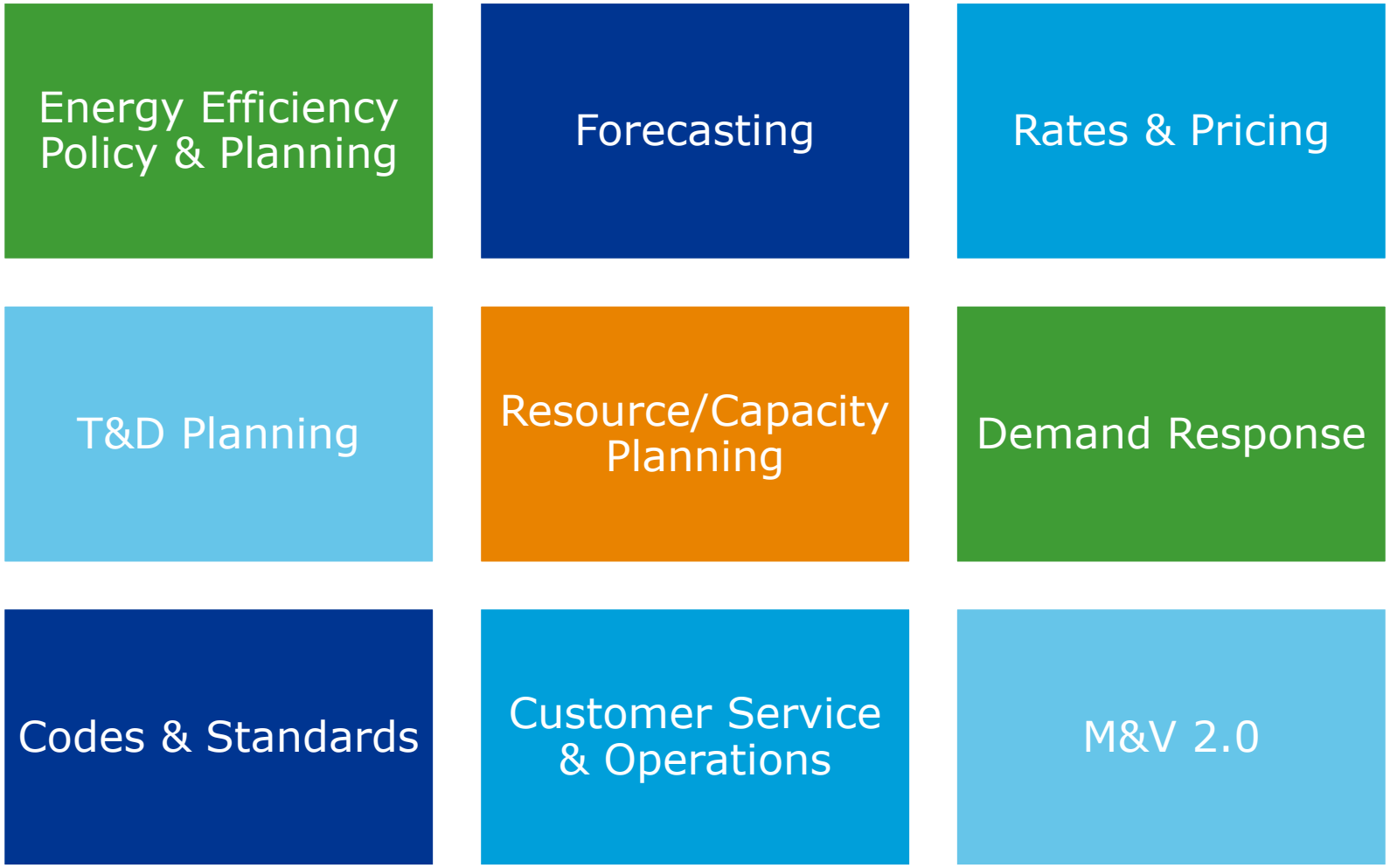
Drivers for going behind the meter

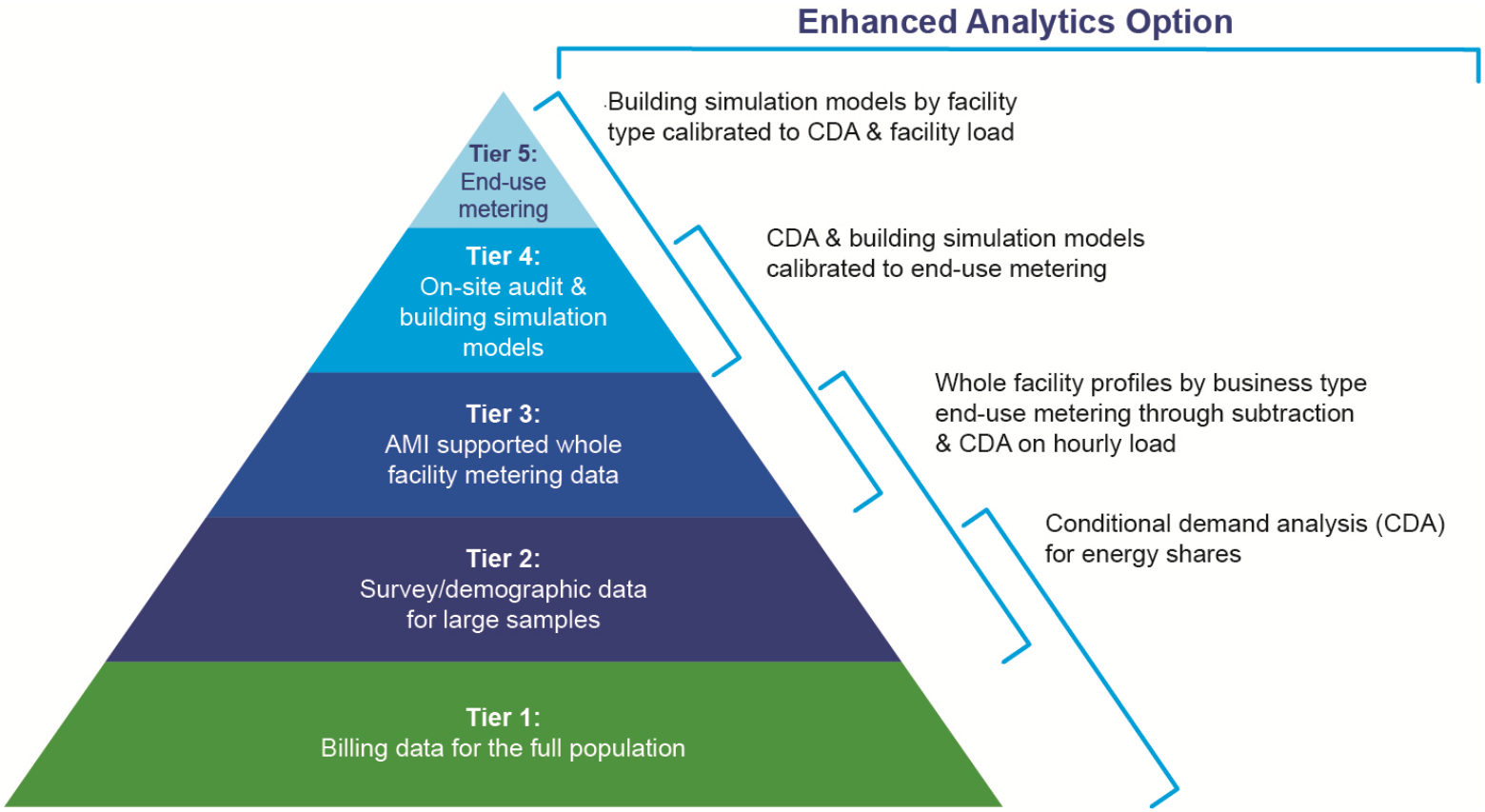


Options for End Use Data Acquisition

- **Direct Measurement**
  - Sensor installed at appliance or circuit breaker
- **Cluster/Event-based Analysis (NILM, disaggregation)**
  - Isolates loads on electrical characteristics
  - Edge data clustering
- **High Frequency Signal Analysis Methods (NILM)**
  - Harmonic frequency analysis
  - Modified Fourier transform
- **Statistical**
  - Statistically adjusted engineering estimates (SAE) (single site approach)
  - Proportional fitting: Adjust end-use loads to known totals
  - Hourly (CDA): Regression method that uses variance in appliance presence to estimate aggregate customer or class load shapes
  - Hybrid: CDA with addition of NILM or engineering estimates
- **Pattern Recognition (No sensor, AMI usage data)**
  - Total Usage
  - Minimum & Excess usage

Typical Project Approach

Structured approach builds knowledge at each stage



