Smart Data for the Smart Grid: Opportunities and Challenges

@ Data Science Symposium - Bridging Fundamental Research and Industry, University of Minho

efacec

Rogério Paulo
rdpaulo@efacec.com

I'm on in

Welcome to our world of empowerment.

We face the present as a moment to build a better future. We do it by creating, developing and delivering state-of-the-art solutions with high added-value for energy, mobility, environment, cities and digital connectivity, which will have a positive impact in human life all around the globe.

efacec Empowering the future

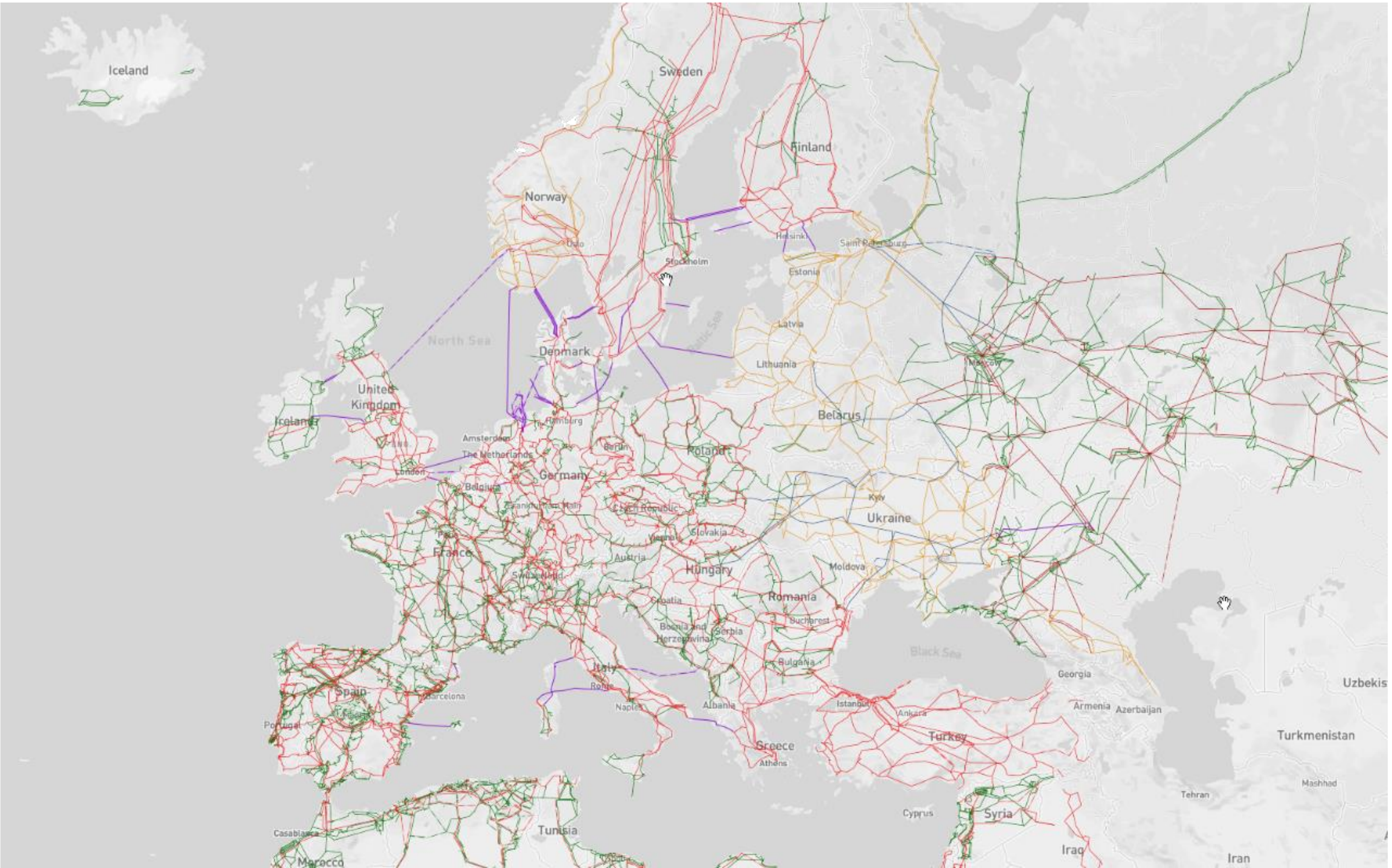
1

The Power Grid and the Energy Transition

Learn everything about today's Smart Grid in 5 minutes and scout for opportunities

Power Grid

A critical wide-area infrastructure that powers almost every modern human need in the modern world



The Interconnected European Transmission System

(>=220kV)

ENTSO-E, 2016

The Energy Transition Trends

Balancing affordability, reliability and sustainability is the new trilemma

Decarbonization

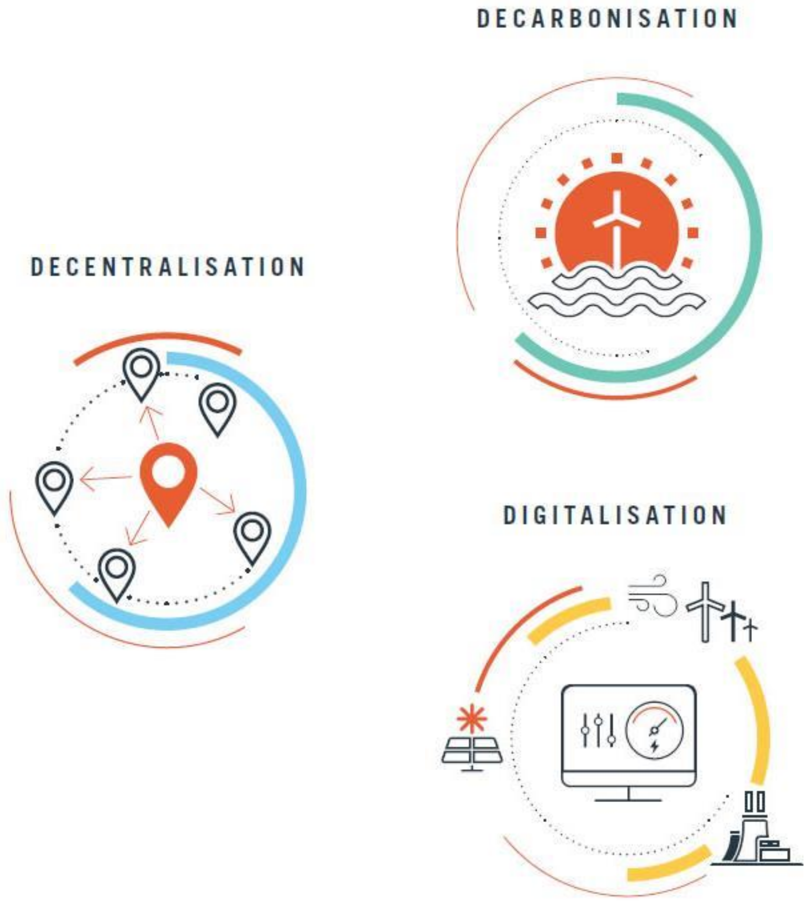
Fighting climate change: a shift from fossil to renewable

Decentralization

Move to distributed energy resources

Digitalization

Employing connected, data-driven, smart grid technologies



The Energy Transition

Key grid challenges

Integration of Renewables

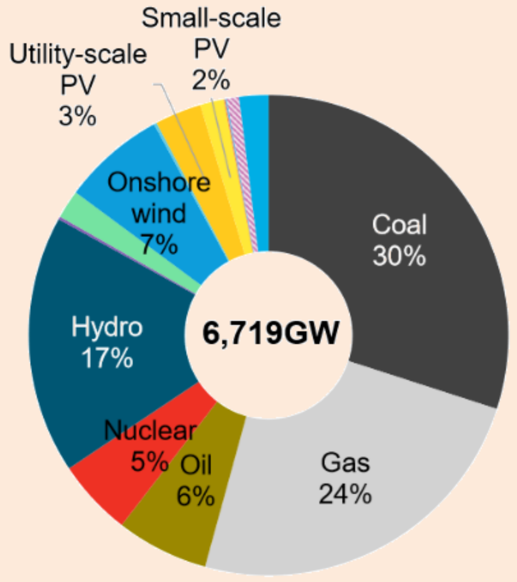
More wind and solar
Less fossil fuel-based generation

Some Issues (Opportunities) to Address

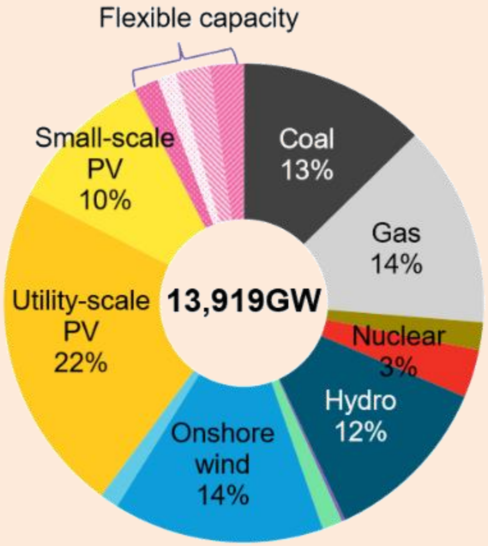
What's new?
Intermittency of renewables
Zero marginal cost of renewable energy
Installed capacity to double in 20 years

Limitations of current control/management methods
Limited predictability/controllability of generators
Large sources of renewables far from large consumption centers

Some solutions
Thermal generation to ensure system stability/ availability
Grid storage to avoid curtailment
New market models, will electricity ever be free?



