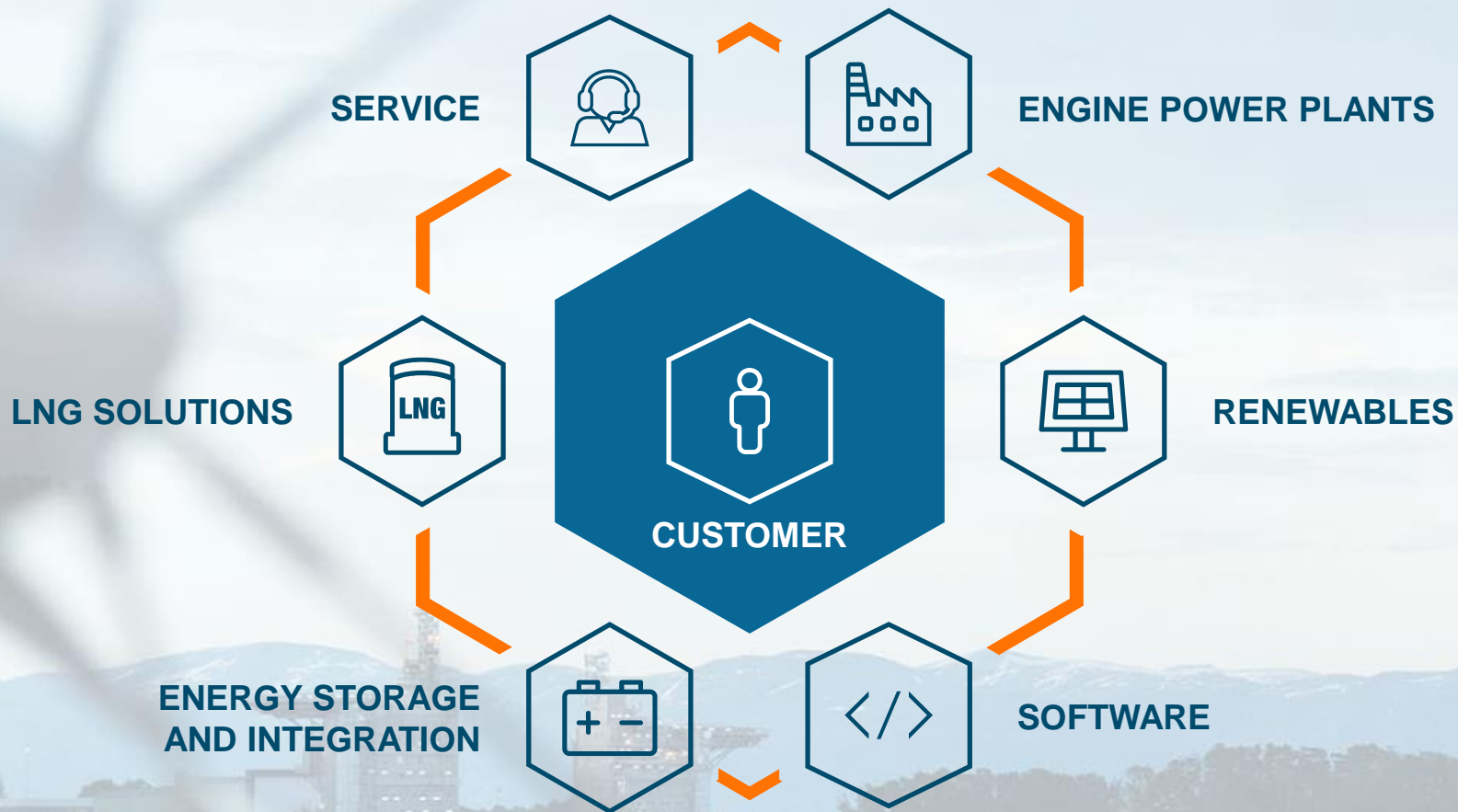


ENERGY STORAGE AND HYBRID SOLUTIONS

John Jung, President and CEO
Greensmith Energy, a Wärtsilä company

**ENERGY SYSTEM
INTEGRATOR**



Investment in renewable generation exceeds thermal generation – irreversible and disruptive

- Power balancing and reliability is the growing concern for grid operators
- Presents unique opportunity to integrate solar, wind and thermal generation with energy storage

