Measuring the “Smartness” of the Electricity Grid

Leen Vandezande

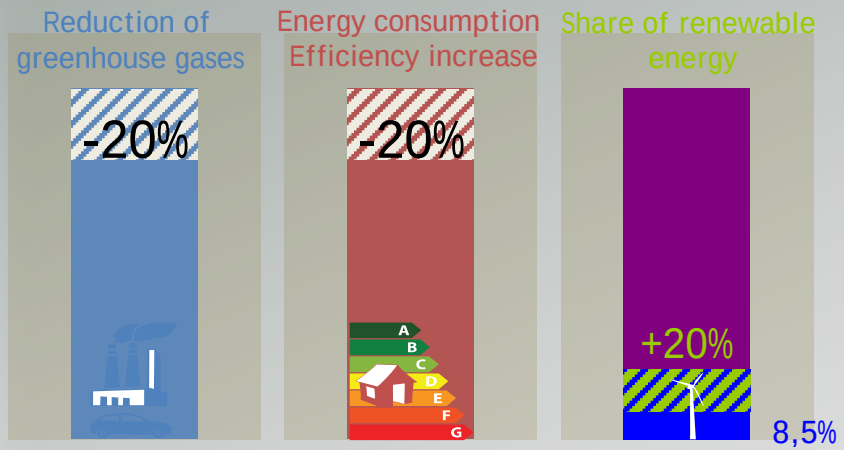
Benjamin Dupont – Leonardo Meeus – Ronnie Belmans

Overview

- Introduction
- Key Performance Indicators (KPIs): what & why?
- Benchmarking the Smart Grid
- Conclusions

Background: European energy policy

- Towards a low carbon economy
  - 3 ambitious targets by 2020
    - Cutting GHG emissions by 20% (compared to 1990 levels)
    - Reducing energy consumption by 20%
    - Reaching a 20% share of energy from RES
  - Min. 80% reduction of GHG emissions targeted by 2050



→ Smart electricity grid = key aspect to reach goals

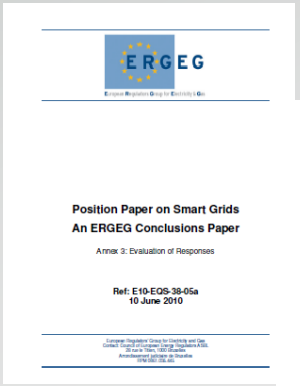
Background: European energy policy

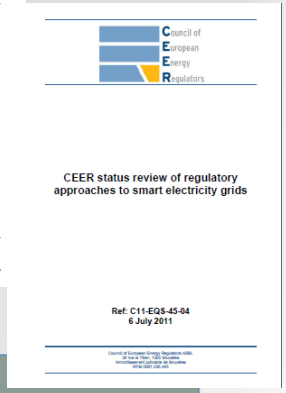
- Strategic Energy Technology (SET) Plan
  - 6 initiatives

Wind energy	Bio-energy
Solar energy	Carbon capture and storage
Electricity grid	Nuclear energy

  - European Electricity Grid Initiative (EEGI)
    - 9-year RD&D program – estimated cost of 2 B€
    - Activities organised in 10 clusters & 29 functional projects

- ERGEG position paper on Smart Grids
- CEER status review of regulatory approaches to Smart Grids
  - Adequate Regulatory framework





Overview

- Introduction
- Key Performance Indicators (KPIs): what & why?
- Key Performance Indicators (KPIs): Why?
- Benchmarking the Smart Grid
- Conclusions

What are KPIs?

