



NAS[®] Akkumulátor

ETE Konferencia
2020 november 25

Miért számíthat érdeklődésre a NAS[®] akku?

A hálózati rugalmasság és a gyorsan növekvő megújuló részarány integrálása egyre hosszabb kitárolási/kisütési idejű tárolókat igényel

DOE Global Energy Storage Database
as of 12.09.2018

Piacérett, megbízható konstrukció 2002 óta forgalmazzák
580MW (4000MWh) telepítve a világ országaiban

MW nagyságrendű akkumulátor típusok telepített
kapacitásának (MWh) részaránya: NAS 45%

Európa első hálózatra kapcsolt akkumulátora
1 MW, Berlin, Younicos és Vattenfall (2012)

Magyarországon eddig nem alkalmazott technológia

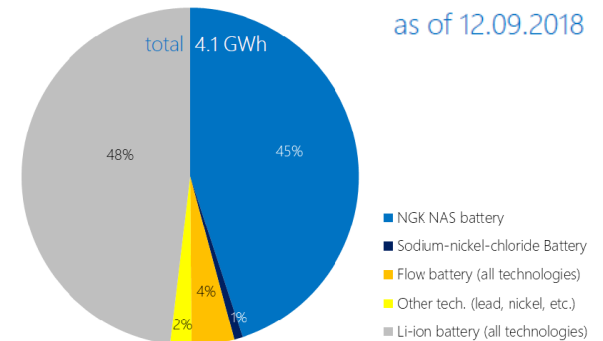
Egyedülálló működési referencia 18 év tapasztalat

Gyors reakcióidő (ms), hosszú kisütési idő (6-8 óra)

Teljes mértékben kisüthető, 0-100% DOD tartományban használható

Nem tartalmaz ritka nyersanyagot

Főként a SZET kiváltására tervezték Japánban



NAS[®] akkumulátor fejlesztés története

1967 1970 1980 1990 2000 2010

Ford introduced the principle

NGK started R&D of NAS Battery in 1984 and commercialized it in 2002

1971–1976 R&D in USA, Europe and Japan for EV usage

1980–1990 Development for utility usage Moon Light Project (NEDO)

1991–1995 R&D for Utilization

1984 Start joint R&D TEPCO – NGK

Element R&D Technical contribution from BBC (now, ABB)

1989 Cell development

1991 Module/System Development Larger capacity Battery Cell/Module

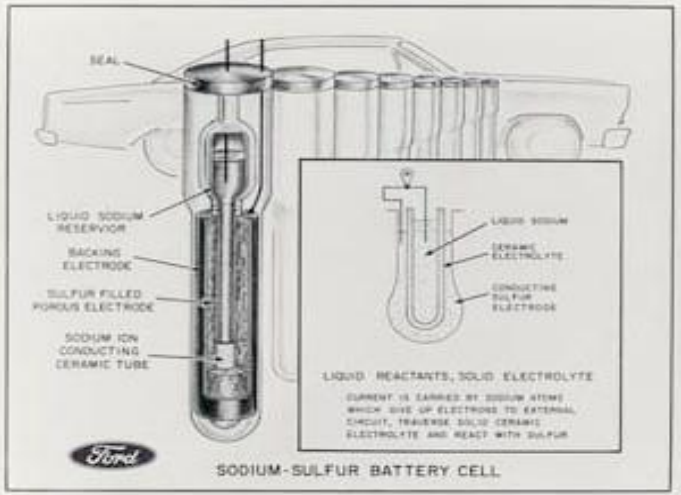
1997 Experiment/Evaluation Experiment in substation at industrial consumers

2002 Commercialization
World's first product of its kind

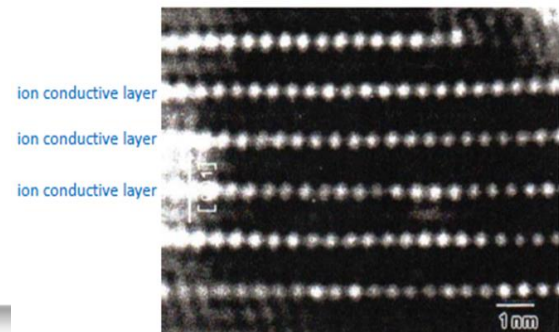
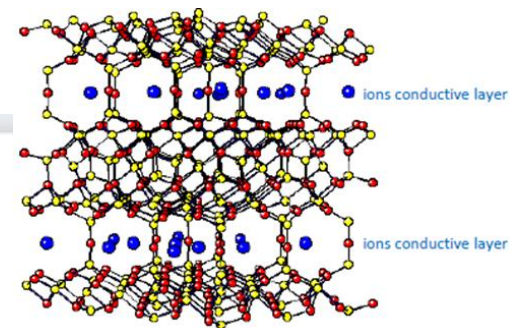
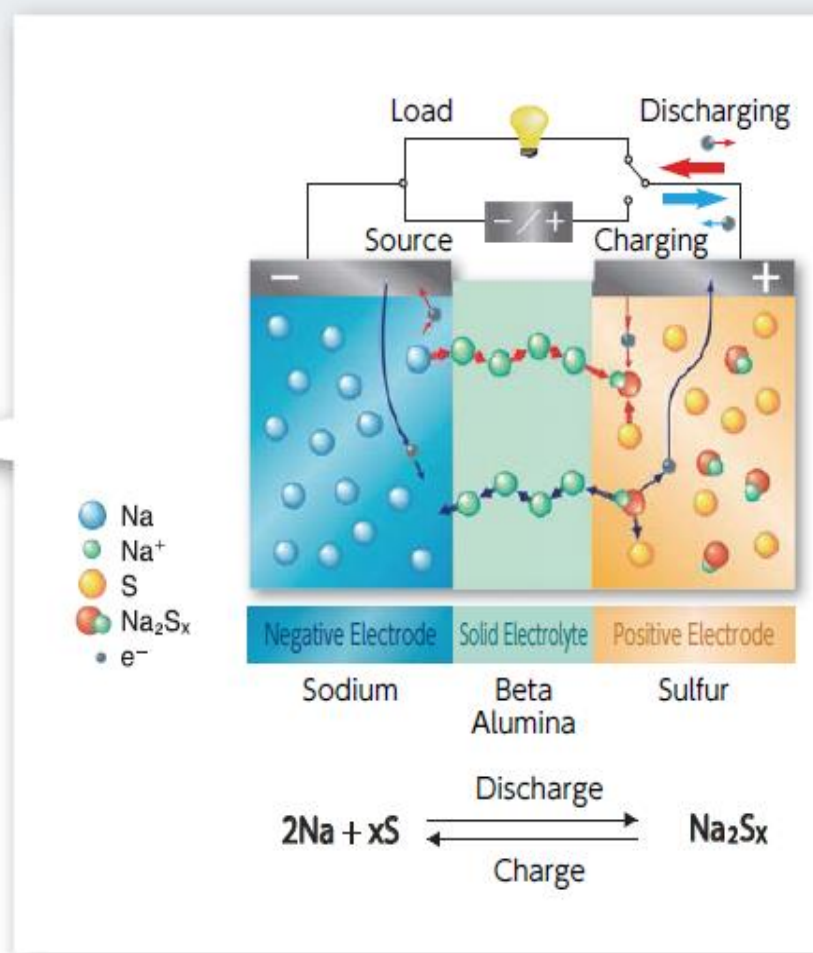
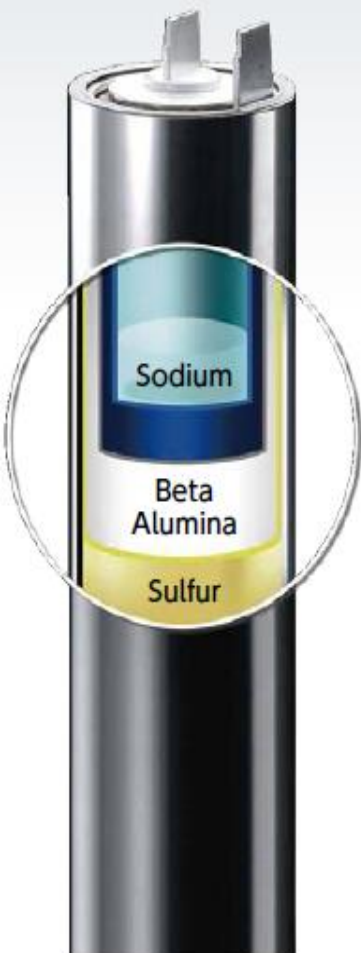
BBC A04 Cell design



Ford



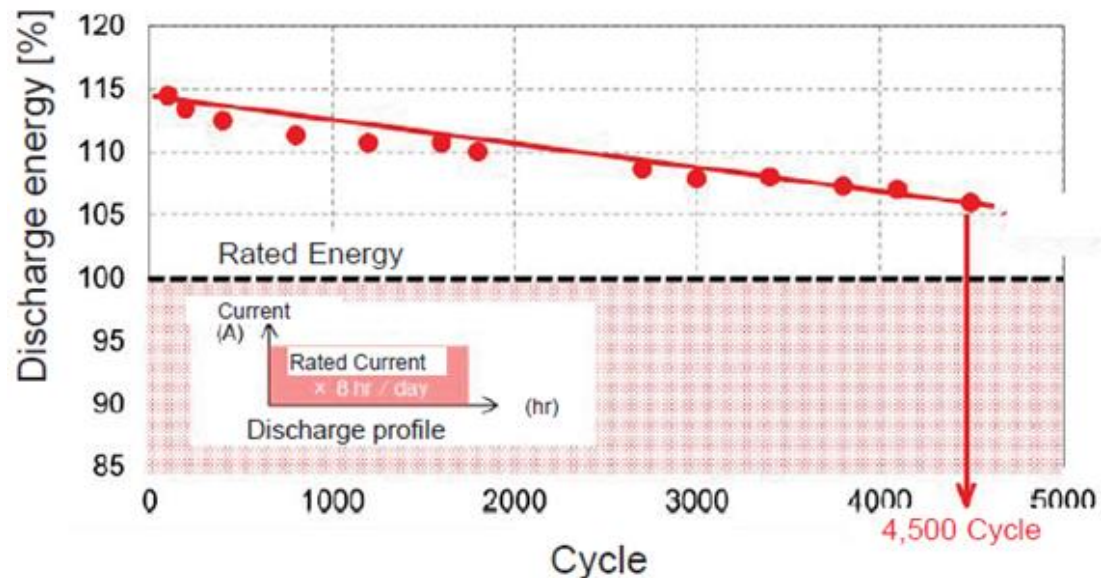
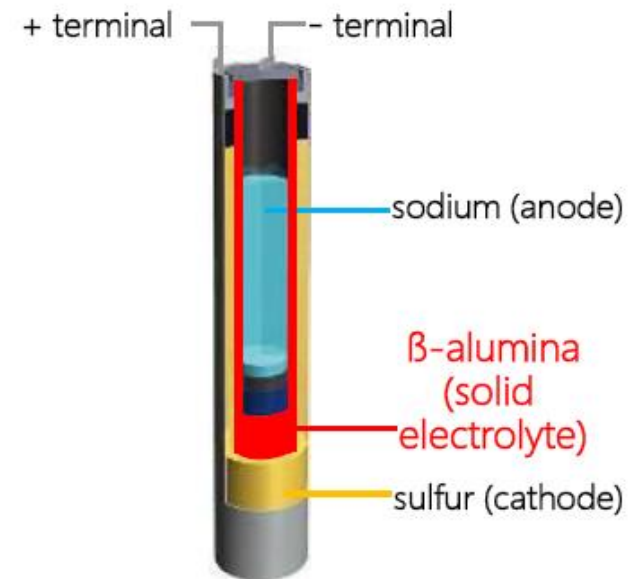
A NAS[®] akkumulátor működési elve