Global Installed Capacity: 2016



Global Installed Capacity: 2040

(New Energy Outlook 2017, BNEF)

The Energy Transition

Key grid challenges

Decentralization

- Grid edge generation (ex: rooftop solar)
- Prosumers (producer + consumer)
- Consumer choice and participation
- More efficient use of energy

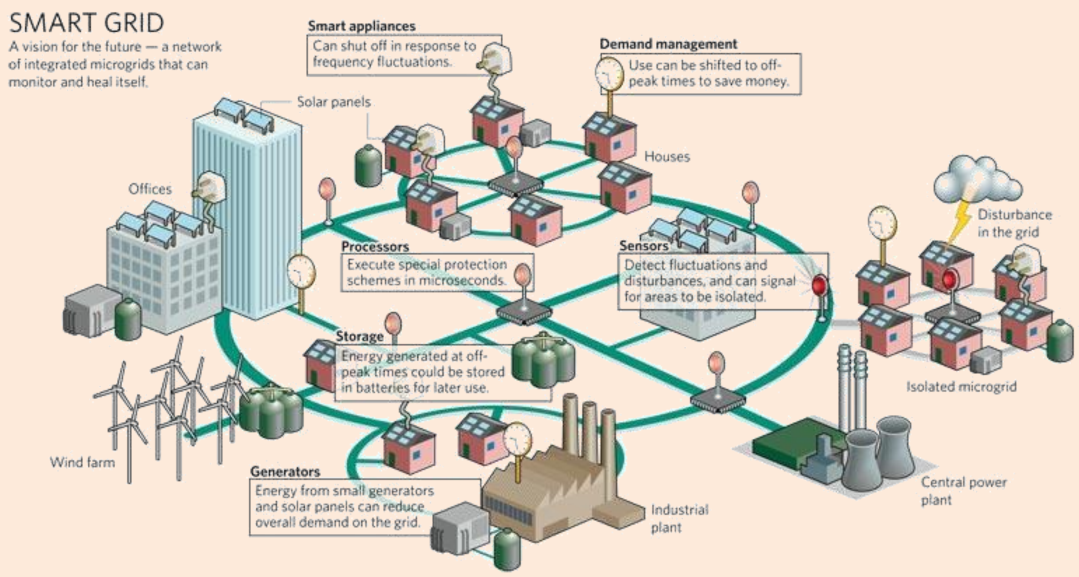
Some Issues (Opportunities) to Address

What's new?
A lot actually, the reinvention of grid as we know it

Technical impacts
Reverse power flows, Grid stability, Fault response

Limitations of current control/management methods
Smart consumption leads to more erratic loads
Limited predictability/controllability of generators
Limited topology information in the LV grid
No monitoring and control of the LV grid
Grid control with millions of measurement and control points

New operating models
Managing small and frequent energy transactions
Managing flexibility options (versus more assets)
Self-consumption and new market models



The Energy Transition

Key grid challenges

Decentralization

Grid edge generation (ex: rooftop solar)
Prosumers (producer + consumer)
Consumer choice and participation
More efficient use of energy

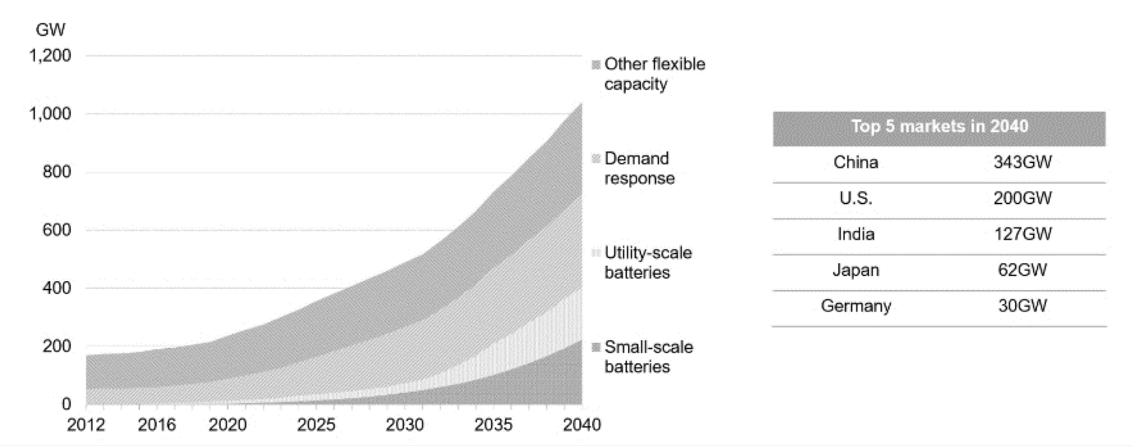
Some Issues (Opportunities) to Address

What's new?
A lot actually, the reinvention of grid as we know it

Technical impacts
Reverse power flows, Grid stability, Fault response

Limitations of current control/management methods
Smart consumption leads to more erratic loads
Limited predictability/controllability of generators
Limited topology information in the LV grid
No monitoring and control of the LV grid
Grid control with millions of measurement and control points

New operating models
Managing small and frequent energy transactions
Managing flexibility options (versus more assets)
Self-consumption and new market models



Flexibility Capacity Worldwide

(New Energy Outlook 2017, BNEF)

The Energy Transition

Key grid challenges

Decentralization

Grid edge generation (ex: rooftop solar)
Prosumers (producer + consumer)
Consumer choice and participation
More efficient use of energy

Some Issues (Opportunities) to Address

What's new?
A lot actually, the reinvention of grid as we know it

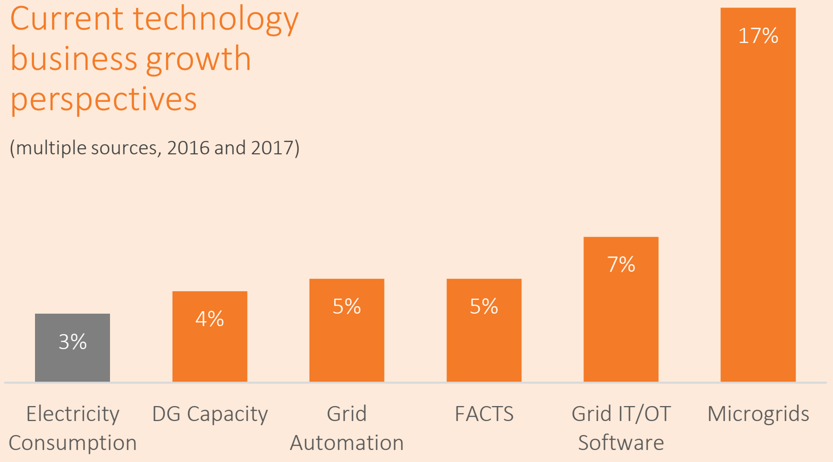
Technical impacts
Reverse power flows, Grid stability, Fault response

Limitations of current control/management methods
Smart consumption leads to more erratic loads
Limited predictability/controllability of generators
Limited topology information in the LV grid
No monitoring and control of the LV grid
Grid control with millions of measurement and control points

New operating models
Managing small and frequent energy transactions
Managing flexibility options (versus more assets)
Self-consumption and new market models

Current technology business growth perspectives

(multiple sources, 2016 and 2017)



The Energy Transition

Key grid challenges

Electrification

Access to electricity worldwide
(rural, islands, developing countries, cities, transportation, industry)
Heating, cooling and electric vehicles

Some Issues (Opportunities) to Address

New solutions for bulk transmission build
Lead time and cost reduction

New electrification/grid models
Autonomous microgrids based on renewables and storage

1.1 billion
have no access to electricity (14%)

1 billion
have intermittent access (13%)

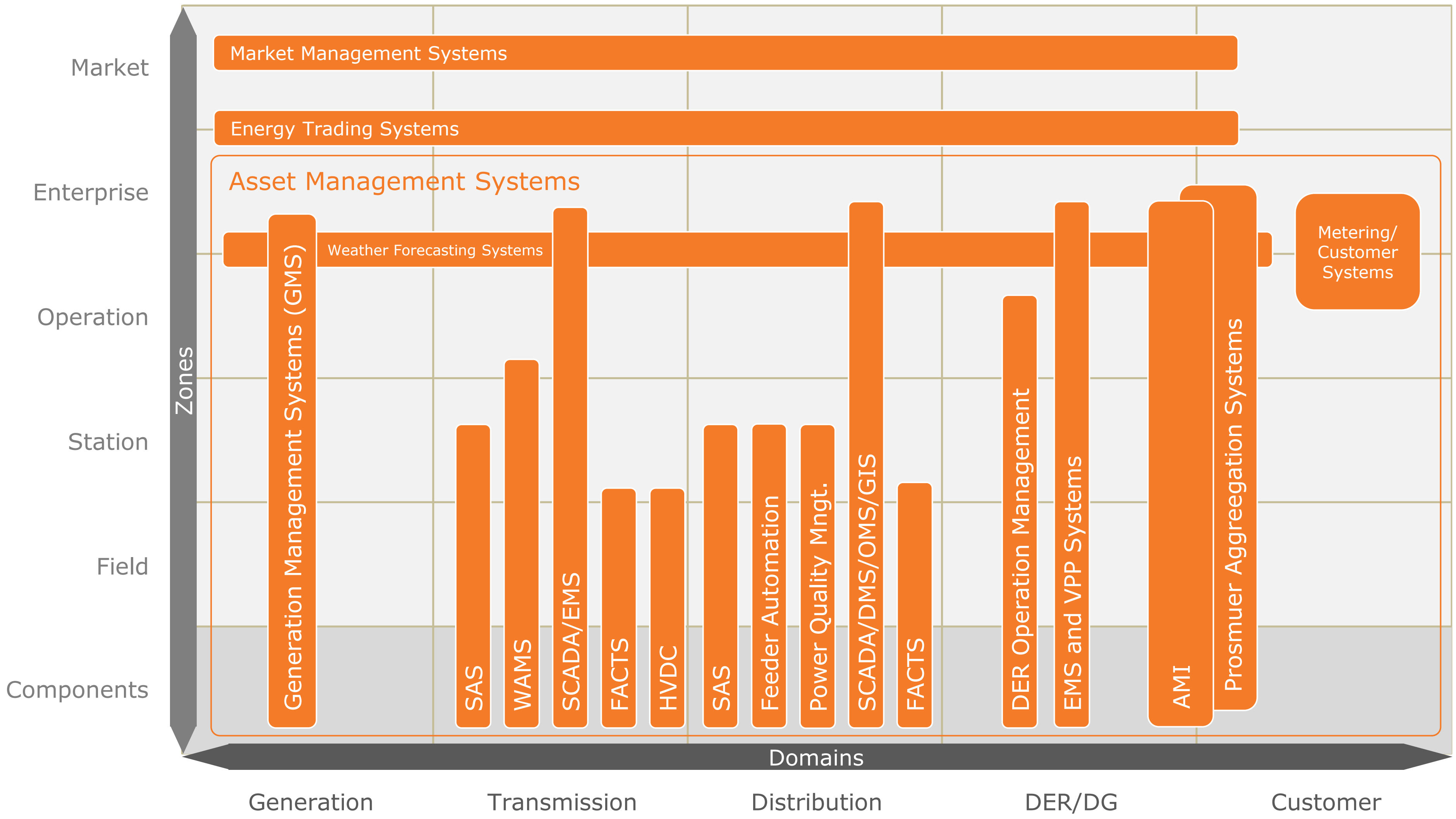
2.3 billion
have no clean cooking facilities (30%)

2.8 million
die prematurely from household air pollution

Think about:
Education, Health, Quality of living, etc.

