CLEEN
Cluster for Energy and Environment

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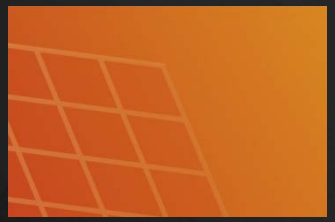
Strategic Planning of Smart Grids



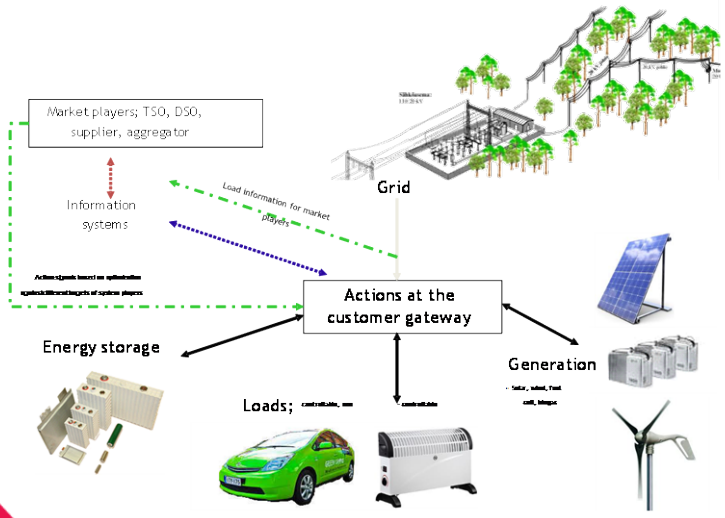
sgem
Smart Grids and Energy Markets

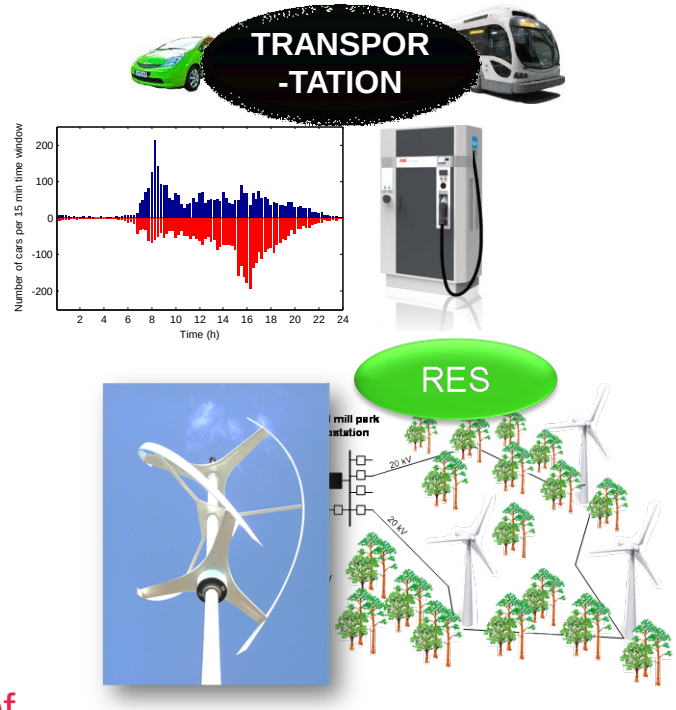
WP2: Future Infrastructure of Power Systems

sgem
Smart Grids and Energy Markets

Strategic Planning of Smart Grids

“Älyverkkojen strateginen suunnittelu”

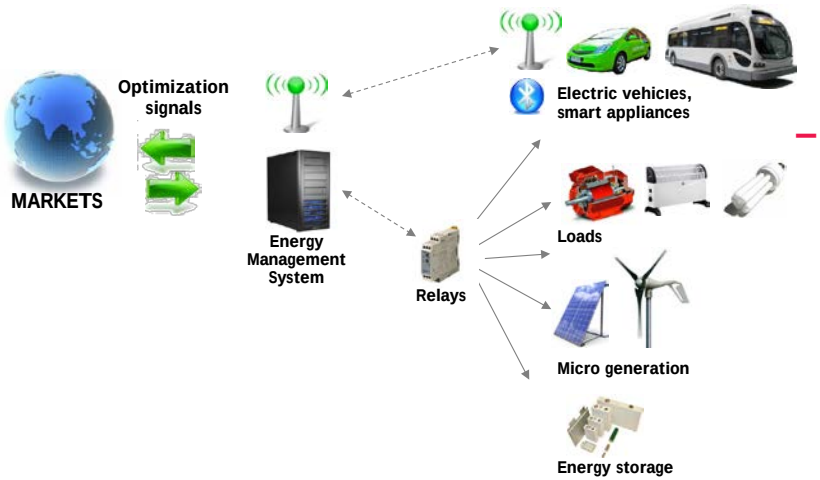




Research Group of
SGEM Task 2.1

Definition of Smart Grid

- "*Electricity networks that can intelligently integrate the behaviour and actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies*"
  - EC, Strategic Deployment Document for Europe's Electricity Networks of the Future, 2010



- Electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators, for purposes such as:
  - to integrate the behaviour and actions of the network users and other stakeholders,
  - to efficiently deliver sustainable, economic and secure electricity supplies
    - (1/2173/FDIS Amendment 1 to IEC 60050-617: International electrotechnical vocabulary - Part 617: Organization/market of electricity)