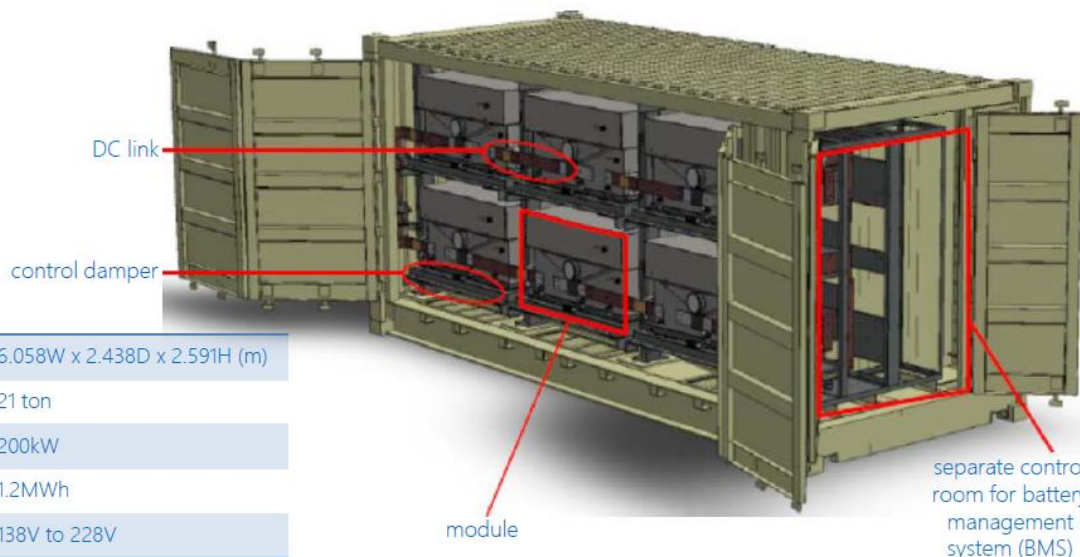
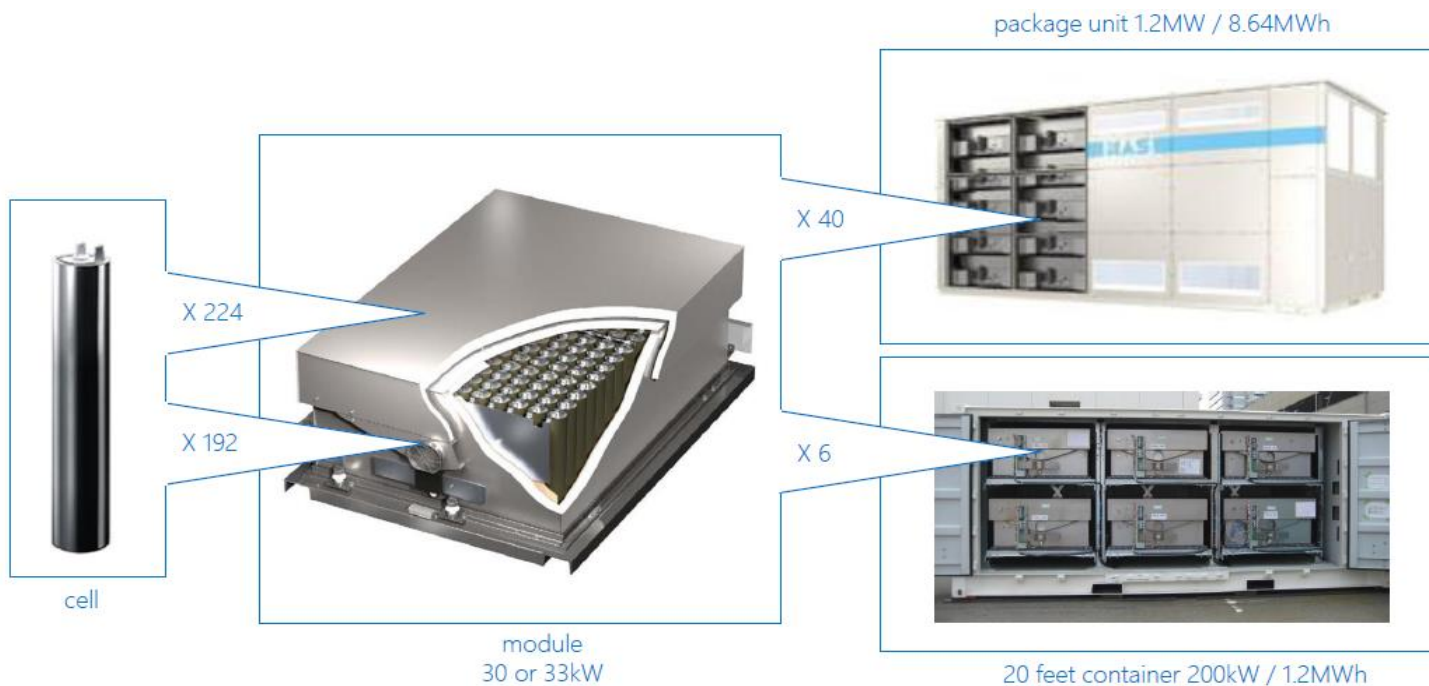
A NAS[®] akkumulátor cella adatai



voltage	~2V
energy density	367Wh/l
	222Wh/kg
power density	36W/kg
c-rate	1 / 6 = 0.17
optimal t° range	300 - 340°C
maximal t° range	290 - 360°C
life time	4500 cycles 15 years
partial cycle	no memory effect







A NAS[®] akkumulátor rendszer felépítése

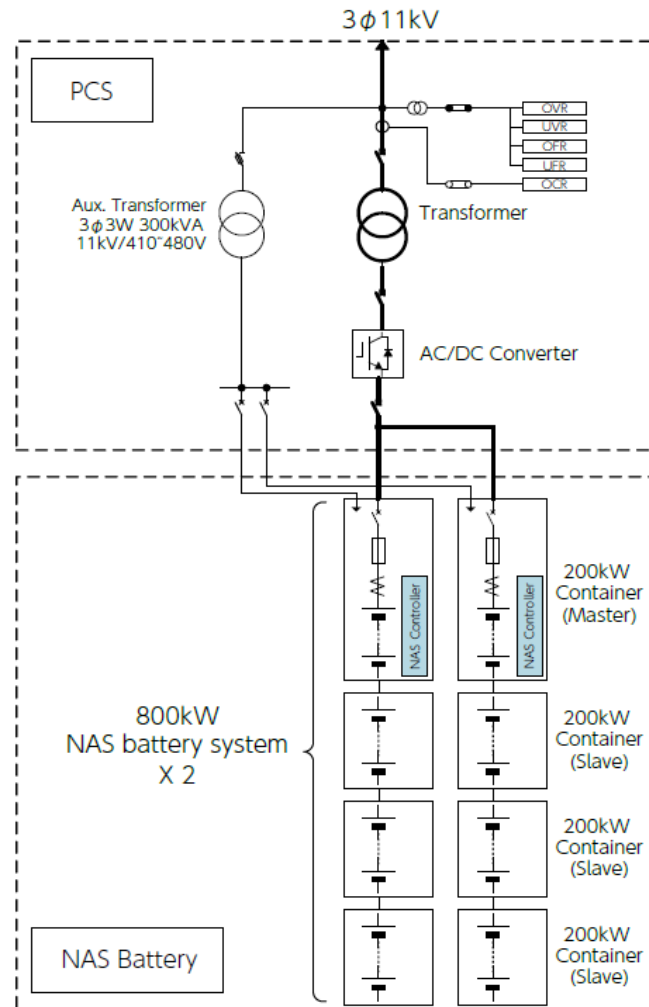


size	6.058W x 2.438D x 2.591H (m)
weight	21 ton
rated power AC	200kW
rated energy	1.2MWh
DC voltage	138V to 228V

NAS[®] akkumulátor rendszer konfiguráció

Rated Output ⁽¹⁾ [kW]	200	400	600	800
Energy Capacity ⁽¹⁾ [kWh]	1,200	2,400	3,600	4,800
Weight ⁽²⁾ [t]	21	42	63	84
Numbers of Containerized NAS Batteries Connected in Series	1	2	3	4
DC Nominal Voltage [V]	192	384	576	768
Width X Depth Area	6.1 X 2.4 [m] 15 [m ²]	6.1 X 2.4 [m] 15 [m ²]	6.1 X 5.6 [m] 34 [m ²]	6.1 X 5.6 [m] 34 [m ²]
Footprint ⁽³⁾ Assumed Arrangement				

- (1) AC output base. PCS conversion efficiencies from AC to DC and vice versa are assumed to be 96%.
 (2) Weight of battery unit alone.
 (3) PCS and maintenance spaces are excluded. Containers are assumed to be stacked in two steps.



A NAS[®] akkumulátor fő jellemzői

NGK's sodium-sulfur (NAS) battery is a world leader in megawatt-scale, multi-hour advanced battery energy storage technology

High efficiency (~85% DC, ~75% AC)

High calendar/cycle life 15-year; 4500, 6 MWh/MW cycles

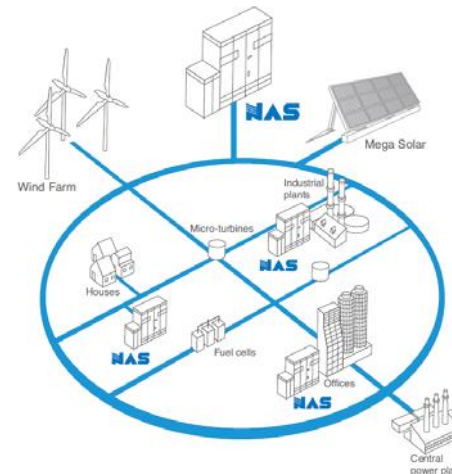
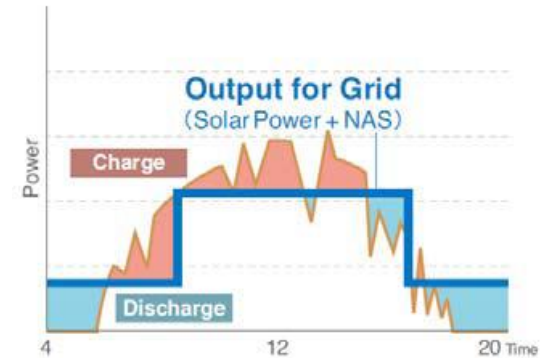
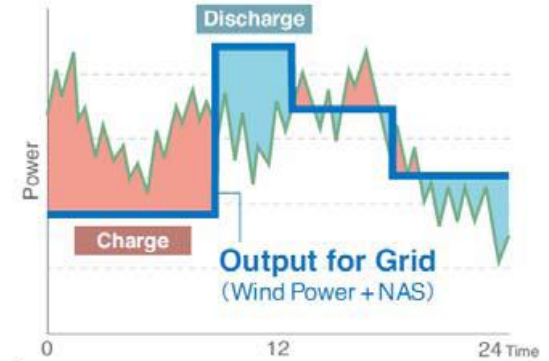
High energy density – relatively small footprint

Prompt response – NAS capable of full power charge to discharge in 1 millisecond

No emissions, noise or vibrations

No self-discharge or memory effect

Over 18+ years of experience with more than 580 MW, 4000MWhr deployed globally

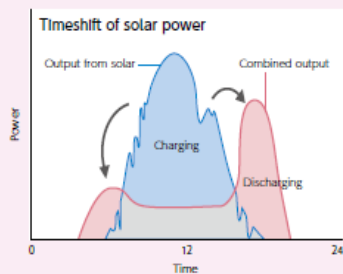
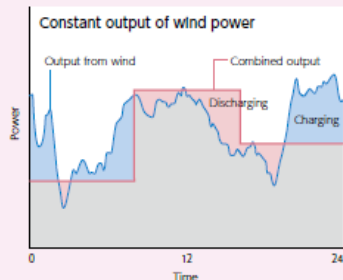


A NAS[®] akkumulátor alkalmazási területei

Renewables Renewables / Power Plants

Renewable Stabilization

By absorbing fluctuating renewable energy such as wind and solar during off-peak times, NAS batteries can provide additional power during periods of peak demand.