(International Energy Agency)

Smart Grid Architecture Model (SGAM)

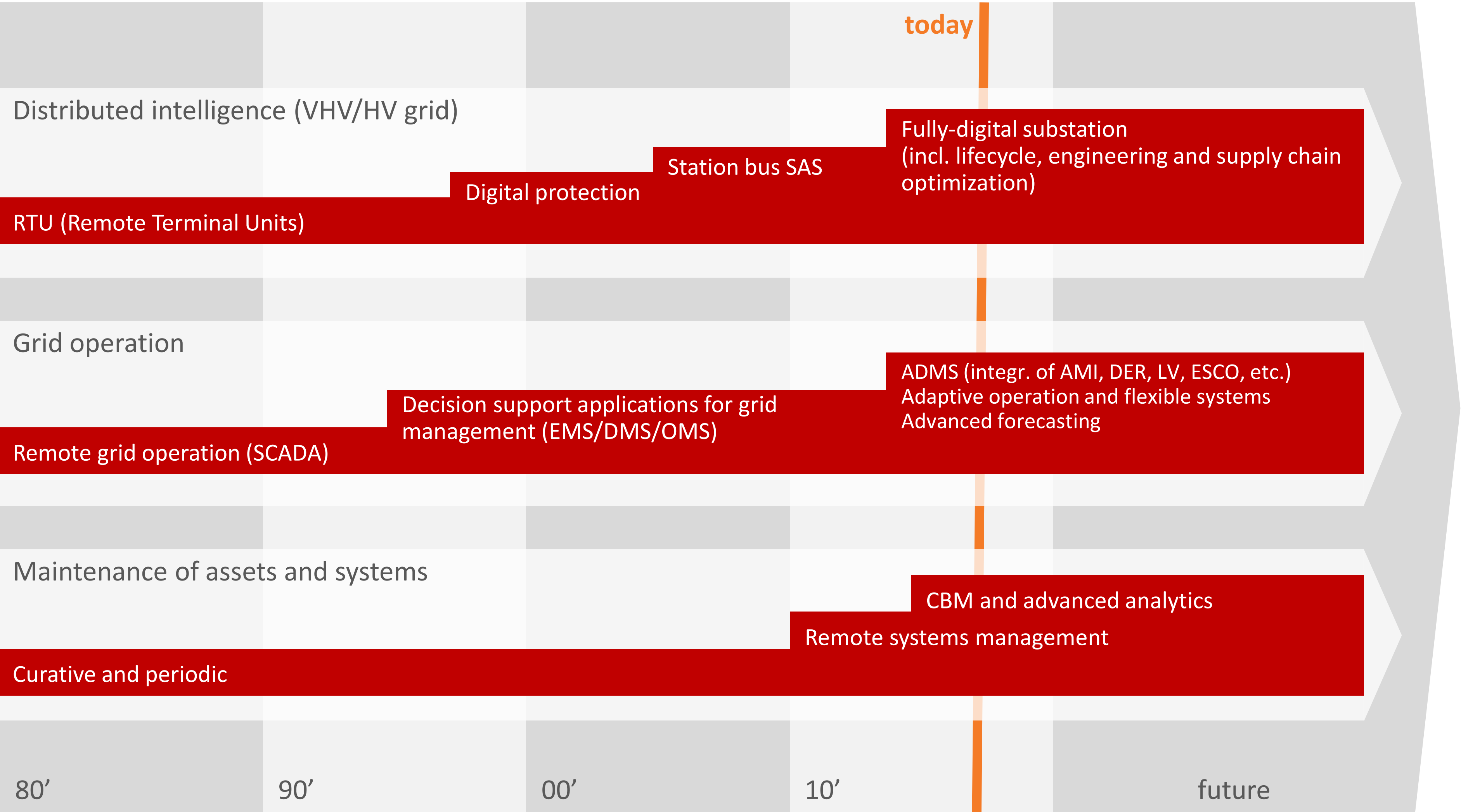


SGAM Model, CEN-CENELEC-ETSI Smart Grid Coordination Group, 2012

Smart Grid Technologies

Digital and IoT have been a reality in the grid for many years…

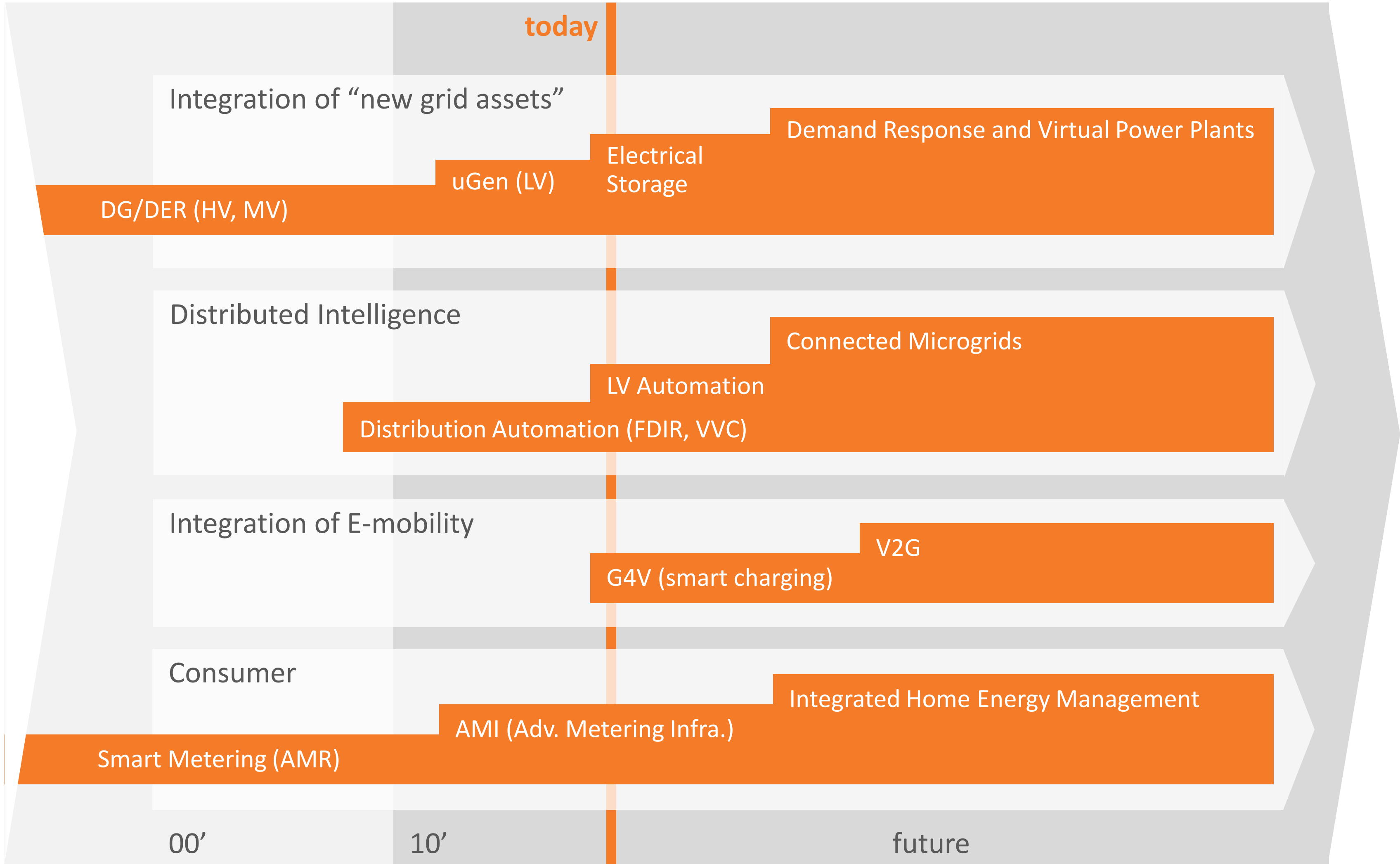
Evolution of smart grid technologies @ the grid core



Smart Grid Technologies

…but the future is data-driven on all grid management technologies

Evolution of smart grid technologies @ the edge of the grid



Smart Grid Data and Applications

Highly heterogenous: source, structure, volume, quality, time requirements, access method, applications, etc.

Structured Data

All sorts of time series data from equipment and systems (statuses, measured values, signals, controls, events, power quality and disturbance data, etc.)