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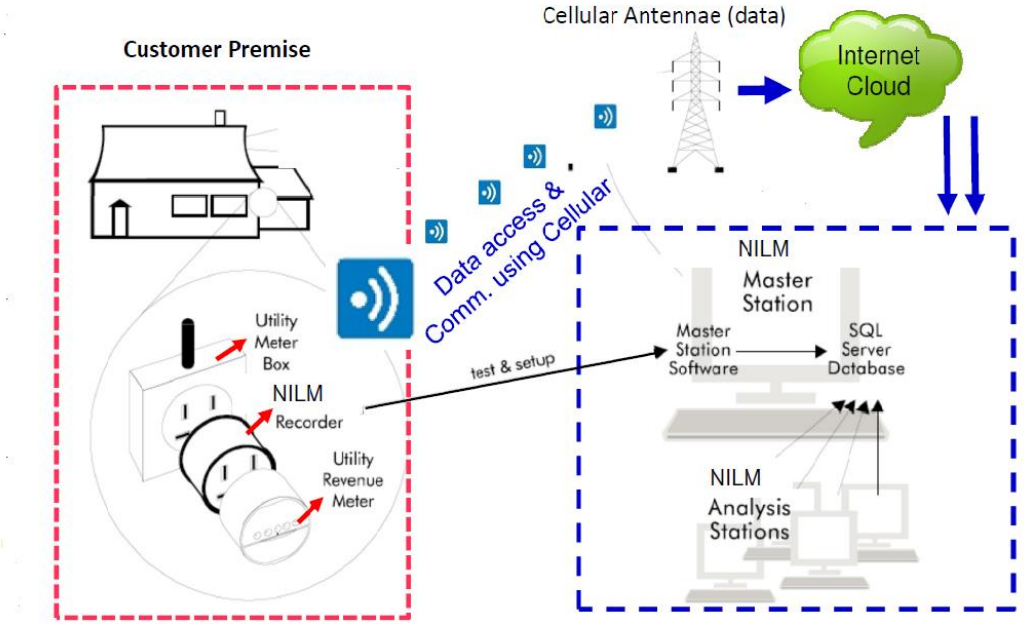
Residential Instrumentation

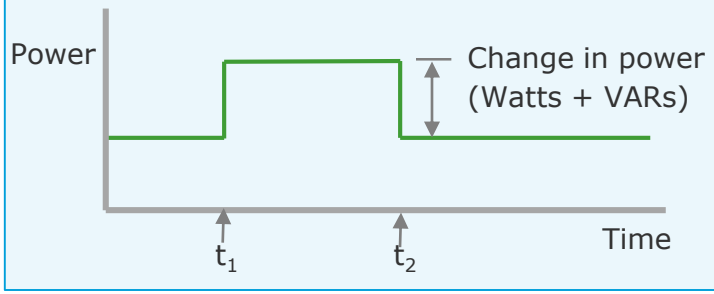
Non-intrusive approach required due to cultural constraints



Approach to Electric Disaggregation

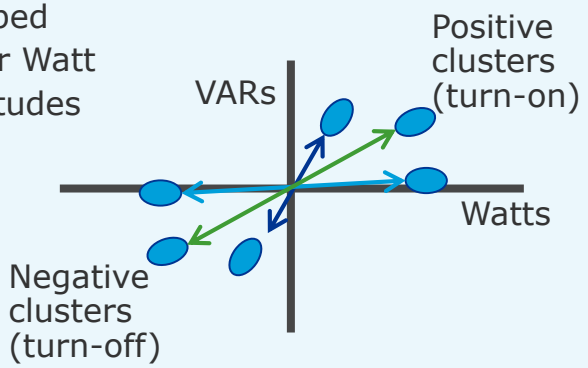
1. Edge detection

Captures and time stamps normalized changes in whole house power



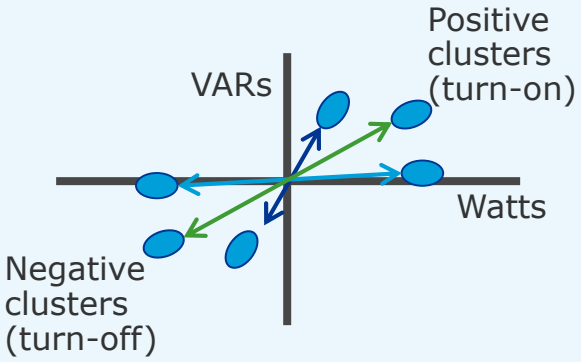
2. Cluster analysis

Edges are grouped based on similar Watt and VAR magnitudes



3. Cluster matching

Match positive and negative clusters



4. Resolve Data Anomalies

5. Appliance identification

- Single or two-leg appliance
- Connected load (Watts, VARs)
- Inductive, resistive or capacitive load
- Periodic (cycles on and off regularly)
- Timed (on and off times are nearly same)
- Typical on-time duration
- Time-of-day when operated

The algorithm assigns a confidence measure to the identification and annotation process. The above parameters each have weights of significance that are user-configurable.