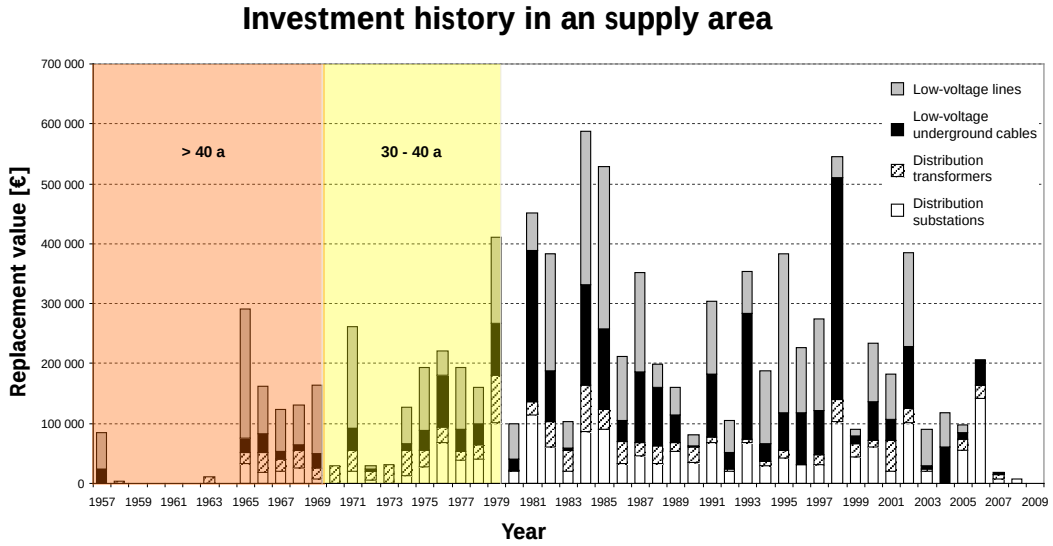
- Strategic planning:
  - What are the impacts of changes in the operating environment on the distribution business and on the network development?
  - How the objectives of Smart Grids can be integrated in the distribution networks and related business on most effective way?

Introduction to strategic planning

- Background
  - Electricity distribution business is in the middle of its most significant change since the beginning of electrification of the society
  - Even though the Smart Grids is mainly development of intelligent applications and related ICT, the biggest investments will be made to the primary electric infrastructure
- Strategic Planning
  - Strategic planning is a central part of power system asset management and required to be able to handle all existing and coming challenges in the long term, after all the distribution systems built today will still be in use in year 2040 and beyond
- Main concept
  - Strategic planning combines versatile information, both external and internal to distribution business, and produces inputs for long-term planning of distribution networks and business
- Key questions
  - What are the objectives set for the development of distribution systems and what are the effects of different development options, such as full-scale underground cabling, on the price of distributed electricity and the owner's return on investment
- Motivation
  - Right methodologies, principles and business models enable development of primary network and integration of smart grid functionalities in optimal way
  - Capital-intensive nature of the distribution business emphasizes the significance of a well-planned strategy

Critical infrastructure and renovation needs

ELECTRICITY (375 000 km, need > 10 000 km/a)



TELE
(+ 40 000 km
before 2015)

WATER
(100 000 km,
need 1 000 km/a)

ROADS
(78 000 km,
need __ km/a)

SEWER NETWORK
(50 000 km,
need 900 km/a)

DISTRICT HEATING
(12 000 km
+200-300 km/a)

RAILWAYS
(5 900 km,
need __ km/a)

Electricity distribution business

Electric utility
-Generation
-Transmission
-Distribution
-Sale

Generation | Transmission | **Distribution** | Sale

Network ownership
- Financing arrangements
- Target setting
- Network management agreements

Asset management
- Setting principles of operation **(= strategy)**
- Management of service agreements

Service providers
- Equipment supplier
- System supplier
- Network operation
- Construction
- Measurement

35–40% of the total price of electricity for the end-users

Cost optimisation in distribution business

$$C_{\text{total}} = \min \int_0^T \left(C_{\text{investment}}(t) + C_{\text{opex}}(t) + C_{\text{interruption}}(t) \right) dt$$

Investment costs

- Construction
- Materials
- Capital costs
- Planning, research and development
- Storages, transportation (logistics)