Calculated data from state estimation and other power applications such as EMS, DMS or ADMS systems or edge device operation

Asset, device and function characteristics and parameters

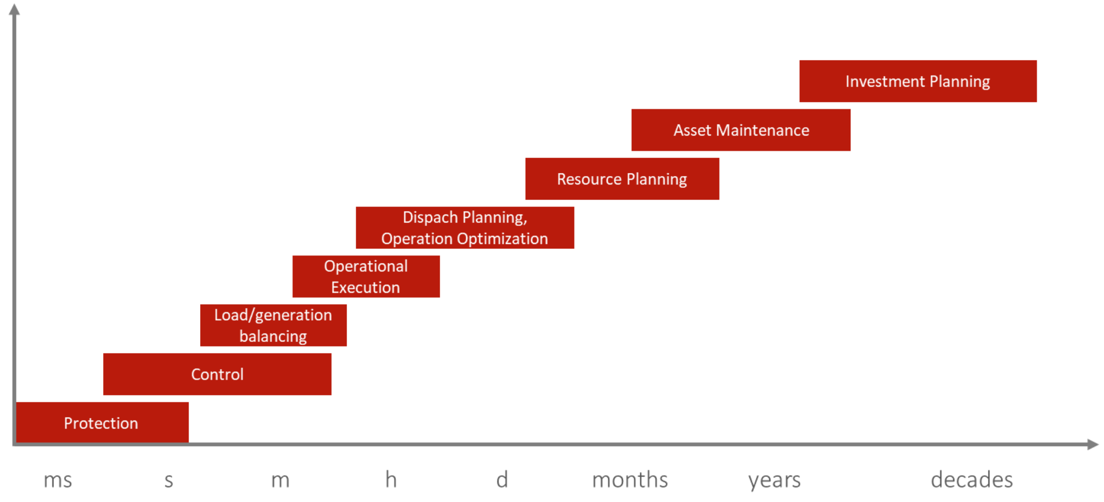
Semi-structured Data

Field-force information, maintenance data, video surveillance, cybersecurity data, economic data, business process data, context information for real-time data

Unstructured Data

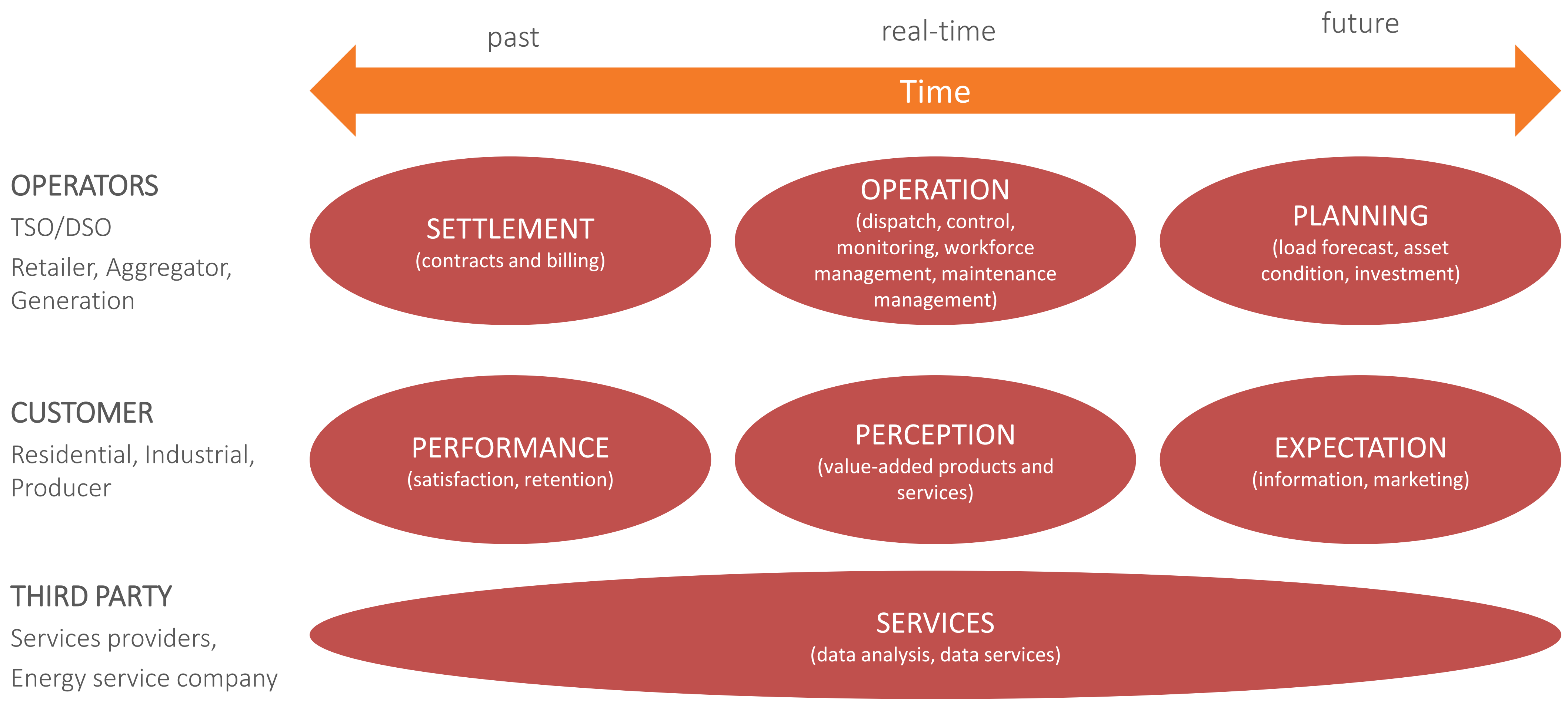
Customer service data, meteorological information, social media, energy usage patterns, technical documents, practical knowledge

Real-time response requirements for typical grid applications



Smart Grid Data and Applications

Highly heterogenous: source, structure, volume, quality, time requirements, access method, applications, etc.



adapted from “Data analytics in the electricity sector”, DNV GL, 2018

Challenges

Mostly Technical

Data Volume

Data Availability

Data Quality

Interoperability

Algorithm Design and Validation

Cybersecurity

Data Security

Mostly Non-technical

Empowerment of Grid Users

Scarcity of Human Resources

Regulation

Business Case

2

Use Cases

Examples where data science can deliver value

Smart Alarms

Alarm management in MV and LV networks with high penetration of edge devices

Problem

Volume and velocity of event generation generates too many power system alarms for control room operators to analyze and react in real-time.

Grid edge is large and too complex and dynamic to **setup alarm rules through conventional methods** (ex: GIS mapping frequently not available).

Solution

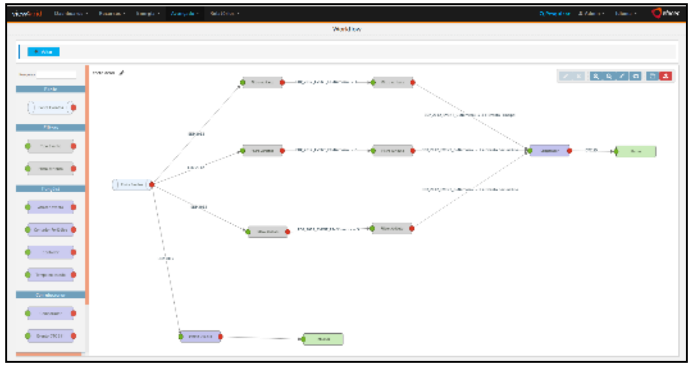
Real-time automatic alarm grouping and causal hierarchization
Enables assisted identification of distinct events and root cause analysis

How

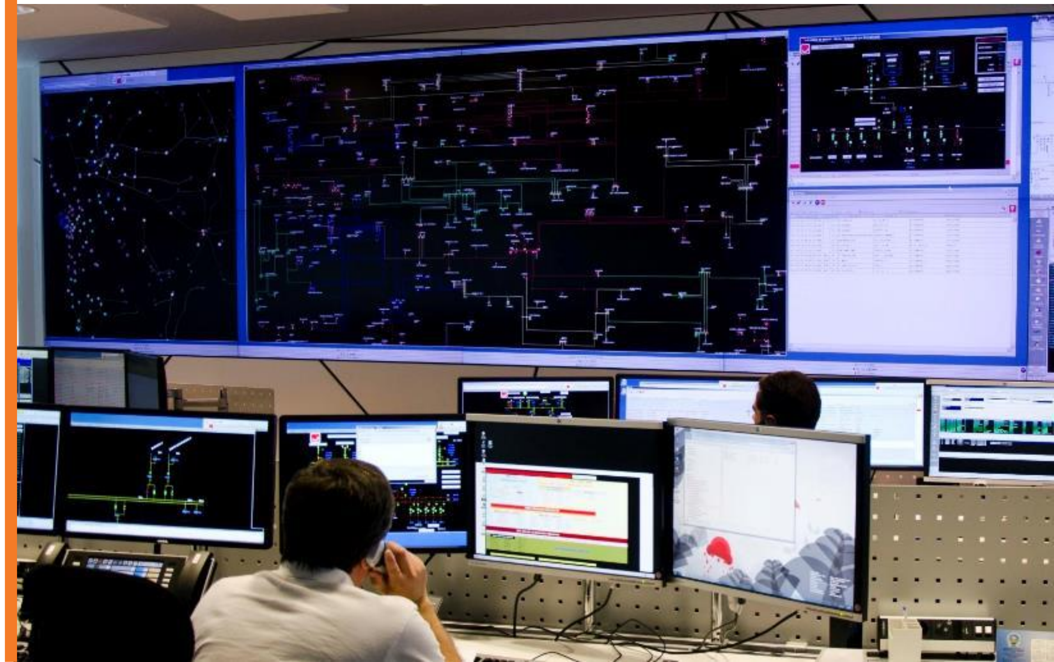
Time-based correlation of data using Apache Storm engine in SCADA/ADMS alarm system.
Automatic configuration of Apache Storm topology based on grid and communication model.

Possible Next Step?

Combining expert rules with incomplete model base?
Machine learning from operator actions?