- In general
  - Purpose: performance measurement
  - Used in business activity monitoring
    - E.g. in construction industry, health industry, for quality regulation in electricity distribution systems,…
- In a Smart Grid context
  - No common view
    - SET-plan: evaluation of progress towards 2020 targets
    - EEGI: evaluation of demo projects
    - ERGEG: evaluation of regulatory incentives

  → No clear framework exists today

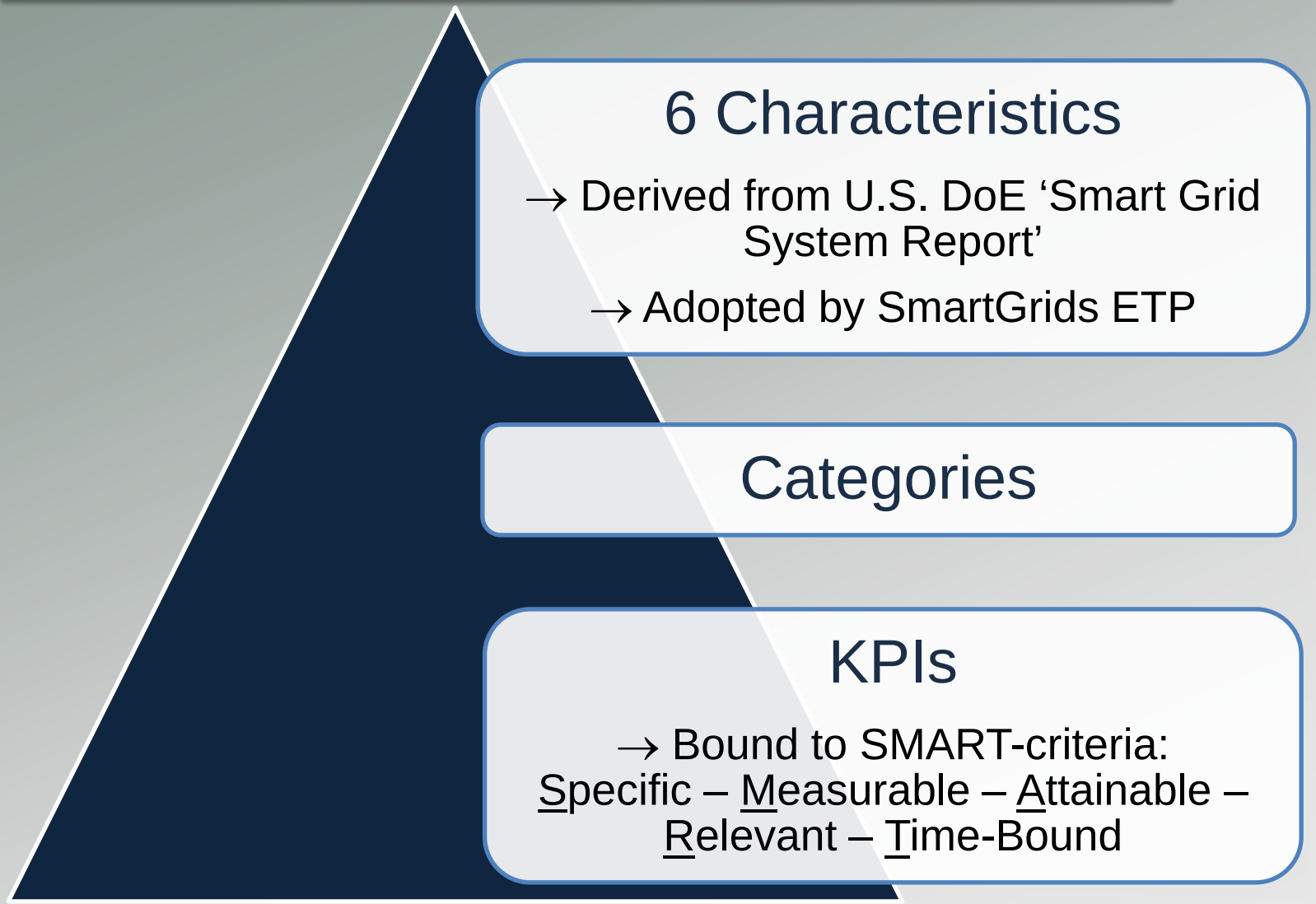
Why using KPIs?