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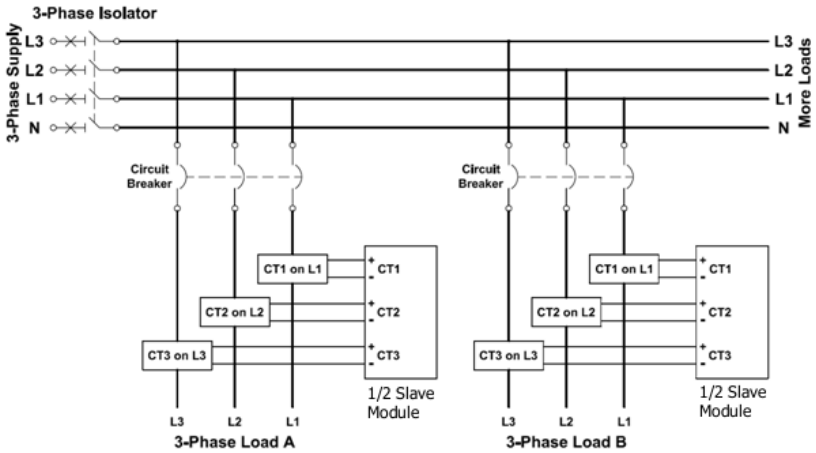
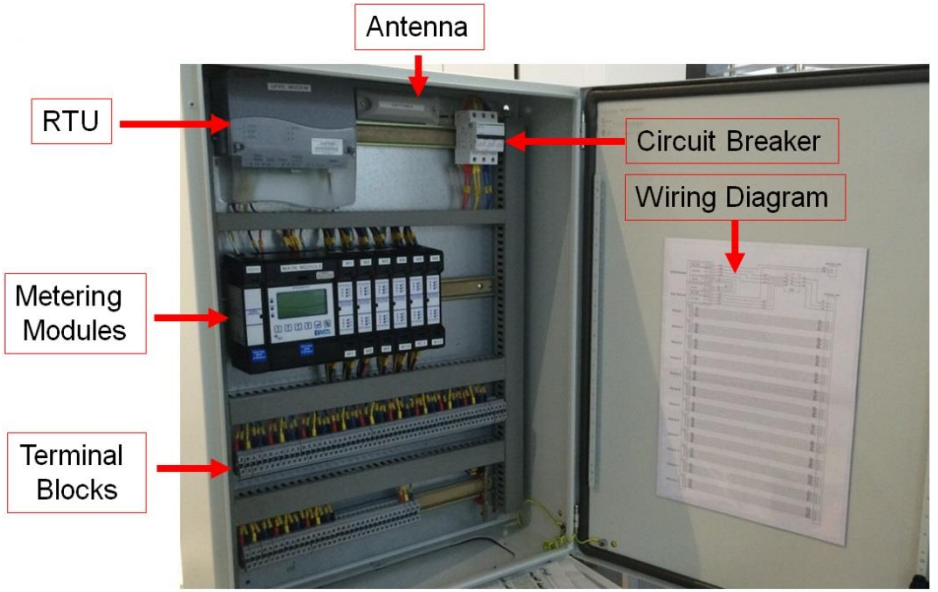
Non-Residential Instrumentation

Major loads instrumented at customer tableau or directly at load centres

Technology selected used by major retailers, industrials, and utilities throughout the world for advanced energy management initiatives. (Wal-Mart, NYPA, TESCO)