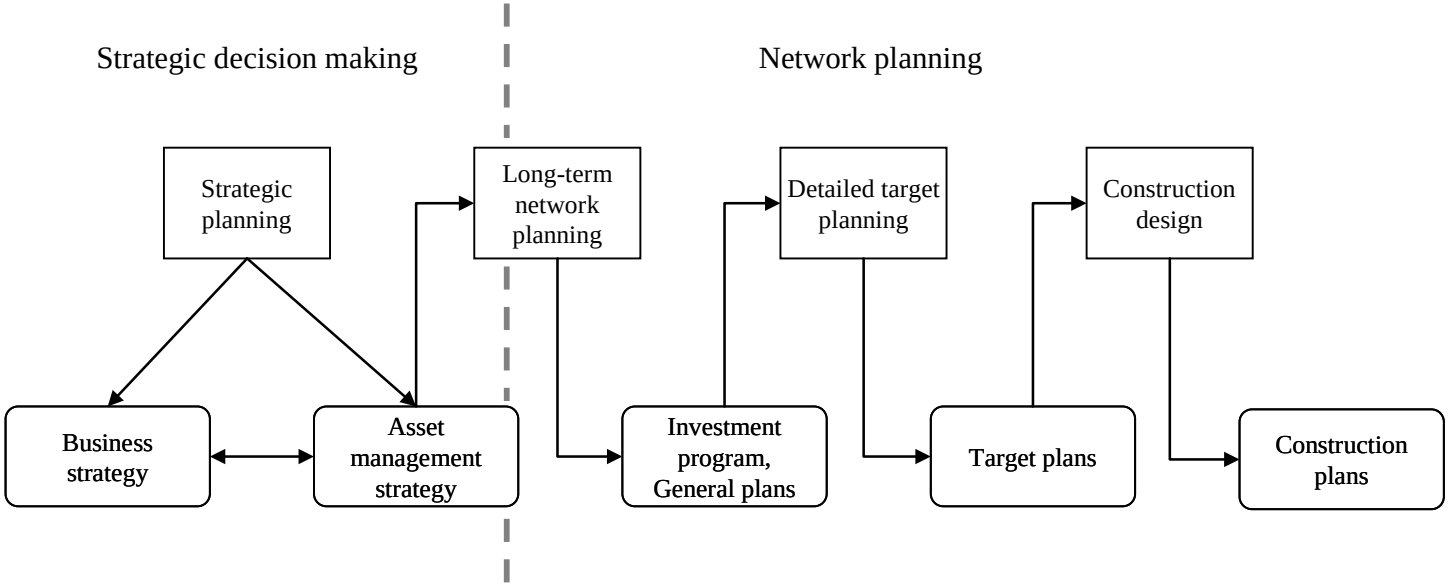
Operational costs

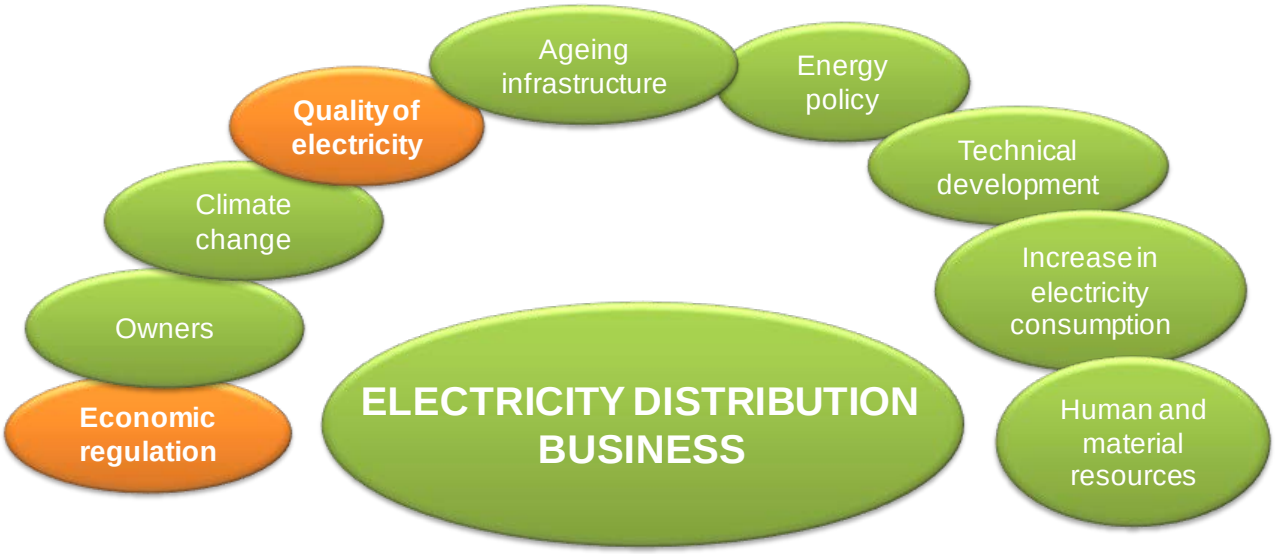
- Network operation
- Network maintenance
- Network losses
- Fault repairing

Interruption costs

- Economic harm for end-user because of outage
- Loss of income

Role of strategic planning process

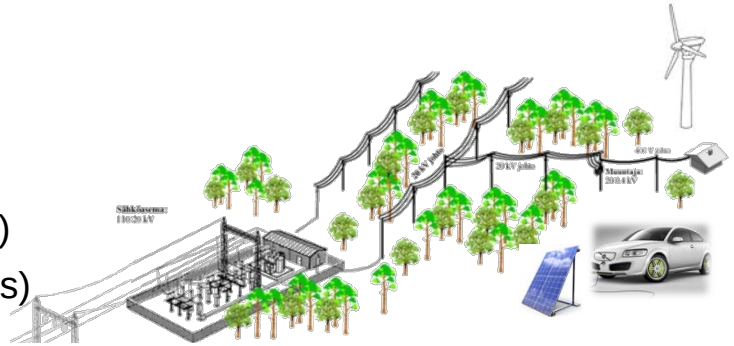




Strategic planning - Transition from the present network infrastructure to the smart grids

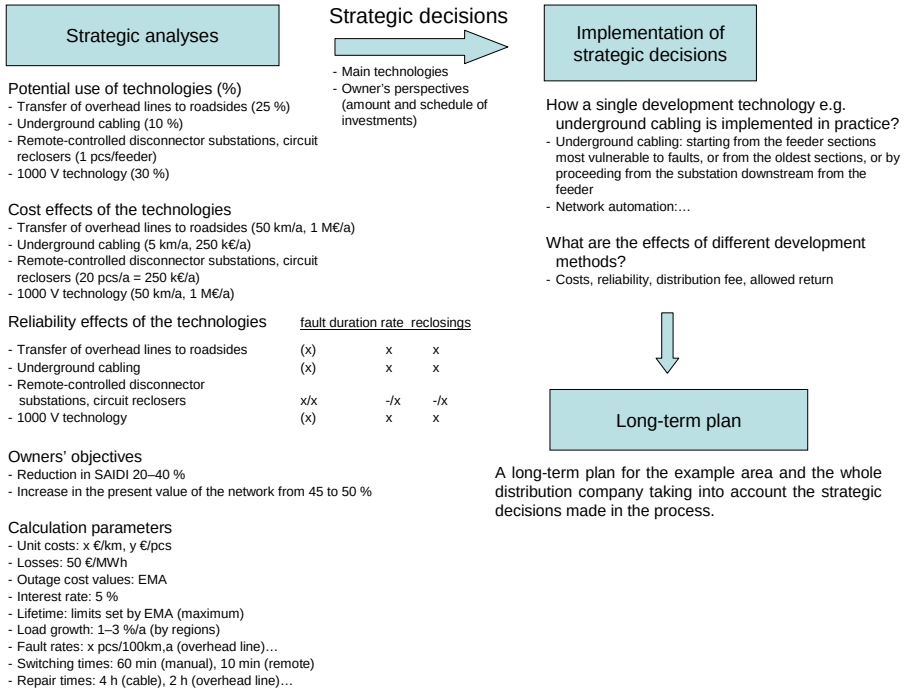
- **Research questions**
  - The most probable development scenarios for new energy solutions?
  - New challenges and opportunities that these solutions create for the grid business?
  - Technology alternatives to deal with the challenges and make use of the opportunities?
  - The best transition strategies for a grid company in each development scenario?
  - Reactive or proactive network development strategy?
  - Indicators and drivers to follow and critical values for them?
  - Development technologies which can and should be used now and in the future?
  - The way how the increasing amount of DG has to be taken into account?
  - The role of electric transportation (cars, busses) in the network development?

