SMART POWER GENERATION

18th National Energy Conference
Energy and Development 2013
Athens

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Content

Smart Power System (SPS)

Smart Power Generation (SPG)

The traditional power system

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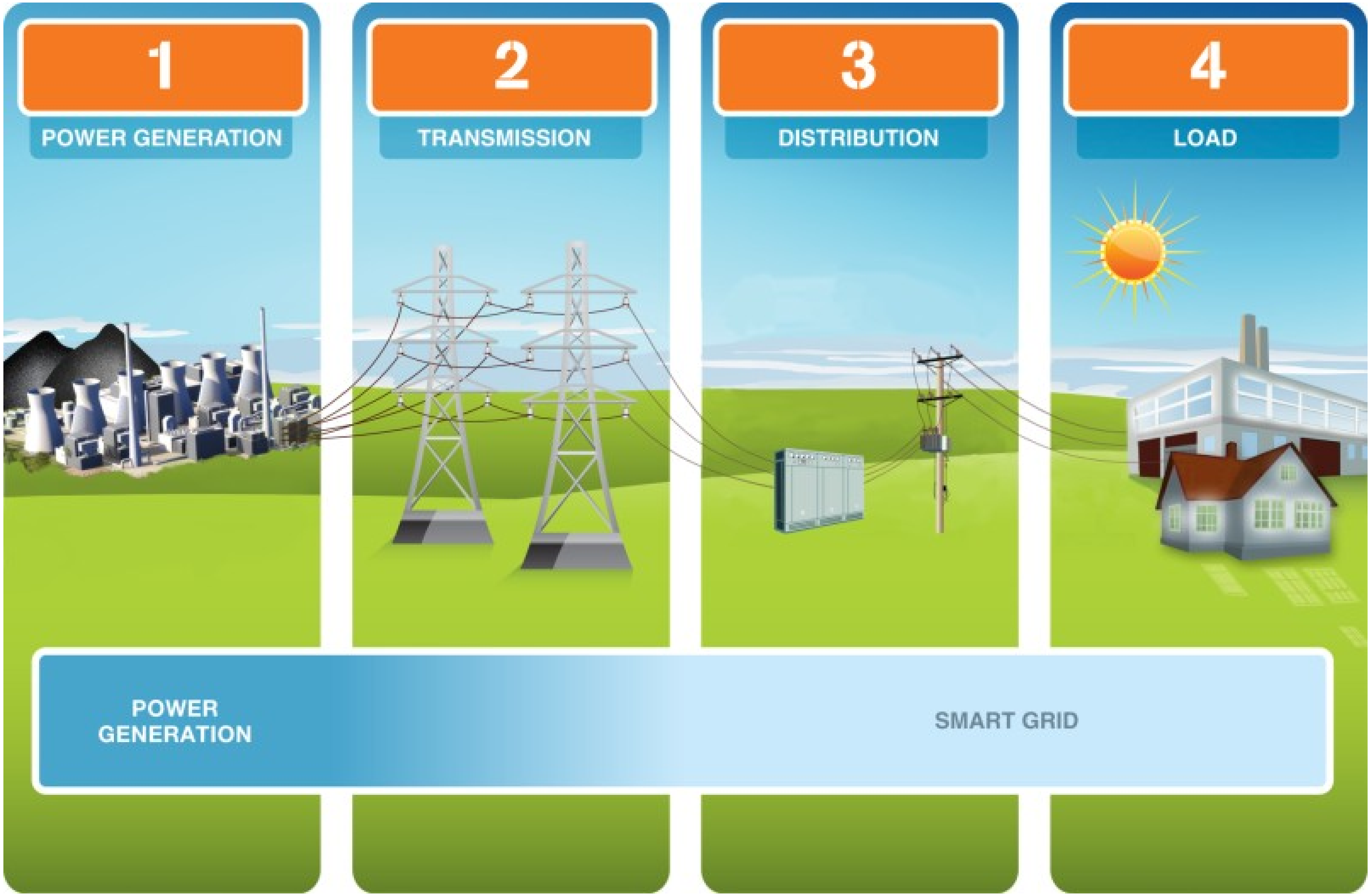

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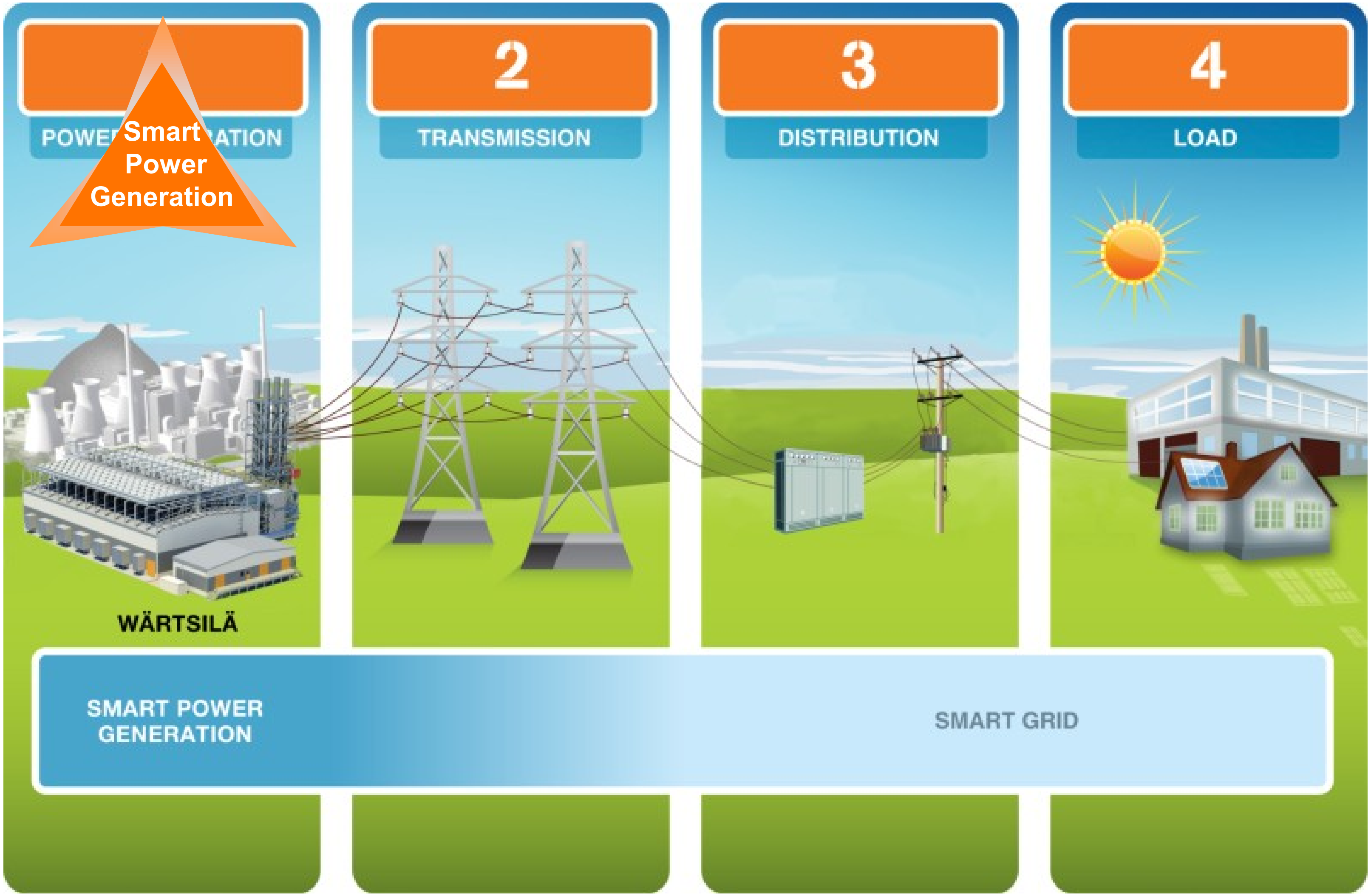
Smart Power System – with Smart Power Generation

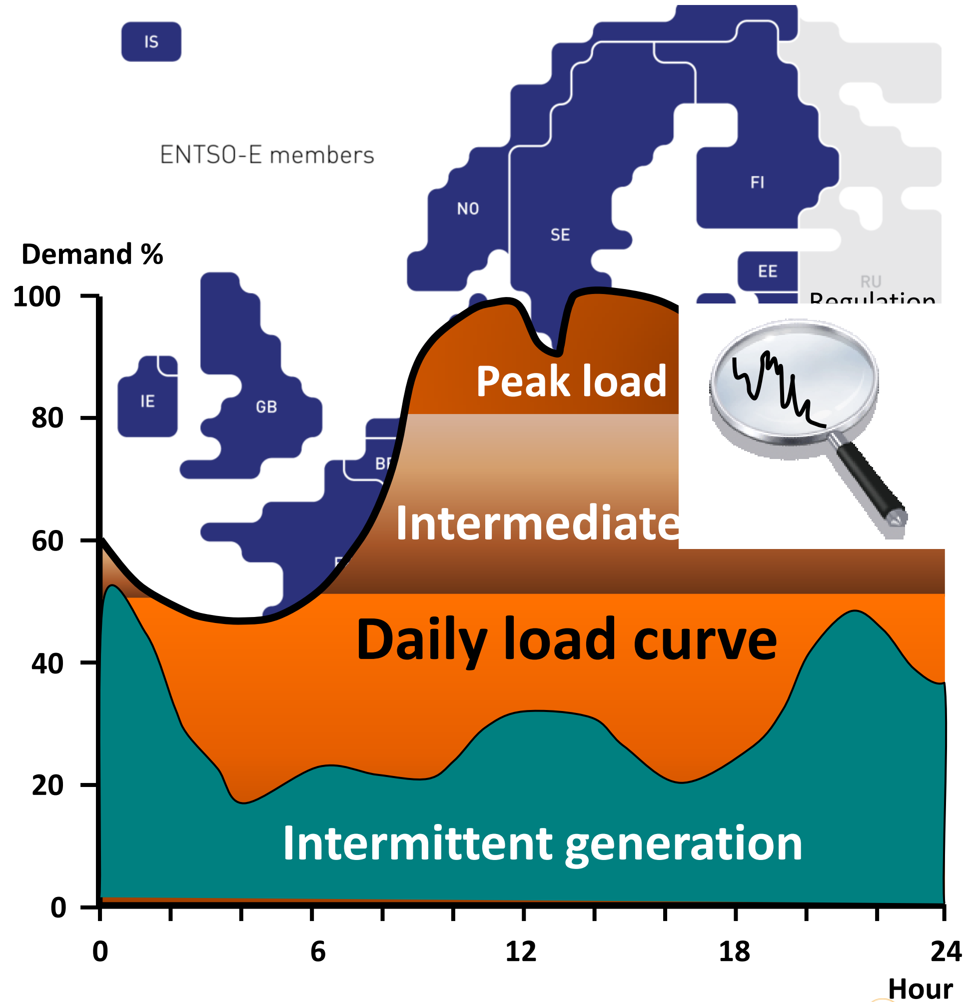


The CHANGE in power systems

Power systems are the largest man made dynamic systems – inherently complex systems for any optimization

Intermittency of wind and solar power represent the biggest challenge and CHANGE to the Power system operation since the dawn of power generation

New investment is needed for the power system, but what and how?



