LUT
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University of Technology

LUT developments on microgrids-related research

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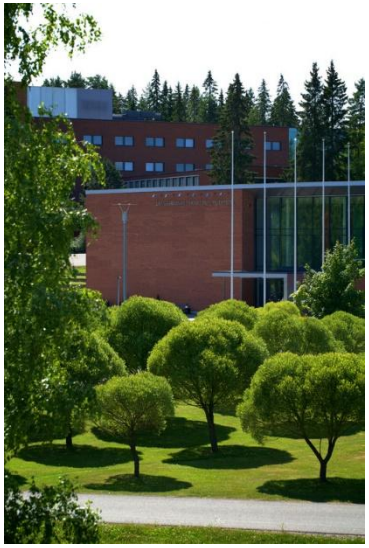
Lappeenranta University of Technology

School of Energy Systems

Bucharest 2018 Symposium on Microgrids, Sep 2-6 2018

LUT: Hierarchical structure



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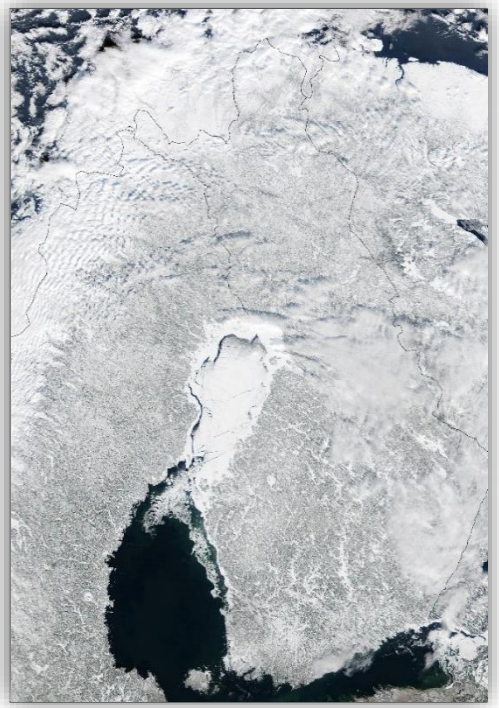
LEMPS

LEMPS: Lab. of Electricity Markets & Power Systems

Finland: “Land of a thousand lakes”

Finland is a very particular country!

- The 5th largest in the EU, but the **least densely-populated** one
- Houses approximately **187.000 lakes** (one for every 26 Finns)
- Water makes up **10% of its area**, and **>60% is forested**
- Land area dominated by **rural environments (>70%)**
- Population strongly **concentrated in urban areas** (**>70%**)



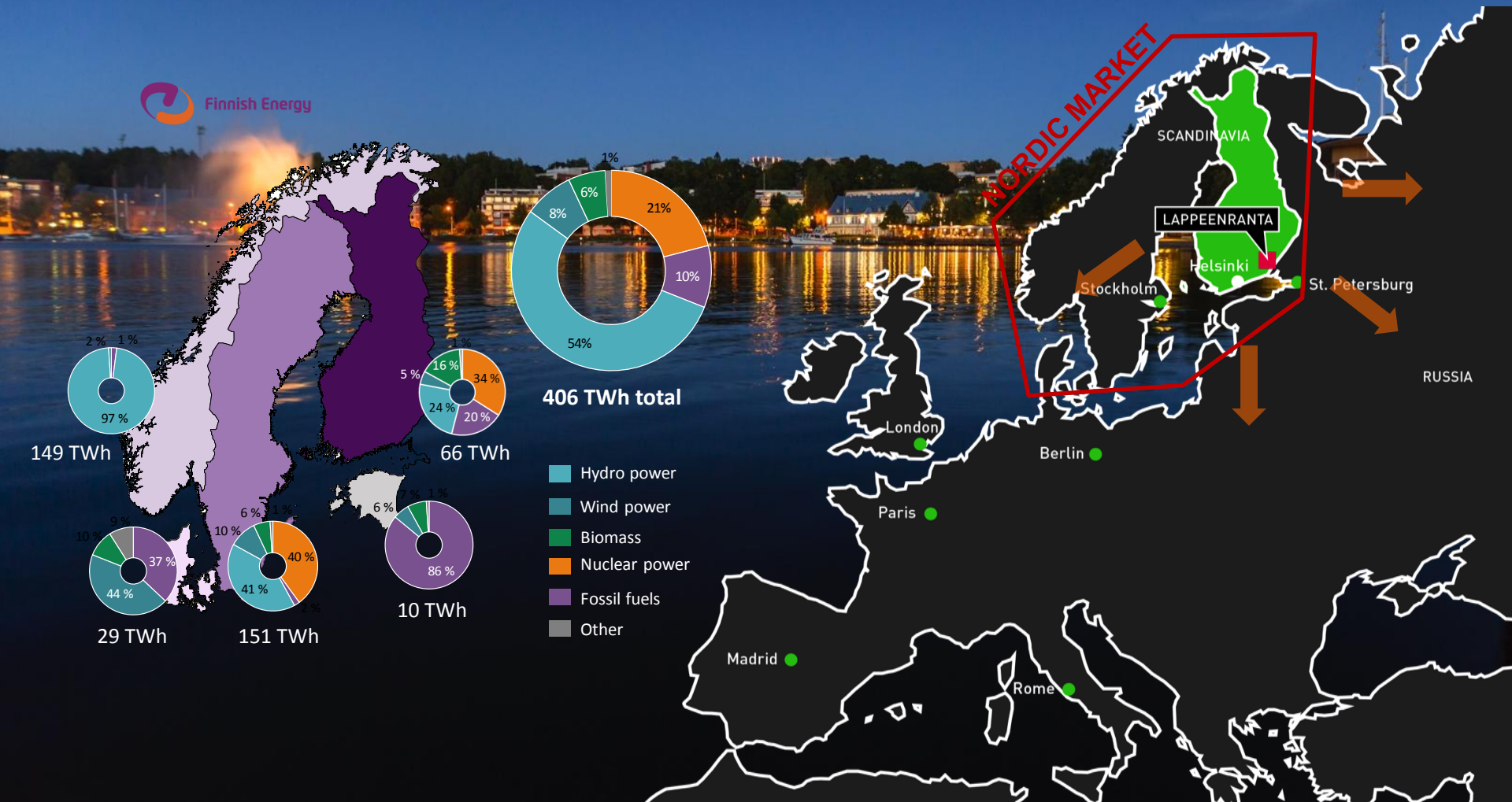
U - Urban (5%) → 70% p.

PU - Peri-urban (25%), 25% p.

R - Rural (70%) → 5% p.

FINLAND

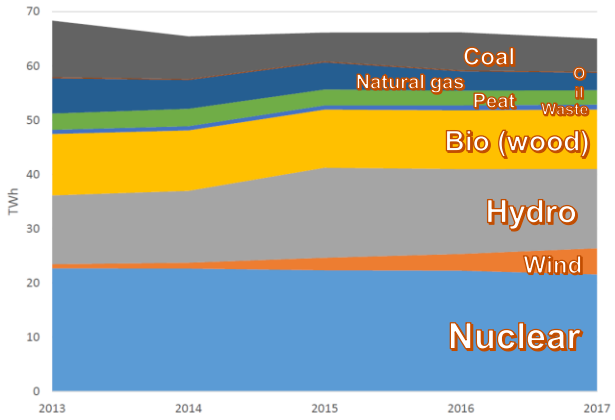
International crossroads



National electric generation mix

The country depends largely on **nuclear (33%)** and **hydro (23%)** resources - 2017

- Close to **50% RES electricity**, but wind power less than 8% and solar is negligible
- **Inflexible generation increasing** due to nuclear and wind capacity additions



65 TWh

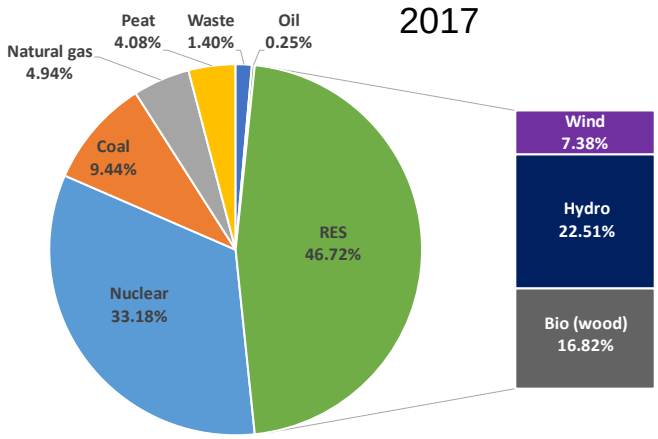
Totals (TWh)