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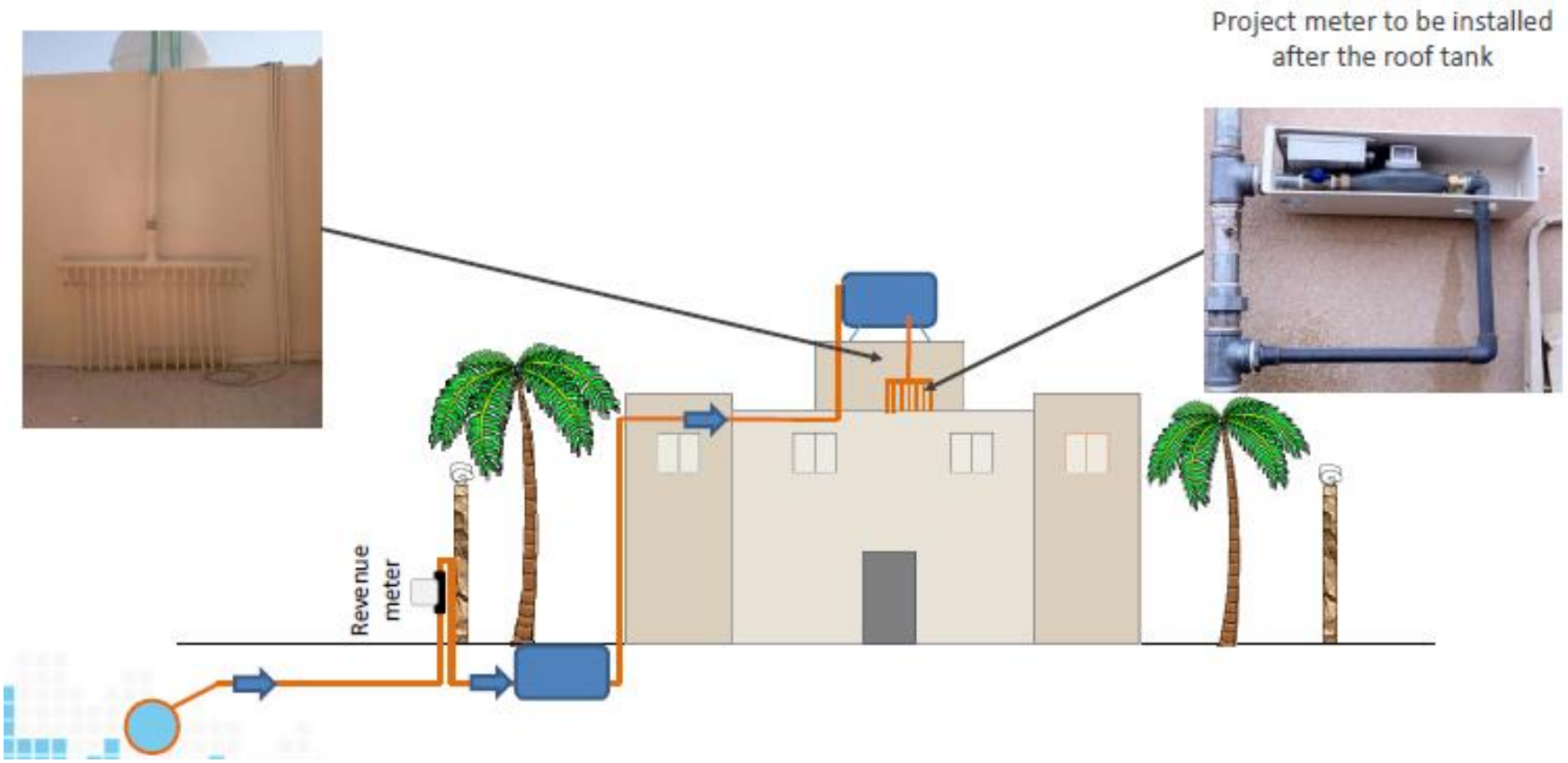
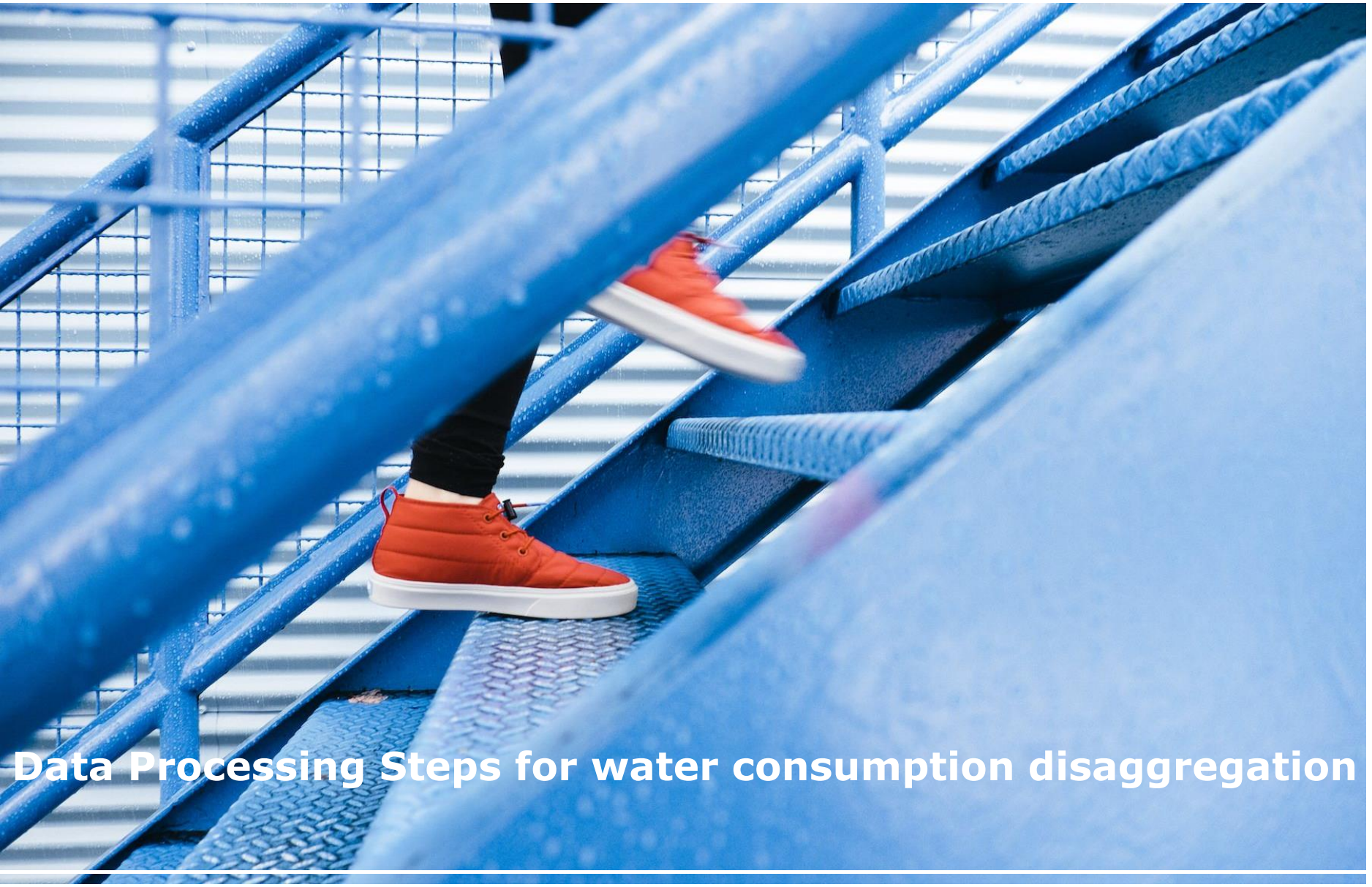
If it works for electricity, why not water?





Data Processing Steps for water consumption disaggregation

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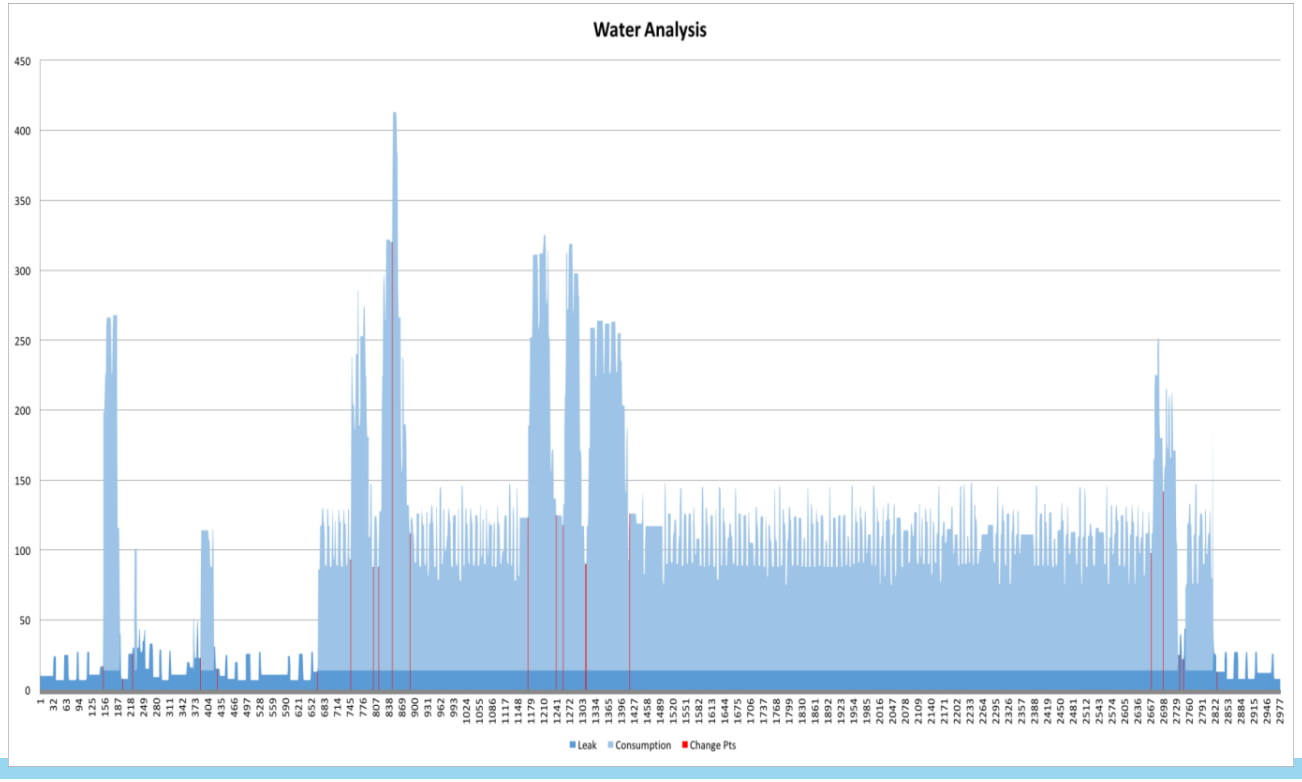
Step 1