Daily load curves, 20 % at 2020 system

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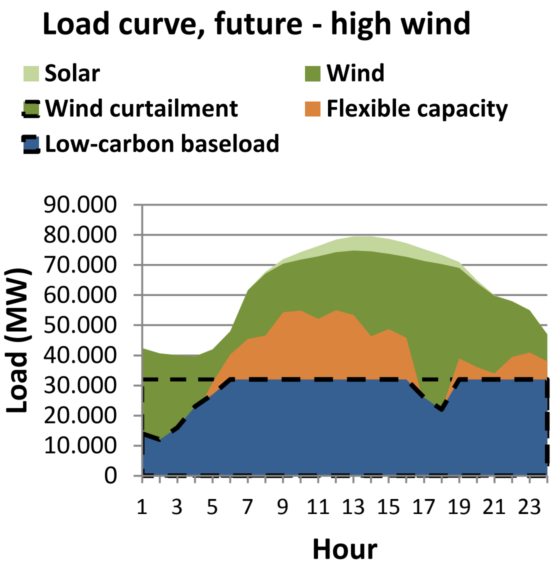
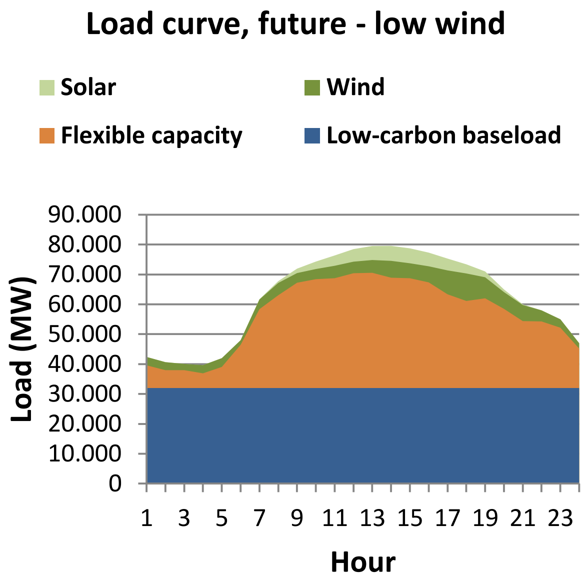
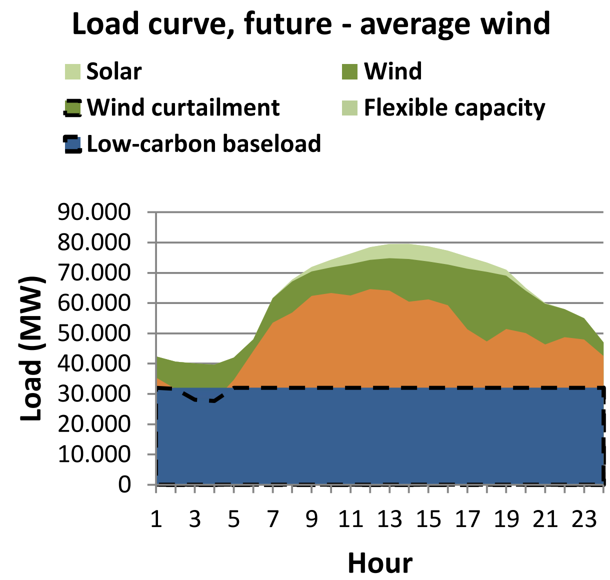
Daily system load curve and capacity dispatch







System dispatching challenges

- 49 GW wind capacity > more than system night load!
- Wind speed change 7 → 9 m/s leads to a wind power output change of 13,5 GW! Such wind speed changes happen all the time!
- Dynamic thermal capacity will have to stretch tens of GWs up and down within less than 30 minutes
- System balancing will be a major challenge

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System capacities, 20 % at 2020 system 1(2)

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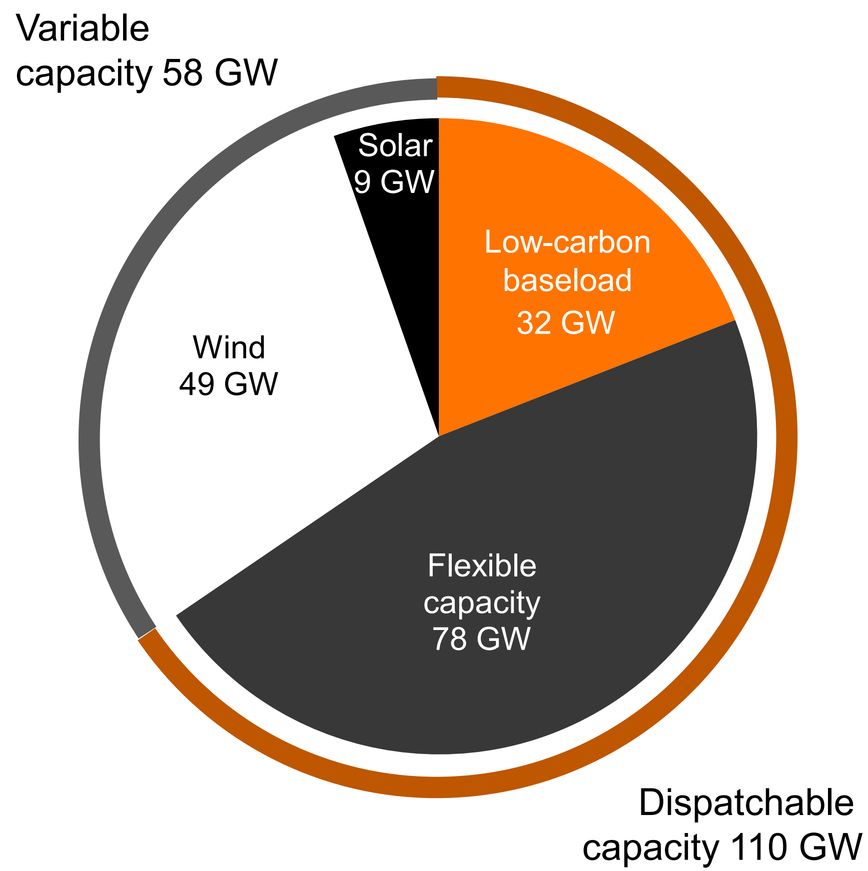
- System peak load 100 GW
- Needs 110 GW installed dispatchable capacity (10% margin for contingency situations)
- 20% of power produced with renewables requires e.g.:
  - 49 GW wind capacity (capacity factor 25%)
  - 9 GW solar capacity (capacity factor 20%)
- The >8000h base load capacity need is about 32 GW
- The gap between installed base load capacity and the system peak load must be covered with 78 GW of flexible, dispatchable capacity

Capacity, future system



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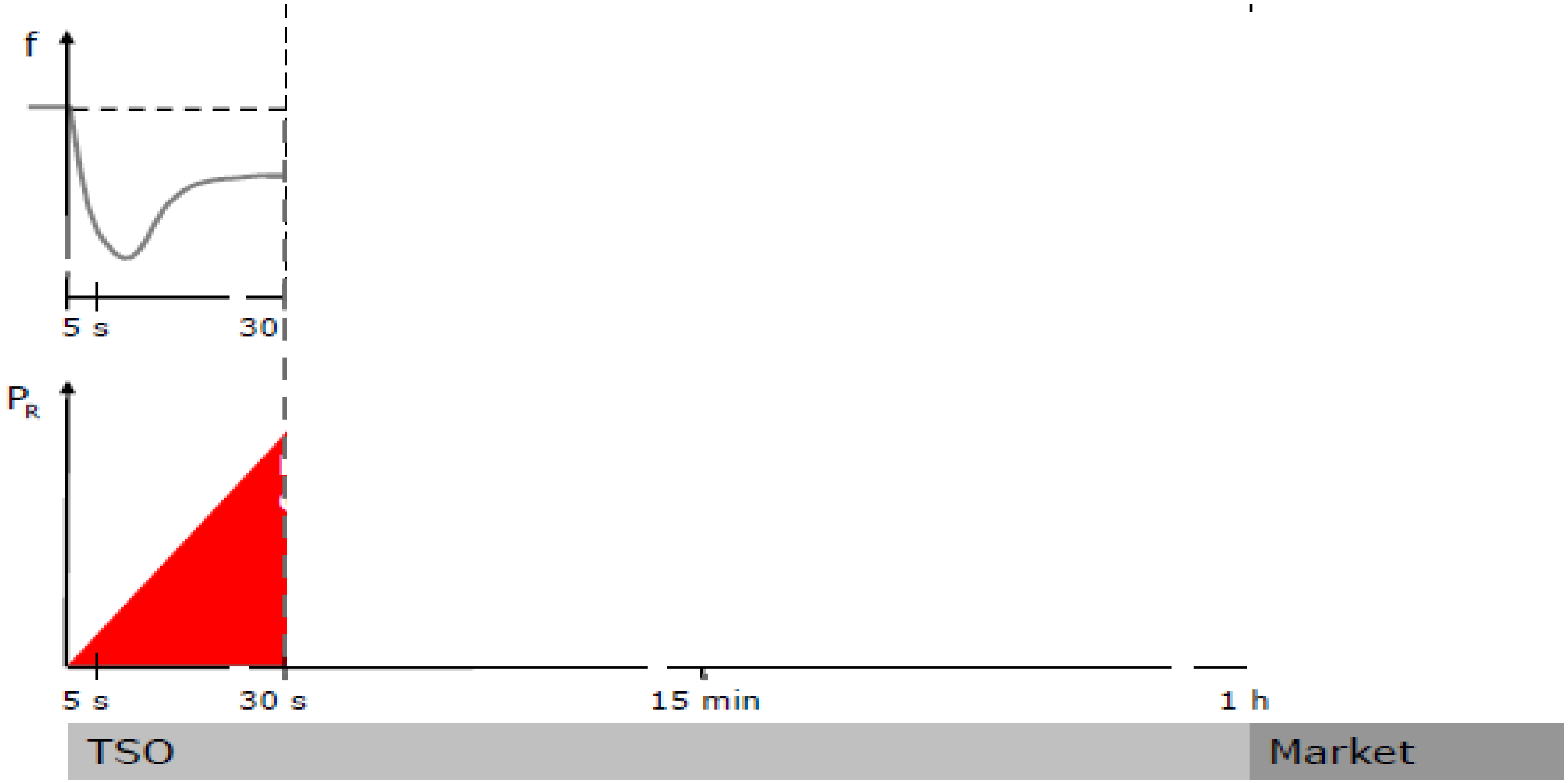
Power system reserves