Finnish Energy

Electricity generation in Finland

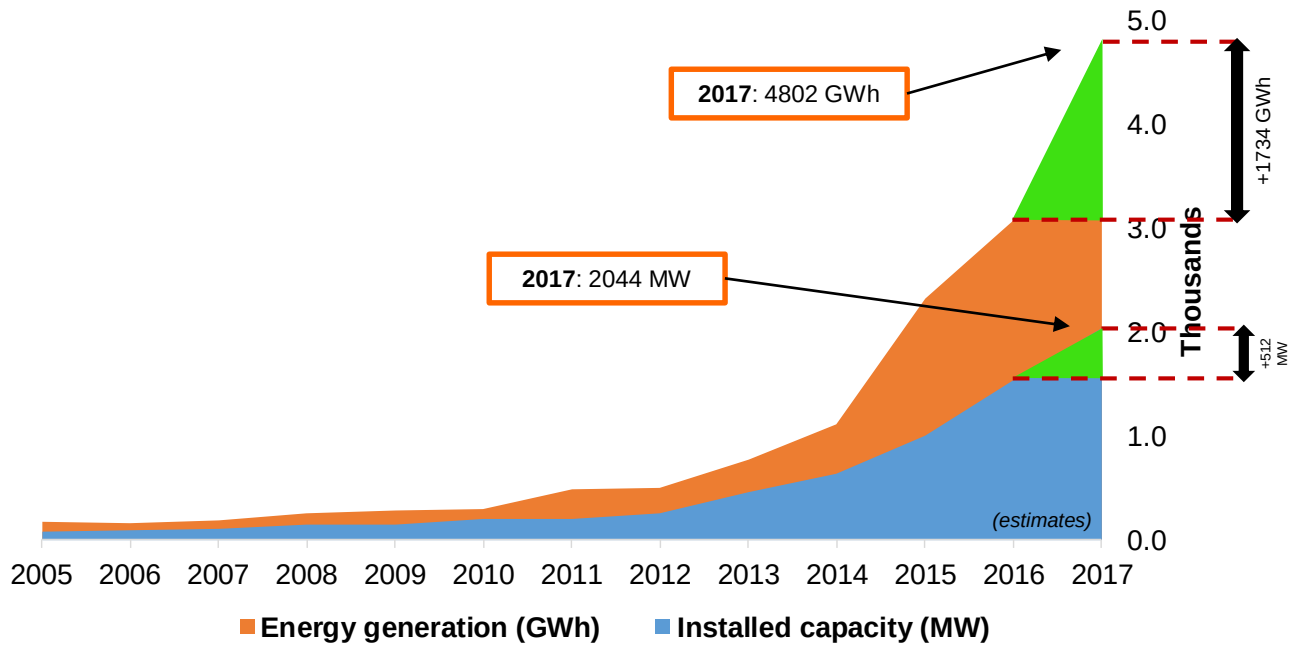
(exports and imports excluded)

Shares (%)



Development of intermittent capacity

The **wind power capacity** is expected to double from 2016 to 2020



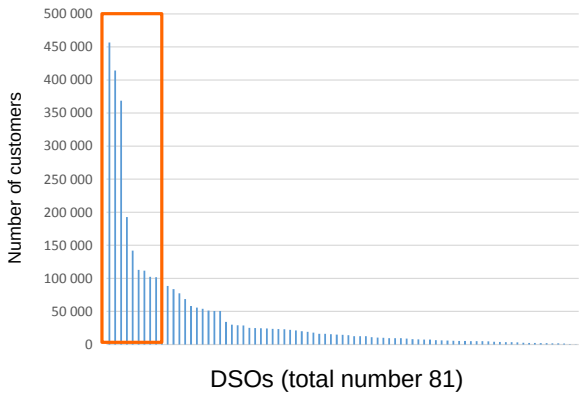
Finnish Energy

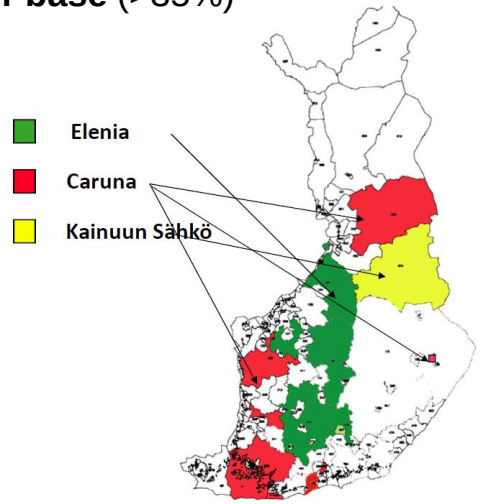
Structure of the electricity sector

The Finnish electricity sector was partially deregulated in 1998

- Generation, Retail and Wholesale became then **free competitive markets**
- Transmission and Distribution are still **monopolistic markets**
- Over 80 locally-regulated DSOs (3.5M c.) but 3 **dominate customer base** (>35%)

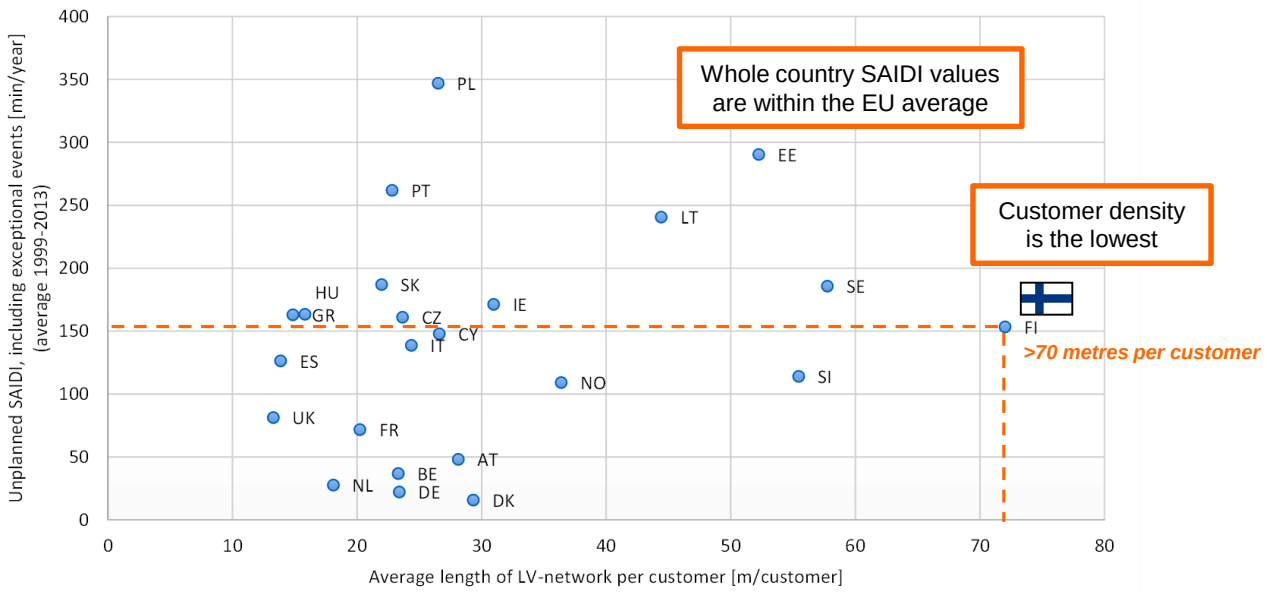
	DSO	Customers
1	Caruna Oy	455 986
2	Elenia Oy	414 049
3	Helen Sähköverkko Oy	367 879
4	Caruna Espoo Oy	192 544
5	Tampereen Sähköverkko Oy	141 979
6	Savon Voima Verkko Oy	112 732
7	Vantaan Energia Sähköverkot Oy	111 568
8	Kymenlaakson Sähköverkko Oy	102 206
9	Järvi-Suomen Energia Oy	101 632
10	Oulun Energia Siirto ja Jakelu Oy	97 220