Key power equipment OEMs are pursuing leadership in hybrids

- Competitors who bring complete solutions and integration capabilities via software are well-positioned
- Market size for global smart grid is expected to grow from \$21B USD in 2017 to \$51B USD in 2022

Markets and grid operators are learning and adapting to rapid changes

- Regulation and incentives are being reshaped to accelerate adoption of renewables and energy storage
- Customers are looking for long-term strategies and partnerships for success

Comparing storage energy capacity today and in a 100% renewable world

Energy storage technologies will become an **inevitable part** of the power system, both capacities and throughput of storage will increase hundredfold.

STORAGE ENERGY CAPACITY



1,3 TWh
TODAY

1,050 TWh
100% RES

- Battery
- Power-to-gas
- Pumped hydro storage



Greensmith Energy

Energy storage technology, integration and software



- Founded in 2008 and backed by E.On, AEP and venture capital funding
- Comprehensive capabilities including design, integration and energy optimisation software
- Delivered a third of all US deployments in 2016 and to-date, over 70 grid-scale systems in 8 countries integrated with solar, wind, fossil and hydro generation
- Installed six advanced frequency regulation systems to the largest wholesale market in the world - PJM
- GEMS – proprietary software platform now in its fifth generation, used to integrate 16 different batteries to-date with a technology-neutral business model
- Serving both utilities and power developers such as Duke, E.On and AltaGas



Advanced Energy Storage - Sample

20MW Frequency Regulation PA, USA



20MW Capacity + Wholesale CA, USA



7MW Island Micro grid Recharge AS, Portugal



2MW Grid Deferral CA, USA



10MW Solar Integration AZ, USA



1MW Solar Micro grid Puerto Rico, USA



Global leader in energy storage expanding into new markets



Market progressing towards flexible energy and integration

2008-2013



Utility pilot phase

Small scale pilots to test technology

2014-2015



Ancillary market

Developers and IPPs enter the market
PJM land-grab

2016-2017



Renewable penetration

Global markets open and impact grid scale opportunities

2018+



Expanding markets, Expanding products

Solar + storage becoming requirement
Island grid / microgrid economics compelling
EMS becoming a required asset



GRID RELIABILITY

Meeting demand
for power 24/7/365



RENEWABLES INTEGRATION

Ensuring seamless
integration of solar, wind
and other renewables



HYBRID OPTIMISATION

Creating a flexible fleet
of assets working
in harmony

GEMS: Software is at the Heart of Integration

SOLUTIONS



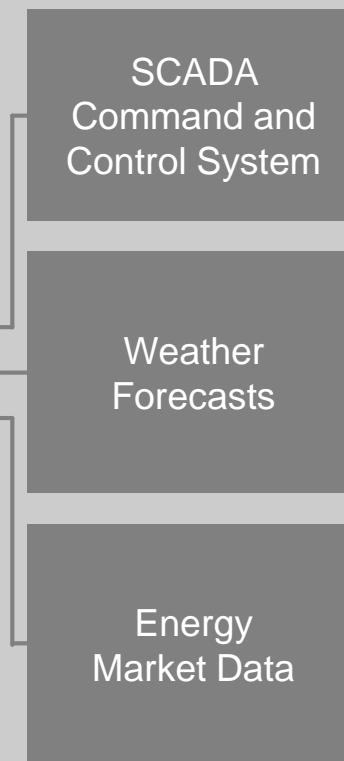
INTELLIGENCE



EQUIPMENT



EXTERNAL



Broadest selection of use-case algorithms in the industry

CATEGORY	APPLICATIONS/FEATURES	
ANCILLARY	FR (regulated) (PJM, CAISO)	✓
	Frequency response	✓
	Voltage resp./PF correction	✓
	Spinning reserve	✓
RENEWABLE INTEGRATION	PV firming	✓
	PV ramp control	✓
	PV smoothing	✓
	Self-consumption	✓
	Curtailement capture	✓
	PV + storage	✓
CAPACITY	ISO dispatch signal	✓
	T&D deferral/Peak-shift	✓
	Energy arbitrage	✓
	Load leveling/Peak shaving	✓
FLEET MGMT.	DER management	✓
	Fleet aggregation	✓
	Asset optimisation	✓