- Demand for and generation of electricity must be kept in constant balance in order to maintain stability in a power system
- The system operator must schedule sufficient **operating reserves** to ensure that the required real time power needs can be met
- Because the future is uncertain, there is some risk that either too much or too little capacity is scheduled and committed, resulting in operative challenges during the operating day
- Differences between forecast and actual real time situation can arise from 3 main reasons
  1. **Unplanned outages of power plants or/and transmission lines**
  2. **Electricity demand (load) deviating from the forecast**
  3. **Intermittent renewable generation output deviating from forecast**
- **Operating reserves** are called to act over short timescales, from seconds through to a few hours, depending on the challenge at hand.

Types of operating reserves



Primary reserve: activation in 1 to 30 seconds
Generators must automatically act on the frequency deviation to cause the **frequency to be maintained** at certain stable level

Secondary reserve: activation after 30 seconds, up to 10...15 minutes
Restore power balance and free up primary reserve

Tertiary reserve: activation after 10-15 minutes
After secondary control reserves are used, **Tertiary reserve free up secondary reserves,** in order for the system to be able to respond to the next contingency

Dispatch additional capacity: start up capacity thru market to free up tertiary reserves

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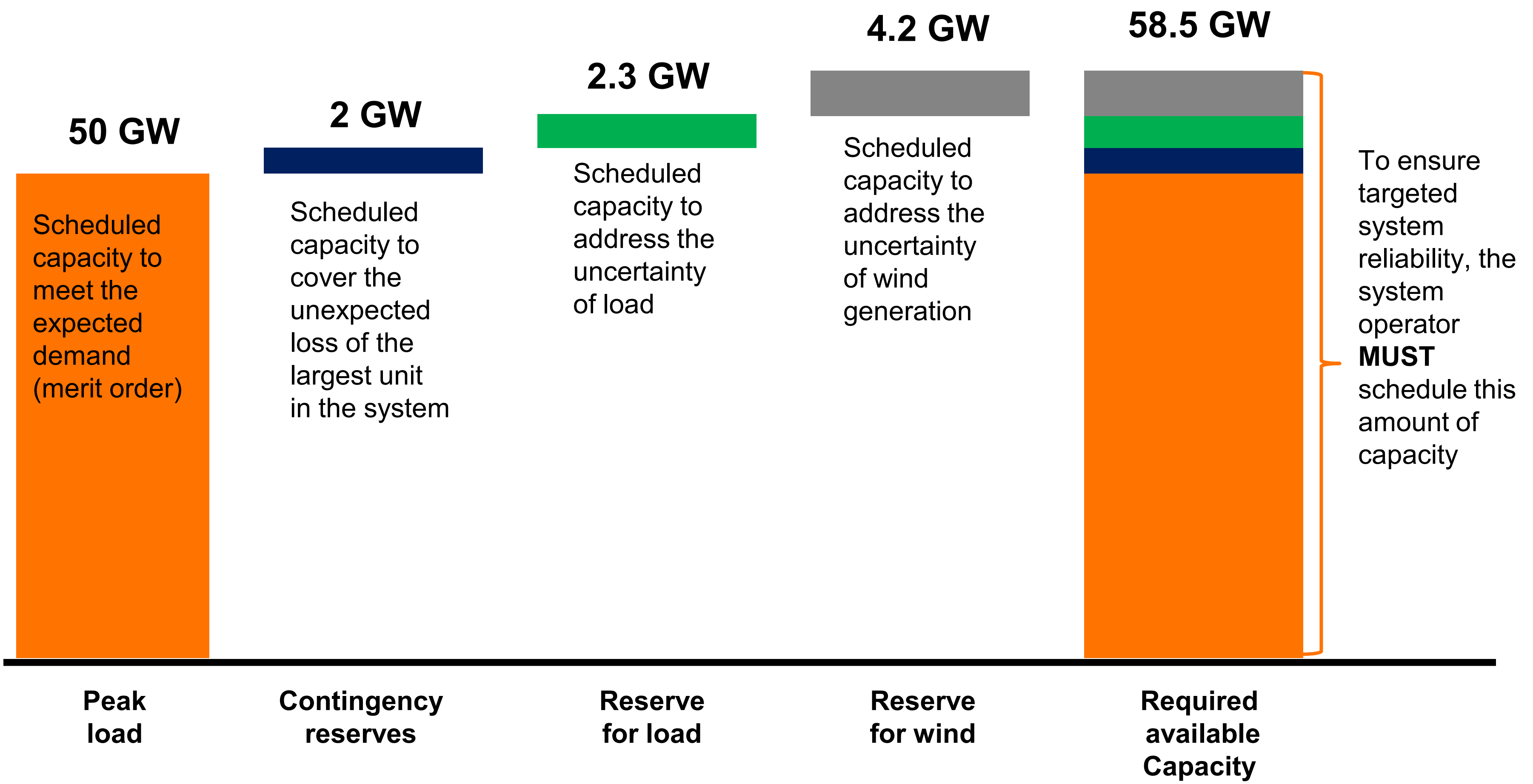
Amount of system reserves

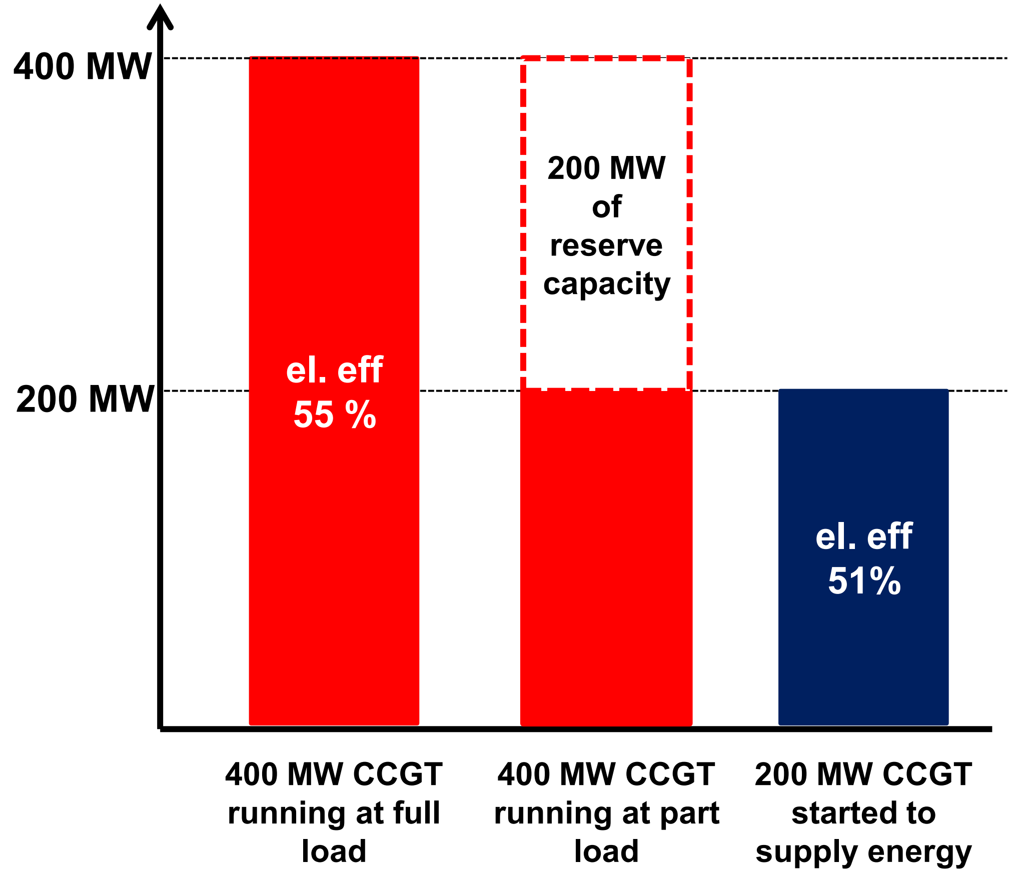
Typical 4 hours ahead requirement for 50 GW system with 10 GW forecasted wind output and 99.7% reliability target



Traditional way to create reserves

- Traditionally, conventional generating plant is used for providing operating reserve
- In order for synchronised plant to provide operating reserve it must run part-loaded
  - Thermal units operate less efficiently when part-loaded
- Since efficient generating units will be part loaded to provide the operating reserve, plant with higher marginal cost will need to be brought on the system to supply energy
  - Another source of cost associated with the provision of operating reserve

Illustrative example



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Smart way of creating reserves