Electricity distribution: EU comparison

SAIDI vs. Relative LV network length

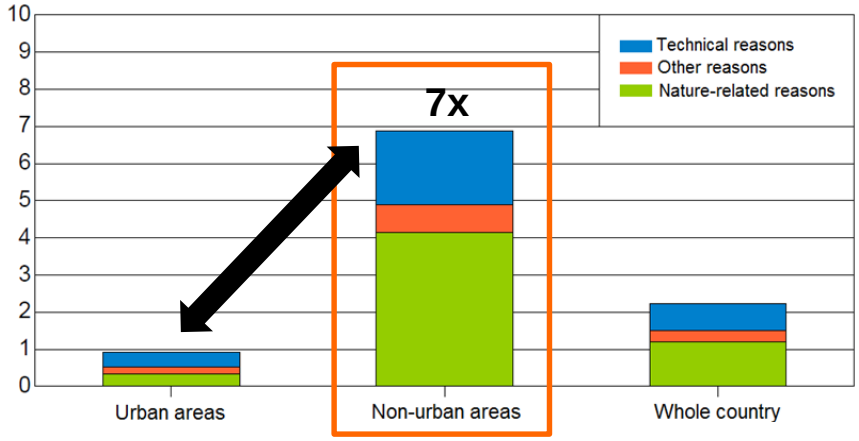


CEER
Council of European Energy Regulators

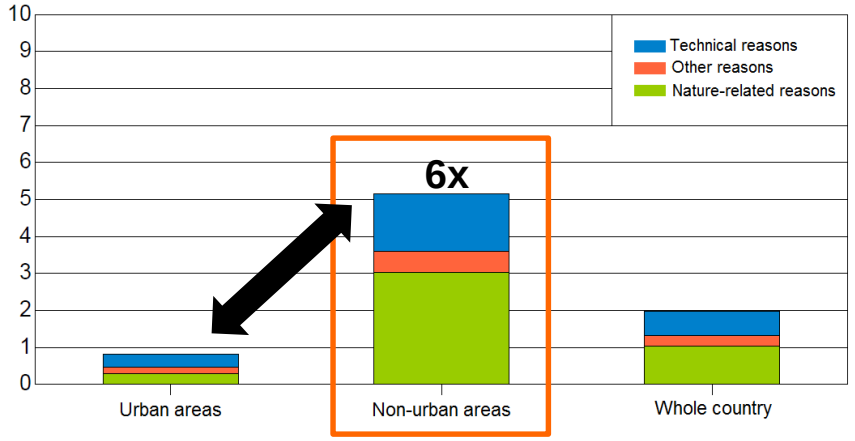
Electricity distribution: Performance

- **SAIFI** (and **SAIDI**) diverge significantly between urban and rural areas

SAIFI 2016



SAIFI 2017



- New regulation: From 2013, caps exist for outage duration

energy authority

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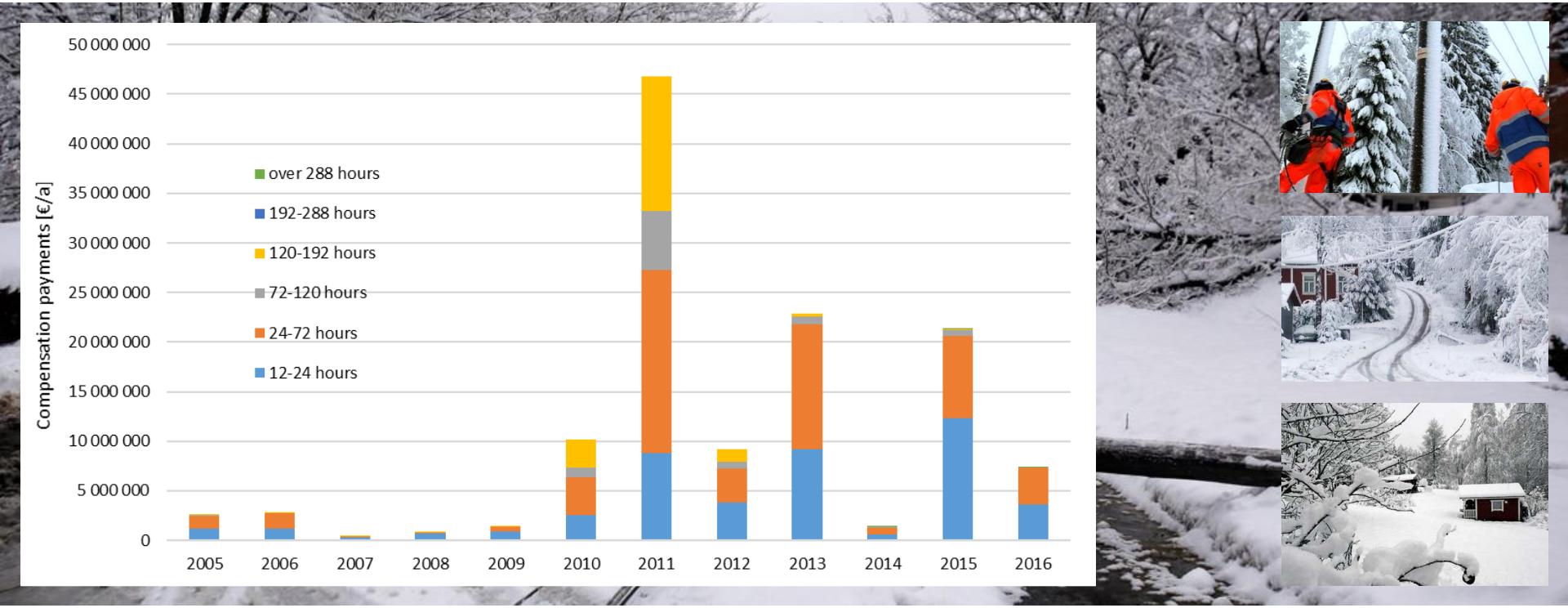
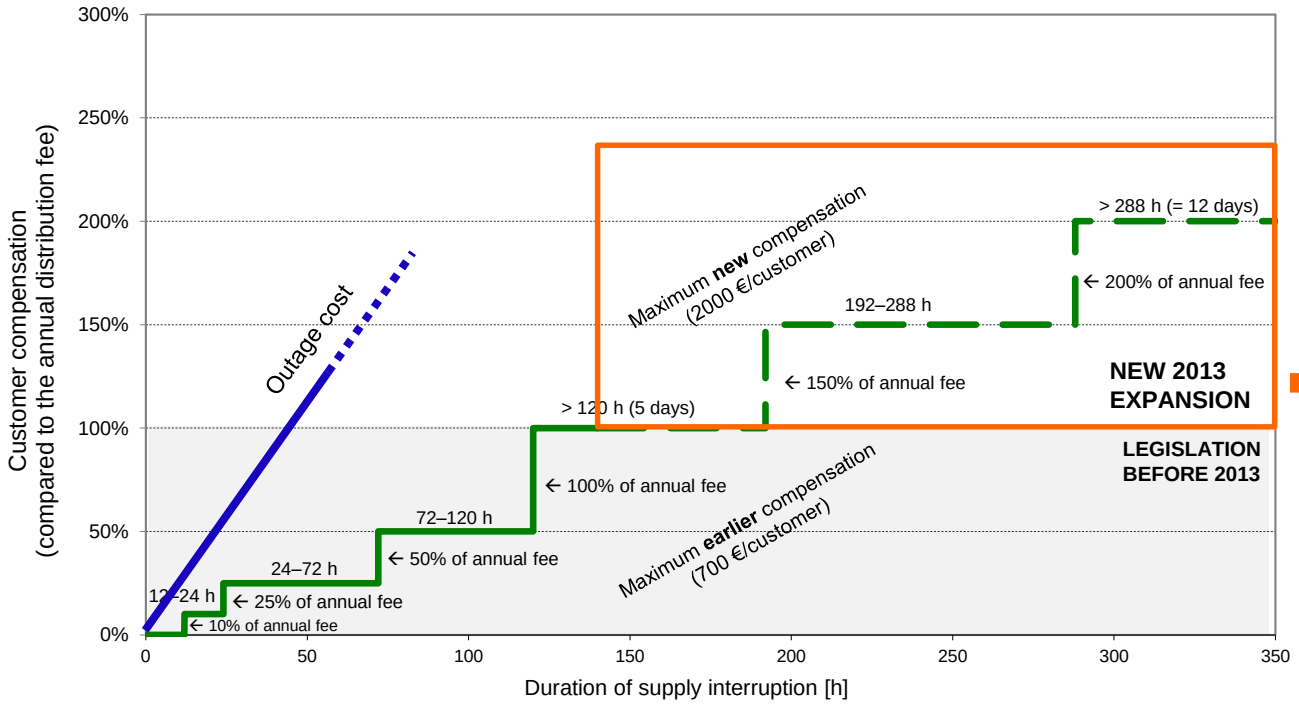
Electricity distribution: Challenge



Customer compensation structure

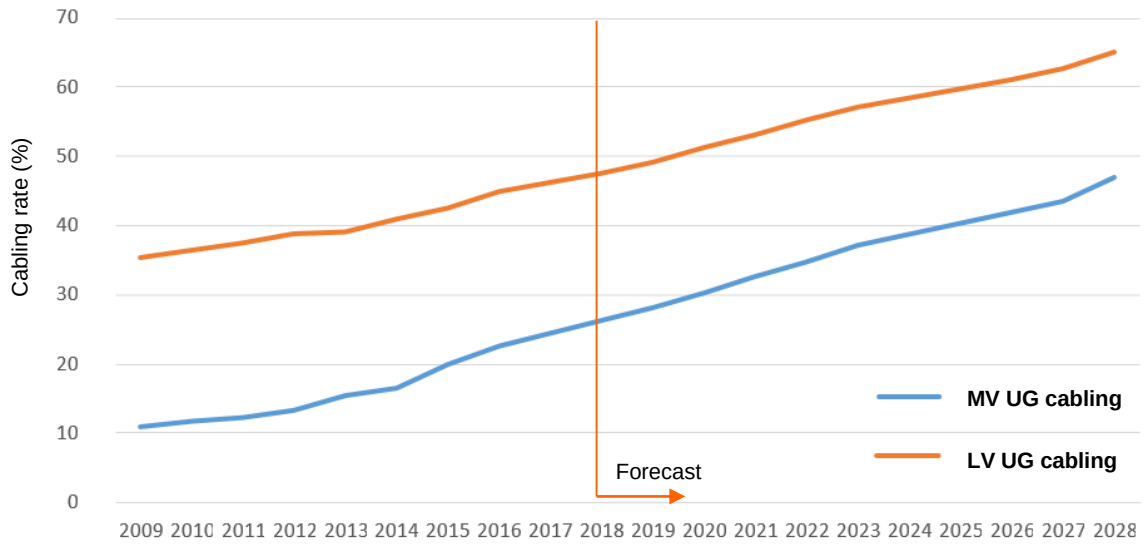


1. Maximum outage duration:
- 6 h (urban)
- 36 h (rural)

2. Additions to penalty structure:
- Up to 200% of fee compensations
- Compensation cap

Development of underground cabling

So far, the main solution adopted by DSOs to address reliability challenges



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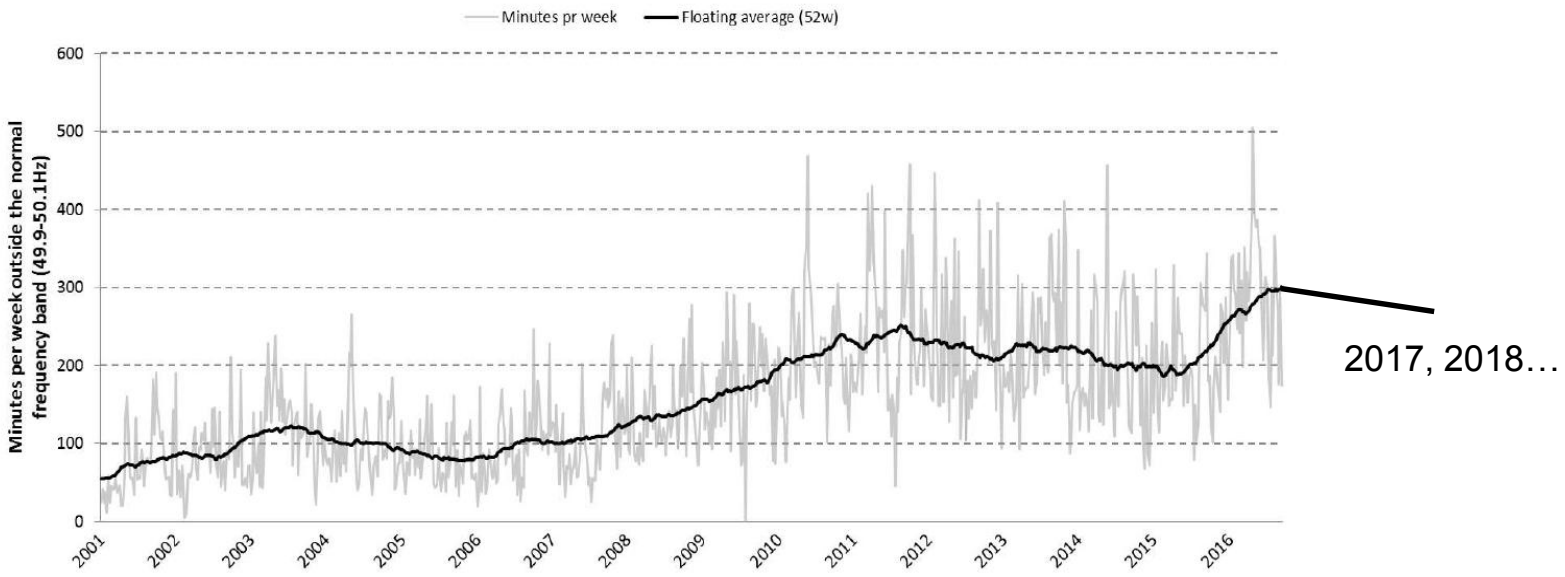
Nordic power system's frequency oscillations