CATEGORY	APPLICATIONS/FEATURES	
PREDICTIVE ANALYTICS	Weather forecast integration	✓
	Load forecast	✓
	Tariff engine integration	✓
	Bill optimisation	✓
BTM	Demand charge management	✓
	Demand response integration	✓
	TOU (Real time pricing)	✓
	EV charging integration	✓
MICRO GRID	Islanding	✓
	Grid forming	✓
	Seamless transfer	✓
	Frequency drooping	✓
	Black start	✓
	Fault handling	✓
	Control DER	✓

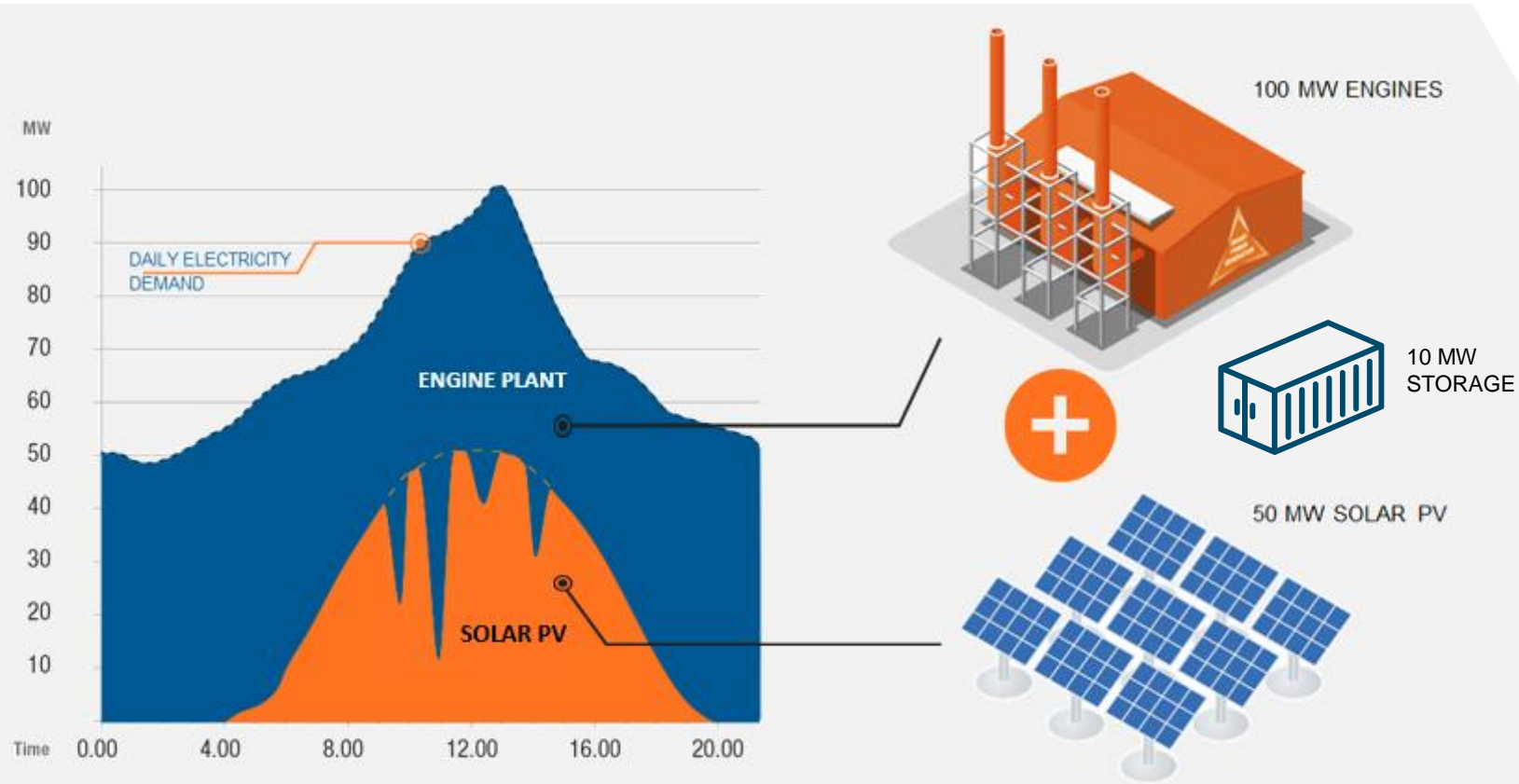
GEMS: Modern software tools and architecture