Data filtering and auto-cropping of events

- Search for relevant change points in the signal, while ignoring noise, in order to identify start & endpoints of different end uses (see figure, orange lines)
- Identify and extract base leak flow (see figure below, dark blue area)



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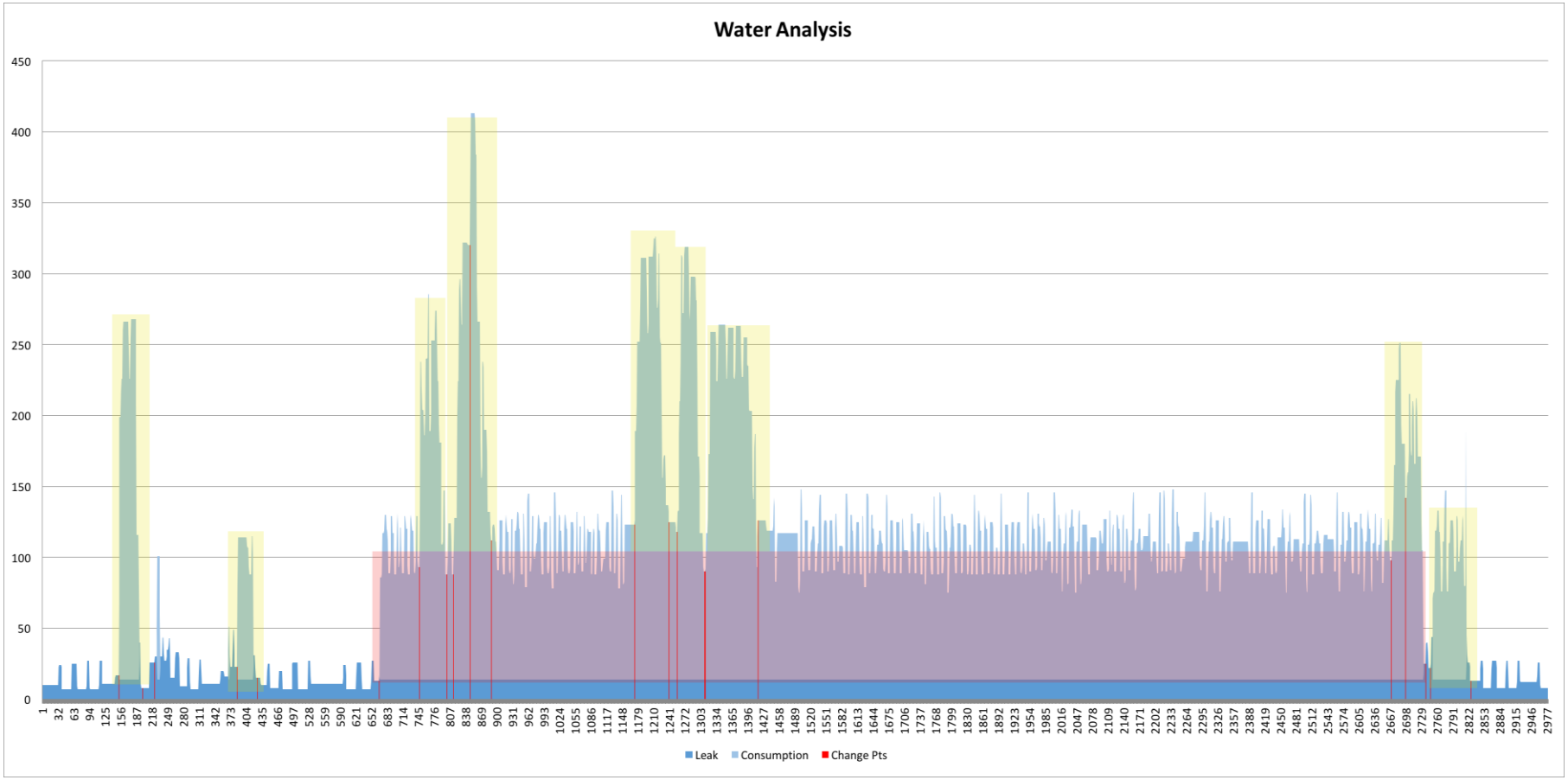
Step 2

Disassemble complex events into basic end-use events



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Step 3

Calculate characteristics of basic events

- Average & standard deviation 250 l/h
- Flow octiles: 8 flow (l/h) values [180l/h, 200l/h, etc.]
- Length in seconds: 310 secs.
- Time of use: 7 a.m.