To maintain frequency within the normal band is a growing challenge



FINGRID

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DR participation in ancillary service markets

Operated by TSO Fingrid

3rd parties eligible

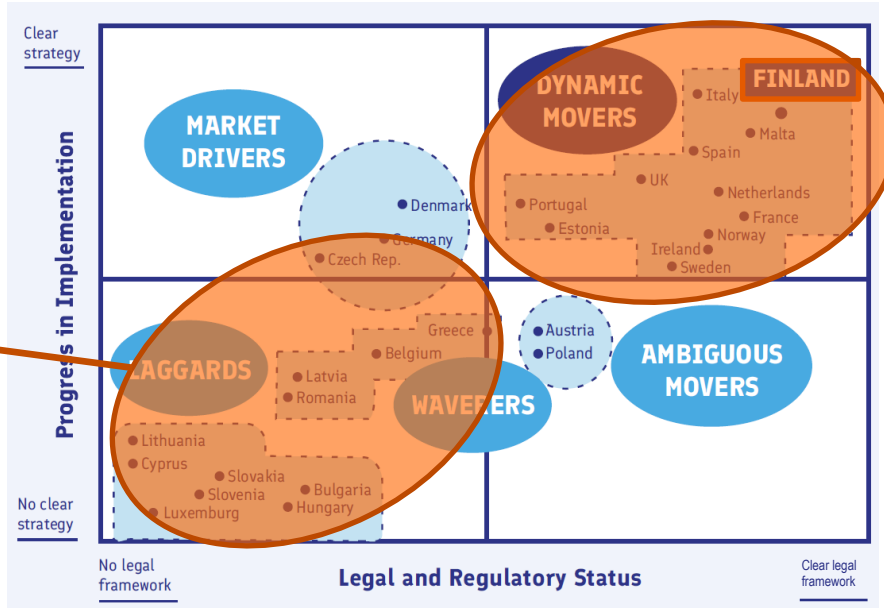
Market	Type of contract	Minimum bid	DR participation in Jan. 2018
Frequency containment reserve for normal op. (FCR-N) (Primary control)	Yearly/ hourly	0.1 MW	4 MW
Frequency containment reserve for disturbances (FCR-D) (Primary control)	Yearly/ hourly	1 MW	40 MW **>70% FCR-D 2017 volume**
Automatic frequency restoration reserve (aFRR) (Secondary control)	Hourly	5 MW	0 MW
Balancing power market (mFRR) Balancing capacity market (mFRR)	Hourly	5 MW	100 – 300 MW
Strategic reserves acquired by the Energy Authority	Weekly auctions	10 MW	22 MW (2017-2020)

AMI implementation level

A **wide scale smart meter roll out** (≈100% of end-users) was completed in 2013

- Output data is used in **balance settlement** and for building **novel RTP schemes**

Reactive operators

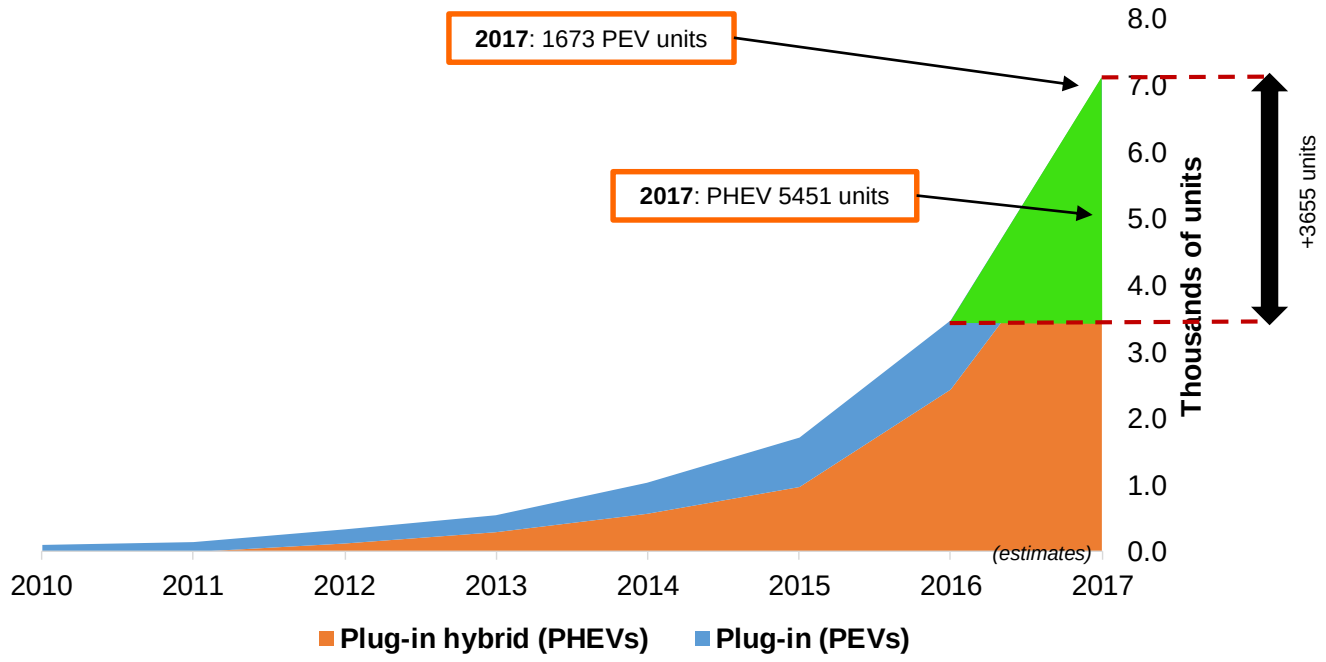


Proactive operators

FIN PRO | INVEST IN FINLAND
gtmresearch

Popularity of electric vehicles

The **electric vehicle stock** continues to rise steadily



Finnish Energy

LUT's perspective on microgrids

A PRIME source of grid FLEXIBILITY and PQR

1. Can complement UC as means to addresss the growing grid **flexibility**, **power quality** and **reliability challenges** brought either by rising nuclear and intermittent generation, extreme weather events, and a shifting demand dynamics (EVs, etc.)

2. Its development is backed by an increasingly demanding **continuity of supply regulation**, a high level of **grid digitalization**, and a sophisticated **framework for ancillary services provision** that is conducive to the entry of new market players

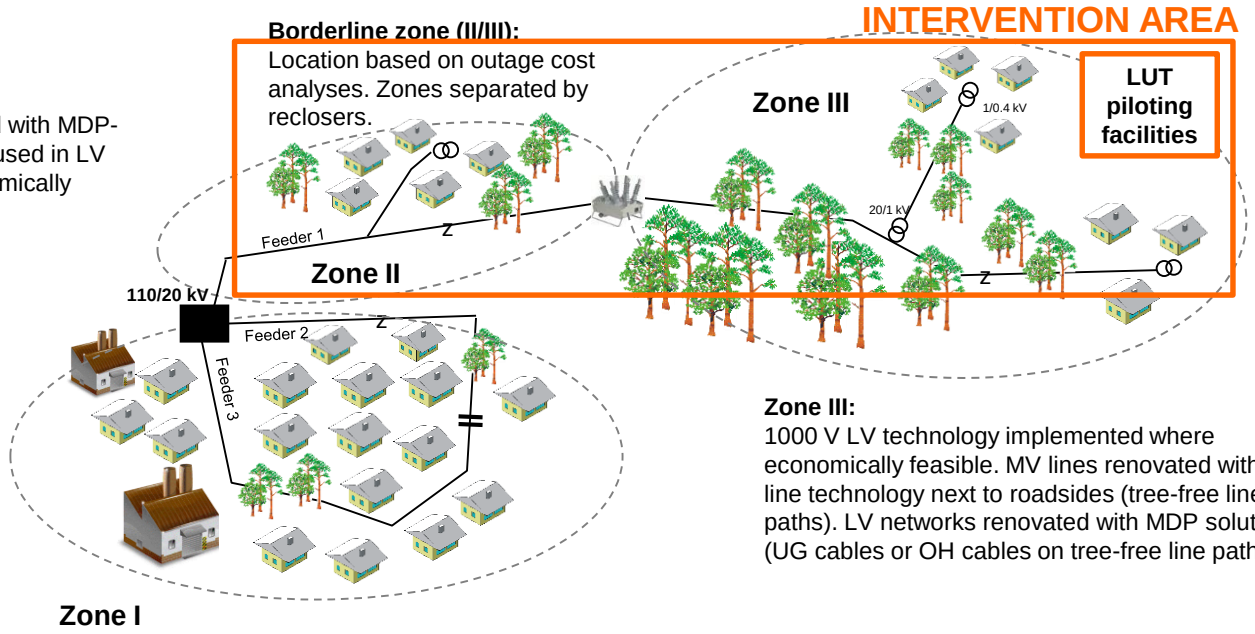
Strategy: Major-disturbance-proof (MDP) networks

10 to 40% of MV AC branches can be economically renovated w/ **LVDC microgrids**

Zero Hertz Systems 0Hz
DC distribution. Today.

Zone II:
Rural area feeders renovated with MDP-network technology. 1000 V used in LV network where techno-economically feasible.