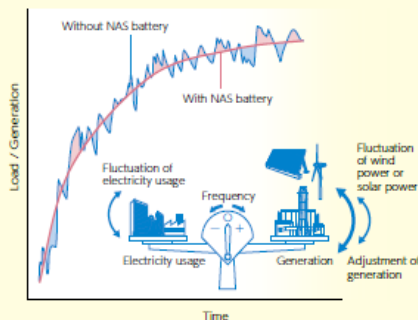
Fossil Fuel Peaker Plant Replacement

NAS batteries can provide resource adequacy capacity of six hours or more per day, providing a green alternative to fossil fuel peaker plants. Moreover, NAS batteries can also provide on-peak/off-peak price arbitrage, frequency regulation, ramping services, VAR support and other grid functions.

Grid Solutions Ancillary / Investment Deferral

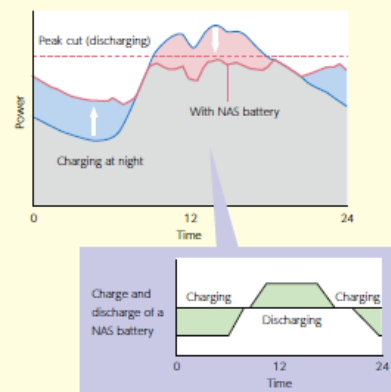
Ancillary Services

Imbalance between demand and supply could cause frequency fluctuation. NAS batteries can achieve minimization of frequency fluctuation by utilizing their high-speed response.



Investment Deferral

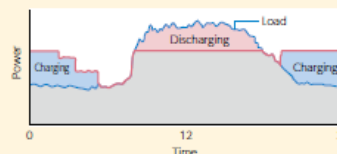
NAS batteries can defer or eliminate the need for transmission and distribution upgrades. Power can be imported into a transmission constrained area when loads are light, charging NAS batteries that are positioned nearby. During peak load, NAS batteries are discharged to supplement the power from the at-capacity transmission lines.



Consumers Industrial / Commercial & Residential

Peak Shaving

NAS batteries can reduce peak demand automatically by simply setting the desired peak threshold. This can be used to reduce demand charges for users with fluctuating loads.

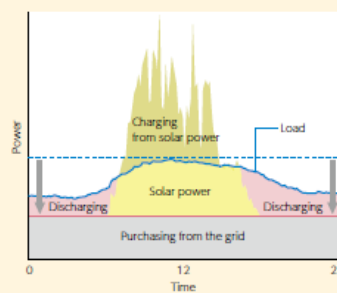


Backup Power and Resilience

NAS batteries can provide continuous power to critical loads for six hours or more in the event of grid outages. In addition to providing multi-hour backup, NAS batteries can also provide other functions, including peak shaving, demand charge reduction, solar power storage, and management of power quality. With solar or other local power generation, additional resilience can be provided by using NAS batteries in a microgrid configuration with islanding (self sustaining) capability.

Storage of Local Solar Power

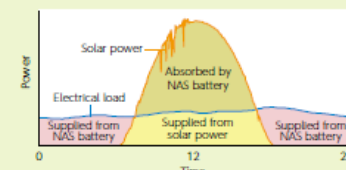
The rapidly declining cost of solar power has led to widespread deployment of solar power generation by end users. NAS batteries can reduce or eliminate grid power usage by timeshifting excess solar power from daytime to nighttime, and can also cut grid costs for end users by simultaneously providing solar power storage, peak shaving and demand charge reduction.



Microgrids Islands / Remote Grids & Microgrids

24/7 Power Supply with Solar Power for Microgrids

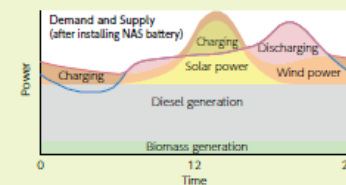
On sunny days, four to five times maximum solar power output against average load and NAS battery with capacity of two-third against solar power are required to cover the most of the load for 24/7. Battery storage needs to discharge for 14-18 hours to shift the surplus solar energy to nighttime and early morning. NAS batteries can discharge for six hours at rated output, but they can discharge for a much longer duration by lowering the output. Roughly speaking, the discharge duration will be increased up to 18 hours if a NAS battery discharges at one-third the rated output. Only proven long-duration energy storage like NAS batteries could be expected for this application. As an example, for a 200kW load, 24/7 power supply could be achieved by utilizing 1,000kW of solar power and 600kW (3,600kWh) of power from a NAS battery. This will enable higher penetration of solar power, optimum use of solar power including its surplus energy and reduction of non-environmentally friendly and costly diesel generator operation, which will lead to a greener society.



Backup power supply, such as diesel generation, is necessary for cloudy/rainy days with solar power shortage.

Microgrids

NAS batteries can provide essential functions for smaller grids, such as microgrids, island grids and grids in remote locations. These functions include support for higher levels of renewables, timeshifting and stabilization of wind and solar, voltage support, frequency regulation, protection against frequency collapse during contingencies, black start energy and backup power. Furthermore, NAS batteries allow fossil fuel and biomass generators to be operated at a fixed output setting that minimizes fuel use and emissions.



580MW (4000MWh) NAS[®] akkumulátor a világon



NAS batteries are the #1 choice worldwide for large-capacity energy storage

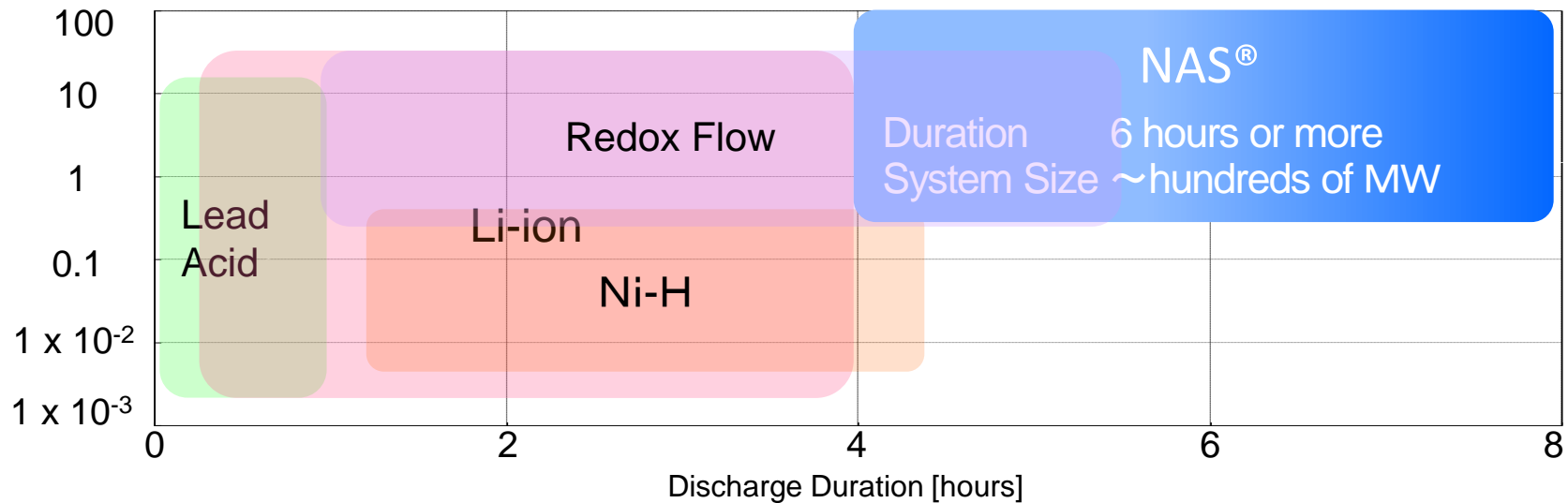
NGK's NAS batteries are the world leader in large-capacity energy storage. The cumulative field experience of NAS battery systems far surpasses that of every other large-capacity energy storage system. NGK's NAS battery systems have been deployed for over 25 years, at over 200 projects, with total deployments of 580MW and 4GWh.

- R Renewables (Renewables, Power Plants)
- G Grid Solutions (Ancillary, Investment Deferral)
- C Consumers (Industrial, Commercial & Residential)
- M Microgrids (Islands, Remote Grids & Microgrids)



Akkumulátor technológiák összehasonlítása

System size [MW]



	Lead Acid	LIB	Ni-MH	Redox Flow	NAS [®]	
System Size	Medium	Medium	Small	Small	Large	
Compactness	Large	Medium	Large	Large	Small	
Lifetime	Long	Medium	Short	Long	Long	
System Cost	Price/kW	High	Low	Medium	High	Medium
	Price/kwh	Medium	High	High	High	Low

Akkumulátor technológiák összehasonlítása

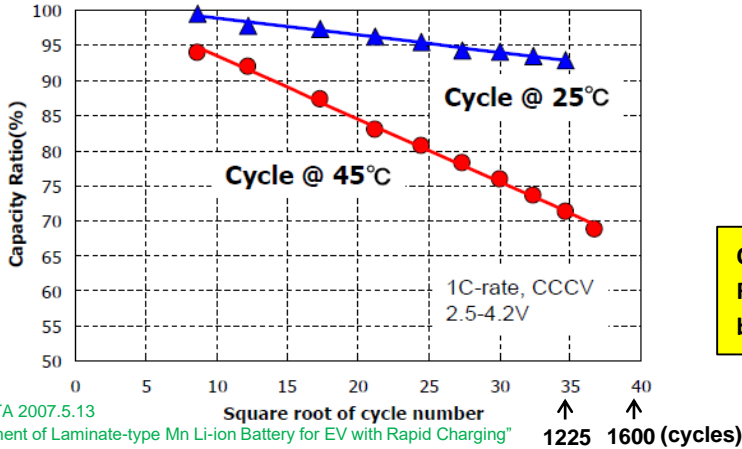
	NAS	LiB	Redox
Capacity Degradation *1 Cycle: rated energy discharge	Small (Rate: 0.22% / 100 Cycle)	Large (Rate: 2.16% / 100 Cycle) - Caused by crystal structure change and SEI growth - Deep discharge and high temp. accelerate capacity degradation. - Degradation is calculated from the data in Tehachapi Wind Energy Storage Project report	Small High temp. leads to a slight decrease in columbic efficiency.
Safety	No risk of fire propagation	Risk of thermal runaway exists.	Low risk (Fire incident due to hydrogen gas in 2005)
Aux. power	Heater power for keep cell temp. at 300C.	Air cooling/ air conditioner power for keep cell temp. at low level	Pumping of liquid electrolyte flow
Material limitation	No limitation	Limit for lithium, cobalt	Limit for vanadium
Maintenance	Easy Similar to normal electrical equipment.	Easy Similar to normal electrical equipment.	Not easy Many piping for acid liquid needs careful maintenance.

