Vanadium Redox Flow Battery Technology

FOR POLICY DIALOGUE ON ENERGY STORAGE

15 March, 2016

LE SYSTEM

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Company Profile

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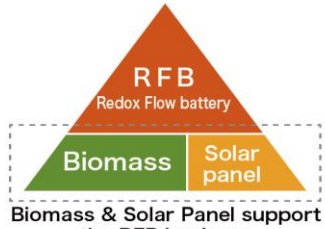
[HP]	http://www.lesys.jp
[Established]	January, 2011.
[Stated Capital]	355,041,000yen (including capital reserve 121,270,50yen)
[Principal Shareholders]	Energy & Environment Investment Inc., LIGITEK ELECTRONICS CO., LTD., Mitsubishi UFJ Capital Co., Ltd., Japan Investment Adviser Co., Ltd.(JIA) , IP Alliance Co., Ltd., Nishimatsu Construction Co., Ltd., etc.
[Corporate Employees]	Board Members: 7 Employees: 13 Engineering Advisors: 4

Business Concept



Biomass & Solar Panel support the RFB business.

RFB

RFB is safe, long-life, can be increased in size and requires little maintenance costs. VRFB may be used for various purposes: output variation relaxation, alignment of power usage disparities between day and night, back-up power sources, smart grid. The features of electrolyte of redox flow battery is almost no deterioration, enhanced life and stability, long term for using.

Biomass

Biomass: LE system is primary consulting biomass project. We have been excellent experience and Knowledge in planning a methane fermentation plant.

Solar panel

Solar panel: LE system affiliated with Ligitek Group which is registered on the Taiwan stock exchange .We sale the solar panel which made by Ligitek. The features of the solar panel is high quality and durability.

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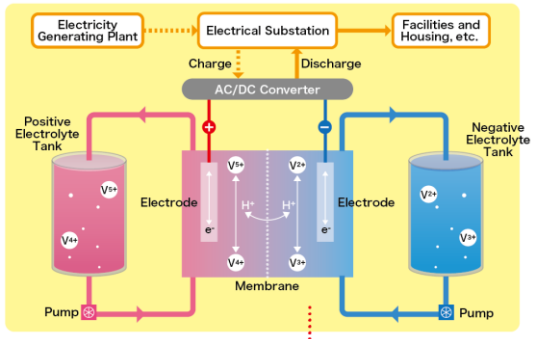
RFB mechanism



Redox Flow Battery Structure

Basic principle of RF Battery (Redox Flow Battery) is by perform the charging and discharging by circulating the liquid which cause the electron transfer in the potential difference between positive and negative electrodes.
For other batteries, they are structured to charge and discharge for the chemical change by the electrodes. Whereas, this RF Battery perform charging and discharging for chemical change by the electrolyte which is called the oxidation-reduction process, which result the possibility to maintain the long period electrolyte.
By this principle, SAFE, LONG LIFE, and LOW MAINTANANCE COST are the features of this battery.

The actual device greatly composed by four parts.

●Control

Electric control (including inverter, etc.)

●Cell

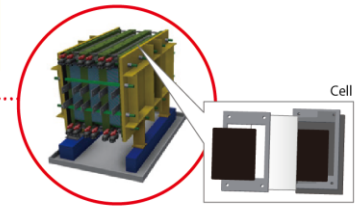
Role to control the input and output (charge and discharge)

●Electrolyte

Each positive electrode liquid, negative electrode liquid is in the tank of the positive electrode, negative electrode and has a role to accumulate electricity.
(If liquids increase, quantity of accumulation of electricity increases)

●Pump

Pump necessary to pour an electrolyte into a cell



The size of cell and electrolyte tank can be changed depending on the needs.

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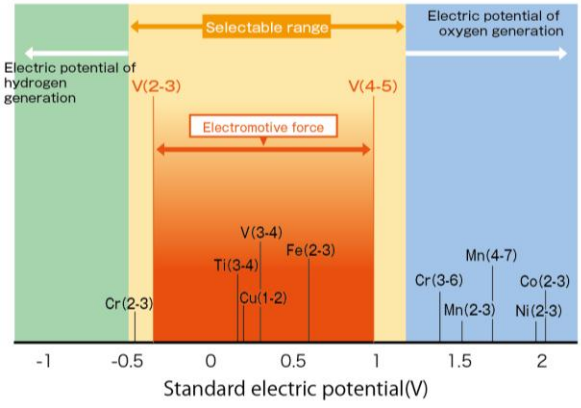
Characteristic of V (vanadium)



Vanadium ore

Vanadium is an element of atomic number 23. The symbol of an element is V. Vanadium is one of the group elements.
"Redox Flow Battery" is one type of rechargeable battery which occurs by the vanadium valence change in the electrolyte containing vanadium sulfate (III) and oxide vanadium sulfate (IV) during charge and discharge.
Redox Flow Battery using vanadium is expected to become large batteries for power storage then Sodium-Sulfur Battery (NaS Battery).