Zone I:
Urban area feeders renovated with UG technology during first years of the investment program. Role of network automation (remote controlled disconnectors and reclosers) based on techno-economic analyses (savings in outage costs vs. investment cost)



Zone III:
1000 V LV technology implemented where economically feasible. MV lines renovated with OH line technology next to roadsides (tree-free line paths). LV networks renovated with MDP solutions (UG cables or OH cables on tree-free line paths).

Microgrids to ensure network PQR

VTT

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06/02/2018

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In Finland, distribution network companies are obliged to improve and maintain the resilience of electricity distribution to weather related interruptions at an adequate level. Current legislation and the regulatory model of the distribution network companies drive companies to do underground cabling in order to meet their obligations. A recent study by the EL-TRAN Consortium proposes microgrids as an alternative to underground cabling.

"Local microgrids could become an overall cost-effective solution in rural areas. This arrangement would presume that technologically feasible and applicable solutions and their costs are assessed as a whole", says **Sanna Uski**, senior scientist at VTT. A microgrid solution would mainly be based on the network customer's own electricity production and battery storage. The distribution network company could partially cover the battery costs and participate in the planning and maintenance of the microgrid while avoiding the more costly underground cabling option.

A microgrid is a small local consumption and production cluster, which in the normal mode is connected to a wider power system, but which is also able to function as an independent island sporadically. Microgrids are currently a very topical technology trend worldwide.

Nowadays, farming can use a significant amount of electricity and the security of uninterrupted power supply – even from short interruptions – is very important. Farms have an inherent potential of producing their own energy and even electricity. Case-specifically, an investment in the farm's own electricity production may currently be on the borderline of being cost-effective compared to buying electricity from the grid. However, a case study conducted by

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NAVIGANT RESEARCH BLOG

Is Finland Europe's Best Hope for Microgrids?

Peter Asmus — December 7, 2017

While Europe is considered a global leader in moving toward a low carbon energy future, the tightly regulated EU markets have several features that severely limit the development of microgrids:

- The focus has been on large-scale renewable energy development such as offshore wind, which requires massive investment in transmission infrastructure.
- Deployment of distributed energy resources such as rooftop solar PV has primarily been based on feed-in tariffs, a business model precluding the key defining feature of a microgrid—the ability to seal off resources from the larger grid via islanding.
- EU markets are tightly interwoven and methods to address the variability of renewables such as wind and solar lean toward cross-border trading, not localized microgrids.

As the forthcoming update to Navigant Research's *Microgrid Deployment Tracker* demonstrates, Europe represents approximately 9% of the global microgrid market. The vast majority of microgrids deployed in Europe are actually on islands in the Mediterranean, the Canary Islands off the coast of Spain, or projects such as Bornholm or the Faroe Islands of Denmark.

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Motivation to Build, Partner, and Buy in the Intelligent Buildings Market
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Digital Twinning in the Energy Industry
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By Date

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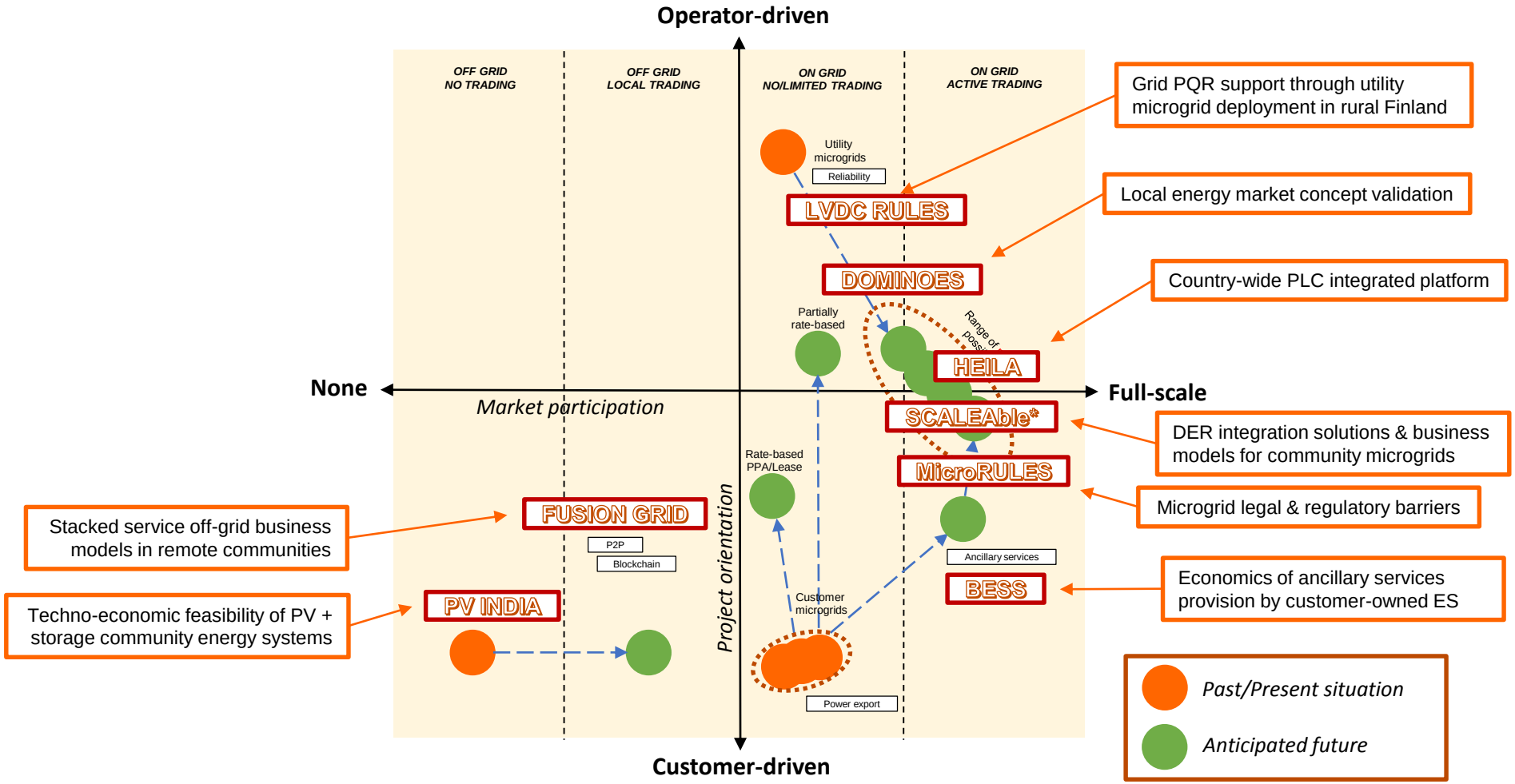
May 2018

Microgrid model trends map

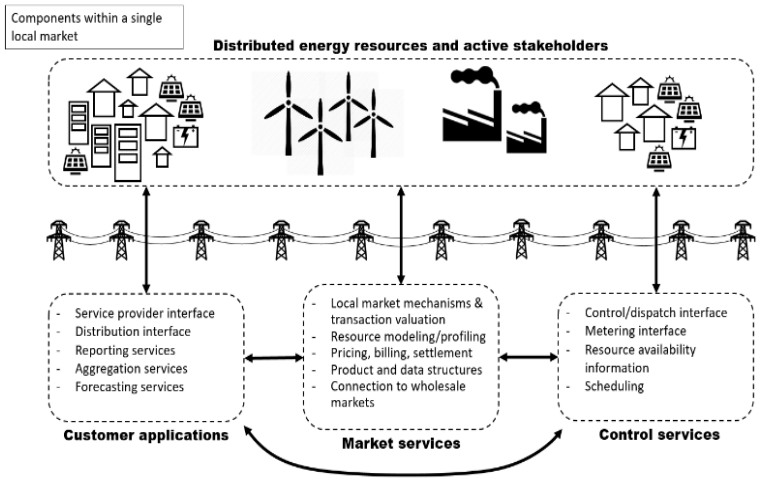


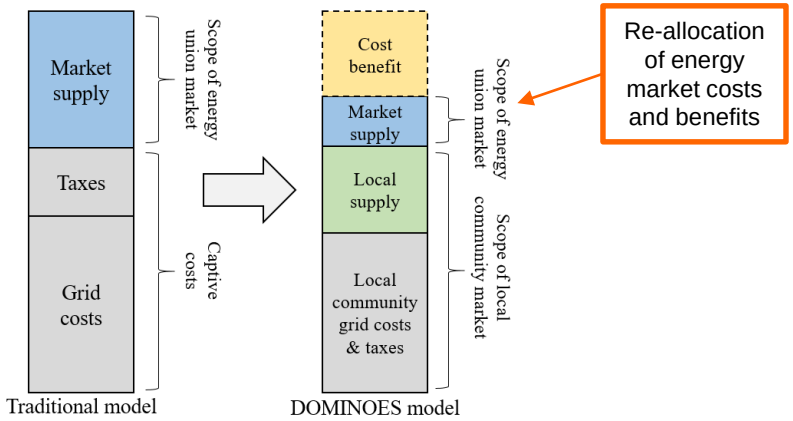
DOMINOES: Smart Distribution Grid

H2020 Grant Agreement No. 771066

"Market-driven approach for next generation advanced operation models & services"

R&D of new DR, **aggregation**, grid mgmt. and **peer-to-peer trading** services by designing/developing/validating a transparent/scalable **local energy market** solution.