Li-ion és NAS[®] akkumulátor összehasonlítása

NAS[®] battery has long cycle life (4500 cycles at 100% DOD) with no temperature dependency

Li-ion battery is sensitive to operation temperature and DOD

Li-ion Battery (Typical)

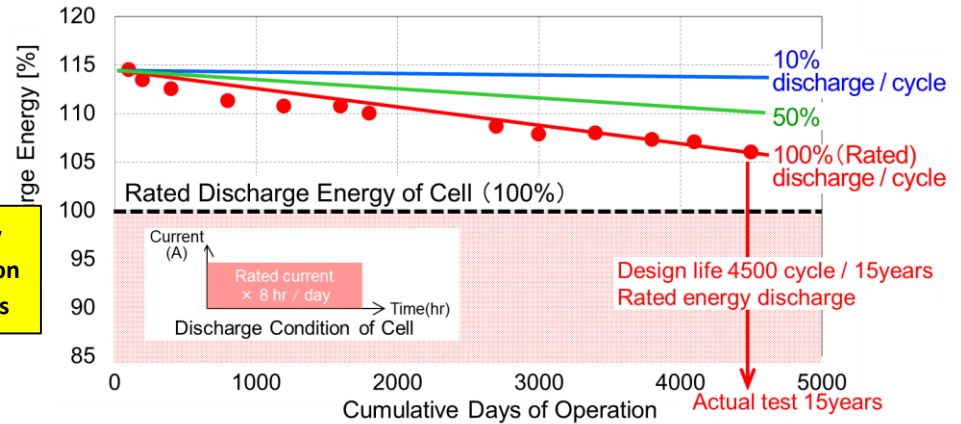


Ref: LLIBTA 2007.5.13

"Development of Laminate-type Mn Li-ion Battery for EV with Rapid Charging"

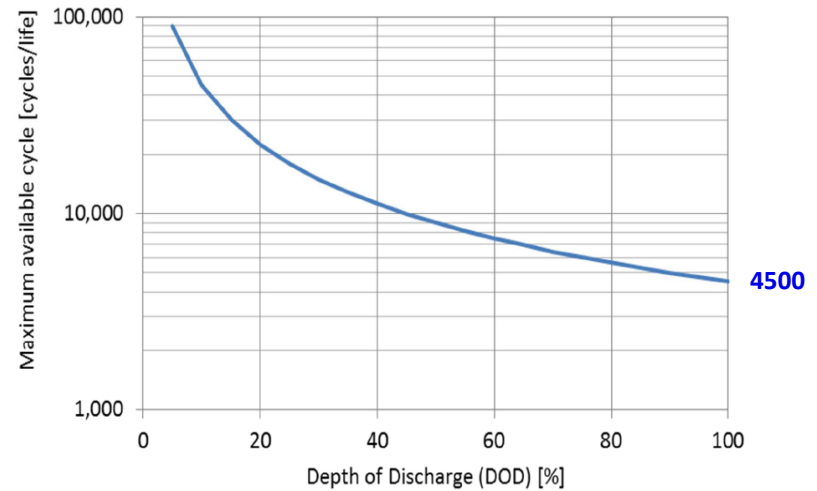
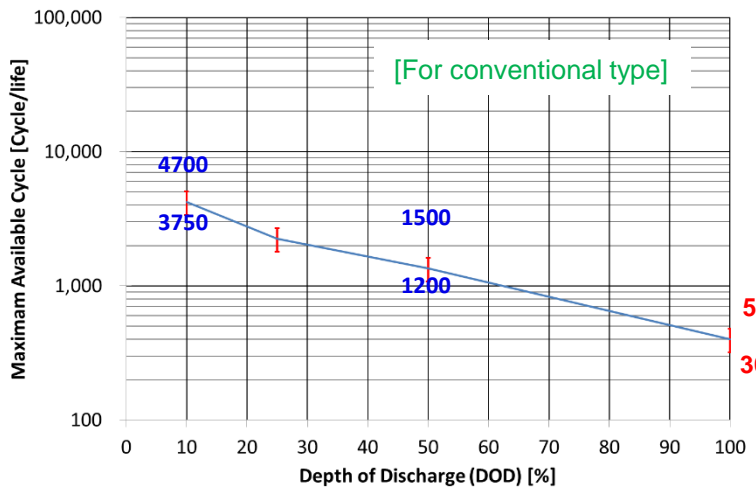
(no temperature dependency)

NAS[®] Battery



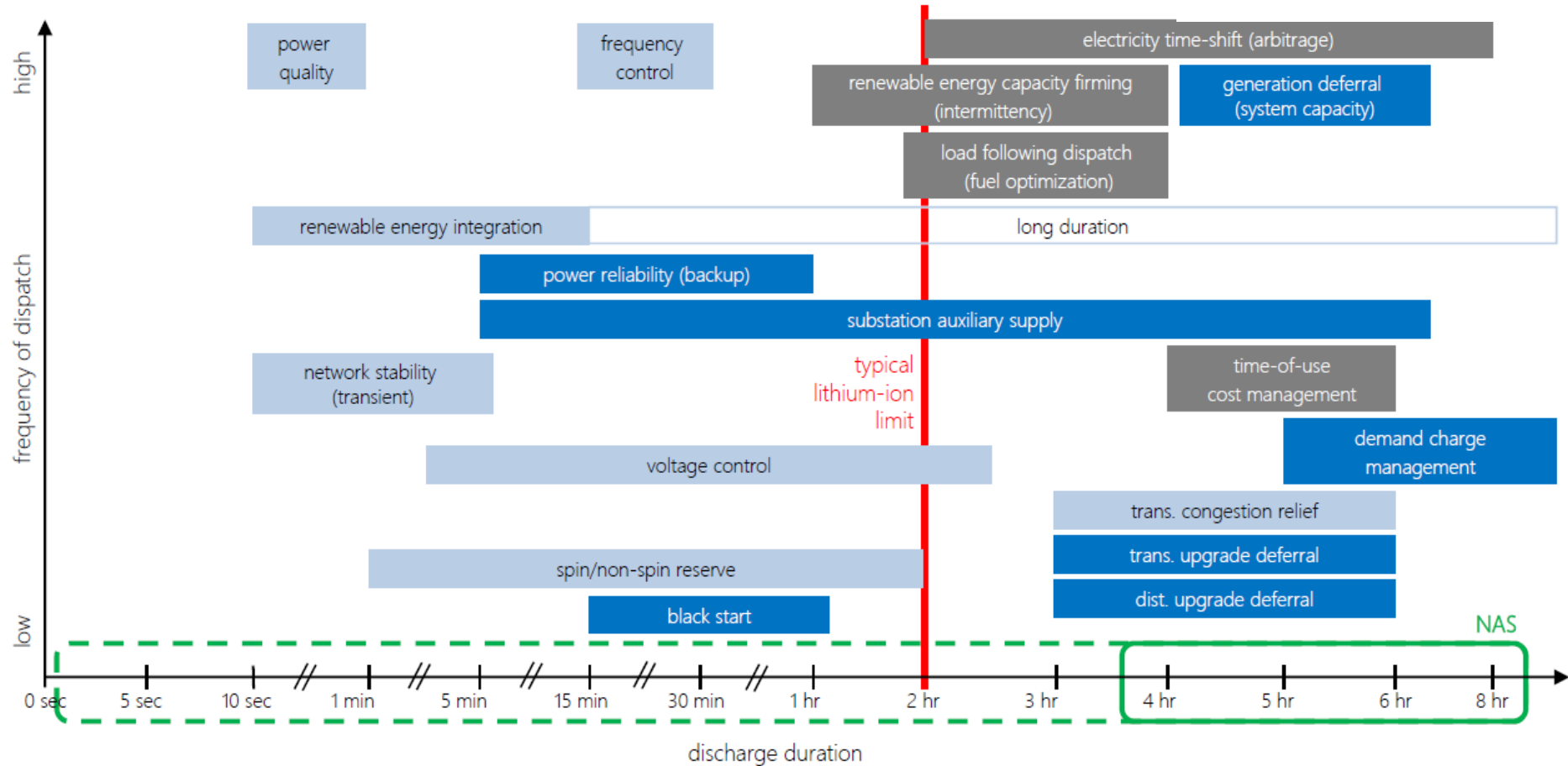
Capacity Reduction by Cycles

Available Cycles by different DOD



A NAS[®] akkumulátor optimális használati tartománya

NAS and Li-ion batteries discharge range difference provides for “cost effective partnership”
Pending on application NAS can be combined with Li-ion battery



Szélerőmű és NAS[®] akkumulátor

Rokkasho, Futamata wind farm (Aomori pref. Japan)

34MW (224MWh) NAS batteries stabilizing 51MW wind farm.
In operation since 2008

51MW wind turbine (1.5MW x 34 units)