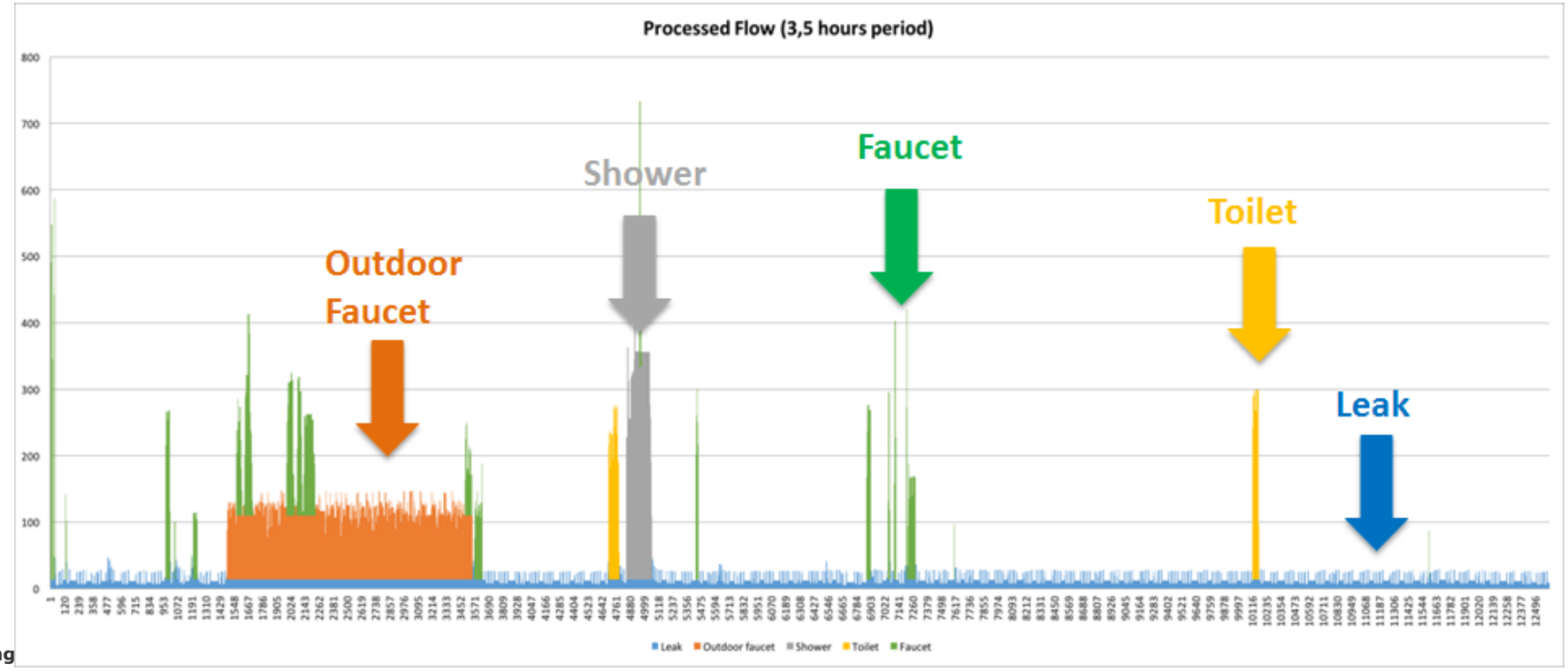
Add contextual information

- Eg: a toilet flush is often preceded by a faucet (toilet/shower)
- Repeating usage events in case of a dishwasher or washing machine

Step 4

Each site is pre-processed and analysed to detect clusters that identify typical end uses

- Eg : showers typically happen at more or less the same time during weekdays and take usually between 3 and 5 minutes, consuming between 30 and 60 litres. The calculated characteristics of each basic event are matched with that information in order to detect the possible end use



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Observations

Advanced clustering algorithms serve as the base for further exploration, but not sufficient to determine actual end use

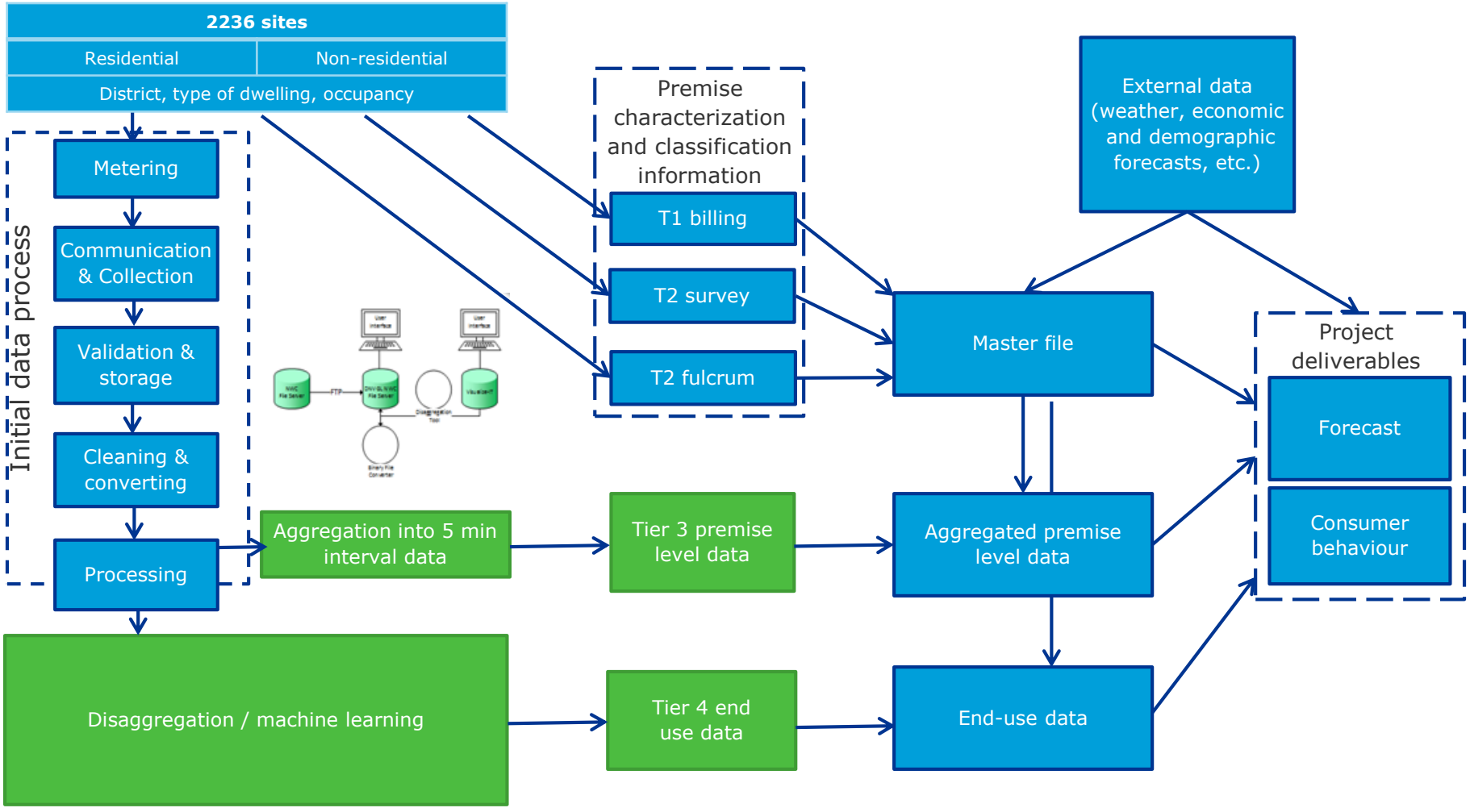
To get proper classification, inter-segment relations are also important