- To answer the questions
  - What makes an electricity system smart?
  - How can this smartness be measured?

Overview

- Introduction
- Key Performance Indicators (KPIs): what & why?
- Benchmarking the Smart Grid
- Conclusions

Methodology



6 Characteristics

- Enable informed participation by customers
- Accommodate all generation & storage options
- Sell more than kWhs
- Provide power quality for the 21st century
- Optimize assets & operate efficiently
- Operate resiliently to disturbances, attacks & natural disasters

Enable informed participation of customers

- Categories

Advanced Meters	Dynamic Pricing Signals
Smart Appliances	Demand Side Management
Prosumer	

Enable informed participation of customers

- KPIs

Enable informed participation by customers	
Advanced Meters	1A: Number of advanced meters installed
	1B: Percentage of total demand served by advanced meters
Dynamic Pricing Signals	2A: The fraction of customers served by tariffs
	2B: The fraction of load served by tariffs
Smart Appliances	3A: Total yearly retail sales volume for purchases of smart appliances [€]
	3B: Total load capacity in each consumer category that is actually or potentially modified by behaviours of smart appliances [MW]
Demand Side Management	4A: Fraction of consumers contributing in DSM [%]
	4B: Percentage of consumer load capacity participating in DSM [MW/MW]
	4C: Potential for time shift (before start-up and during operation) [h]
Prosumer	5A: Total electrical energy locally (decentralised) produced versus total electrical energy consumed [MWh/MWh]
	5B: Minimal demand from grid (maximal own production) versus maximal demand from the grid (own production is zero) [MW/MW]
	5C: Fraction of time prosumer is net producer and consumer [h/h]

Accommodate all generation and storage options

- Categories

DG and storage	PHEVs
DER interconnection	

Accommodate all generation and storage options

- KPIs

Accommodate all generation and storage options	
Distributed Generation and Storage	6A: Amount of production generated by local, distributed generation (MW/MW)
	6B: Potential for direct electrical energy storage relative to daily demand for electrical energy [MWh_{el}/MWh_{el}]
	6C: Indirect electrical energy storage through the use of heat pumps: time shift allowed for heating/cooling [h]
PHEVs	7A: The total number and percentage shares of on-road light-duty vehicles, comprising PHEVs
	7B: Percentage of the charging capacity of the vehicles that can be controlled (versus the charging capacity of the vehicles or the total power capacity of the grid) [MW/MW]
	7C: Percentage of the stored energy in vehicles that can be controlled (versus the available energy in the vehicles or the total energy consumption in the grid) [MWh/MWh]
	7D: Number of charging points that are provided to charge the vehicles
DER Interconnection	8A: The percentage of grid operators with standard distributed resource interconnection policies

Sell more than kWhs

- Categories

New energy services	Flexibility
Customer Choice	Support Mechanisms
Interoperability Maturity Level	

Sell more than kWhs

- KPIs

Sell more than kWhs	
New Energy Services	9A: Number of customers served by ESCO's
	9B: Number of additional energy services offered to the consumer
	9C: Number of kWh that the consumer saves in comparison to the consumption before the energy service
Flexibility	10A: The number of customers offering flexibility to aggregators
	10B: The flexibility that aggregators can offer to other market players [MWh]
	10C: The time that aggregators can offer a certain flexibility [h]
	10D: To what extent are storage and DG able to provide ancillary services as a percentage of the total offered ancillary services
	10E: Percentage of storage and DG that can be modified vs. total storage and DG [MW/MW]
Customer Choice	11A: Number of tariff plans available to end consumers
Support Mechanisms	12A: The average percentage of smart grid investment that can be recovered through rates or subsidies
	12B: The percentage of smart grid investment covered by external financing
Interoperability Maturity Level	13A: The weighted average maturity level of interoperability realised among electricity system stakeholders