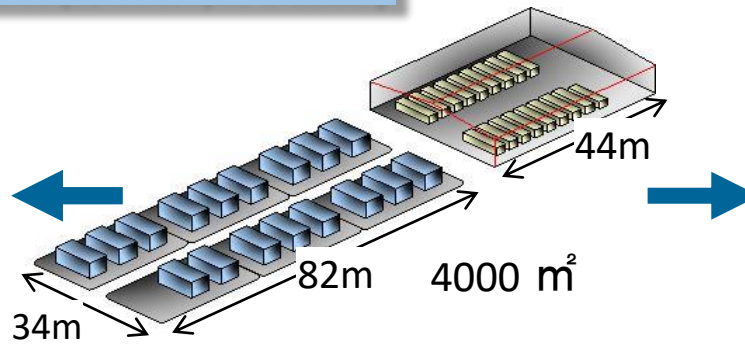


Largest BESS
in the world
in 2008

34MW (224MWh) NAS battery



NAS battery 2MW x 17 units

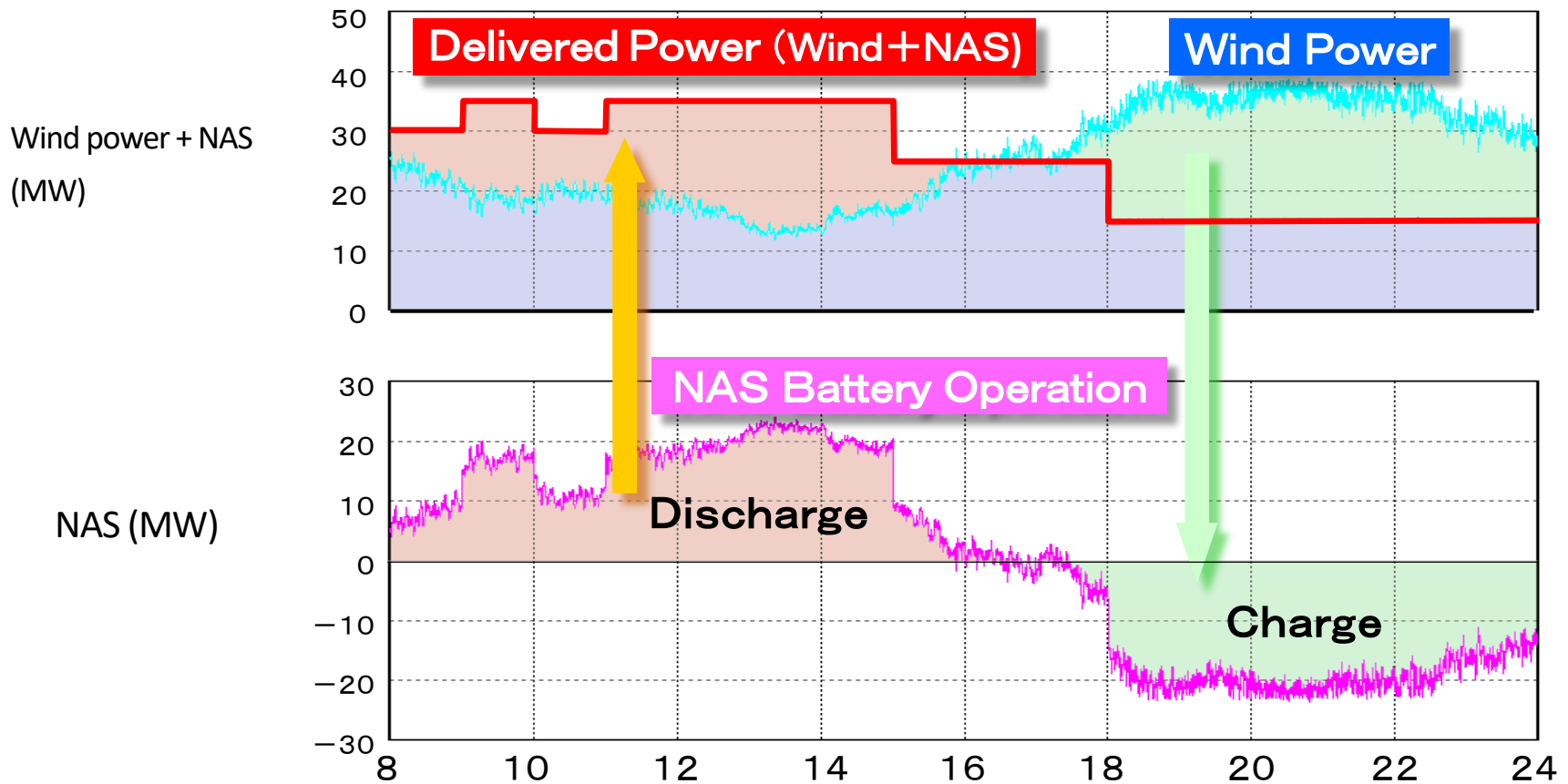


2MW PCS 17 units

Szélerőmű és NAS[®] akkumulátor

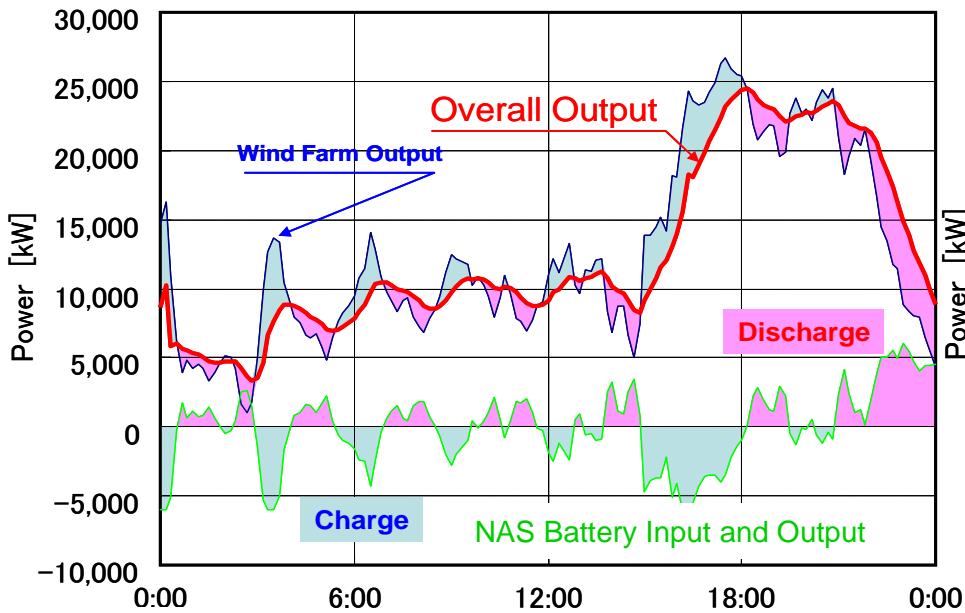
Rokkasho, Futamata wind farm (Aomori pref. Japan)

Wind forecast and NAS battery is used to deliver scheduled constant power next day.
(NAS battery mitigates fluctuations and forecasting errors)



NAS[®] akkumulátor kapacitás hatása

Smoothing operation: Absorbing short-time fluctuations
Firming operation: Firm capacity can be supplied as scheduled.

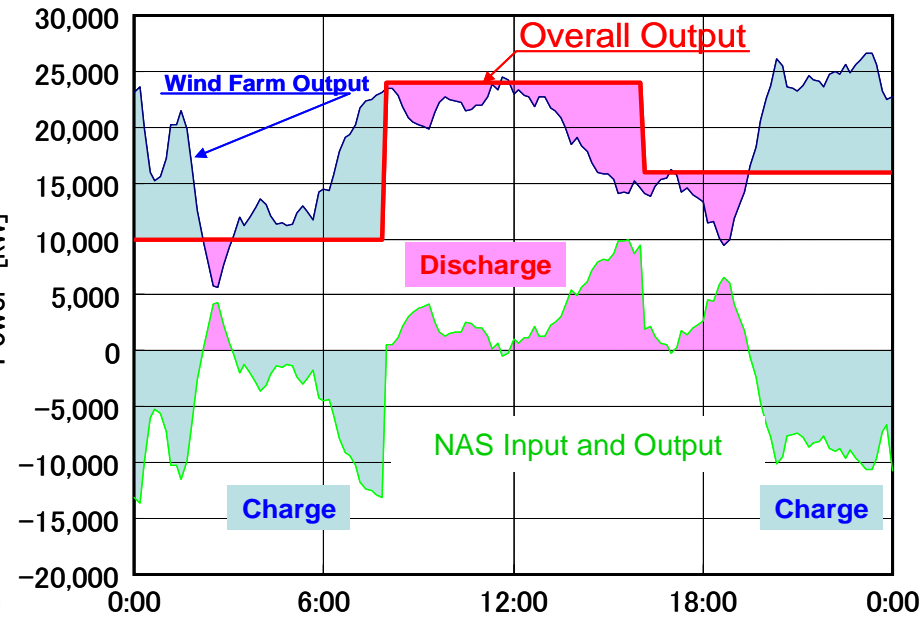


Smoothing Operation

Simulated Condition

- Wind Farm: 30MW
- NAS Battery: 6MW (36MWh)

NAS: 1/5



Firming Operation

Simulated Condition

- Wind Farm: 30MW
- NAS Battery: 20MW (120MWh)

NAS: 2/3

PV túltermelés integrálása a hálózatba

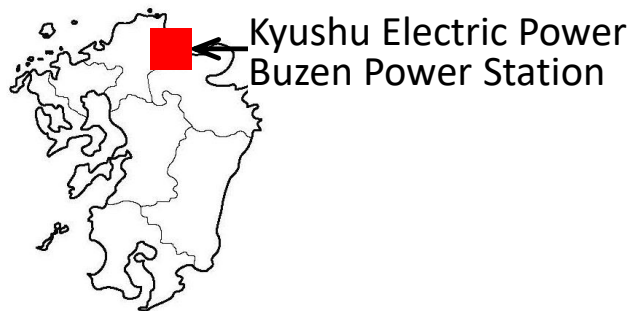
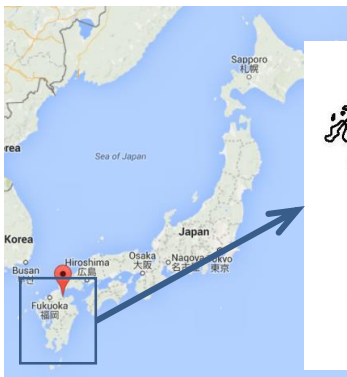
Buzen city substation, Fukuoka pref. Japan

Planned PV connections to the grid were suspended due to **over-generation problem**. The government of Japan decided on an emergency plan to install large scale battery in a short project schedule.

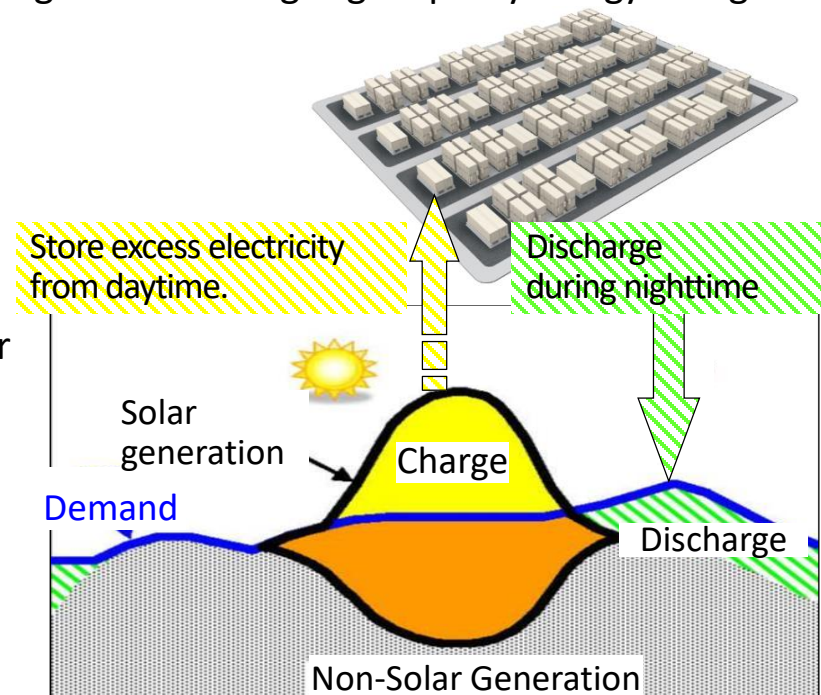
NAS[®] (50MW/300MWh) battery was installed only in **10 months after order**.

**Largest BESS
in the world
in 2016**

Output Power 50MW
Energy Capacity 300MWh
Start of Operation March 3, 2016



Improving Demand-and-Supply balance of solar generation using large capacity energy storage



PV túltermelés integrálása a hálózatba

Buzen city substation, Fukuoka pref. Japan

Power Conversion System

2nd bank

1st bank

140m

100m

6kV Substation equipment

66/6kV Transformer
(30MVA x 2 units)

Containerized NAS battery
Total 252 containers
Total 50MW/300MWh
Power 800kW/unit (4 containers)



PV túltermelés integrálása a hálózatba

Buzen city substation, Fukuoka pref. Japan

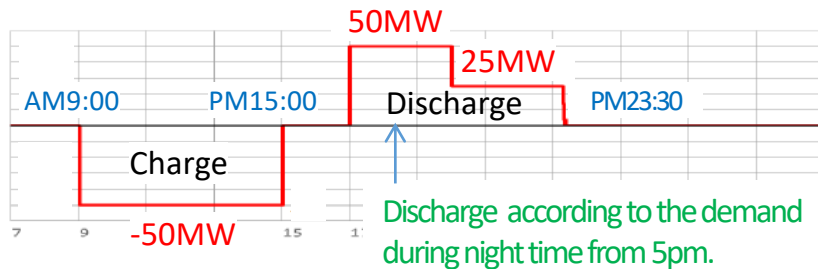
Implementing two charging patterns

Planned DC Efficiency is confirmed as follows;

Round-Trip DC Efficiency with battery heater losses: ca. 83%

(Round-Trip AC Efficiency with other Aux. losses: ca. 73%)

Pattern1: Constant Charging



Discharge Energy : AC234MWh

Charge Energy : AC300MWh

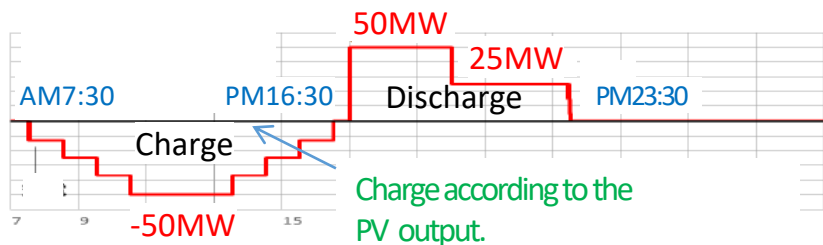
Round-Trip DC Efficiency : 83.1%

(with heater loss 2.4%)