Repeating consumption patterns for clothes washers, dishwasher during one use cycle (+/-2 hours)

Toilet use often preceded by use of toilet shower or faucet use

Showers happen at specific times of the day or day type (working days vs. non-working days)

Data processing overview for live project



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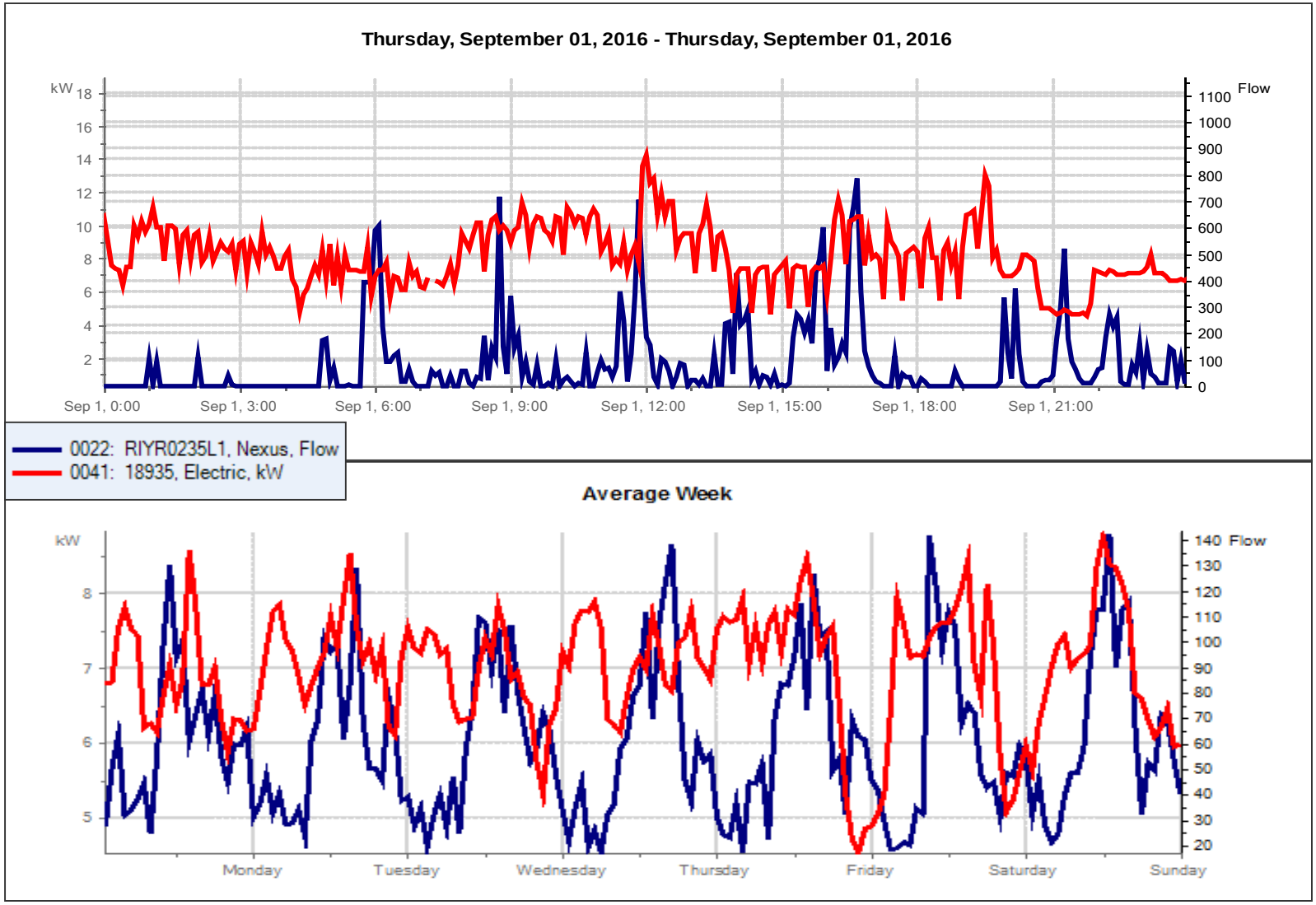
Water/Electric Nexus

- Joint utility/DNVGL R&D project to investigate water/electric Nexus
- Sample water sites selected from electric sample
- Imported the water profiles (using 1 second resolution)
- Imported the disaggregated appliance kWh profiles for those joint sites
- Identified periods where Clothes Washer is running based on the kWh profile
- Identified the different flow segments for periods the Clothes Washer activity
- Clustered segments
- Checked for recurring cluster patterns
- Clustering output example on a single run:

run (1):
Cluster 0 = "#elements 2 mean flow : 407 vol : 5L shape: [276 407 452 452 462 463 454 330]"
Cluster 1 = "#elements 1 mean flow : 30 vol : 9L shape: [34 35 36 32 30 32 24 23]"
Cluster 2 = "#elements 1 mean flow : 527 vol : 8L shape: [23 310 618 748 892 685 528 481]"
Cluster 3 = "#elements 1 mean flow : 823 vol : 8L shape: [579 749 917 941 973 922 845 820]"
Cluster 4 = "#elements 1 mean flow : 887 vol : 18L shape: [952 1010 1039 1049 1049 910 582 478]"

So Cluster 0 models 2 segments in the analyzed window with a mean flow of 407 L/h and a total volume of 5L