Provide power quality for the 21st century

- Categories

Power Quality	Required Power Quality
Microgrids	

Provide power quality for the 21st century

- KPIs

Provide power quality for the 21st Century	
Power Quality	14A: Amount of voltage variations in the grid [RMS]
	14B: Time of a certain voltage variation [h]
	14C: The percentage of customer complaints related to power quality problems (excluding outages)
Required Power Quality	15A: Range of frequencies [Hz] contracted and range of voltages [V] contracted
Microgrids	16A: The number of microgrids in operation.
	16B: The capacity of microgrids [MW]
	16C: The total grid capacity of microgrids to the capacity of the entire grid [MW/MW]

Optimize assets and operate efficiently

- Categories

T&D Automation	Dynamic Line Rating
Capacity Factors	Efficiencies

Provide power quality for the 21st century

- KPIs

Optimise assets and operate efficiently	
T&D Automation	17A: Percentage of substations applying automation technologies
Dynamic Line Rating	18A: Number of lines operated under dynamic line ratings
	18B: Percentage of kilometres of transmission circuits operated under dynamic line ratings [km]
	18C: Yearly average transmission transfer capacity expansion due to the use of dynamic (versus fixed) line ratings [MW-km]
Capacity Factors	19A: Yearly average and peak generation capacity factor (%)
	19B: Yearly average and average peak capacity factor for a typical kilometer of transmission line (%-km per km)
	19C: Yearly average and average peak distribution transformer capacity factor (%)
Efficiencies	20A: Efficiency of generation facilities [energy output (MWh) / energy input (MWh)]
	20B: Energy losses in transmission and distribution [MWh/year]

Operate resiliently to disturbances, attacks and natural disasters

- Categories

Advanced sensors	Information Exchange
T&D Reliability	Standards in tele-communication infrastructure

Operate resiliently to disturbances, attacks and natural disasters

- KPIs

Operate resiliently to disturbances, attacks and natural disasters	
Advanced Sensors	21A: Number (or percentage) of grid elements (substations, switches, …) that can be remotely monitored and controlled in real-time
	21B: The percentage of substations possessing advanced measurement technology
	21C: The number of applications supported by these various measurement technologies
Information Exchange	22A: Total SCADA points shared per substation (ratio)
	22B: Fraction of transmission-level synchrophasor measurement points shared multilaterally (%)
	22C: Performance (bandwidth, response speed, availability, adaptability, …) of the communication channels towards grid elements
T&D Reliability	23A: SAIDI represents the average number of minutes customers are interrupted each year [Minutes]
	23B: SAIFI represents the total number of customer interruptions per customer for a particular electric supply system [Interruptions]
	23C: CAIDI represents the average outage duration that a customer experiences [Minutes]
	23D: MAIFI represents the total number of customer interruptions per customer lasting less than five minutes for a particular electric supply system [Interruptions]
Standards in telecommunication infrastructure	24A: The compliance of electric power industries with European and international telecommunication standards and protocols.

Using the results for policy making

- Assess progress towards a smart grid on national & European level
  - Benchmarking between countries or with other continents
- Regulation
  - Sunshine Regulation
  - Incentive regulation
  - Direct regulation
  - …
- Evaluate project results on smart grids