The screenshot displays the GreenSmith software interface, which is used for monitoring and managing energy storage systems. The interface is divided into several sections:

- Top Navigation:** Includes 'All Customers', 'Operations', and 'Site Alerts'. It also shows a 'Print' button and a user profile 'Hello, Demo'.
- Dashboard:** Displays key performance indicators (KPIs) such as 'CURRENT ESS POWER' (2,846kW), 'PEAKS' (50kW), 'ENERGY TODAY' (10,000kWh), and 'POWER SAVINGS'.
- Map View:** A map of North America showing the locations of various sites, with a sidebar listing sites like 'Allied ESCO', 'Iron Energy', and 'Solar Village'.
- Device View:** A sidebar on the left lists various devices and systems, including 'PV Ramp Rate Control', 'PJM FR', 'AUX Meter', 'LDK ESS', 'Battery Subsystem', 'Battery Container 1', 'Battery Bank 1', 'Rack 01', 'Rack 02', 'Module 01', 'Module 02', 'Module 03', 'Battery Bank 2', 'Battery Bank 3', 'Battery Container 2', 'Battery Container 3', and 'Battery Container 4'.
- Status and Alarm Section:** Shows the 'Status' and 'Alarm' tabs. The 'Status' tab displays 'Recorded Time: Sep 30, 2015 11:16:06 AM' and a list of parameters:

<input checked="" type="checkbox"/> AReg	20000 KW
<input type="checkbox"/> Energy Charged	14870786 KWh
<input type="checkbox"/> Energy Discharged	14399892 KWh
<input type="checkbox"/> SOC	48 %
<input type="checkbox"/> SOH	97 %
<input type="checkbox"/> CReg	7939 KW
<input type="checkbox"/> Effective SOC	45 %
- Plot Section:** Features a 'Canvas' and 'Plot #2' showing a line graph of 'Hourly PJM Composite Score (LDK ESS) (%)' over time. The graph shows a fluctuating score between approximately 60% and 90%.
- Device Configuration:** A 3D model of a battery container is shown, with a legend indicating various parameters: Max Cell Voltage, Min Cell Voltage, Min Temperature, Max Temperature Location, Min Temperature Location, and Max Temperature.