Efacec SCATEX SCADA/DMS @ EDP Distribuição



Asset Health Management

Ascertain current asset health condition and provide asset management recommendations

Problem

Reduce **cost of maintenance**, **extend life** or **control overloading** of critical assets while ensuring reliable performance.

Critical assets are expensive and consequences of failures are significant.

Solution

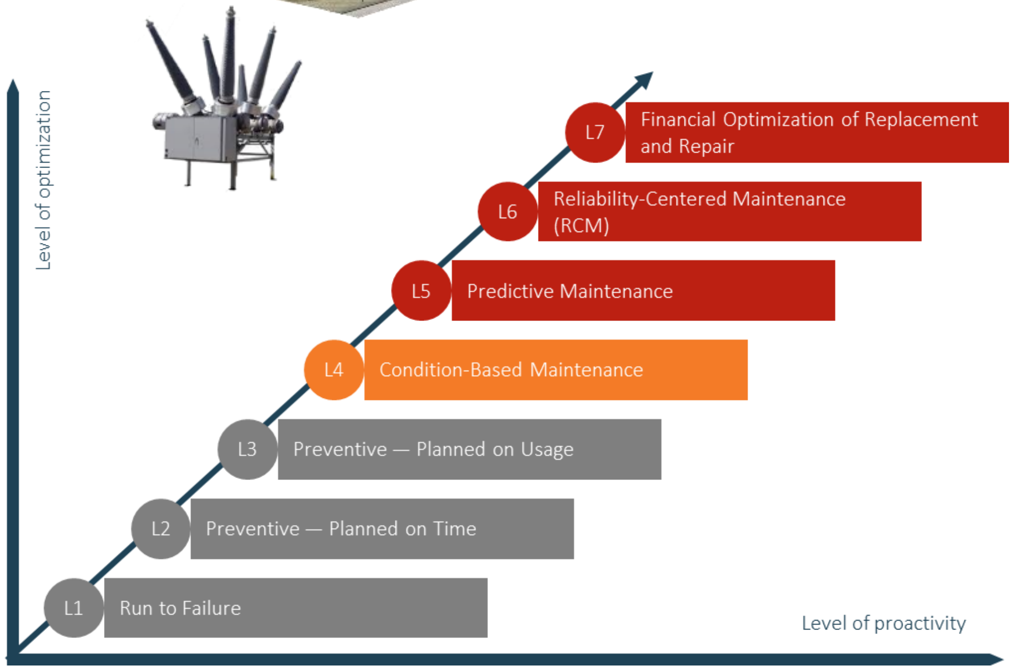
Combine data analytics with domain knowledge to deliver **accurate health indexes** of critical assets based on a mix of online and historical operational and maintenance data and deliver **recommendations** based on condition. **Rank** and **prioritize assets** and action by combining risk and health.

How

Use of cloud-based analytics, real-time platform and IT systems integration. Solutions delivered by interdisciplinary teams.

Possible Next Step?

Loss of life prediction under grid operating conditions?
Predictive and prescriptive analytics?
Providing dynamic rating options for grid operators?



Asset Health Management

Ascertain current asset health condition and provide asset management recommendations

Problem

Reduce **cost of maintenance**, **extend life** or **control overloading** of critical assets while ensuring reliable performance.

Critical assets are expensive and consequences of failures are significant.

Solution

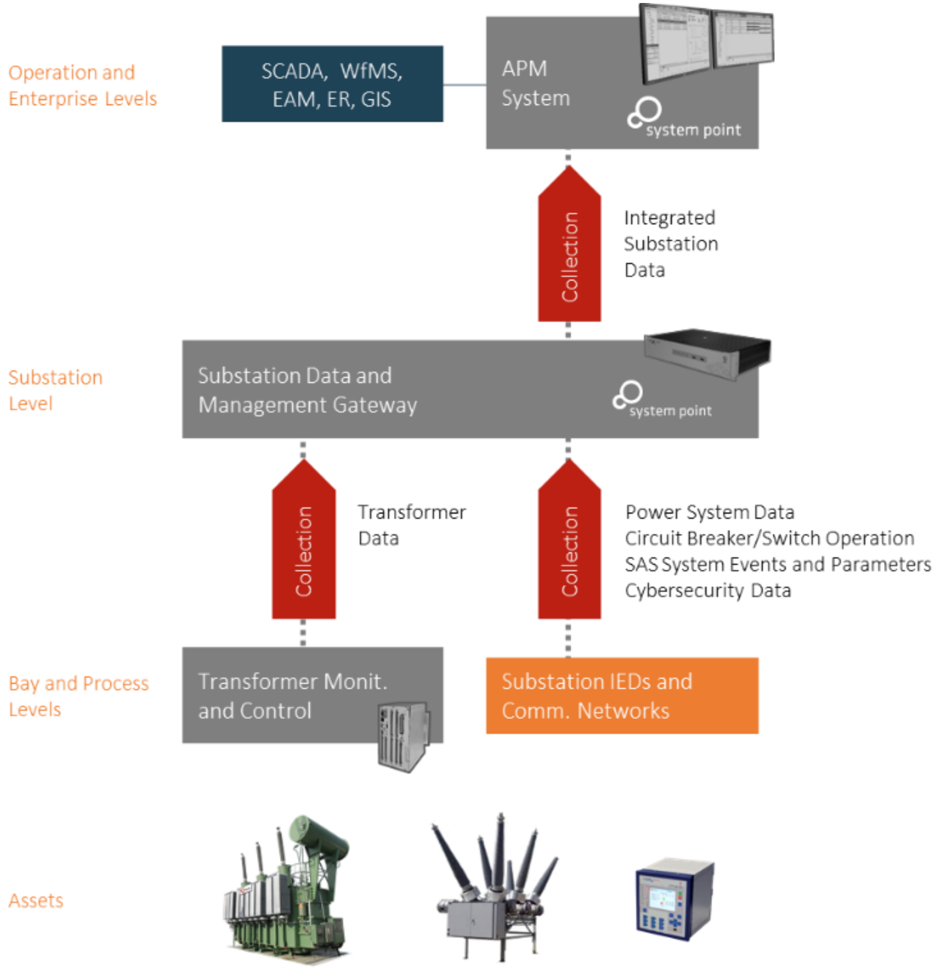
Combine data analytics with domain knowledge to deliver **accurate health indexes** of critical assets based on a mix of online and historical operational and maintenance data and deliver **recommendations** based on condition. **Rank** and **prioritize assets** and action by combining risk and health.

How

Use of cloud-based analytics, real-time platform and IT systems integration. Solutions delivered by interdisciplinary teams.

Possible Next Step?

Loss of life prediction under grid operating conditions?
Predictive and prescriptive analytics?
Providing dynamic rating options for grid operators?



Asset Health Management

Ascertain current asset health condition and provide asset management recommendations

Problem

Reduce **cost of maintenance**, **extend life** or **control overloading** of critical assets while ensuring reliable performance.

Critical assets are expensive and consequences of failures are significant.

Solution

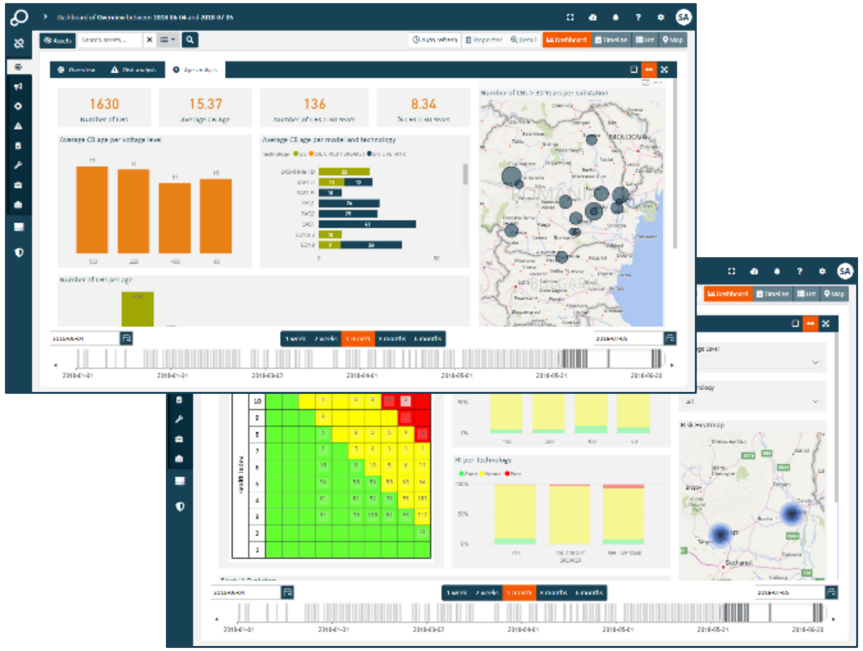
Combine data analytics with domain knowledge to deliver **accurate health indexes** of critical assets based on a mix of online and historical operational and maintenance data and deliver **recommendations** based on condition. **Rank** and **prioritize assets** and action by combining risk and health.

How

Use of cloud-based analytics, real-time platform and IT systems integration. Solutions delivered by interdisciplinary teams.

Possible Next Step?