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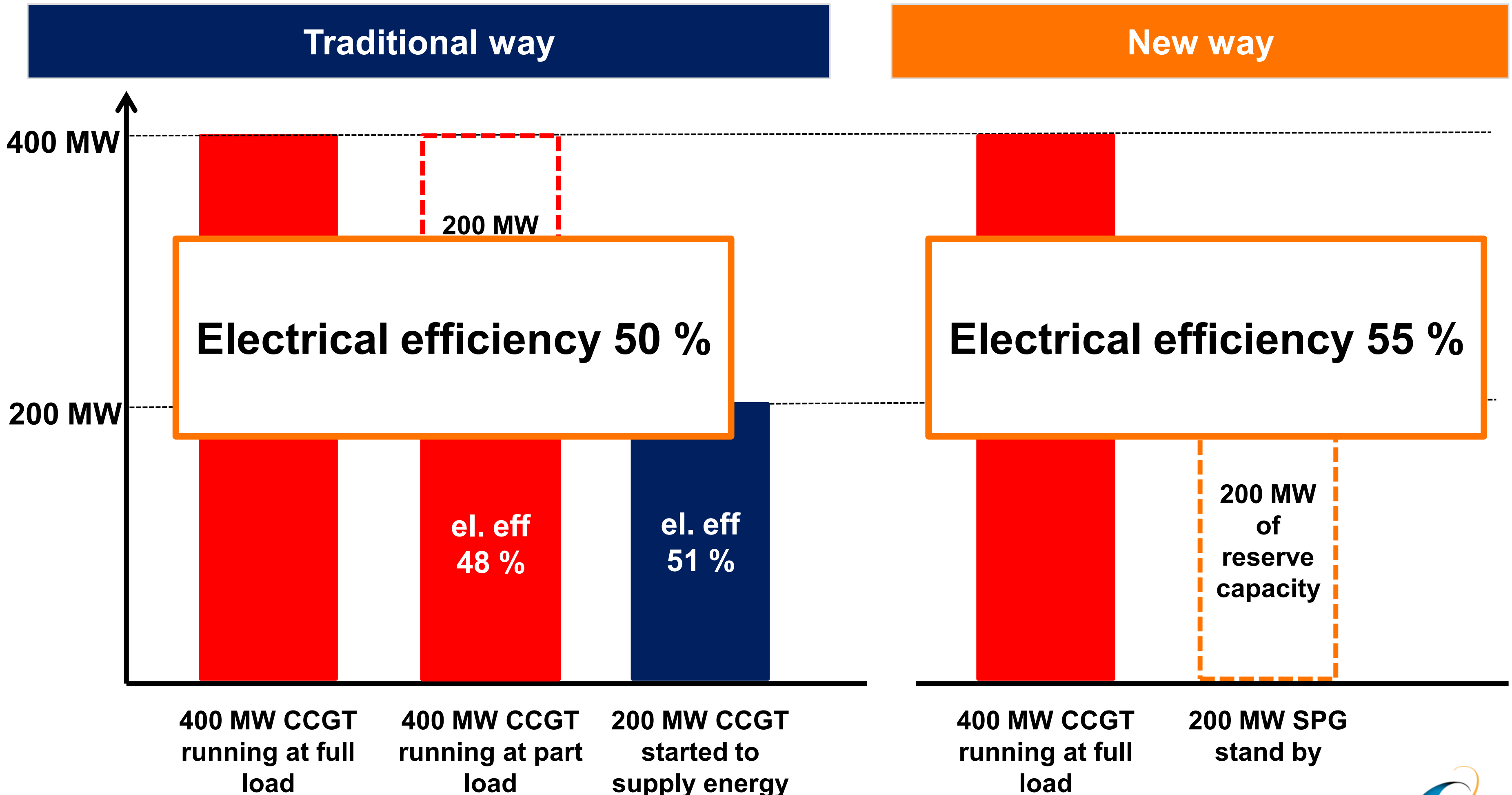
- New way to create reserve = Flexible, fast starting generation units
- Benefits = Optimize the operations of total fleet (no need to run plants at part load)
- Benefits = No need to start costlier generation to provide energy



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Need for spinning reserve

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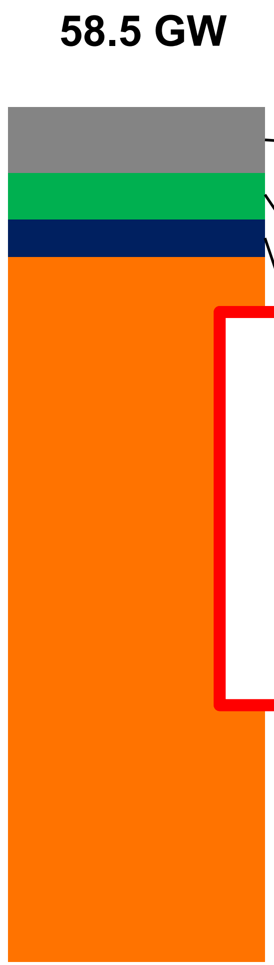
- Need for spinning reserves = Uncertainty that needs to be covered in less than 5 minutes



Wind

- Biggest change in 5 minutes is ~ 3 % of generation
- Need for spinning reserve is 300 MW

6.7 GW of cost-efficient generation could run at their design point, providing affordable electricity!

Plant / power line loss

- Primary + secondary response
- Need for spinning reserve is 1000 MW

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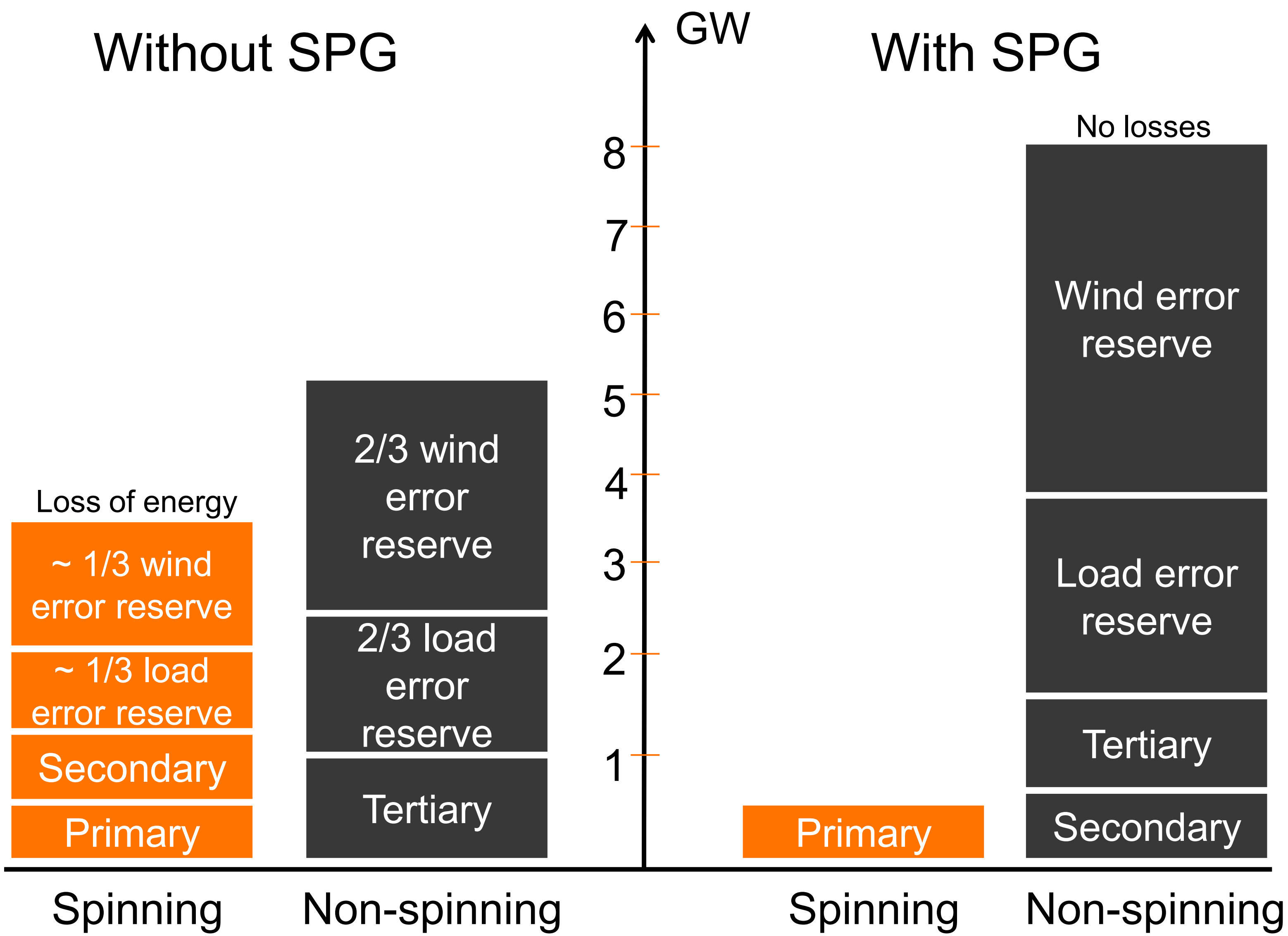
Replacing spinning with non-spinning



Competitive technology comparison

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	Electrical efficiency full load, %	Typical plant size, MW	Normal starting time to full load, minutes	Dynamic capabilities	CO_2, g/kWh
Nuclear	31-33	1000 - 2000	>2000	Poor	-
Coal	33-45	300 - 4000	>180	Poor	820 - 1050
CCGT gas	50-57	200 - 1500	60-90	Not good	370
Gas engines	49	1 - 500	2-10	Excellent	430
Aero GT	33-41	1-300	10-13	Good	500
HDGT	30-35	100-1000	13-30	Decent	560
Flexicycle	49/53	100-500	5/45 *	Very good	400

*) Simple cycle / combined cycle

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Operational flexibility vs. electrical efficiency