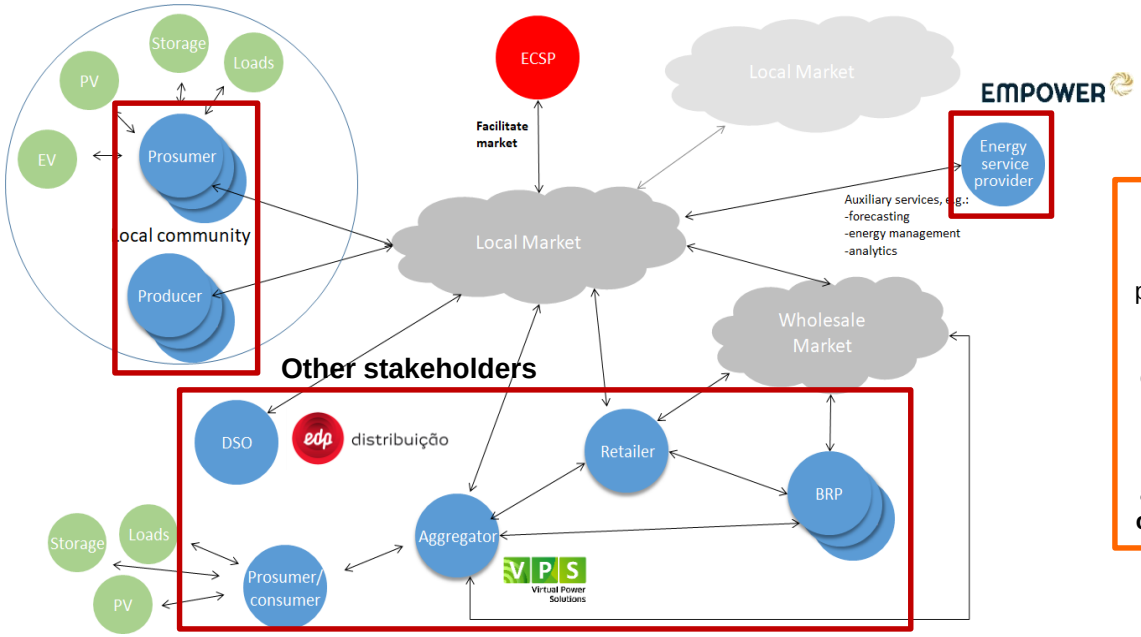


DOMINOES: Stakeholder map view

H2020 Grant Agreement No. 771066

In **red**, the **changeable** role of the community microgrid service provider (ECSP)

In the DOMINOES concept, **an ECSP facilitates the local market**, which enables the local community to be represented as a **single entity** in the various operations.



The local market established by the ECSP offers prosumers and/or DER the possibility of **forming local communities**, as well as other participants the option to **acquire flexibility** from the available resources or **offer services locally**.

BESS: Remote control of multiple storage assets

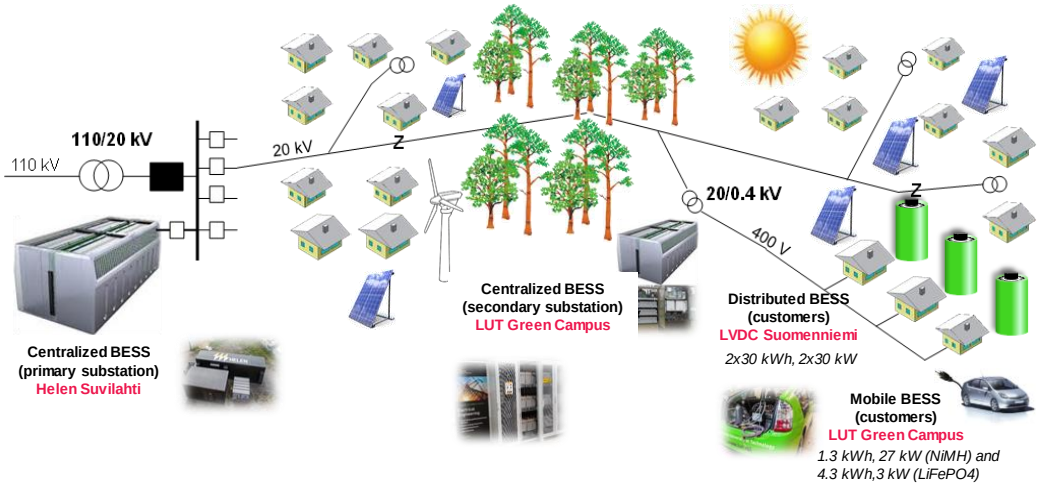
Techno-economic feasibility found for **stacked-service applications**, according to:

- FCR-N/hourly market (1st p.)
- Reactive power compensation (2nd p.)
- Peak shaving (3rd p.)

Multi-use application of various battery storage units

- **Interactions** between different storage applications different owner/operator background
- **Operation strategy** of individual and multiple storage units
- **Stakeholder** –specific strategy
- **Feasibility and profitability** of battery energy storage in different multi-use cases
- **Implementation** of control strategies into existing storages (Suvilahti, Suomenniemi, LUT Greencampus)

PHASE I



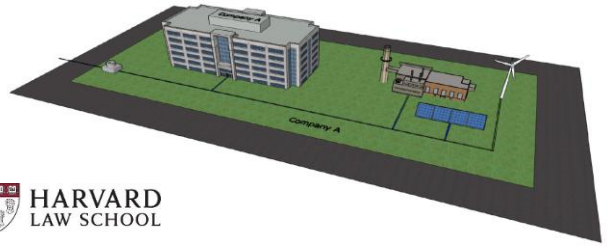
MicroRULES: Overhauling legacy regulation frameworks

Joint project will address **pressing legal/regulatory bottlenecks**, such as:

- Ownership/management models (wires, generation assets…)
- Rights over electric distribution and DSO franchise conflict