Round-Trip AC Efficiency : 72.4%

(with other auxiliary)

Pattern2: Stepwise Charging for PV



Discharge Energy : AC237MWh

Charge Energy : AC300MWh

Round-Trip DC Efficiency : 82.9%

(with heater loss 3.0%)

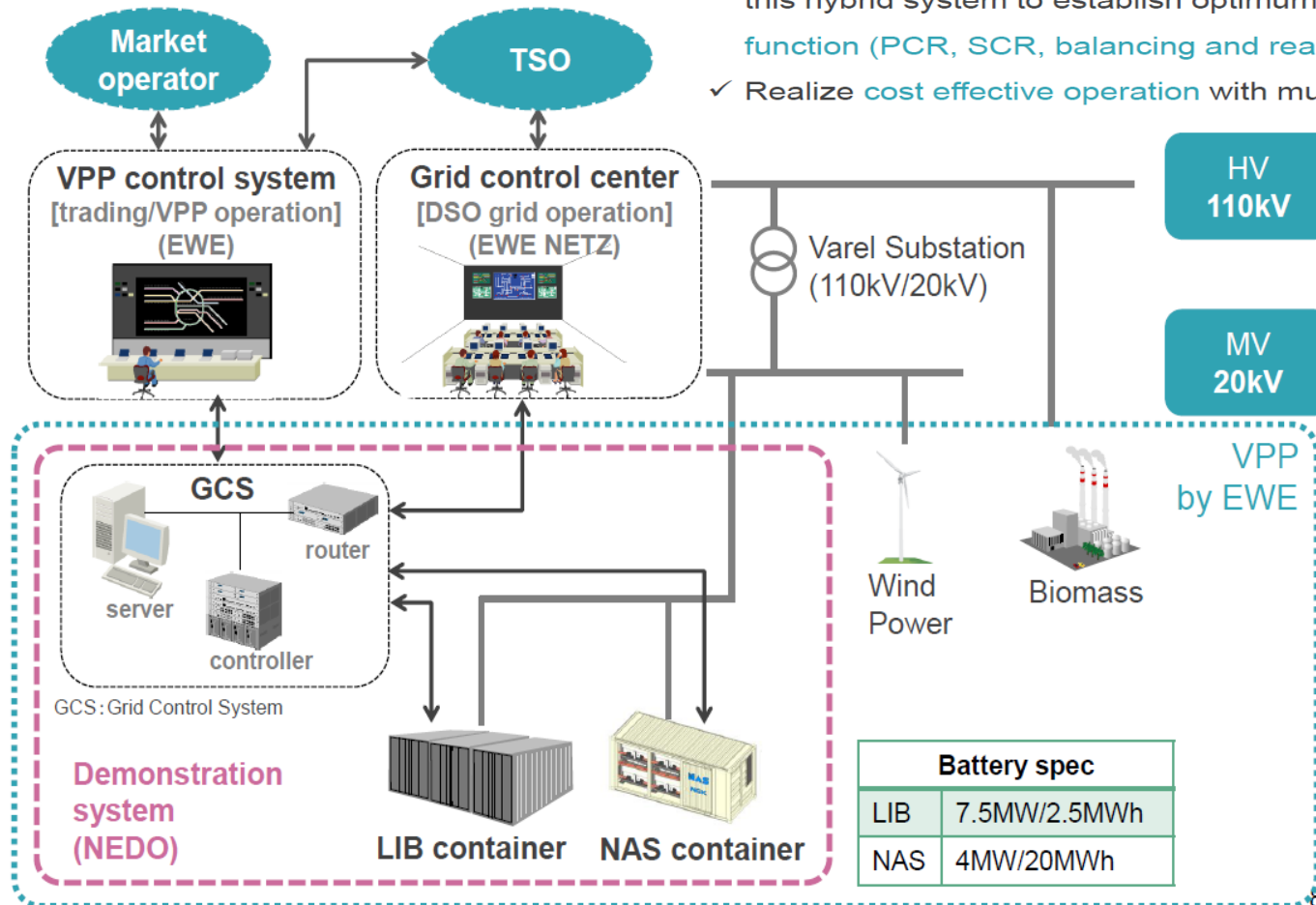
Round-Trip AC Efficiency : 73.0%

(with other auxiliary)

NAS[®]-Li hibrid akkumulátor rendszer

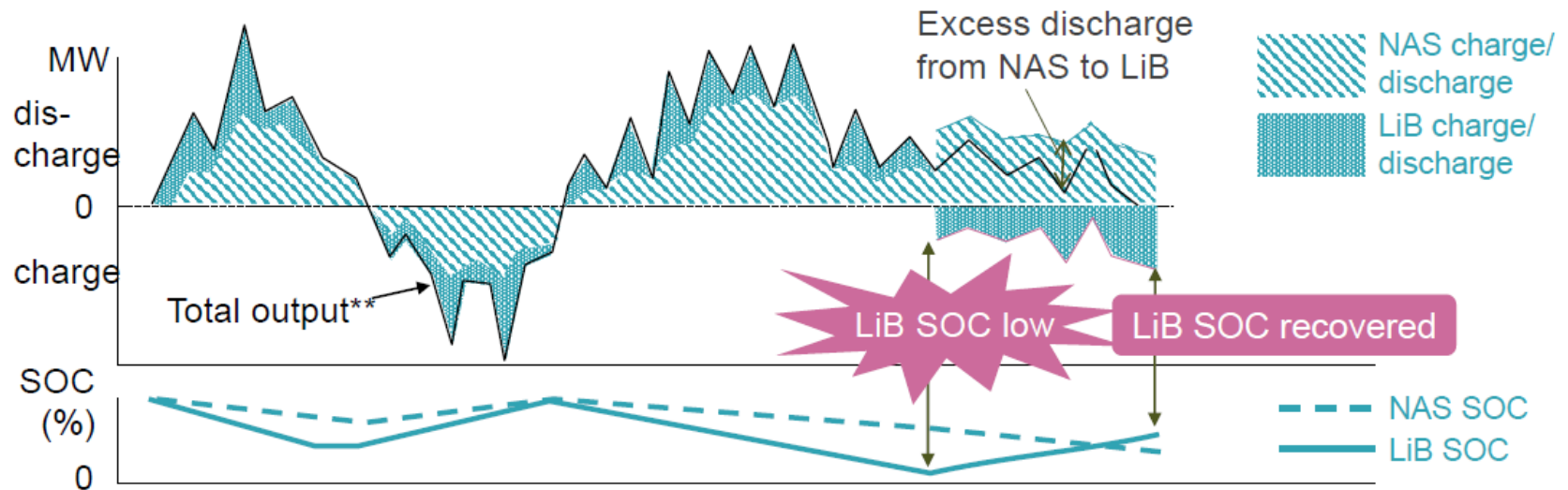
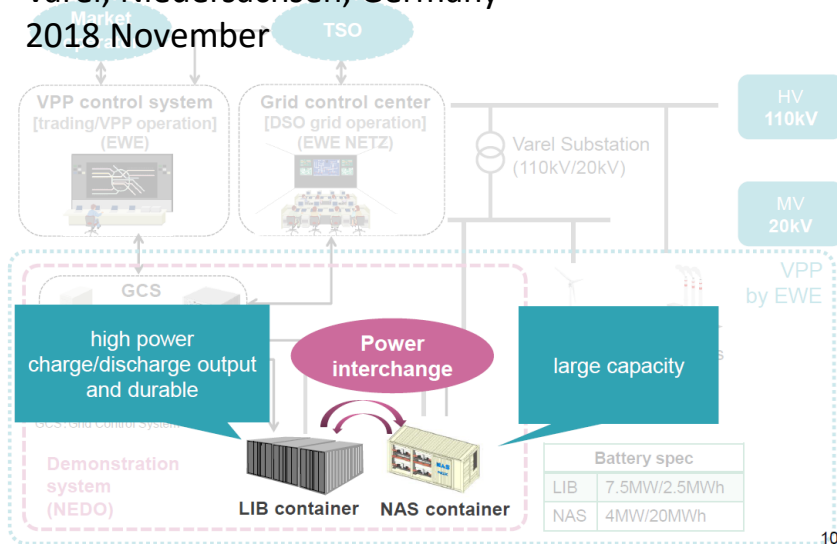
Varel, Niedersachsen, Germany
2018 November

- ✓ To establish the **hybrid battery system** LiB with a high power charge/discharge output and durable and large capacity NaS battery which is cooperate with GCS.
- ✓ Reduce imbalance and control voltage fluctuation in electricity grid with this hybrid system to establish optimum system model like **multi-use of function** (PCR, SCR, balancing and reactive power).
- ✓ Realize **cost effective operation** with multi-use.



NAS[®]-Li hibrid akkumulátor rendszer

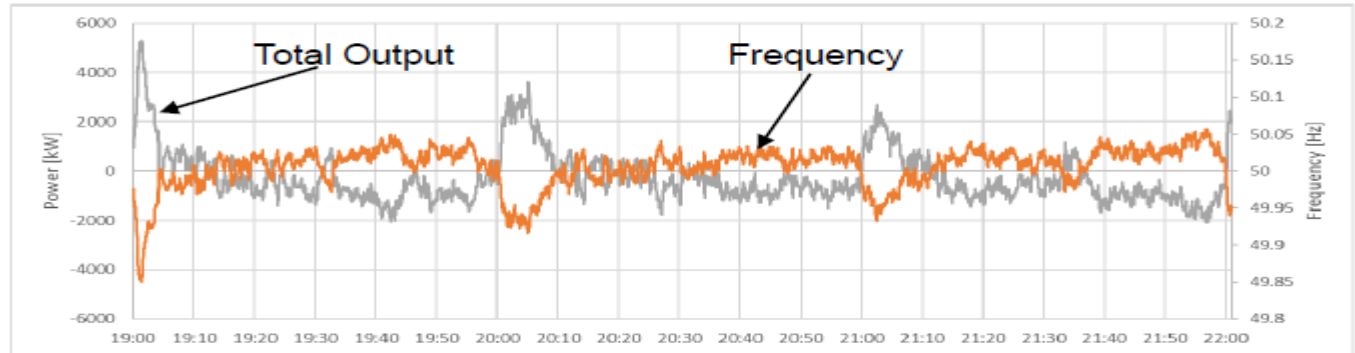
Varel, Niedersachsen, Germany
2018 November



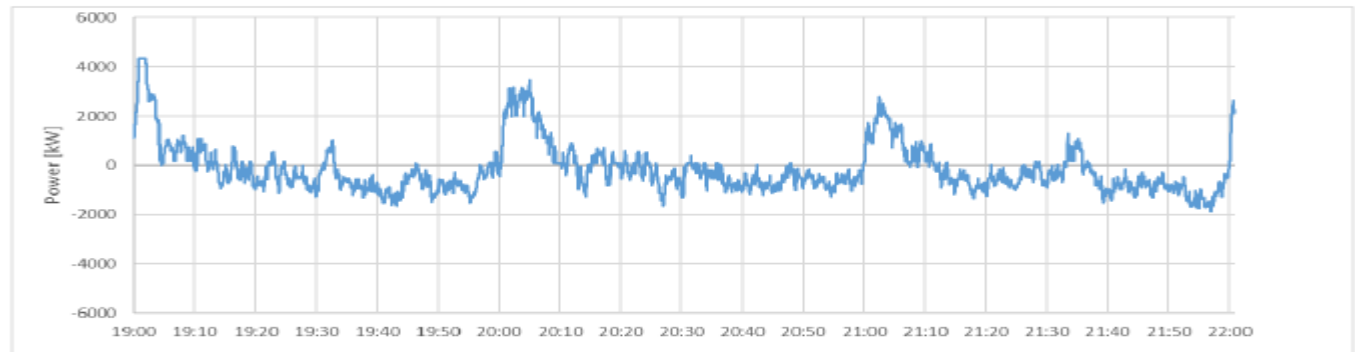
NAS[®]-Li hibrid akkumulátor a primer szabályozásban