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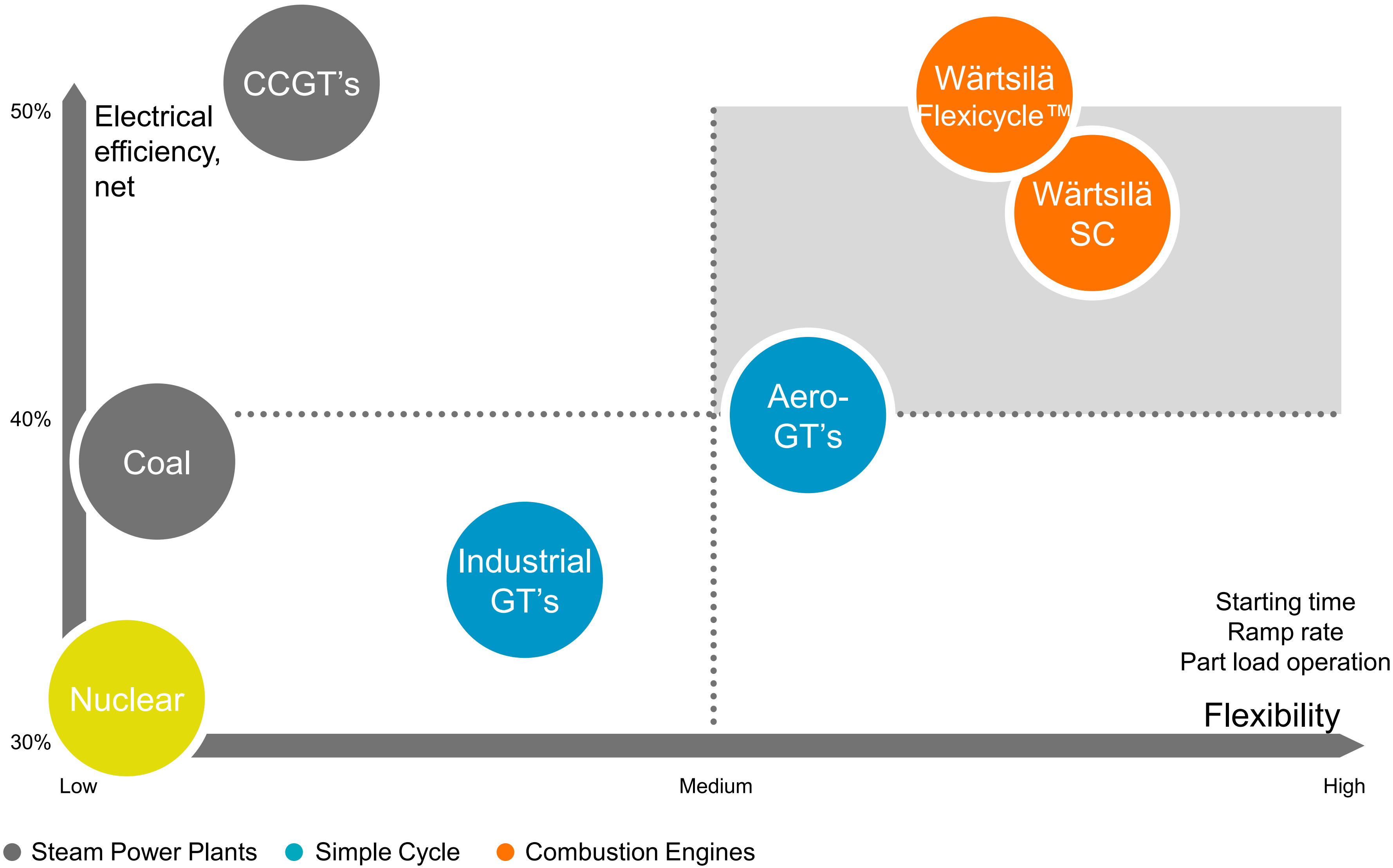

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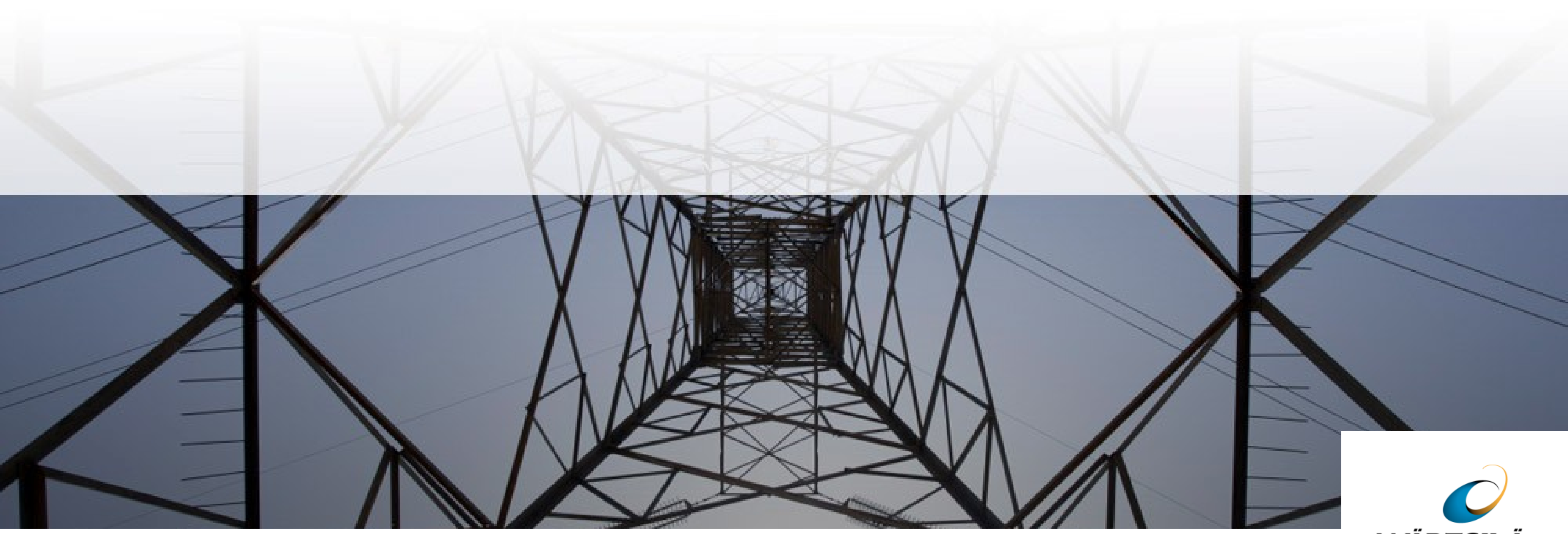
Smart Power System (SPS)

Smart Power Generation (SPG)



What is Smart Power Generation

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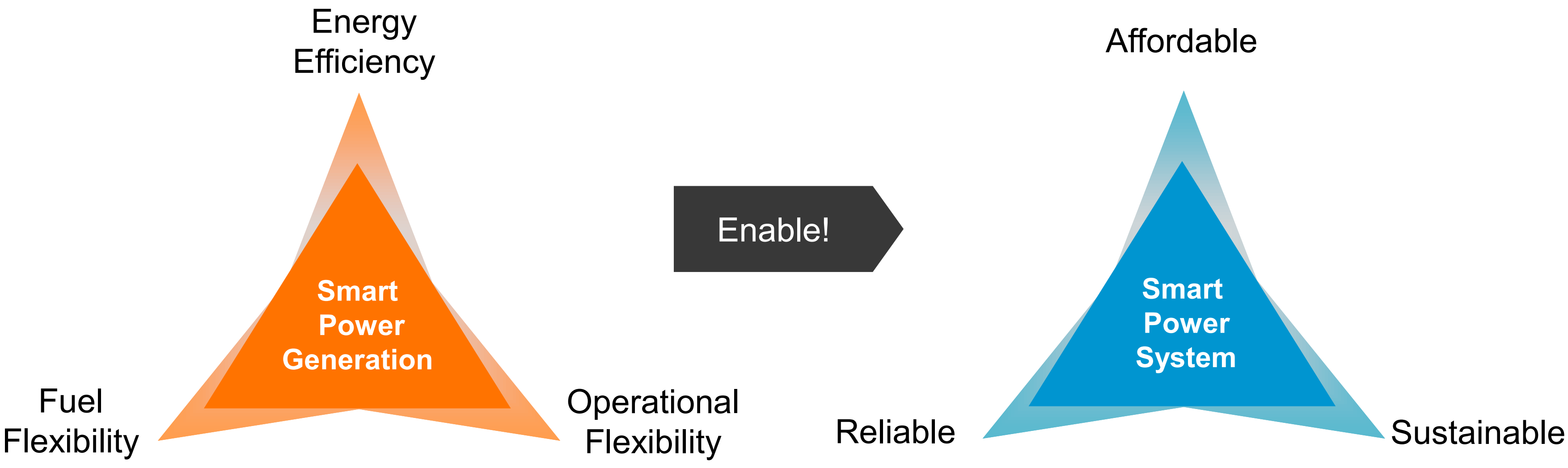
The missing piece of the low carbon power system puzzle!

Smart power generation enables the global transition to a sustainable, reliable and affordable energy infrastructure.

It is a new, unique solution for flexible power generation and an essential part of tomorrow s optimized and secure low carbon power systems.

Smart power generation can operate in multiple modes, from efficient base load power production to ultra fast dynamic system balancing.

Smart Power Generation improves the system total efficiency, and solves the variability challenges of maximized wind integration.



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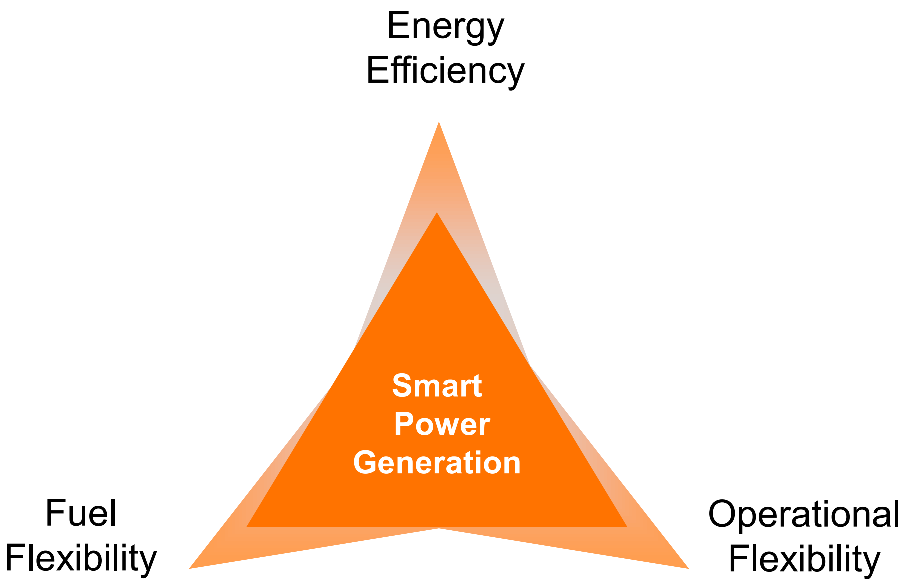
Benefits to power producers