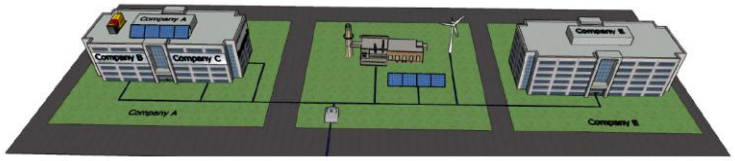
Carnegie Mellon University

FULBRIGHT

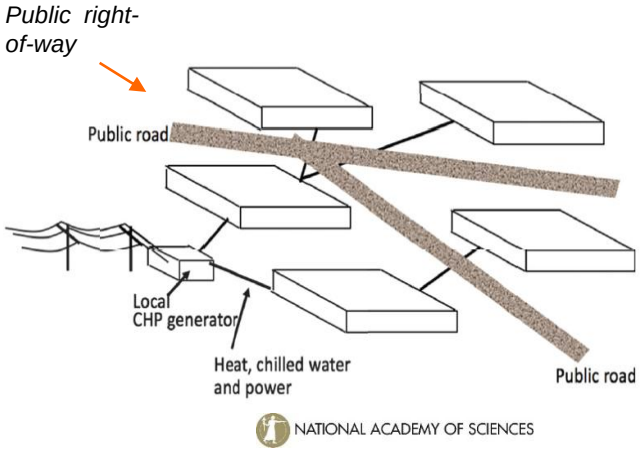


HARVARD LAW SCHOOL

*Example **single** participant with **on-site generation** (behind the meter)*

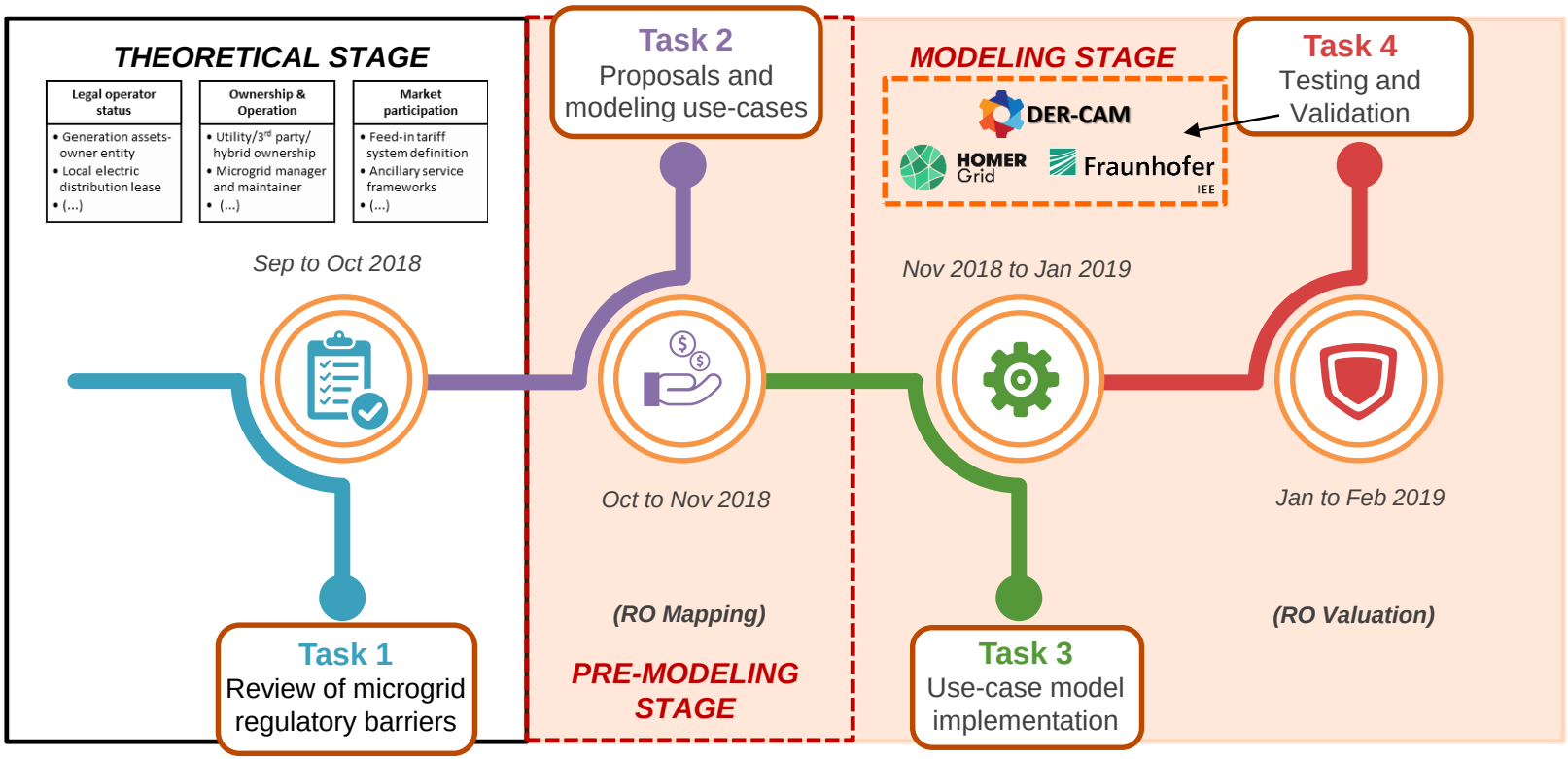


*Example **multi**-participant with **both on-site and off-site** generation*



NATIONAL ACADEMY OF SCIENCES

MicroRULES: Testing via techno-economic modeling



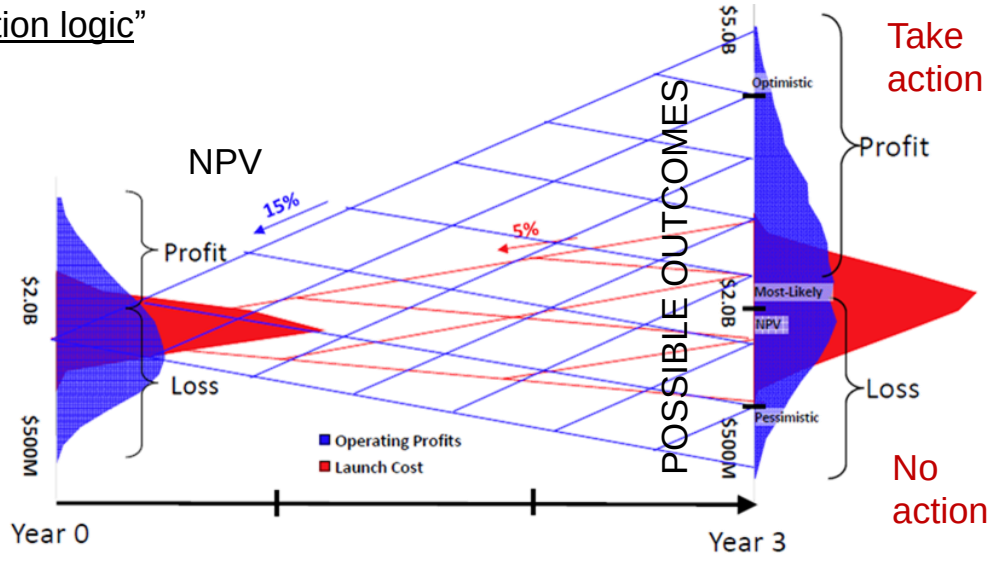
MicroRULES: Real options valuation of microgrids

Coupled approach **with techno-economic modeling** (*SYSTEM DYNAMICS*)

- Hedging against uncertainty in microgrid projects – **Flexibility**
  - Or capturing its potential added value!
  - Traditional methods: ”bond valuation logic”

- Methodology: ROM + ROV
- Valuation: **Operational RO**
  - Level of project knowledge
  - Possibility to change projects

- Various methods: DM, Fuzzy logic…

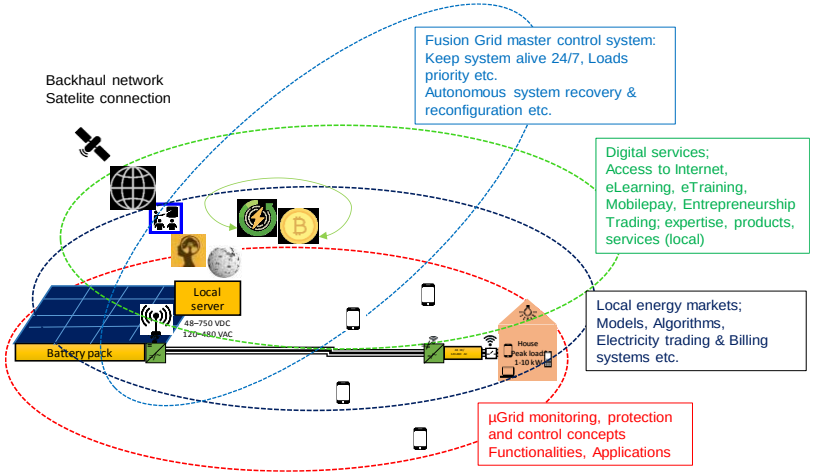


FUSION Grid: Combined service offer for off-grid

Electricity & Connectivity for rural communities in remote regions

- Provides households with **affordable electricity**
- RES-powered base station offers 600 user-wide **4G LTE connectivity**
- Tackles key **social/educational** challenges
- Product-based **industry-focused** initiative

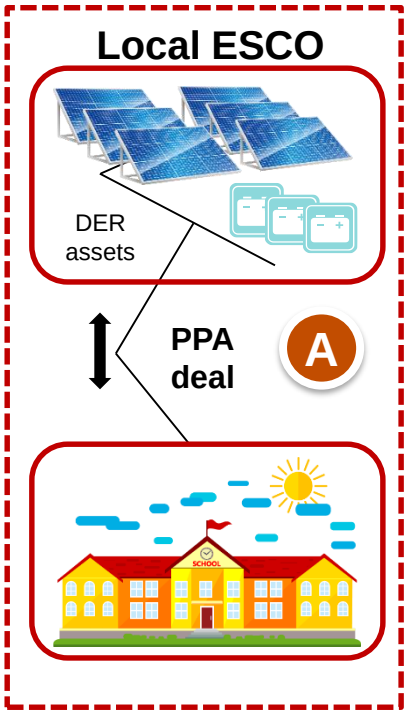
- Core **design and business innovation**:
  - Compact, Plug&Play, Scalable, Replicable
  - e-Government/**e-Education**
  - Local **commerce/entrepreneurship**



RES-based FUSION Grid concept platform

FUSION Grid: ABC BM framework "with some twists"

The anchor load to the system consists of a **large-sized public school facility**



B

Expansion of energy service

Predominantly day time **BUSINESS customers** use power for increasing operational productivity

OTHERWISE DIFFICULTLY BANKABLE

Expansion of energy service

C

OTHERWISE NOT BANKABLE

Predominantly night time **COMMUNITY customers** are served with affordable energy

Large, reliable, **government school complex load** serves as **ANCHOR** to the deployment: **KEY RELATIONSHIP**

FUSION Grid: ABC BM framework "with some twists"

Long-term project return by **reaping benefits from the digital economy**

- ESCO captures part of the value generated by subsequent local business growth

"Electricity as a service rather than as a commodity"

Revenue streams:

- Fixed PPA payments from anchor customer
- Fee-for-service (local businesses, households) based on WTP
- Fees charged to services/transactions powered by the Digital Market (DM)

$$Revenue = \sum_{t=0}^{T} WTP_t + DM_t$$

$$WTP = WTP\_E + WTP\_C$$

$$DM = \sum_{i=0}^{I} S_i . F_i$$

PPA: Power purchase agreement	**WTP_E**: Willingness to pay for electricity	**S**: Sales from service i
PAYG: Pay-as-you-go	**WTP_C**: Willingness to pay for connectivity	**F**: Fee charged to S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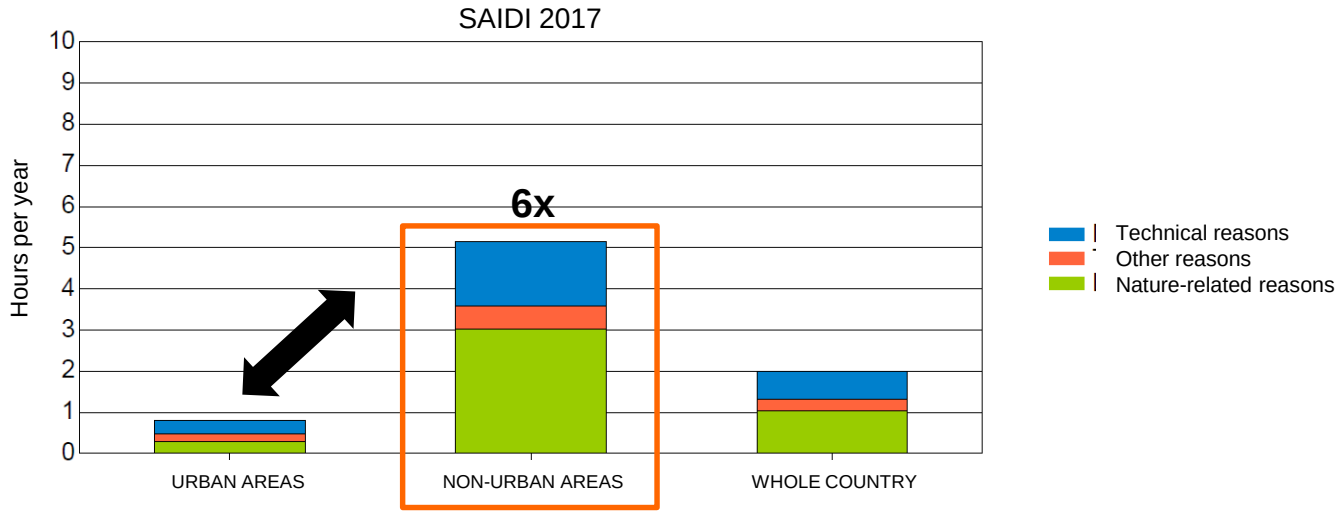
EXTRA SLIDES

Electricity distribution: Performance

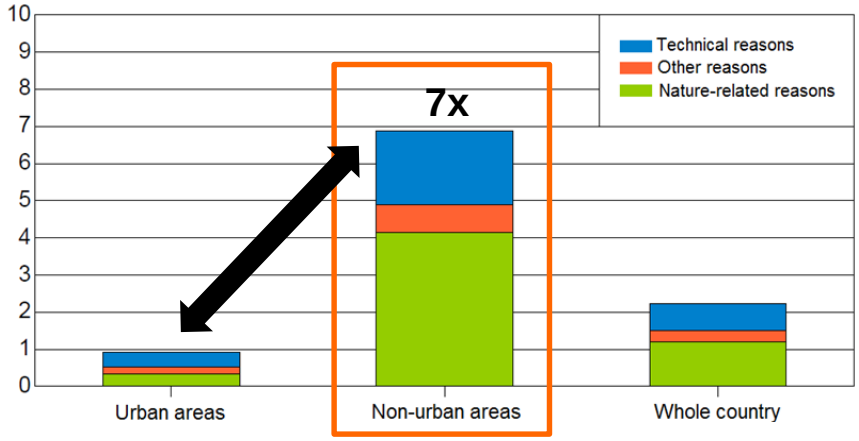
- **SAIFI** (and **SAIDI**) diverge significantly between urban and rural areas