Hybridisation of a power plant



Fuel savings

O&M optimisation
and savings

Regulation
compliance

Enhanced
dispatchability

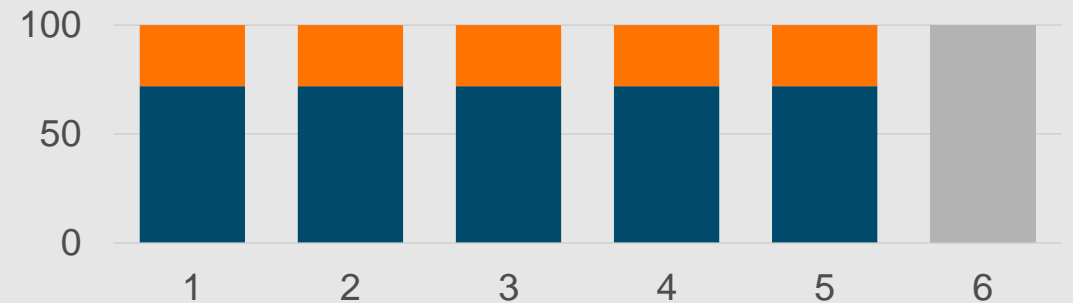
Reduced
emissions

Spinning reserve business case

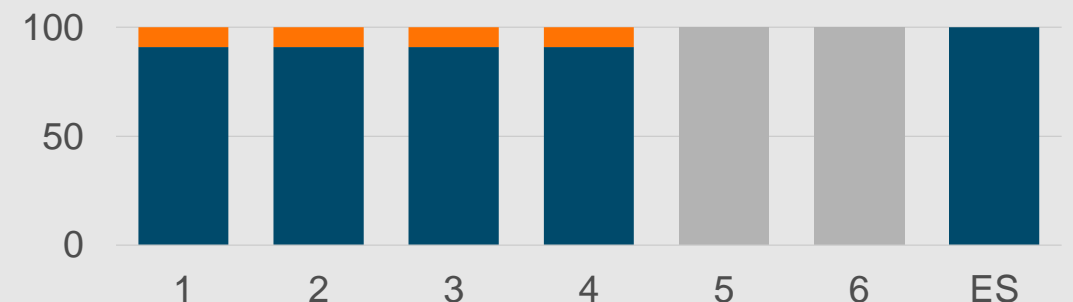
- Base case: Run 5 engines at 72% capacity to maintain reserves
- Run 4 engines at 91% capacity and use ESS to provide spinning reserves
- Business case derives from:
 - Reduced fuel consumption due to engine efficiency increase and decrease in total run-time hours
 - Operating and maintenance expense reduction due to decrease in total run-time hours
- Simple payback 2 years

■ Reserve
■ Operating load

Case 1: Engines

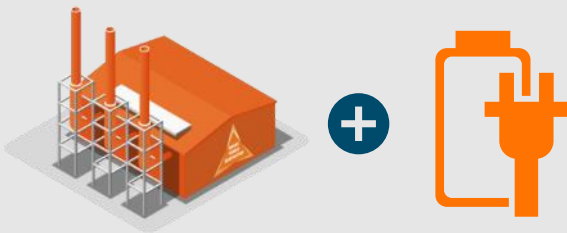


Case 2: Engines + Storage



Ancillary services business case

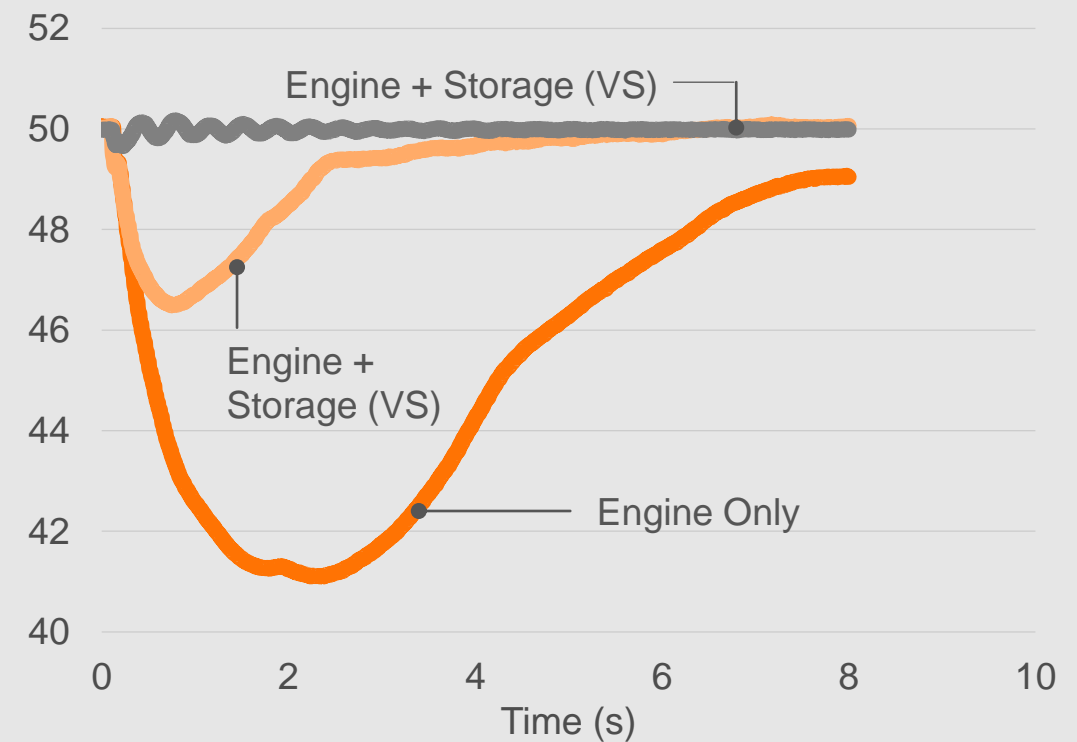
- Fast, accurate response to frequency deviations
- Superior load step capability and stability after load steps
- Business case derives from:
 - High reliability
 - Reduced fuel consumption due to engine efficiency increase
- Simple payback 3 years