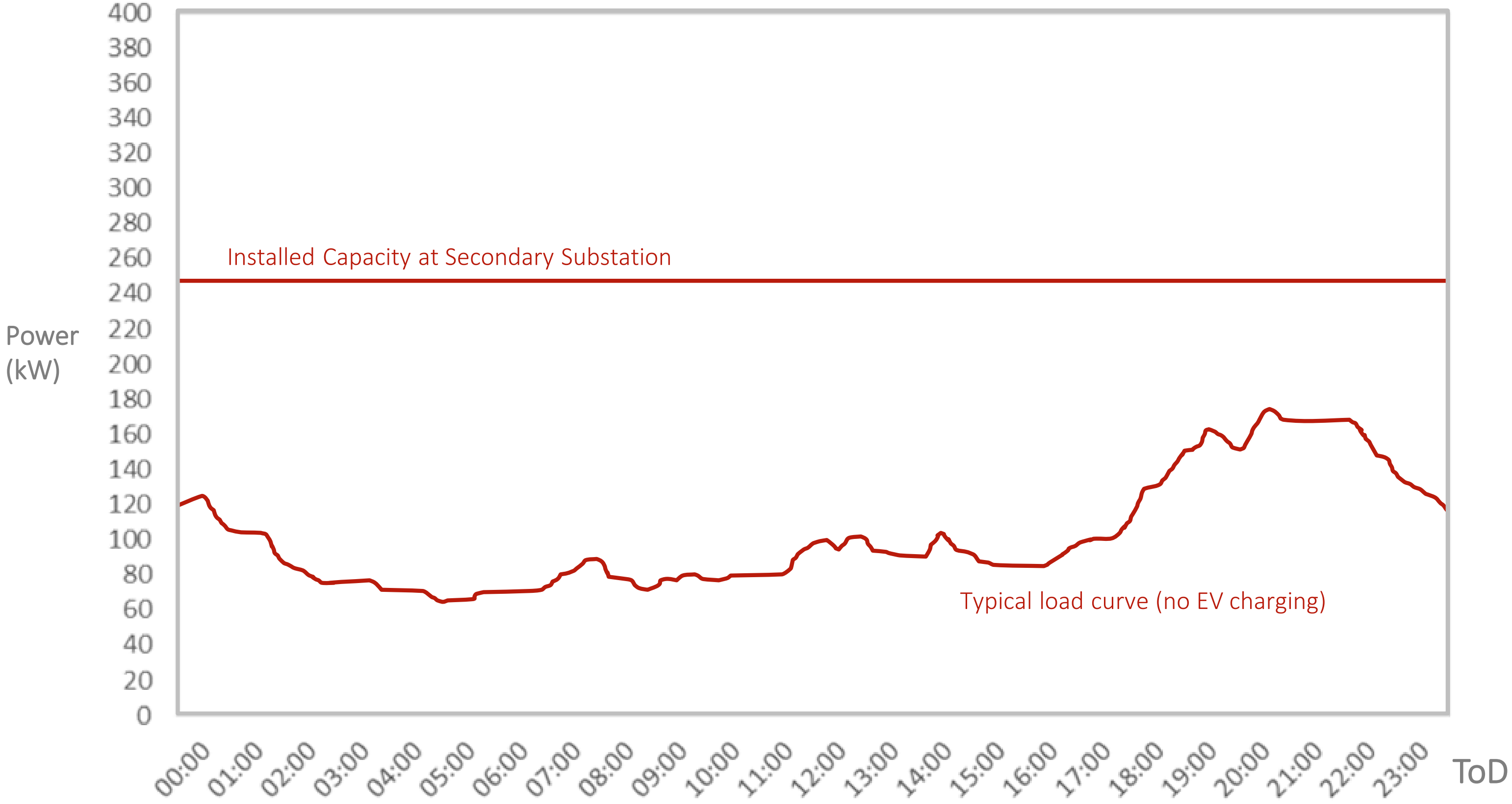
Loss of life prediction under grid operating conditions?
Predictive and prescriptive analytics?
Providing dynamic rating options for grid operators?



EV Charging

Impact on the Grid: Energy (kWh) is not an issue

Load Diagram (Secondary Distribution Substation) *



Charging power levels today in EU **

A) Normal power Private and semi-public	**AC**	< 3.7 kW (10 - 16 A) 1phase
B) Medium power Private and semi-public	**AC**	3.7 kW (16A) – 22 kW (32 A) 1 or 3phase
B) High power AC Public and semi-public	**AC**	> 22 kW (> 32 A) 3phase
C) High-power DC Public	**DC**	> 22 kW (> 32 A)

Evolution in power requirements for fast charging **

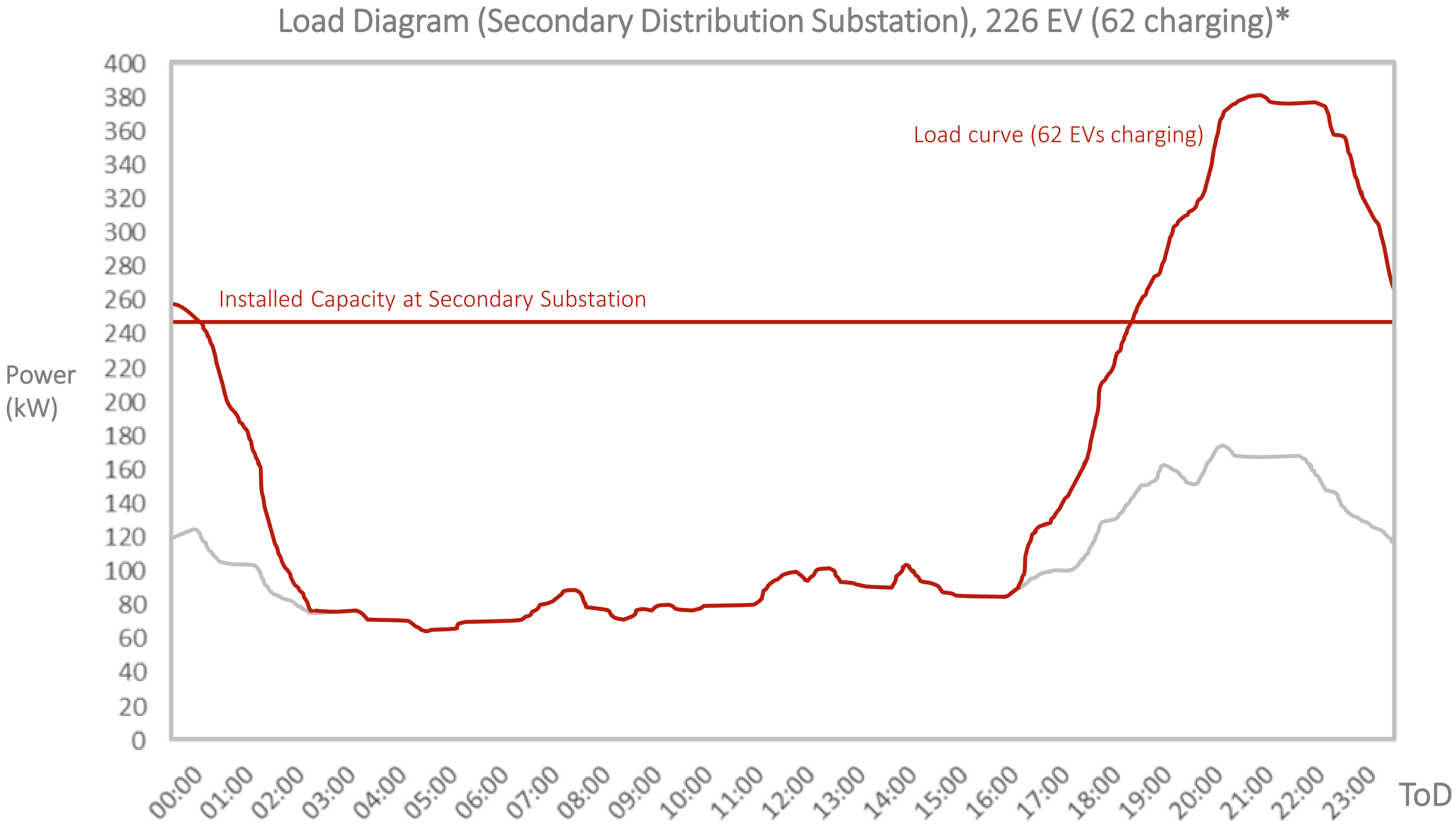
Year	Fast power DC chargers
2016	60 kW (300 km/h)
2020	100 kW (500 km/h)
2025	200 kW (1,000 km/h)
2030	250 kW (1,250 km/h)
2035	300 kW (1,500 km/h)

* Source of analysis: EDP Distribuição

** Smart charging: integrating a large widespread of electric cars in electricity distribution grids, EDSO, March 2018

EV Charging

Impact on the Grid: Instantaneous capacity demand (kW) on LV is problematic



Charging power levels today in EU **

A) Normal power Private and semi-public	**AC**	< 3.7 kW (10 - 16 A) 1phase
B) Medium power Private and semi-public	**AC**	3.7 kW (16A) – 22 kW (32 A) 1 or 3phase
B) High power AC Public and semi-public	**AC**	> 22 kW (> 32 A) 3phase
C) High-power DC Public	**DC**	> 22 kW (> 32 A)