- **Indicators and drivers from**
  - Network calculations (power flow, fault current, losses)
  - Measurements (AMR data, voltage quality, interruptions)
  - Society: political decisions, trends and needs
  - Technology development (e.g. price of solar technology and energy storages)
  - Emergence of novel technical enablers (for instance “Internet of Energy”)



Subtasks of strategic planning

1. Operational environment survey
2. Definition of compelling drivers for network development
3. Determination of the owners objectives, expectations and financial contribution to the business
4. Survey of development alternatives and available technical solutions
5. Determination of the key calculation parameters for techno-economic analyses
6. Analysis of the reliability impacts of development alternatives
7. Analysis of the economical feasibility of development alternatives
8. Analysis of the technical feasibility of development alternatives
9. Definition of the application potential of technical development alternatives



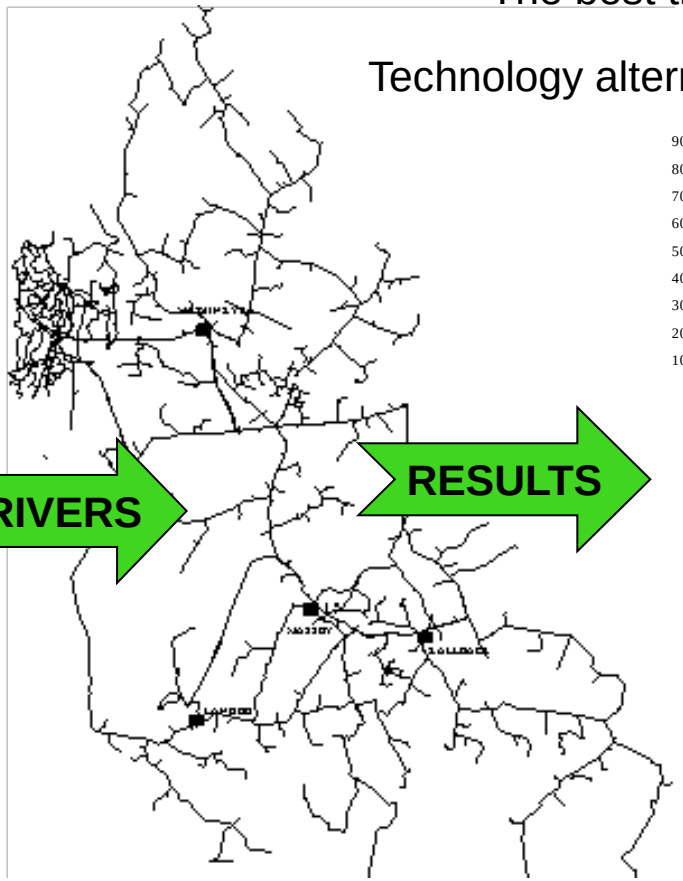
Simulation of impacts of strategic decisions

Society: political decisions, trends and needs

Technology development
(e.g. solar technology and energy storages)

Network calculations
(power flow, fault current…)

Measurements
(AMR data, interruptions,..)

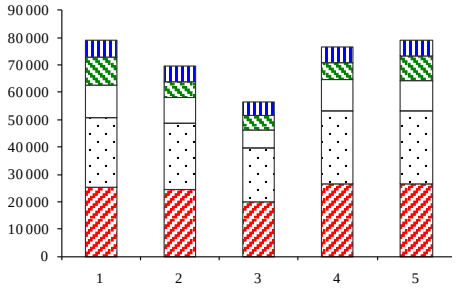


DRIVERS

RESULTS

The best transition strategies?

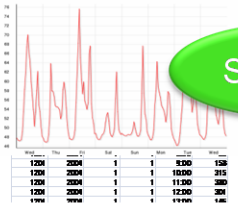
Technology alternatives to deal with?



Effects:
- Reliability?
- Age and condition?
- Distribution fee?
- Public relations?
- Return?

Development of electric load behaviour

Electricity markets



Supplier

Price signals

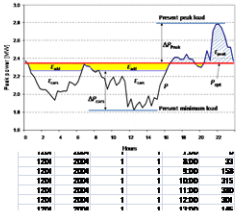
Data: hourly price, price forecasts

Interactive customer interface

DSO

Power signals

Grid



Data: feeder load curve, peak powers, load forecast, distribution fee

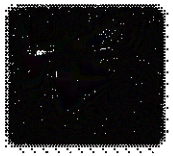
Other information: customer classification; Local weather forecast: outside temperature, day light duration ...

Active customer gateway

Active customer

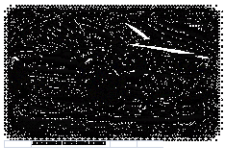
Loads

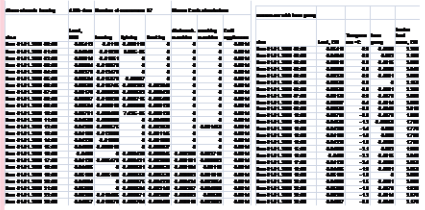
Electric heating, lightning, ...

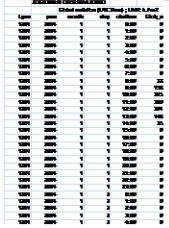


Heat pumps

Electric vehicles (G2V)





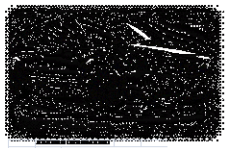


Data: hourly use of electric heating and home devices; heat pump penetration rate, coefficient of performance

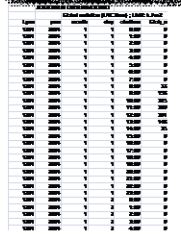
Data: number of EVs, driving schedule, properties of batteries, charging powers

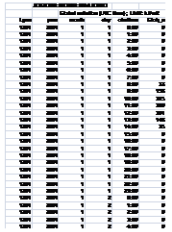
Storages

Electric vehicles (V2G)



Battery

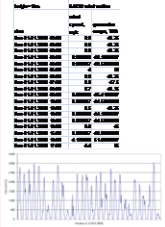




Data: number of EVs and batteries, driving schedule, properties of batteries, dicharging (V2G) powers