Water/Electric Nexus



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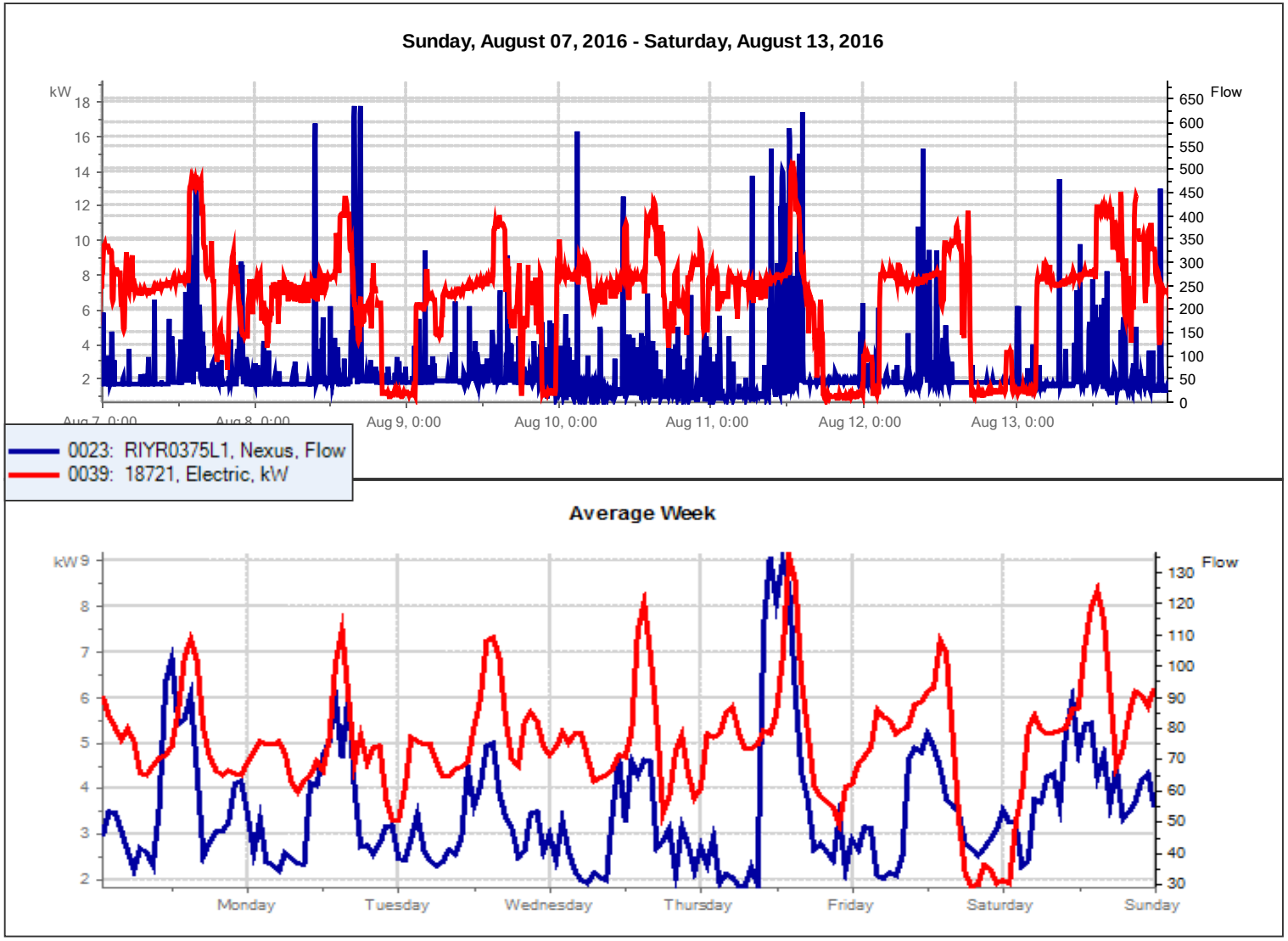
Water/Electric Nexus



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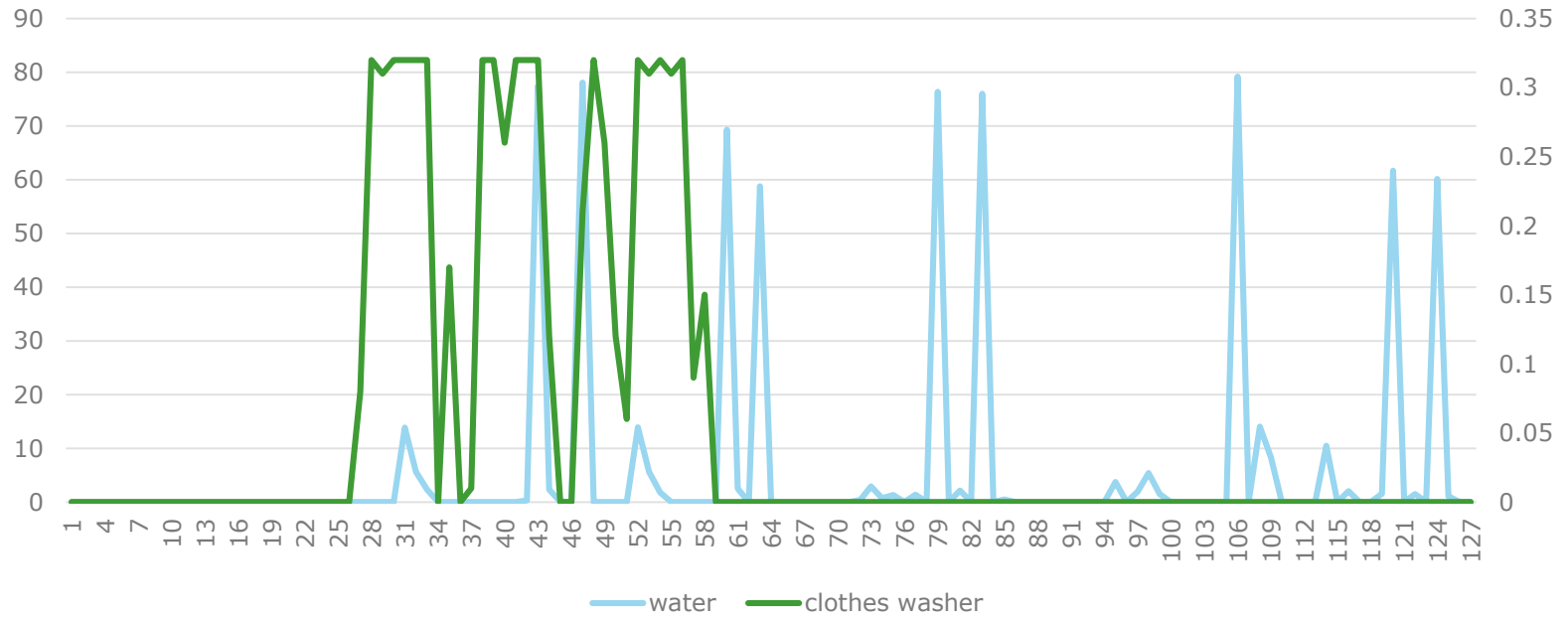
Water/Electric Nexus

- Looking at correlation between electrical consumption and water consumption
  - Dish washers
  - Clothes washers
  - Hot water tanks*
  - Example graph (5 minute samples of water volume vs clothes washer kWh)



Thank You

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SAFER, SMARTER, GREENER

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