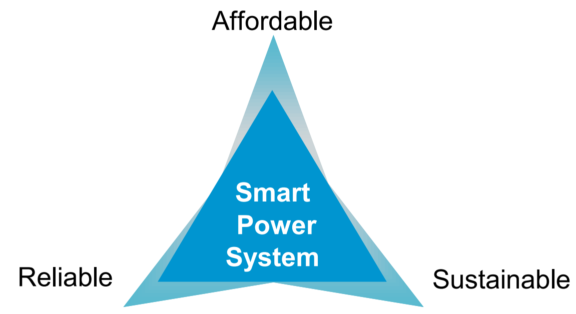
- Operate on multiple markets
  - Energy markets
  - Capacity markets
  - Ancillary services markets
- High dispatch enabled by high efficiency
- Dependable and committable
  - Multiple generating units
  - High unit reliability and availability
- Optimum plant location close to consumers
- Fuel flexibility – hedge for the future
- Fast access to income through fast-track project delivery
- Competitive O&M costs

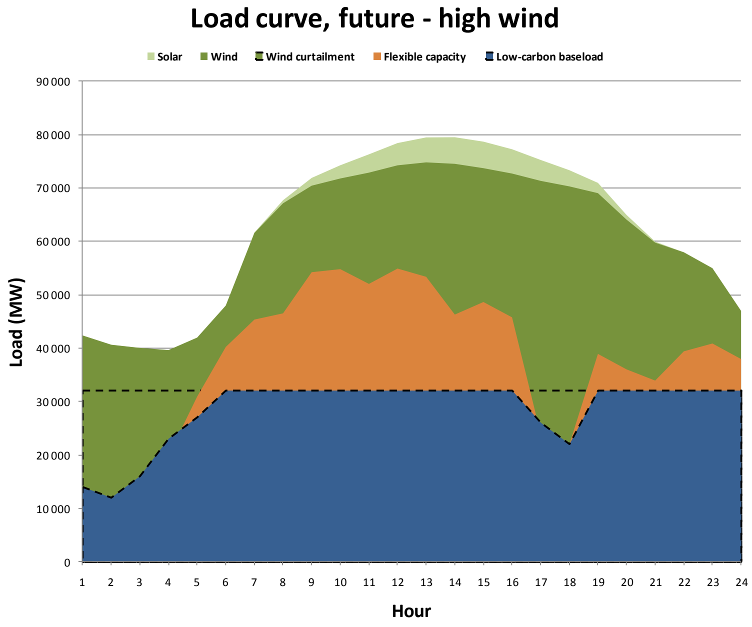


Smart Power Generation is a new concept which enables an existing power system to operate at its maximum efficiency by most effectively absorbing current and future system load variations, providing dramatic savings.

Benefits to power systems

- Secures the supply of affordable and sustainable power
  - Enable highest penetration of wind and solar power capacity
  - Maximizing the use of wind power capacity by minimizing wind curtailment
  - Ensure system stability in wind variability and contingency situations
  - Avoid negative prices
- Ensures true optimization of the total power system operation
  - Remove the abusive starts and stops, and cyclic load from base load plants that are not designed for it
  - Improves the total system efficiency
- Enables reaching the 20 % 2020 renewable energy share targets set by many countries





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Wind chasing in Colorado, USA

In systems with high wind penetration, thermal power plants face

- Lower average load & more part load operation
- Faster ramp up's and down's
- More starts and stops

Colorado Dispatch Center, Xcel Energy, USA

Wärtsilä's Solution – Values & Features

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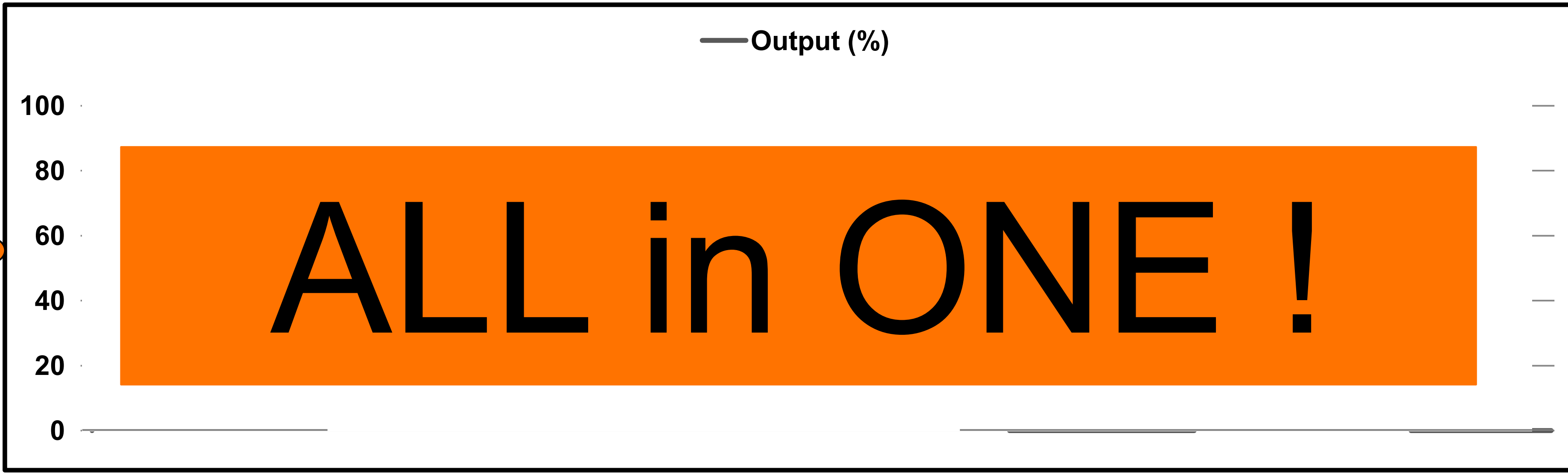

1 FASTSTART	2 BASELOAD	3 LOAD FOLLOWING	4 LOW-LOAD OPERATION	5 FAST STOP
VALUE Grid stability support Ancillary Services Low start-up costs	VALUE Competitive life cycle generation cost	VALUE Wind balancing Ancillary Services	VALUE "low load" = No load	VALUE No opportunity lost RE enabler
FEATURES Power to grid 30 sec Full power 2 min Start-up efficiency	FEATURES Highest SC efficiency Multi unit set-up Flexicycle ™	FEATURES Part load efficiency No EOH cost	FEATURES 1min shutdown No min down time No fuel cost No emissions	FEATURES 1min shutdown No min down time No EOH calculation

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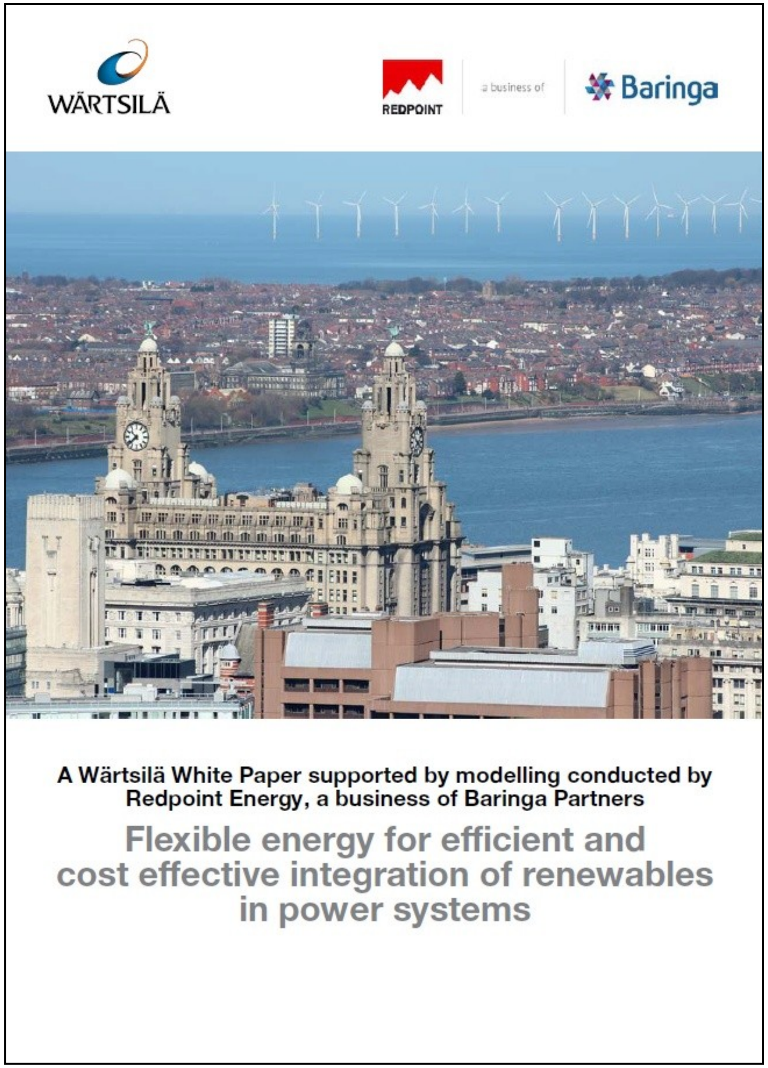
Case study – United Kingdom

- Key features of the model:
  - All major electricity generators represented (~400 generating units) and interconnection to foreign markets
  - Two stage model, including both market trading and then balancing by National Grid
- Key outputs from the model:
  - **Generator costs** (fuel, carbon, maintenance, start-up costs),
  - **System Operator costs** (e.g. incurred by National Grid when taking balancing actions on power plants to ensuring adequate flexibility)
  - **Electricity price**



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Modelled scenarios in the UK

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- Two underlying capacity scenarios were modelled for 2020 and 2030:
  - 'base wind' scenario[1]
  - 'high wind' scenario
- Replacing 4.8 GW of conventional CCGTs with 4.8 GW of gas-fired Smart Power Generation (SPG)[2]

Scenarios Modelled

Scenario	Year	No SPG	With 4.8 GW SPG
Base wind	2020	✔	✔
	2030	✔	✔
High wind	2020	✔	✔
	2030	✔	✔

[1] Base Wind DECC Updated Emissions Projections, central (Oct 2011)
http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx

High Wind National Grid Future Energy Scenarios, Gone Green (Oct 2012)
http://www.nationalgrid.com/uk/Gas/OperationalInfo/TBE/Future+Energy+Scenarios/

[2] The 4.8 GW of SPG approximates the volume of new-build CCGT to 2020 under the base wind scenario. We have assumed no new SPG post-2020.