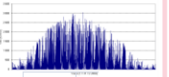
Generation

Wind power



Data: Wind speed, turbines, production

Solar power



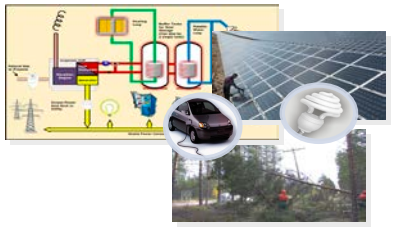
Data: radiation, panel properties, production

Strategic role of novel technologies

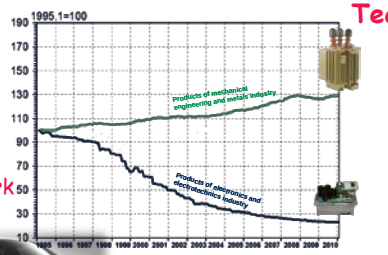
Environment
- Climate change
- Landscape issues
- Land-use issues
- Impregnants
- Electric and magnetic fields

Energy policies
- Legislation
- Energy efficiency objectives
- Reduction of emissions and oil dependency
  - Renewables, DG and EVs
  - Demand response

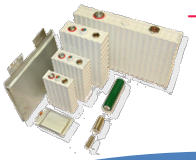
Society and socio-economics
- Safe use of electricity
- Reasonable pricing
- Supply security
- Energy efficiency actions
- Functional markets



Network infrastructure and assets
- Aging infrastructure
- Allowed profit regulation
- Revenue expectations of owners
- Supply quality expectations
- Major disturbance vulnerability
- Increasing prices of conventional network components
- Decreasing prices of emerging technologies



Technical development
- Automation and communication techniques
- DG and energy storages
- Building automation
- Underground cabling
- Power electronics
- Distributed intelligence
- Preventive maintenance techniques
- Software development

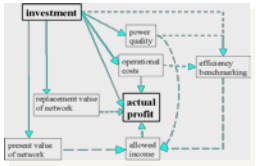


Customers
- Customer expectations on
  - Quality of supply
  - Pricing
  - Functional markets
- Changes in energy usage patterns
  - Energy efficiency actions
  - Dynamic loads
  - EVs and DG
- Equality
  - pricing
  - service quality

Role of power electronics in future electricity distribution infrastructure

Power Quality
- Security of supply
- EMI and EMC, distortion
- Sensitivity of system and load appliances

Utility stake holders
- Profit expectations
- Predictable rules
- Company image
- Consolidation

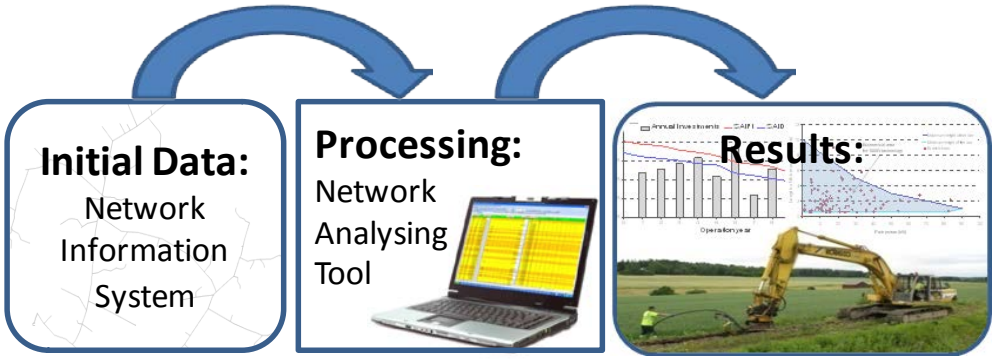


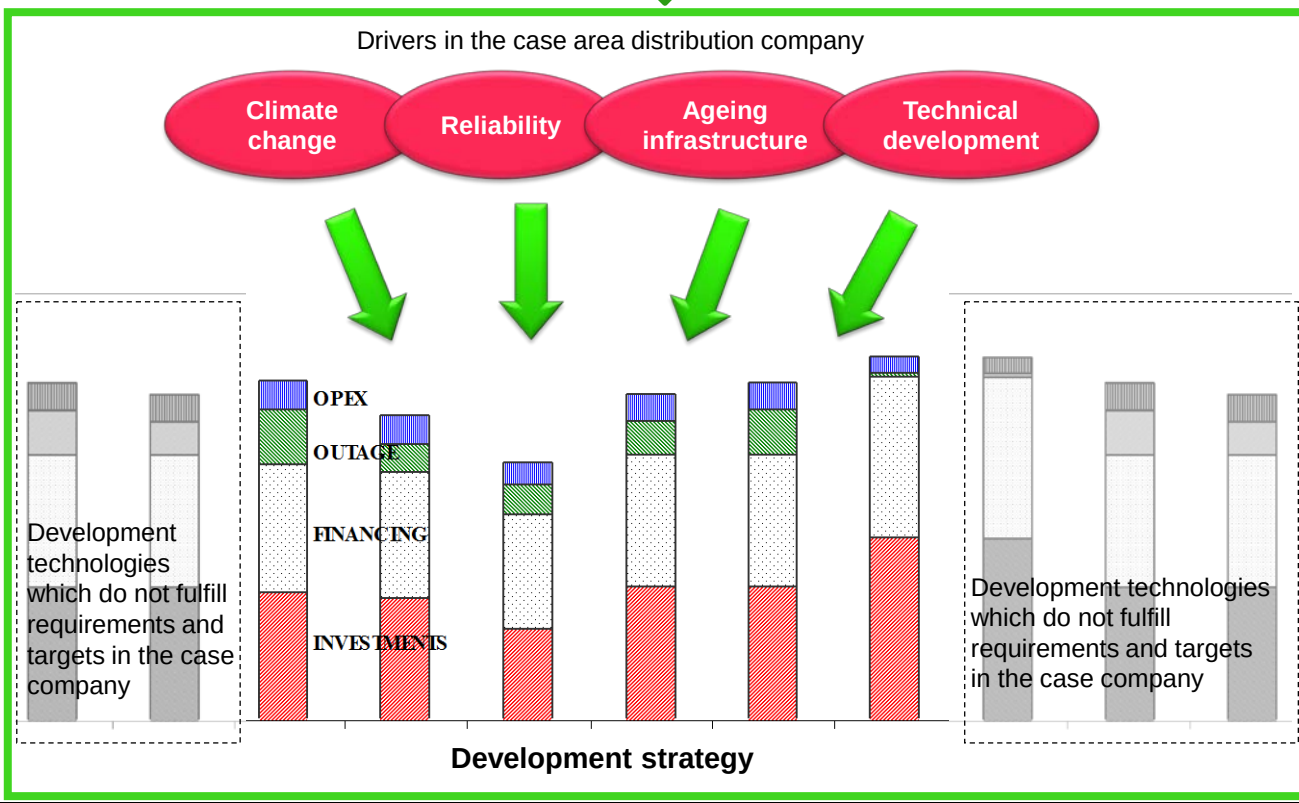
Regulation of network business
- Allowed profit regulation
- Quality of supply
- Cost efficiency
- Energy efficiency