Evolution in power requirements for fast charging **

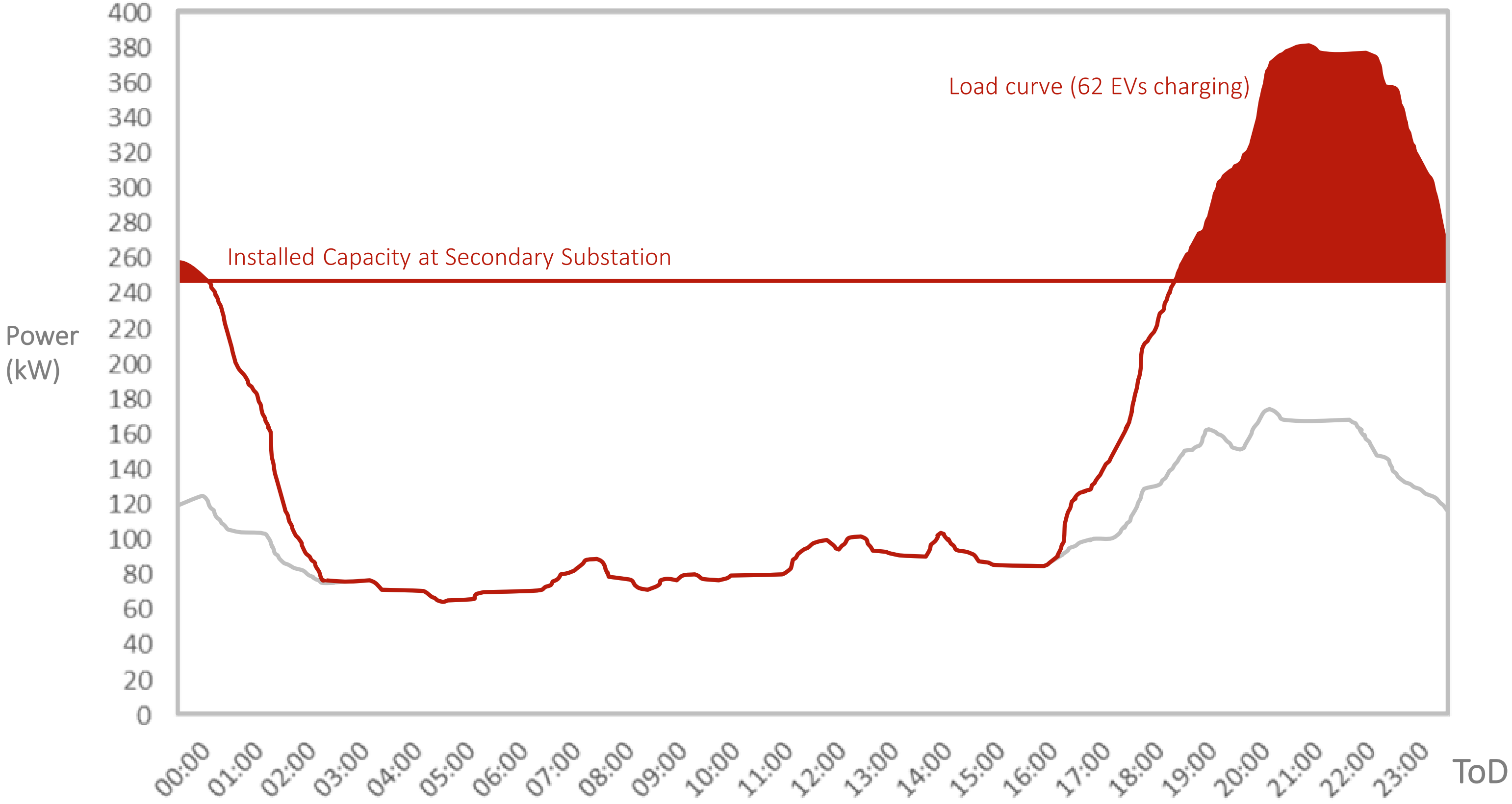
Year	Fast power DC chargers
2016	60 kW (300 km/h)
2020	100 kW (500 km/h)
2025	200 kW (1,000 km/h)
2030	250 kW (1,250 km/h)
2035	300 kW (1,500 km/h)

* Source of analysis: EDP Distribuição
** Smart charging: integrating a large widespread of electric cars in electricity distribution grids, EDSO, March 2018

EV Charging

Impact on the Grid: curtailing is not an option

Load Diagram (Secondary Distribution Substation), 226 EV (62 charging)*



Charging power levels today in EU **

A) Normal power Private and semi-public	**AC**	< 3.7 kW (10 - 16 A) 1phase
B) Medium power Private and semi-public	**AC**	3.7 kW (16A) – 22 kW (32 A) 1 or 3phase
B) High power AC Public and semi-public	**AC**	> 22 kW (> 32 A) 3phase
C) High-power DC Public	**DC**	> 22 kW (> 32 A)

Evolution in power requirements for fast charging **

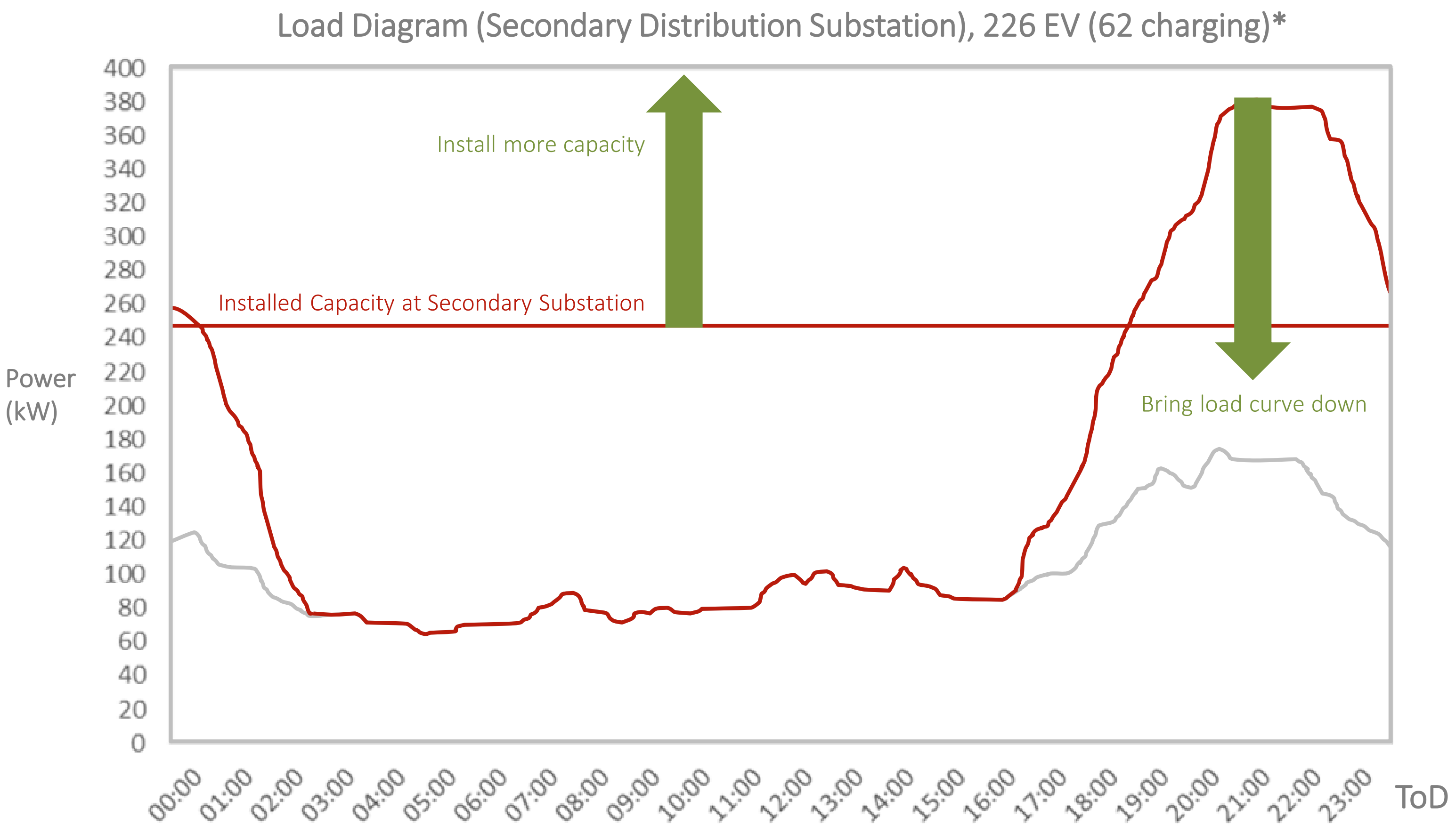
Year	Fast power DC chargers
2016	60 kW (300 km/h)
2020	100 kW (500 km/h)
2025	200 kW (1,000 km/h)
2030	250 kW (1,250 km/h)
2035	300 kW (1,500 km/h)

* Source of analysis: EDP Distribuição

** Smart charging: integrating a large widespread of electric cars in electricity distribution grids, EDSO, March 2018

EV Charging

Impact on the Grid: curtailing is not an option



1) Reinforce LV Infrastructure

Increase transformer capacity, LV lines and feeders to meet new peak demand

2) Manage Demand

Use tariffs to mitigate effects (indirect load control)