Varel, Niedersachsen, Germany
2018 November

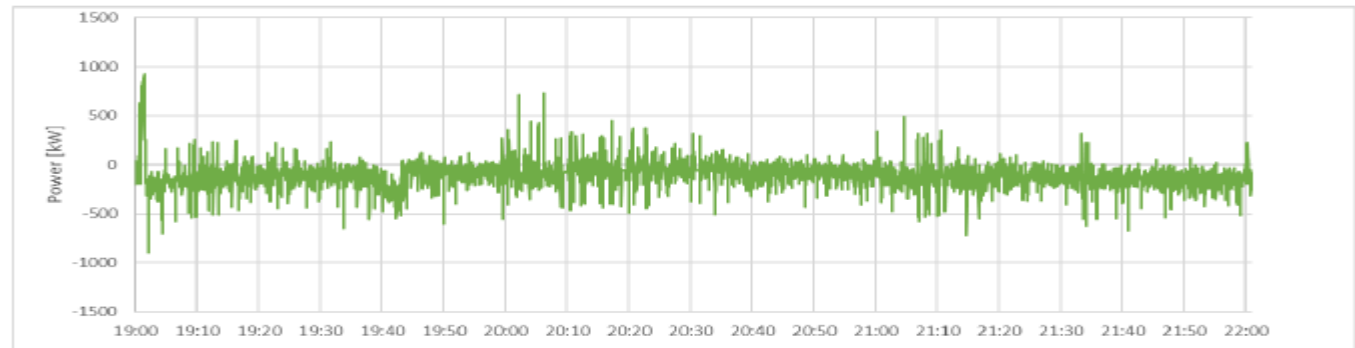
Total Output
and Frequency



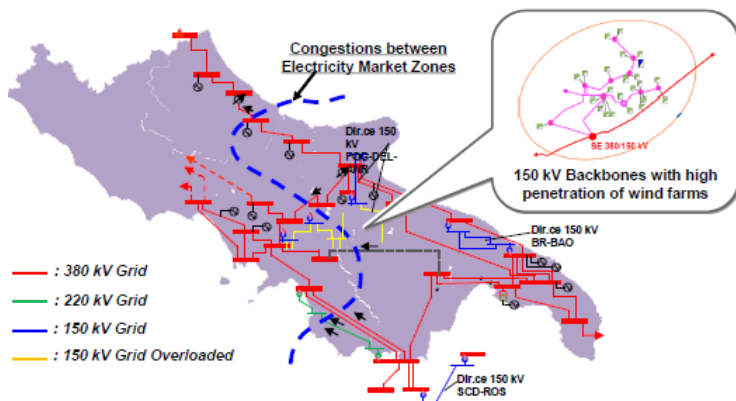
NAS Output



LIB Output



TERNA energiáróló projektje



Total
€300 Million

Energy Intensive
(35 MW)
Grid Development Plan 2011

Power Intensive
(40 MW)
Grid Defense Plan 2012

Critical issues

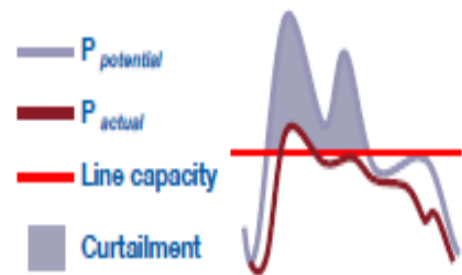
- Local congestions on the HV grid and wind curtailment
- Support to primary reserve and frequency regulation
- Support to tertiary reserve and system balancing
- Voltage support

- Tools inadequate to control frequency transient
- Low primary reserve
- Low inertia of the system due to the increase in static generation
- Difficulties in the management of low-load operation due to RES generation

ESS Technical Features

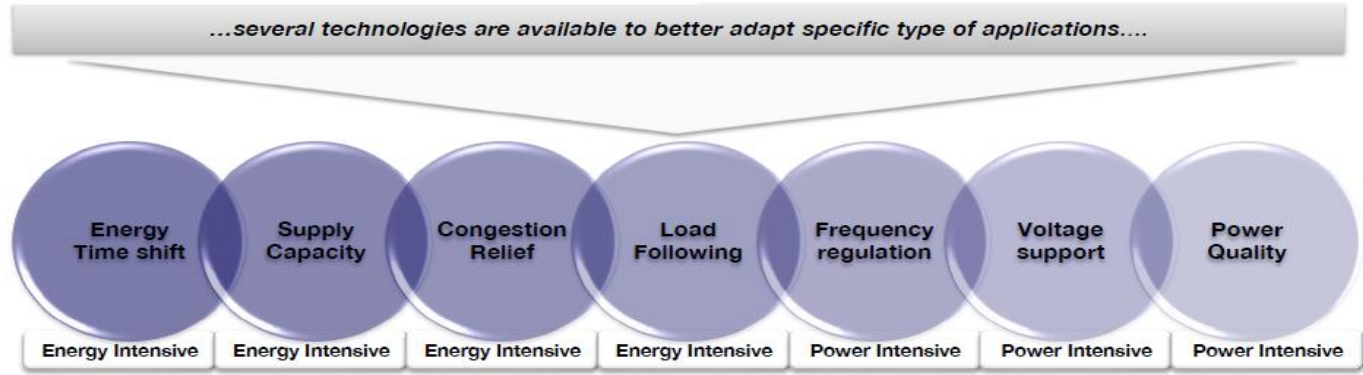
- Energy to Nominal Power ratio ≥ 7 MWh/MW
- AC roundtrip efficiency $\geq 75\%$
- Rapid response time

- Ultra-rapid frequency regulation
- High Power to Energy Ratio
- AC Roundtrip Efficiency $>85\%$



TERNA energiatároló projektje

Total 35MW/230MWh
NAS at 3 substations,
Commissioned in 2015.



Power Intensive

- **Mission:** increase the security of the Electric System
- **Size (MW):** ≈ 16 MW (Phase I) + 24 MW (Phase II)
- **Technologies:** Li-Ion, Zebra, Flow, others (Supercap...)
- **Number of sites:** 2

Phase I: 16 MW Storage Lab

- Site 1) Sardinia - Codrongianos**
- **Size (MW):** $\approx 8,65$ MW
 - **Status:** in operation $\approx 7,9$ MW
in procurement $\approx 0,75$ MW
- Site 2) Sicily - Ciminna**
- **Size (MW):** $\approx 7,30$ MW
 - **Status:** in operation $\approx 5,55$ MW
in procurement $\approx 0,75$ MW
on scheduling ≈ 1 MW

Energy Intensive

- **Mission :** reduce wind curtailment due to HV congestion
- **Size (MW):** ≈ 35 MW
- **Technologies:** NaS (Sodium Sulfur)
- **Number of sites:** 3



- Site 1: Ginestra**
- **Size (MW):** ≈ 12 MW
 - **Status:** in operation
- Site 2: Flumeri**
- **Size (MW):** ≈ 12 MW
 - **Status:** in operation
- Site 3: Scampitella**
- **Size (MW):** $\approx 10,8$ MW
 - **Status:** in operation

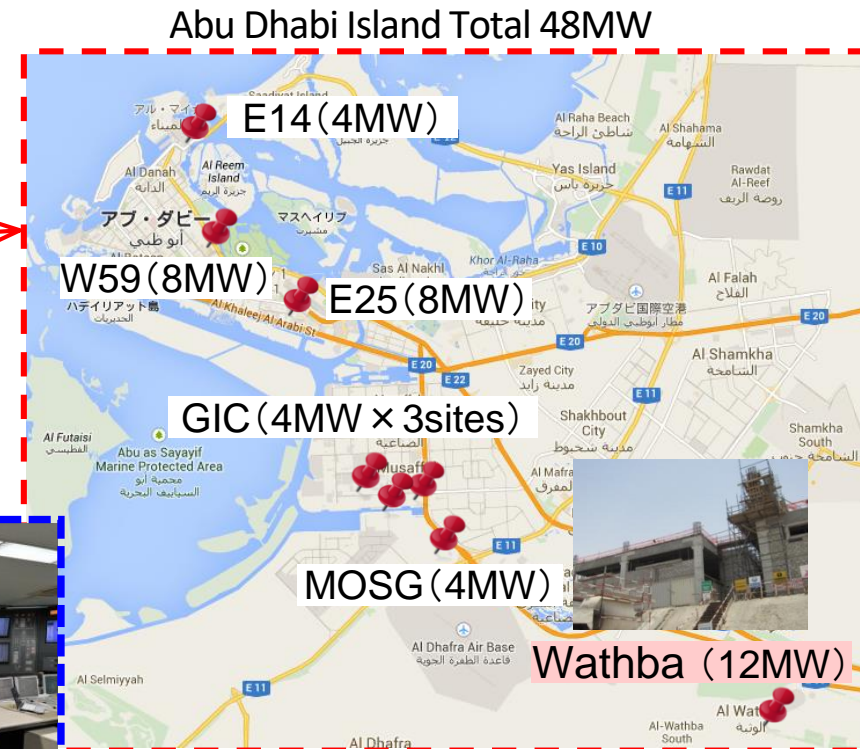
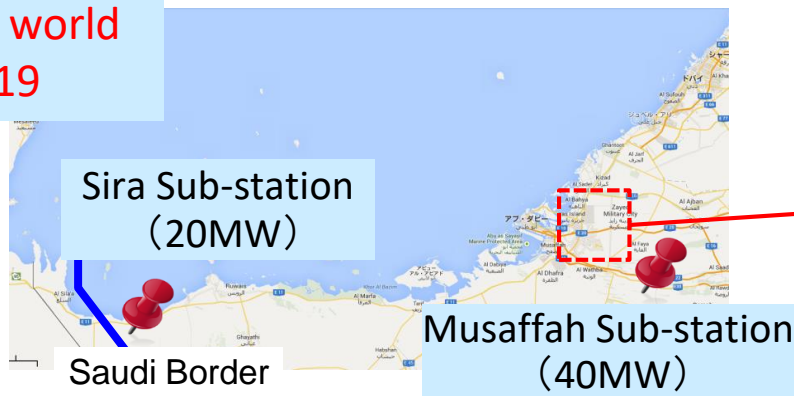


Teheléskiegyszerítési alkalmazás Abu Dhabi (UAE)

NAS[®] Battery (108MW/650MWh) at distribution substations (10 sites, 15 systems in total, 4 ~ 40MW/site) connected with Centralized Integrated System Controller (CISC) supplied by NGK.

The project helps the city load balance across its networks during the daytime, as well as providing up to six hours backup in the case of grid outages.

Largest BESS
in the world
in 2019



Customer (ADWEA) received „Emirates Energy Award 2015”



<https://www.emirates247.com/news/emirates/world-s-largest-virtual-battery-plant-opened-in-abu-dhabi-2019-01-18-1.678218>

NAS[®] akkumulátor tűzeset (2011 szeptember 21)

Joso City, Ibaraki pref. Japan

Damaged battery after the fire incident
2 x 1MW NAS Battery

Front



Cause of the fire: internal short circuit

- 1) Leakage of active material from cell caused local short circuit between module blocks.
- 2) Fire ignited several cells in the module due to the large short circuit current.
- 3) Fire spread to other modules.