Recourses and competences
- Human resources
- Outsourcing
- Tools and methods to aid decision making

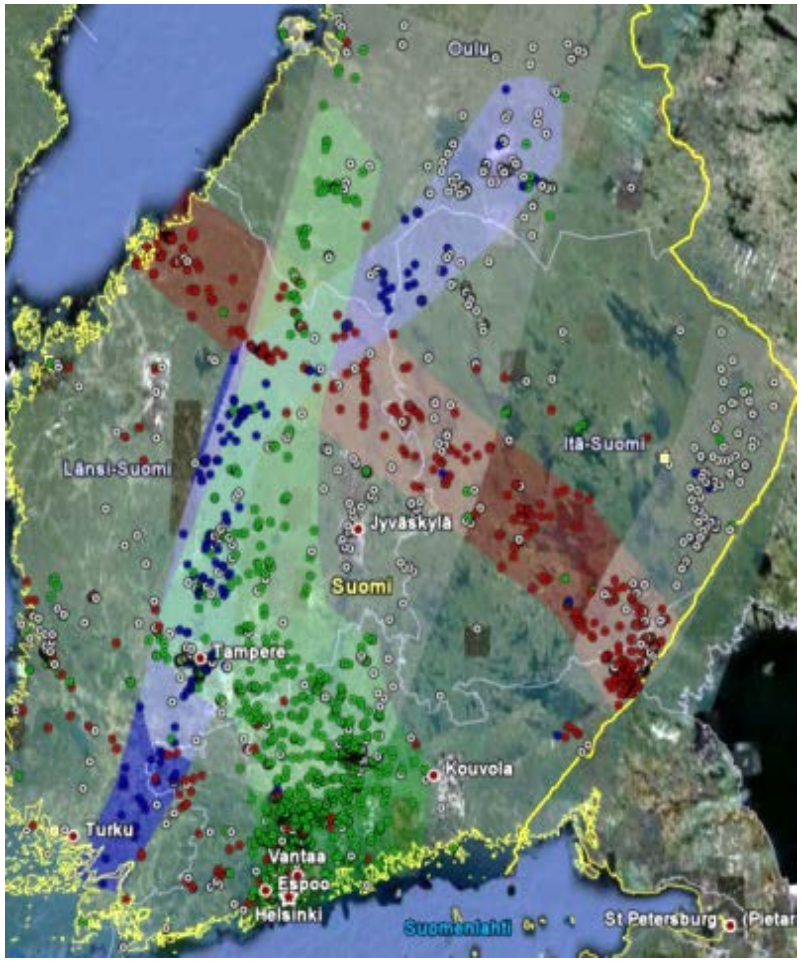
Smart Grid visions
- Self healing and proactive power system
- Market and grid oriented system control
- No market limitations

Selection of development strategies





Major blackouts and large scale cabling



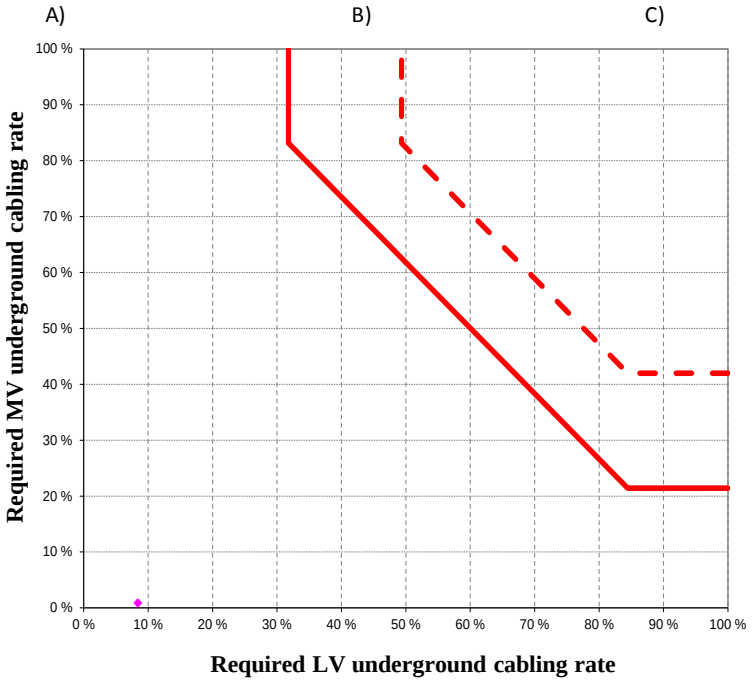
Routes of major storms in summer 2010

Strategic analyses
- Comparison of technologies
- Reliability evaluation
- The goals of network development
- Evaluation of the state of present network
- Assessment of parameters

Strategic decisions

Network structure is changing towards underground cabling

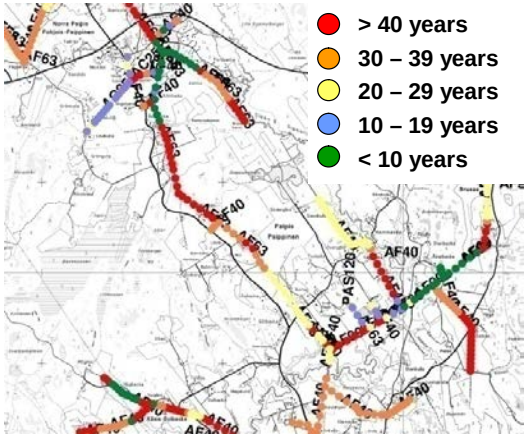
Assessment of the underground cabling process (*Cabling concept*)
- Locating of suitable targets
- Evaluation of the timing
- Priority of the targets in the renovation
- etc