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Provision of flexibility – with & without SPG (UK)

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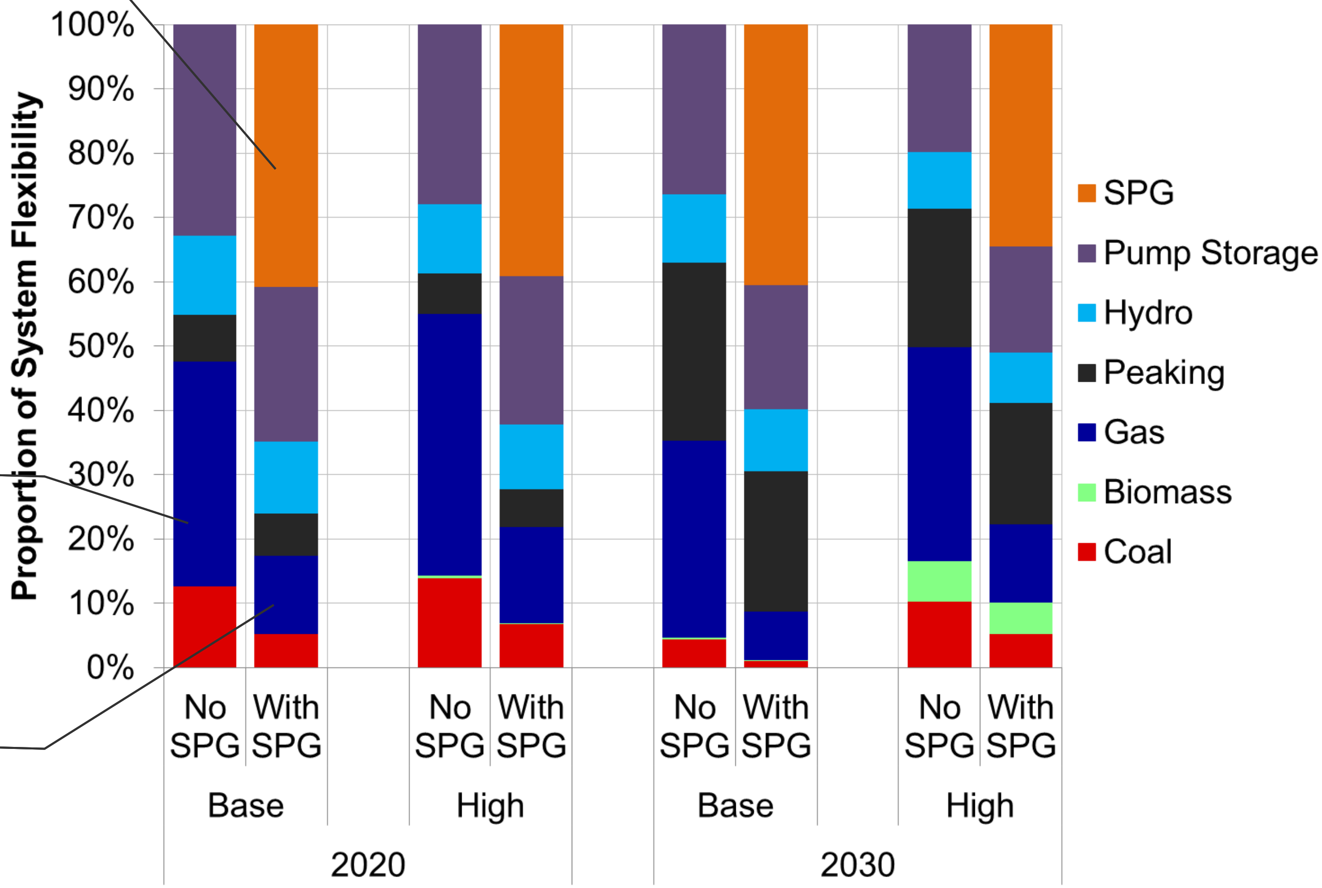
SPG can provide a very large proportion of **flexible generation**, primarily when standing ready but not generating

Without SPG, conventional coal and gas must provide a large proportion of flexibility by running at **part load**, **decreasing efficiency**

With SPG present, conventional coal and gas can provide far less flexibility, and so can **run efficiently** at **full output**



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Value of Smart Power Generation (UK)

SMART POWER GENERATION

- The potential value of the flexibility provided by SPG has been quantified by calculating balancing costs under each of the scenarios:
  - **Balancing costs**: the costs incurred by the National Grid when ensuring adequate flexibility on the Grid[3]
  - These costs are passed onto consumers through BSUoS[4] charges
- There are significant potential savings in all scenarios

Potential cost savings due to Smart Power Generation

Balancing costs – flexibility provision (£ mn per annun, real 2011)	2020		2030	
	Base Wind	High Wind	Base Wind	High Wind
Costs - No SPG	692	1008	834	2781
Costs - With 4.8 GW SPG	311	464	256	1244
Cost Saving due to SPG	**381**	**545**	**578**	**1537**

[3] The potential savings in underlying generation costs (fuel, carbon, imports etc) have also been calculated, and range from £22mn pa (2020 Base wind) to £742mn pa (2030 High wind). These are incurred by generators and are reclaimed through participating in the Balancing Mechanism.
[4] Balancing Services Use of System

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Key messages from the UK

- A large increase in **renewable generation** is required in the UK
  - 30% of electricity generation will come from RES by 2020 on a path to an 80% reduction in emissions by 2050

- Renewable generation is **intermittent** and requires complementary **flexibility** from the rest of the grid to ensure system security and stability

- Analysis shows that **flexibility can have significant value** by allowing a more efficient integration of intermittent renewable generation:
  - **£380m to £550m** p.a. in 2020
  - **£580m to £1540m** p.a. in 2030

Key messages from the UK

SMART POWER GENERATION

- Further analysis has shown that the **value of flexibility** can be even **greater** when fluctuations at a **10 min level** are considered, **25-35% higher** than typical 30 min modelling

Further benefits that are not quantified/valued in the modelling presented:

- The fast response time of SPG **allows the system operator to delay decisions** about the balancing actions needed to provide flexibility
  - By delaying the point at which balancing decisions are made, uncertainty over wind and demand can be reduced – and so **flexibility requirements can be reduced**
- On very **windy days**, **wind power is curtailed** by the system operator, to reduce the flexibility required to cover uncertainty in wind output
  - The modelling suggests 0.8TWh of wind curtailment (1% of generation) in the High 2020 scenario. The **inclusion of SPG reduces curtailment** to 0.2TWh

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Case study – California (CA)

Study system:

The California Independent System Operator (CAISO) due to

- high level RPS [1] of 33%
- publicly available grid data
- well defined new capacity in LTPP [2] (2010)
- upcoming OTC [3] retirements (5.5 GW new)

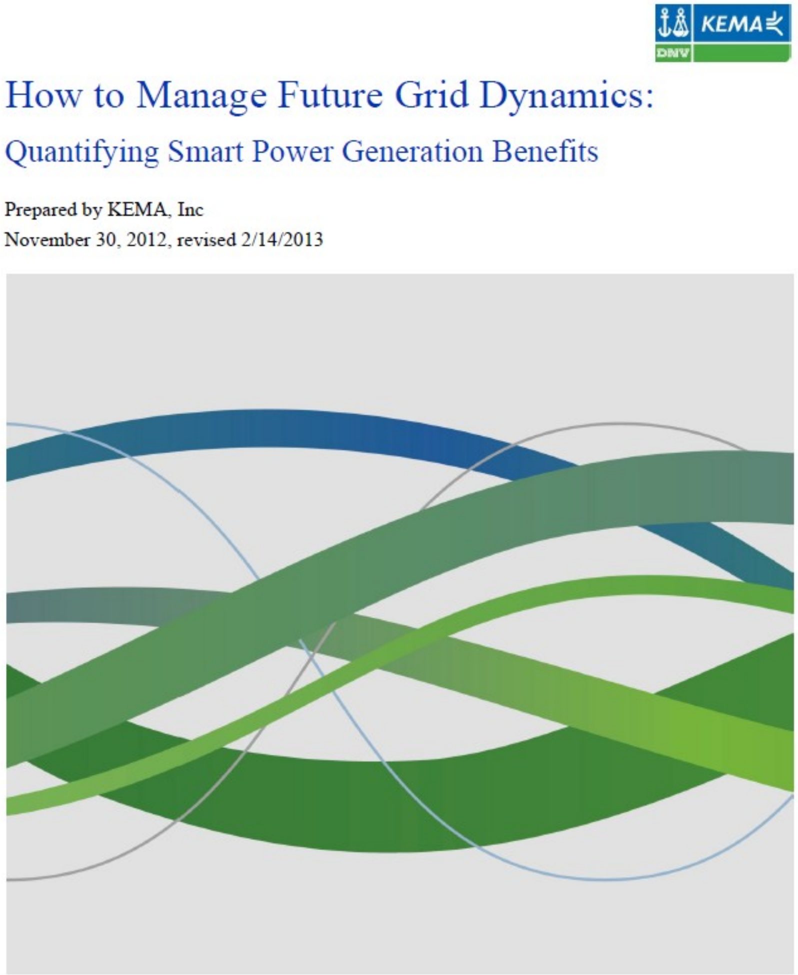
Core Analysis:

A. Confirm market impacts of 33% RES

B. Analyze cost impact of different natural gas capacity expansion/replacement

Methodology:

Optimize energy & A/S [4] costs over WECC [5] & isolate cost impacts to CAISO



KEMA DNV

How to Manage Future Grid Dynamics:

Quantifying Smart Power Generation Benefits

Prepared by KEMA, Inc

November 30, 2012, revised 2/14/2013

[1] Renewable Portfolio Standards
[2] Long Term Procurement Planning
[3] Once Through Cooling
[4] Ancillary Services
[5] Western Electric Coordinating Council

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Modelled scenarios in California (CA)

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- **Scenario 1: Base Case**
  - Environmentally constrained generation asset assumptions
    - Includes 5,5 GW of new and Once Through Cooling (OTC) re-powered assets
  - High Load sensitivity case
- **Scenario 2: SPG in Simple Cycle instead of new GT – based capacity**
  - Base Case assumptions, ***except***
    - Instead of 5,5 GW of new and OTC re-powered assets use 5,5 GW of simple cycle SPG
- **Scenario 3: SPG mix instead of new GT – based capacity**
  - Base Case assumptions, ***except***
    - Instead of 5,5 GW of new and OTC re-powered assets use 3,3 GW of combined cycle SPG and 2,2 GW of simple cycle SPG
- **Scenario 4: New GT – based capacity and SPG Mix**
  - Base Case assumptions, ***and***
    - Add 3,3 GW of combined cycle SPG and 2,2 GW of simple cycle SPG