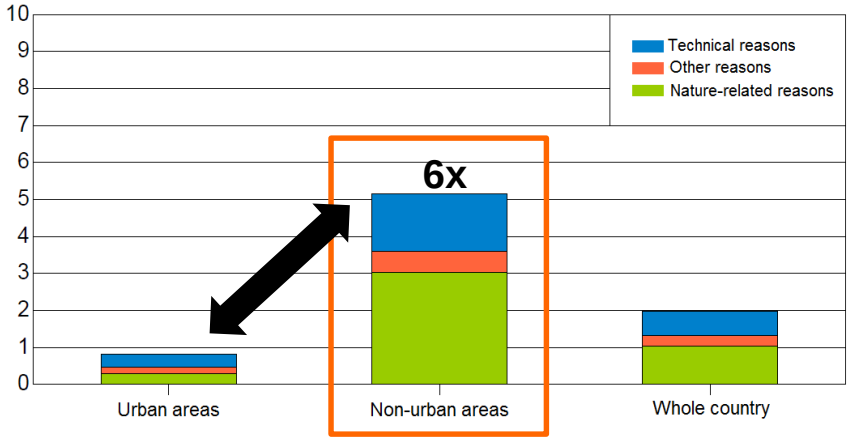
Electricity distribution: Performance

- **SAIFI** (and **SAIDI**) diverge significantly between urban and rural areas

SAIFI 2016



SAIFI 2017



- New regulation: From 2013, caps exist for outage duration

energy authority

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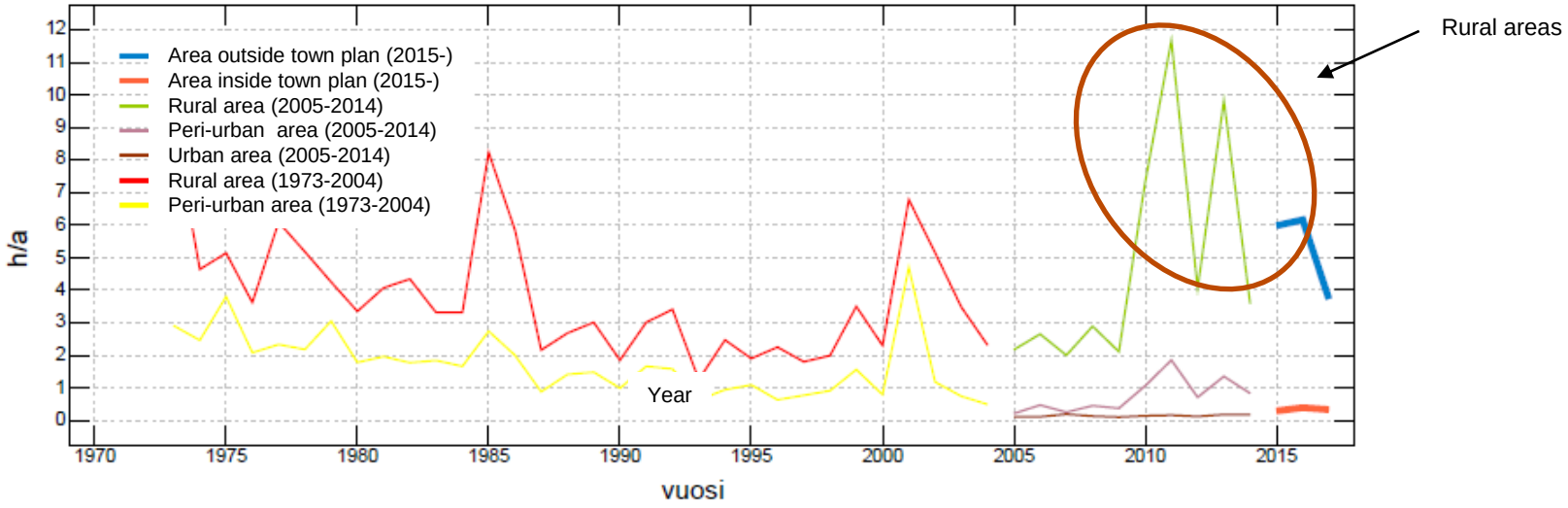
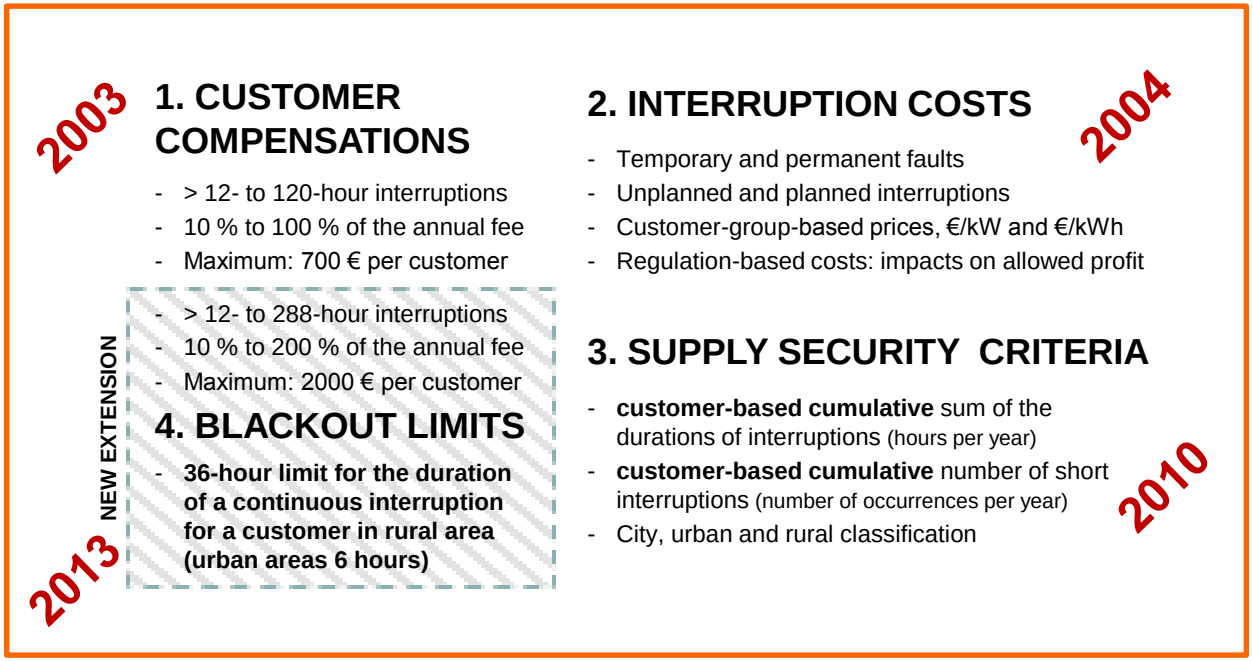
Electricity distribution: Challenge

- **SAIDI** significant divergence between urban and rural areas

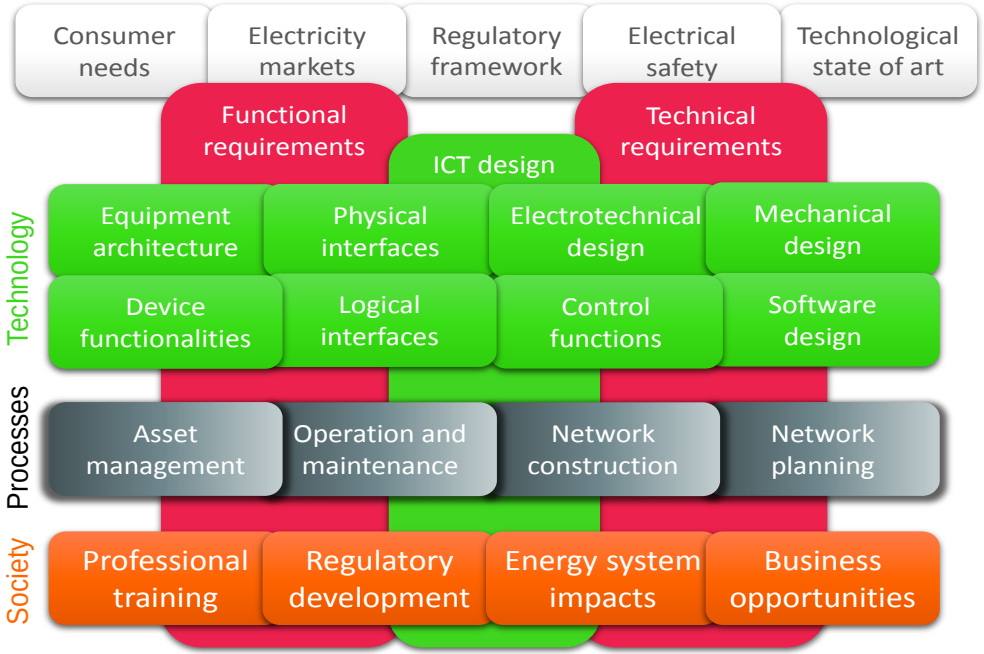


Historical reliability regulation developments



LVDC RULES

- Translating LVDC research knowledge into commercially available solutions



- What are the life-cycle cost-effective solutions and network configurations?
- What is the economic profitability for the network operators?
- What kinds of maintenance programs and fault management processes?
- How DER and ancillary services affect feasibility and the business potential?
- What new professional skills needed and how to organize training?
- What are the regulatory and standardization development needs?