→ Encourage progress in <u>each</u> of the 6 characteristics

Overview

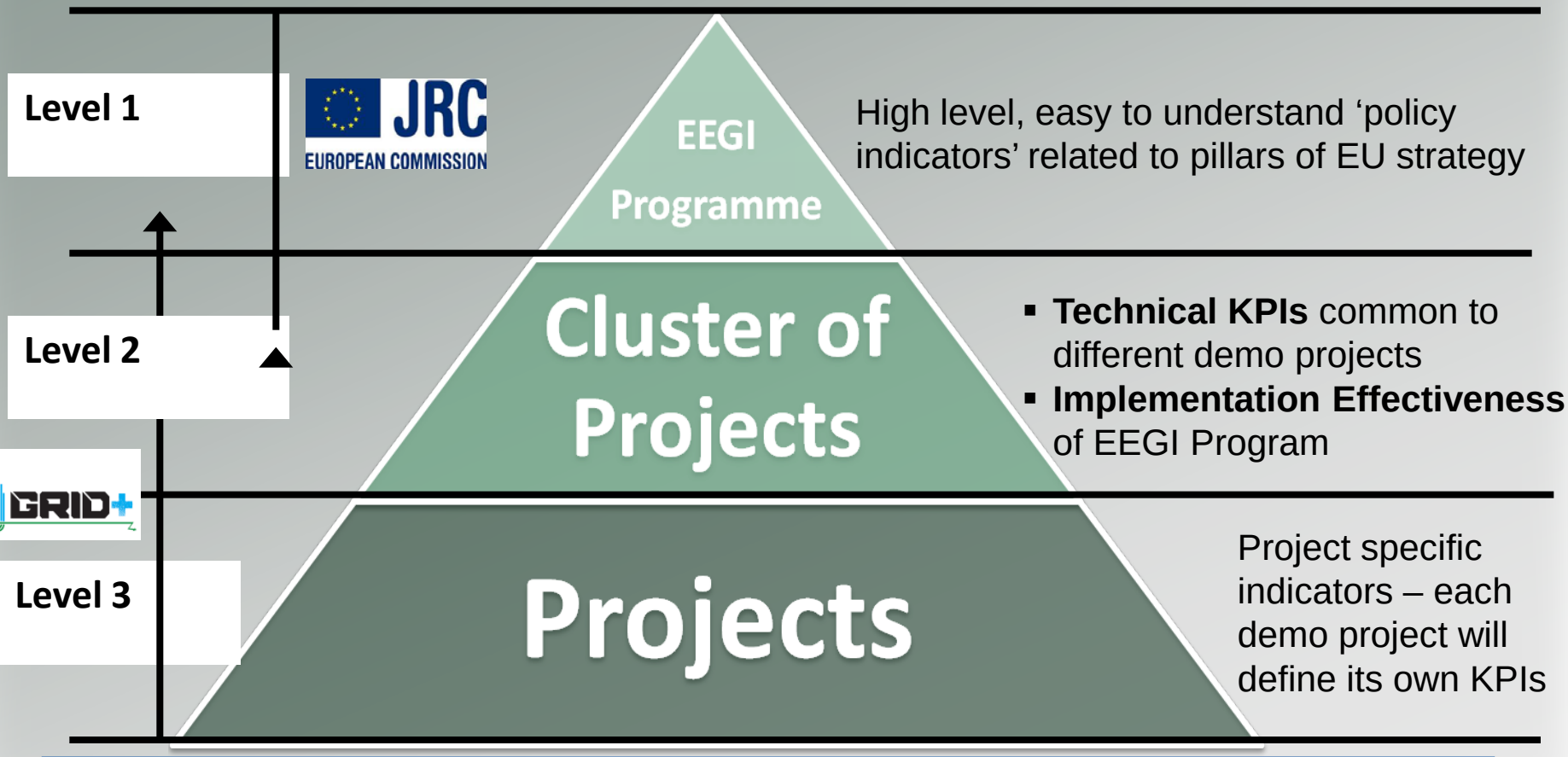
- Introduction
- Key Performance Indicators (KPIs): what & why?
- Benchmarking the Smart Grid
- Conclusions

To conclude

- Differences between initiatives
  - No common understanding of KPIs
  - Measurability sometimes neglected
- List of KPIs
  - Defined around 6 characteristics
  - Clustered in categories
- Further Research
  - Starting Point
  - Workshops/Surveys/Studies

Further research: Example

- Definition of KPIs for evaluation of project results within EEGI program



Source: www.gridplus.eu

Further reading

- Download the full paper at

  http://www.esat.kuleuven.be/electa/publications/fulltexts/pub_2072.pdf