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Value of Smart Power Generation (CA)

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Annual operating costs in 2020			
Cost category	**Base case Million $**	**Flexible case Million $**	**Cost savings in Flexible case**
Variable generation cost	4 963	4764	199
Start and stop cost	179	96	83
Emission cost	1 463	1 401	62
Import cost	327	379	-52
Ancillary service cost	1 201	603	598
TOTAL system operating costs	8 133	7 243	890

CAISO has decided to install 5.5GW of Natural Gas generation, currently specified to be traditional gas generation. If SPG is installed instead of traditional, the monetary value for the system on annual level is almost 900MUSD/a (**11% of system level cost**)

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Key messages from California

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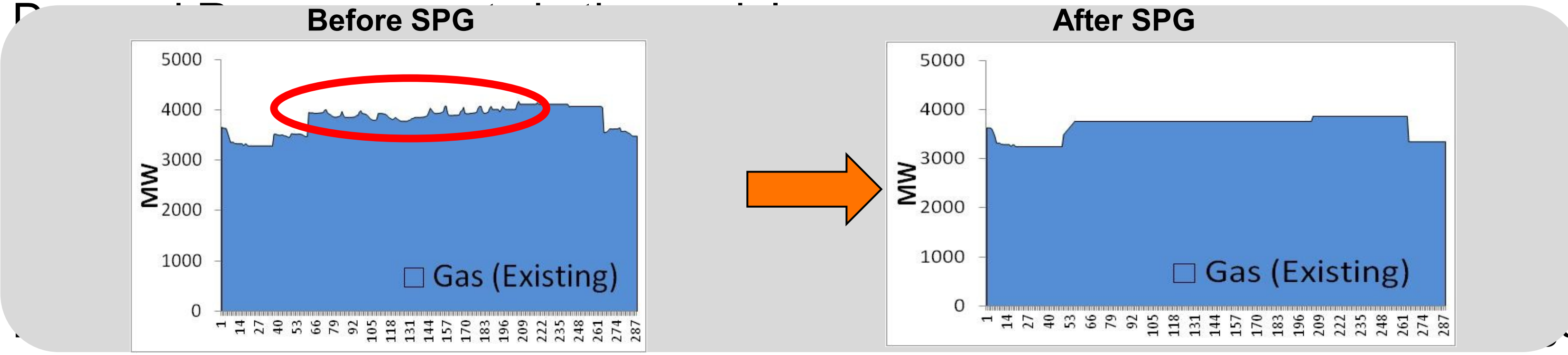
With current plans, California will run out of A/S products on high variability days in 2020.

- This results in curtailments, represented by high Loss of Load Equivalence



will be 4% annualized if Wärtsilä SPG is used.

- With SPG, 300 to 900 MW less capacity is needed to meet the resource adequacy criteria compared to reference scenario
- **SPG provides majority of upward ancillary services**, which **allows more efficient plants (CCGT) to operate in their design point**

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System benefits of Smart Power Generation

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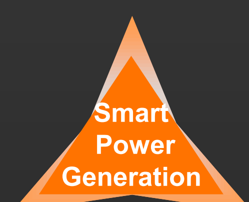
NEED FOR SYSTEM RESERVES

1. Unplanned outages of power plants or/and transmission lines
2. Electricity demand (load) deviating from the forecast
3. Intermittent renewable generation output deviating from forecast

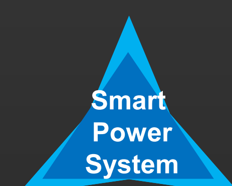
SMART POWER GENERATION CAN

- Provide 5 min...24 h operating reserves from stand-still
- Provide 30 sec secondary reserve (contingency) from stand-still
- Produce energy at ~ 50 % efficiency over a 5…100 % load range



SYSTEM BENEFITS OF SMART POWER GENERATION

- Enable loading high efficiency thermal plants to full load instead of part load
- Enable stopping part loaded low efficiency steam power plants (that are providing reserves)
- Reduce the amount of spinning reserve



VALUE OF SMART POWER GENERATION

- Reduced use of fuels
- Reduced CO_2 emissions
- Reduced system operating costs
- Lower wholesale price of electricity
- Lower cost of electricity to consumers

DNV KEMA REDPOINT

References

Where is the concept of
Smart Power Generation applied?

STEC Pearsall, TX, USA – 202 MW

STEC Pearsall, USA

Output: 202 MW
Fuel: Natural gas
Prime movers: 24 x Wärtsilä 20V34SG
Operating mode: Wind following
Start of commercial operation: 2009

Chambersburg: Orchard Park, USA

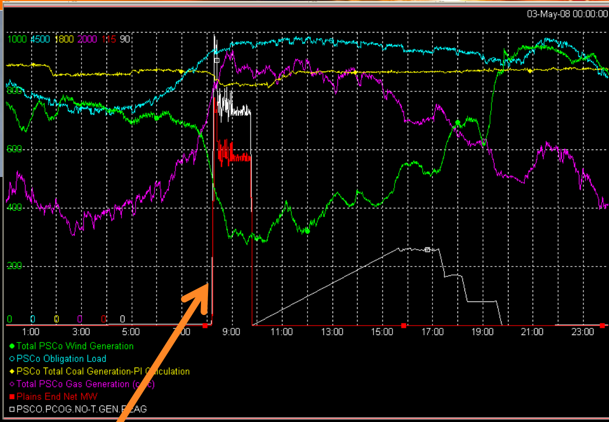
Output: 23 MW
Fuel: Natural gas & fuel oil
Prime movers: 4 x Wärtsilä 18V32DF
Operating mode: Peaking plant
Start of commercial operation: 2003

GSEC Antelope, TX, USA – 170 MW

GSEC Antelope, USA

Output: 170 MW
Fuel: Natural gas
Prime movers: 18 x Wärtsilä 20V34SG
Operating mode: Wind following
Start of commercial operation: 2011

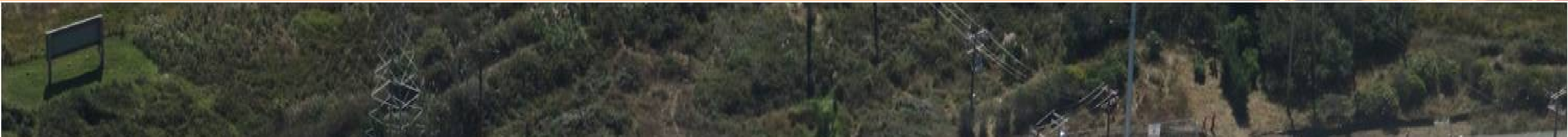
Plains End I & II, CO, USA – 231 MW



Plains End I & II, USA

Output: 231 MW
Fuel: Natural gas
Prime movers: 20 x Wärtsilä 18V34 SG & 14 x Wärtsilä 20V34SG
Operating mode: Peaking / Wind following
Year of completion: 2001 & 2006

Humboldt Bay, CA, USA – 231 MW



Humboldt Bay, USA

Output: 163 MW
Fuel: Natural gas & LFO
Prime movers: 10 x Wärtsilä 18V50DF
Operating mode: Flexible baseload
Year of completion: 2010
Scope: EPC

Elering Kiisa I & II – 250 MW

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Elering Kiisa I & II, Estonia

Output: 250 MW
Fuel: Natural gas & LFO
Prime movers: 27 x Wärtsilä 20V34DF
Operating mode: Grid stability (200 operating hours per year)
Year of completion: 2013 & 2014
Scope: EPC

UTE Suape, Brazil – 380 MW

SMART POWER GENERATION

UTE Suape, Brazil

Output: 380 MW
Fuel: HFO
Prime movers: 17 x Wärtsilä 20V46F
Operating mode: Power supply during dry season when availability of hydropower is insufficient
Year of completion: 2011
Scope: EPC

Conclusion

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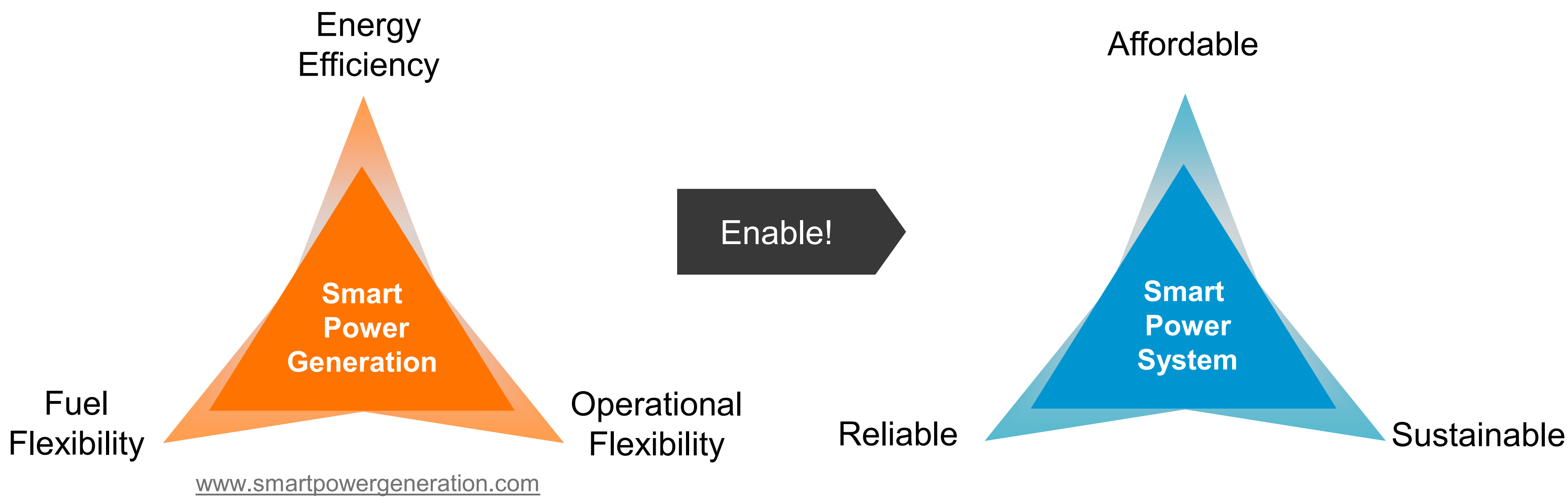

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Making Power Generation Smarter!

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THANK YOU!

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