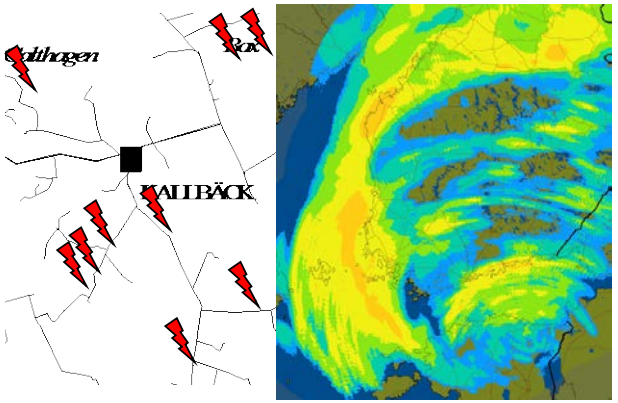
Required amount of underground cabling to survive the events without long supply interruptions for an example network

Priorisation of investments

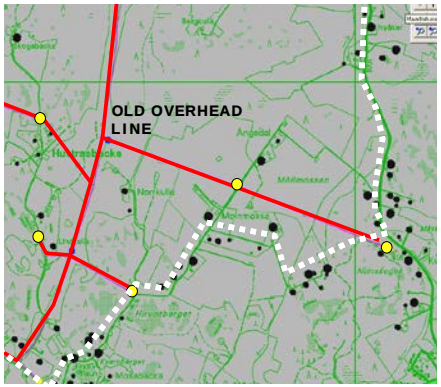
Age



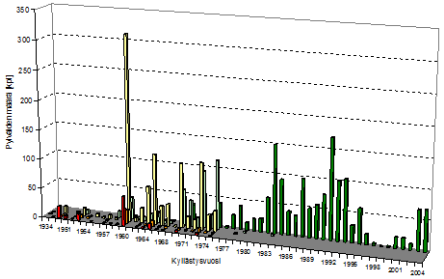
Reliability



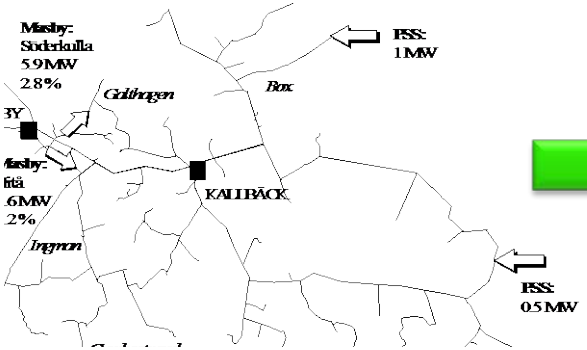
Load and line layout



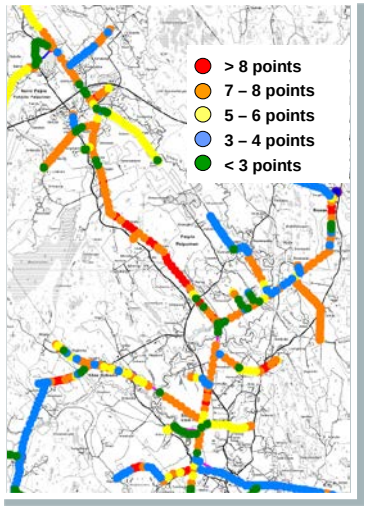
Mechanical condition



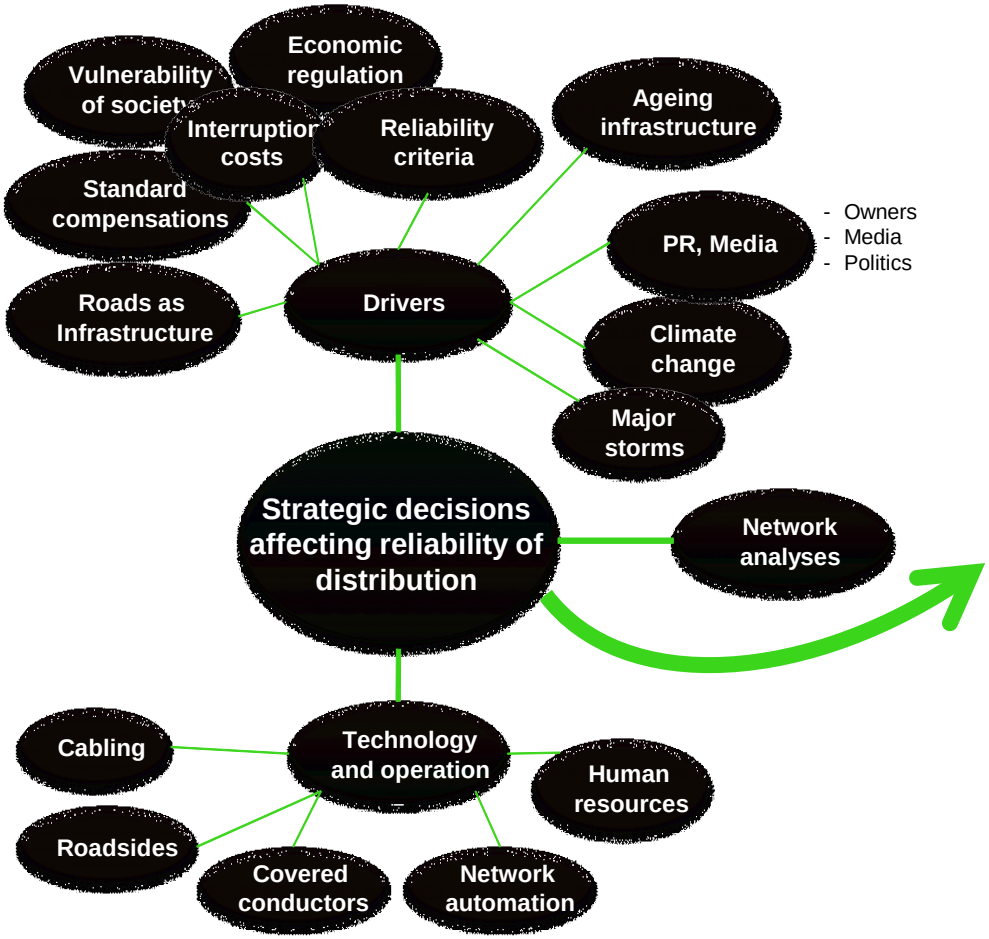
Transmission capacity

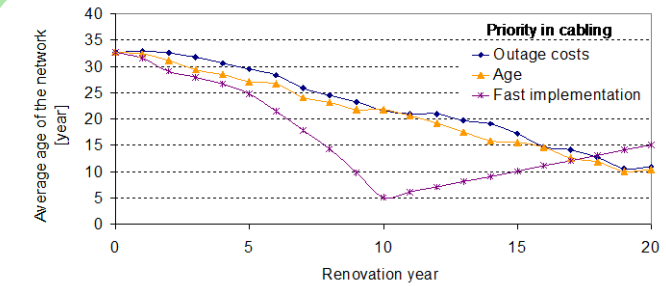


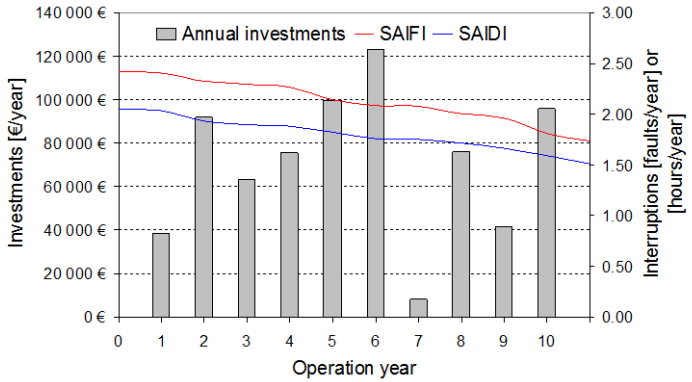
INVESTMENT ORDER

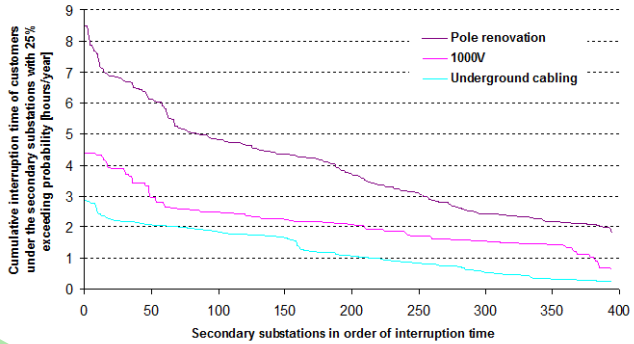


Impact of selected strategy on supply security with different investment programs

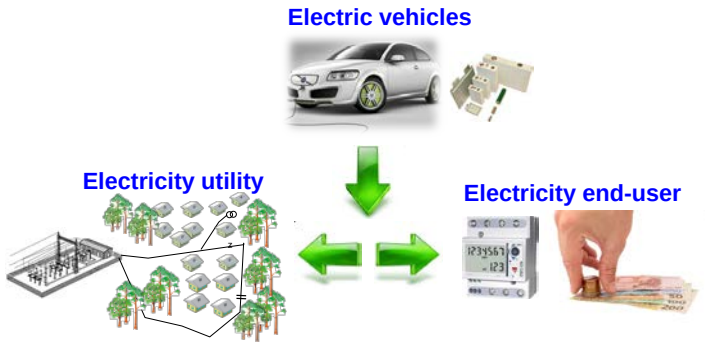






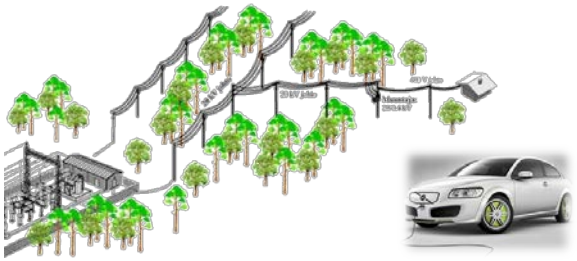


Impact of electric transportation

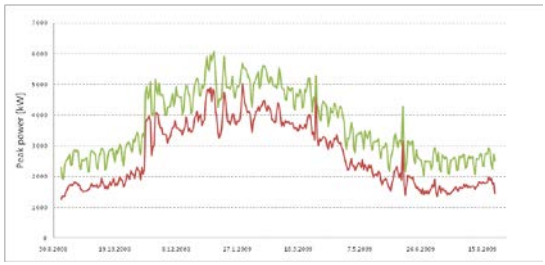


Defining of technical (MW) and economical (€) effects in electricity distribution networks

- Determination of scenarios for use of electric transportation
- Considering applicability of V2G and availability of DR and local DG
- Defining charging behavior for different electric transportation
- Determination of coincidence with other electric loads and generation
- Determining probable scenarios for power flow calculations
- Defining impacts on network development needs
- Defining impacts on distribution business



+MW



+€

Strategic planning in SGEM – Key interests

Drivers	Effect to the strategy work, strategic questions
Large scale cabling	Renovation schedule, order, technology, role of automation, optimal topologies and role of OH networks?
Load development -Electric vehicles -Demand response -Distributed generation -Energy storages	Critical need for real time information, measurements, load forecasts, short-term weather forecasts, understanding of customer behavior, analyses economic incentives, development of battery technology (lifetime, prices)
Reliability -Interruption costs (system level incentives) -Supply security criteria (individual customer perspective) -Interruption time limits (6/24/36 hour limit)	Role of medium voltage networks in the future; reliability and quality can be guaranteed in customer supply point? How number of customers exceeding reliability criteria varies in different network strategies?
Regulation	Impact of regulation in strategic planning; rapid changes in regulation policy,

Open your mind. LUT.

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