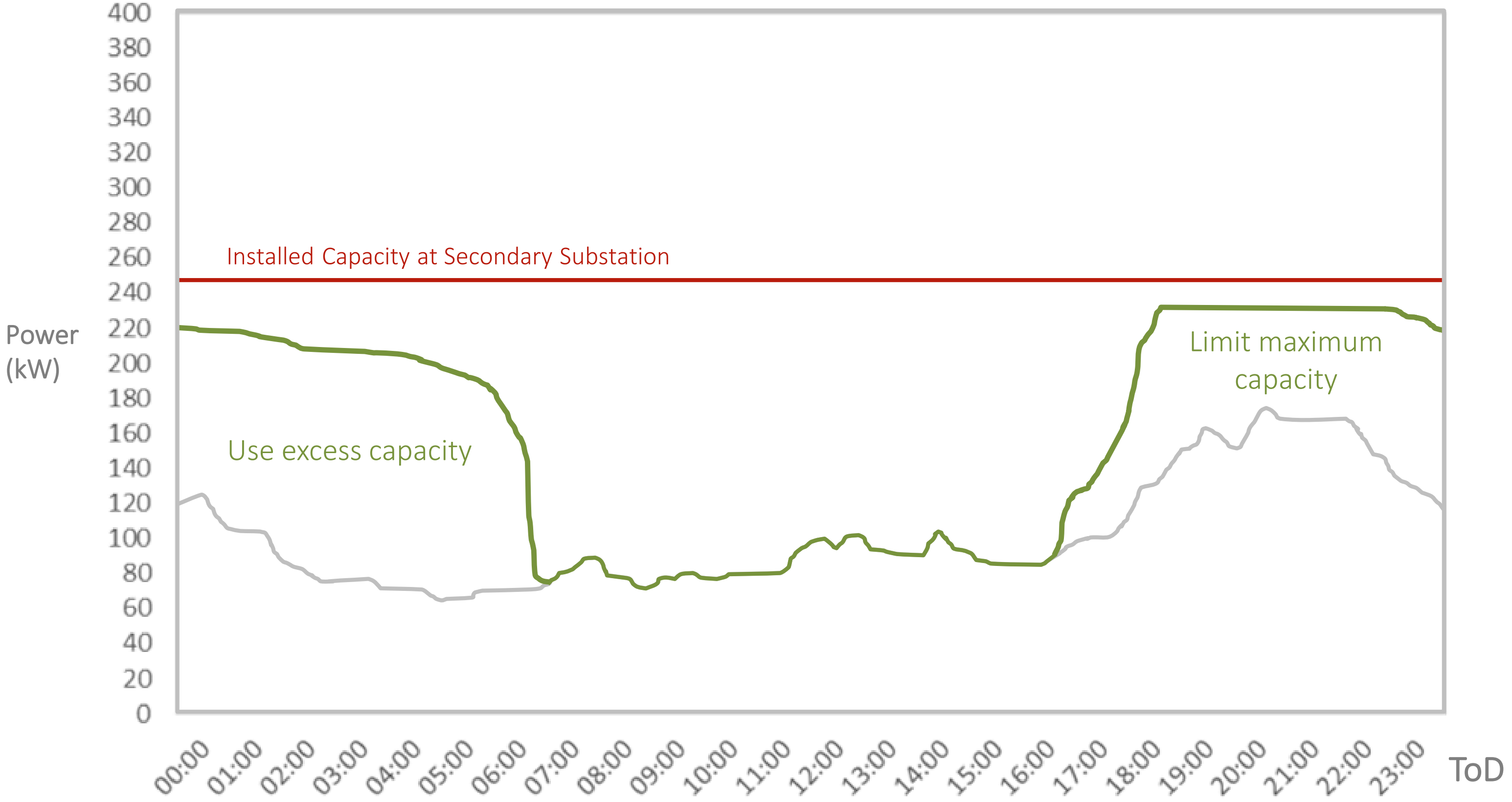
Employ smart charging technologies (direct load control)

* Source of analysis: EDP Distribuição

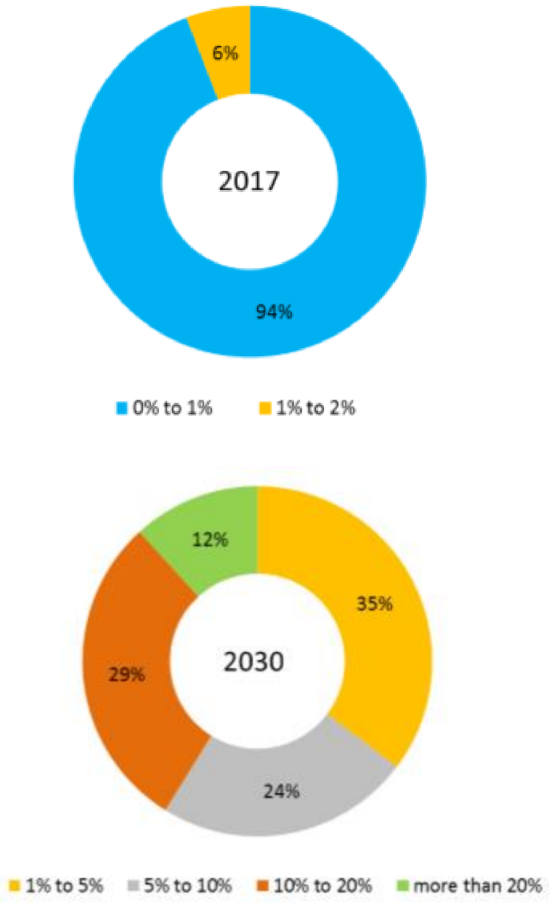
EV Charging

Impact on the Grid

Load Diagram (Secondary Distribution Substation), 226 EV (62 charging) with Smart Charging*



EU DSO EV Adoption Expectation Survey **



* Source of analysis: EDP Distribuição

** Smart charging: integrating a large widespread of electric cars in electricity distribution grids, EDSO, March 2018

EV Smart Charging

Integrate fast chargers into the grid at optimal cost by managing flexibility

Problem

EV chargers have high power requirements that exceed low-voltage grid connection rating

EV charging loads are not controllable by grid or infrastructure operators

Users are mobile and have dynamic power needs

Solution

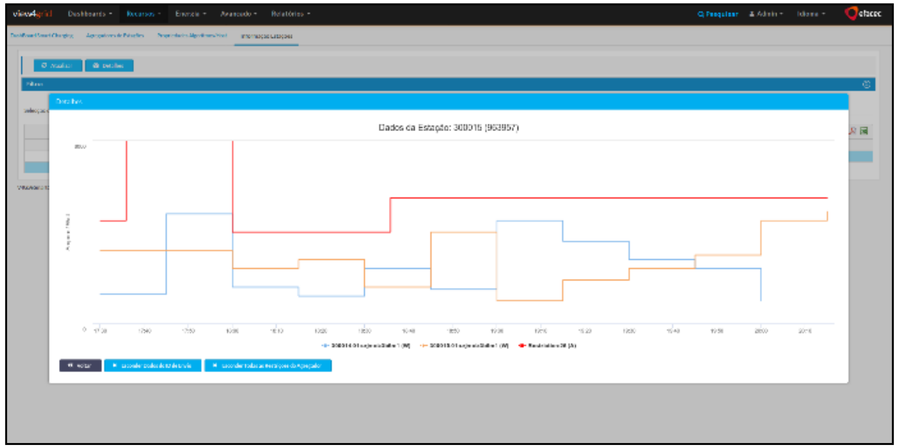
Controlled charging through online management platforms that combine grid constraint information with EV usage profiles to limit power output without driver impact

How

IoT-enabled charging infrastructure combined with real-time EV CP management platform connected to grid information

Possible Next Step?

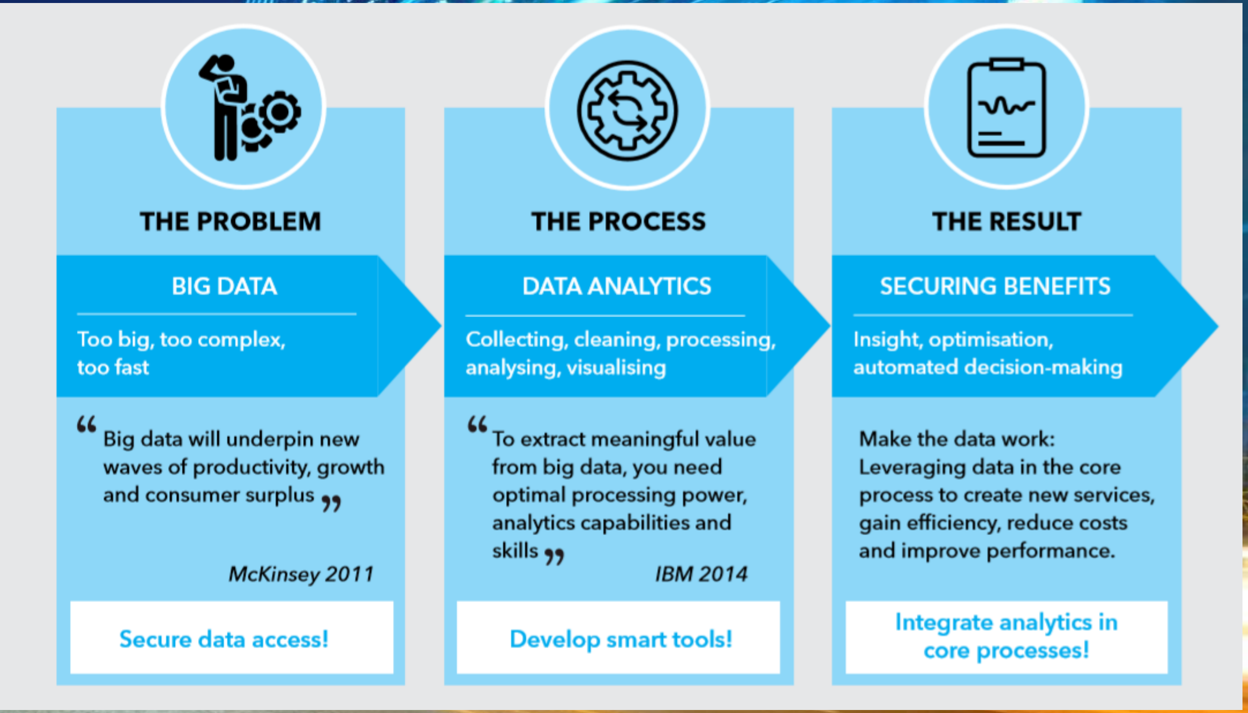
Integrating user behavior prediction?
Integrating grid short-term forecasts (ex: combining with local solar generation)?
Integrating V2G capabilities?



A few other examples of application domains in the Power Grid context

There is no shortage of use cases for data science applications in the Power Grid

- Fault/failure prediction and error/anomaly finding
- Dynamic rating and predictive control
- ML-based adaptive control
- Self-healing and autonomous area control systems
- System-wide power quality management
- Identification of "non-technical losses" (a.k.a. energy theft)
- Systems Management
- Cybersecurity Monitoring (ML-based anomaly detection)
- Grid topology identification
- Real-time energy balancing and power flow management
- Transient stability analysis, state estimation and load flow (PMU-based)
- Faster than real-time network analysis
- Optimum power flow and optimum network configuration
- Renewable resource spatial-temporal renewable forecast and dispatch (wind and sun)
- Demand (load/generation/flexibility) spatial-temporal forecasting (weather, behavior, DER, transportation)
- Load profiling and disaggregation
- Local congestion management (MV and LV grid)
- Automated demand response
- Aggregator management systems (industrial, commercial, residential, etc.)



in “Data analytics in the electricity sector”, DNV GL, 2018

Wrap-up

Join us in the effort!

Wrap-up

Join us in the effort!