- Engine only 4%
- PCS both v&f
- Voltage Source

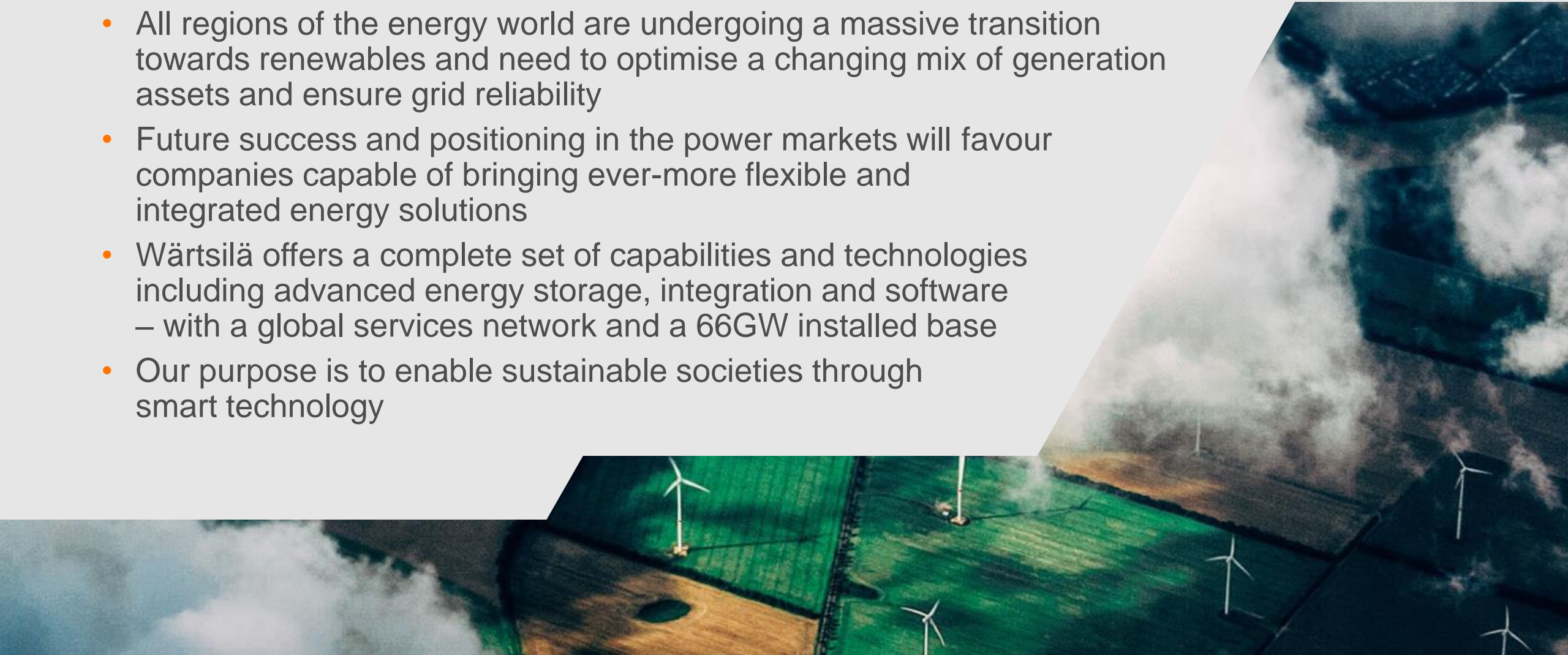
Frequency deviation during 900kW load step

Frequency (Hz)



Summary

- All regions of the energy world are undergoing a massive transition towards renewables and need to optimise a changing mix of generation assets and ensure grid reliability
- Future success and positioning in the power markets will favour companies capable of bringing ever-more flexible and integrated energy solutions
- Wärtsilä offers a complete set of capabilities and technologies including advanced energy storage, integration and software – with a global services network and a 66GW installed base
- Our purpose is to enable sustainable societies through smart technology



THANK YOU



WÄRTSILÄ

Capital Markets
Day 2018