Since 2002 until 2011: 1 fire incident
per 300MW NAS systems in operation
(6,000 modules with 2.2 million cells)

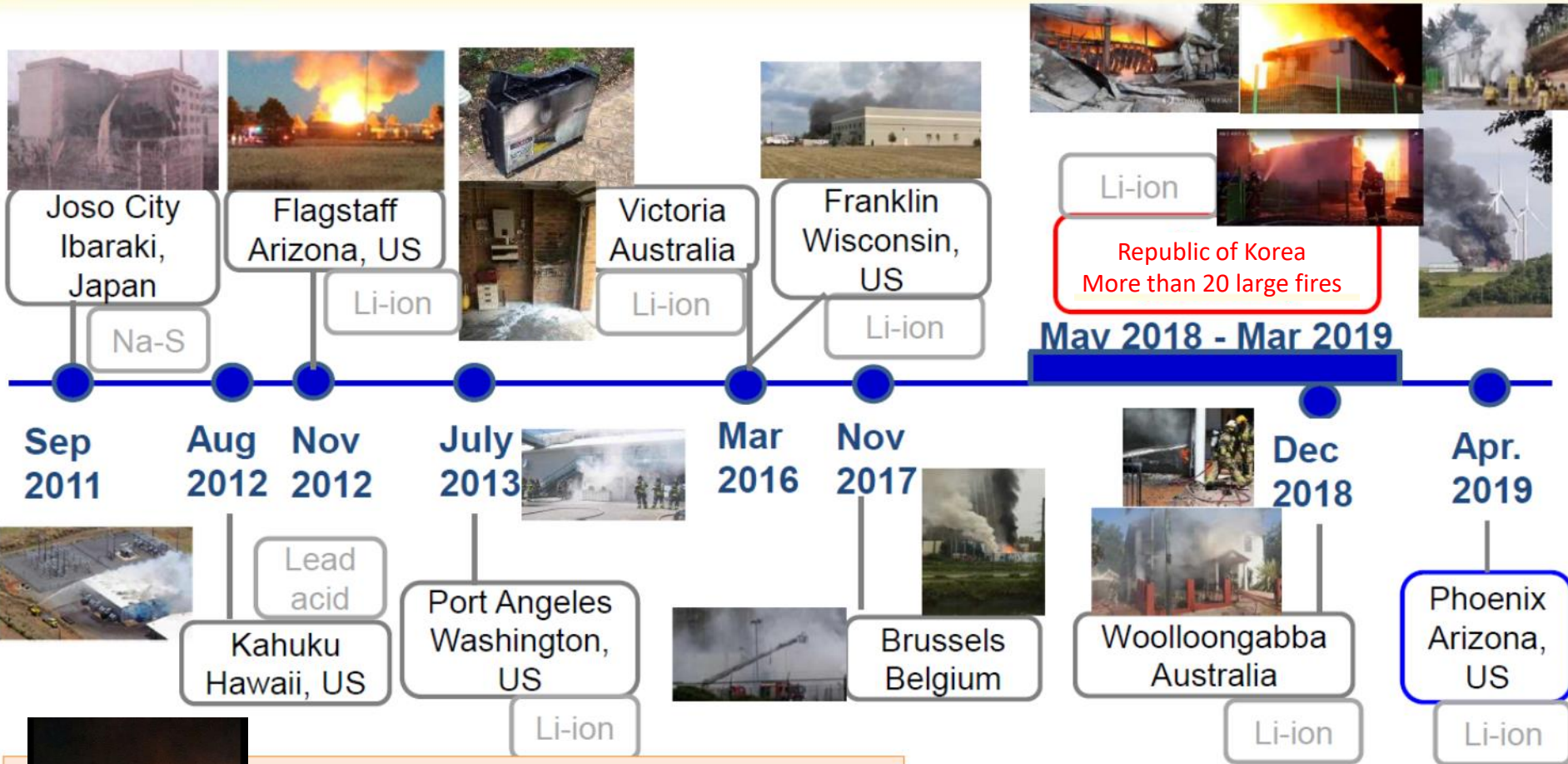
Since renewal to present: No fire accident
580MW NAS systems in operation
(19,300 modules 3.86 million cells)

about 3m

Back



Akkumulátor tüzesetek 2011 óta



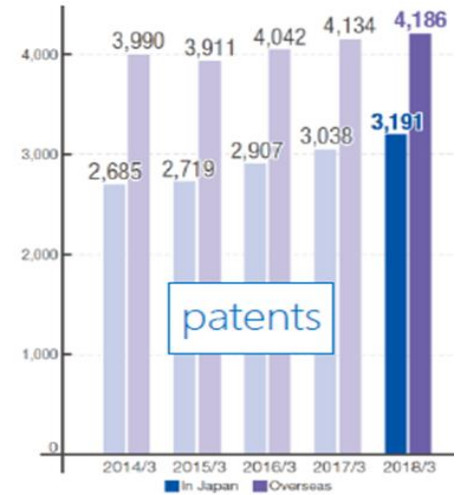
Explosion in Liverpool, UK, Lister Drive 132KV Substation, Sept. 15 2020
 20MW Li-ion battery (LG Chem, integrator NEC)
<https://www.liverpoolecho.co.uk/news/liverpool-news/live-updates-fire-rips-through-18934842>



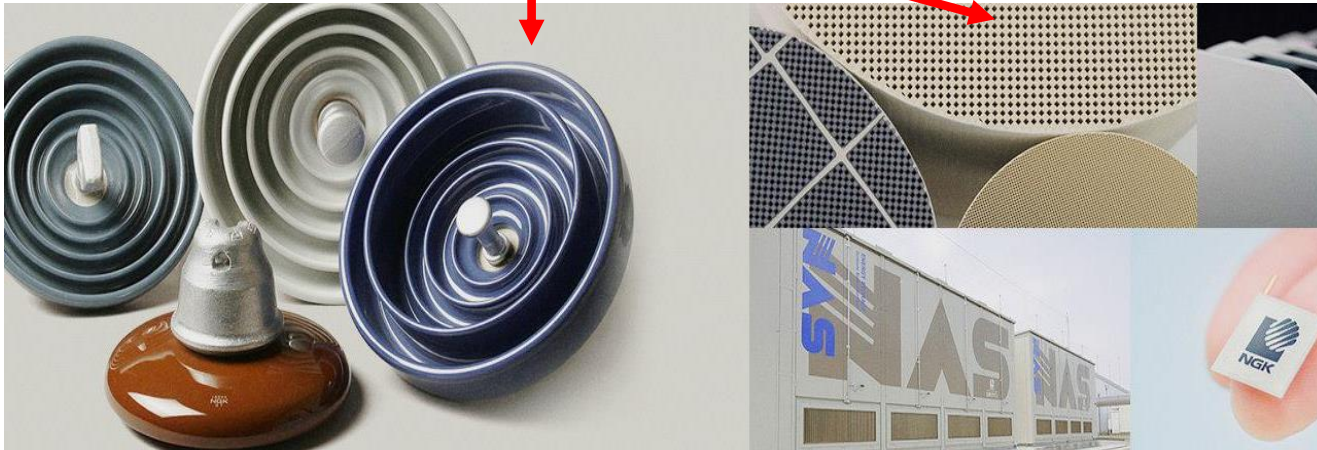
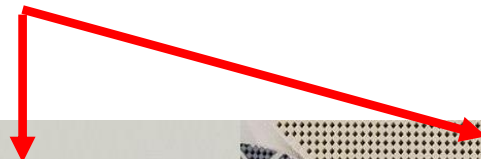
NGK INSULATORS, LTD.

technology provider
SINCE 1919 YEARS
May, 5th

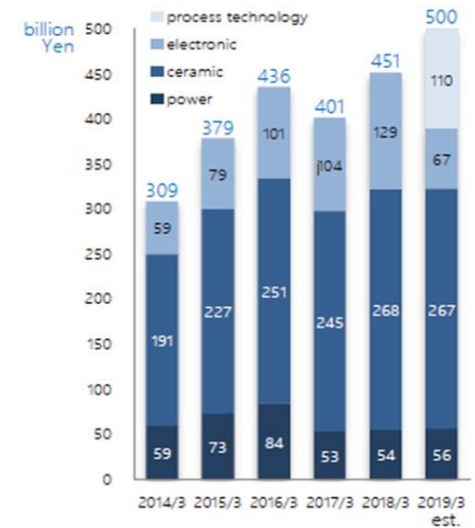
consolidated subsidiaries	21 Japan
	14 Americas
	6 Europe
	17 Asia
	58



World market 60%



consolidated net sales



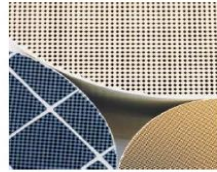


NGK INSULATORS, LTD.



power

array of products to ensure a stable supply of electricity and contribute to energy conservation and sustainability



ceramic products

ceramic catalyst carriers, filters and high-precision sensors that are indispensable in cleaning vehicle exhaust gases that help preserve the environment



electronics

latest in fine ceramic technologies to help drive the technical innovation that makes electronics smaller and lighter yet more advanced



process technology

products in a wide range of industries to meet diverse needs such as manufacturing process innovation, improving productivity, energy savings and more



R & D

we create leading-edge technology and new global standards within the triple E areas of

**ecology
energy
electronics**

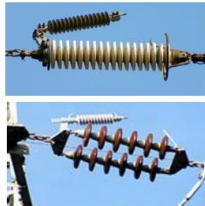
insulators and equipment for substations



- hollow insulators
- support insulators
- bushings
- isolators

megavolt-class

equipment for power transmission



- polymer insulators
- line arresters

equipment for power distribution



- switches and cut-outs
- lightning protection equipment
- voltage regulators (static var generators)

high voltage laboratory



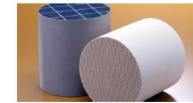
- world's largest insulator testing facility
- internationally accredited
- testing at actual size
- unrivalled support to R&D



HONEYCERAM®

- three way catalyst converts harmful elements (HC, CO, NOx) into harmless elements
- remove up to 99% of particulate matter (PM)
- lattice-like wall of 0.05 mm
- continuous development, in particular to increase surface area in the same volume

world leader



DPF & GPF

- diesel particulate filters
 - lightweight cordierite 700 million pieces
 - silicon carbide SiC since April 2003
- DPF used together with HONEYCERAM® for engine exhaust gas purification



NO_x sensors

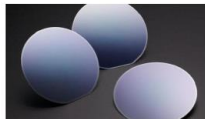
- first sensor in the world to detect NO_x concentration in a vehicle in real time
- high accuracy and long time
- zirconia (ZrO₂) and oxygen pumping technology
- mounted directly on the exhaust pipe
- smart NO_x sensor (SNS) commercialised by Continental, Germany



others

- firing and drying furnace
- refractory products
- corrosion resistant equip.
- membranes and separators
- glass lining products
- DPF washing device
- high temperature gas dust
- low-level radioactive waste treatment systems
- water purifier

bonded wafers



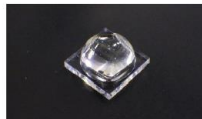
gallium nitride (GaN) wafers



translucent alumina ceramics HICERAM®



micro-lenses for ultraviolet LEDs



industrial heating systems (kilns & drying furnaces)



low-level radioactive waste treatment systems



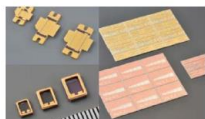
kiln furniture & refractories



corrosion-resistant equipment and systems



ceramic packages & functional circuit boards



electronic components for communication devices



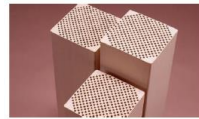
beryllium copper alloy



copper-nickel-tin alloy



high-temperature dust collectors



ceramic membranes & separators



wavelength-control drying system



home-use water purifier





Köszönöm megtisztelő figyelmüket

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