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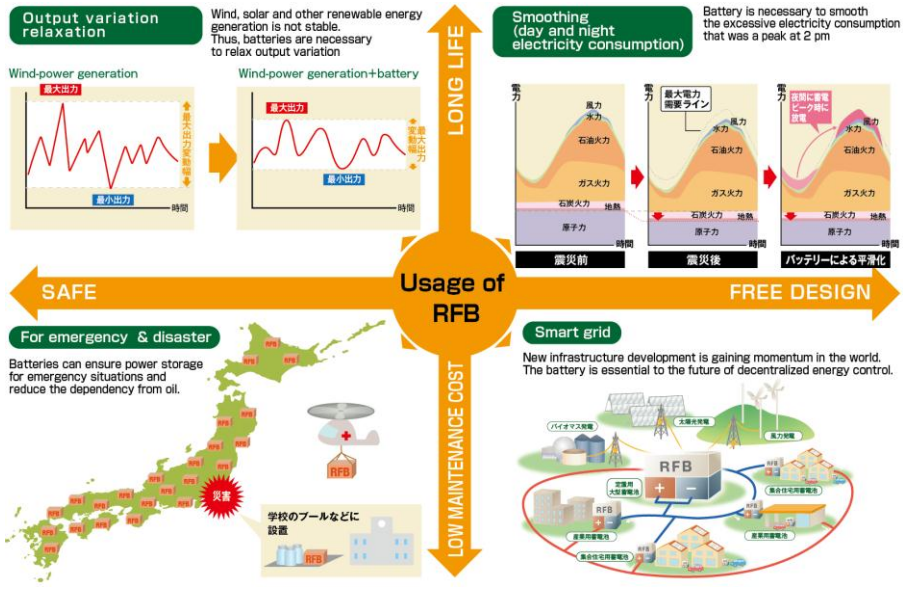
Usage of RFB



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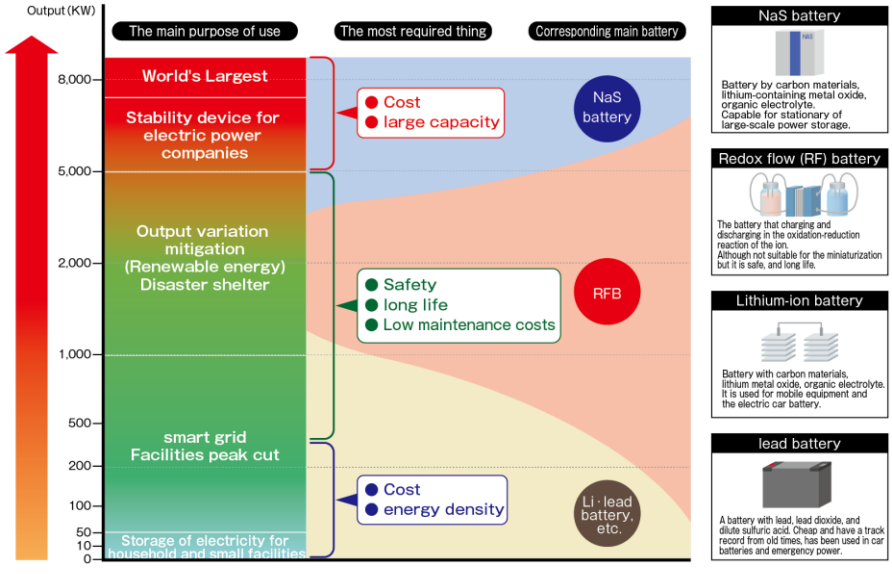
Battery market



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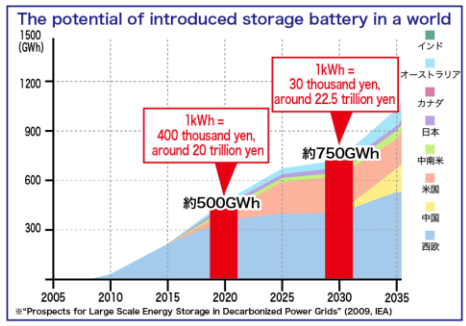

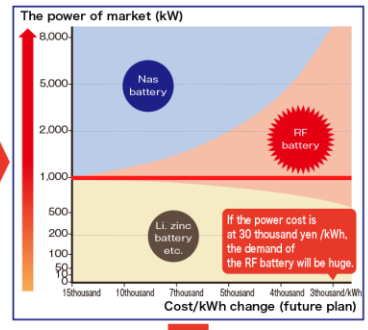

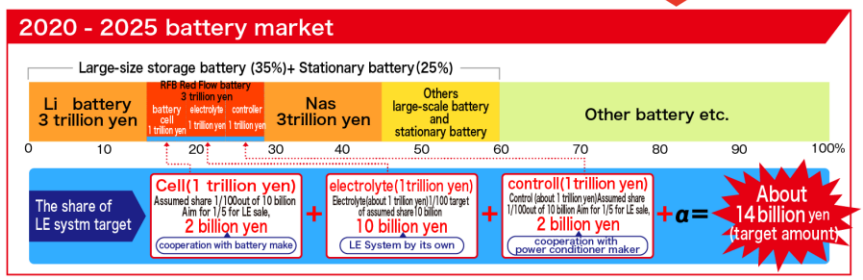

market

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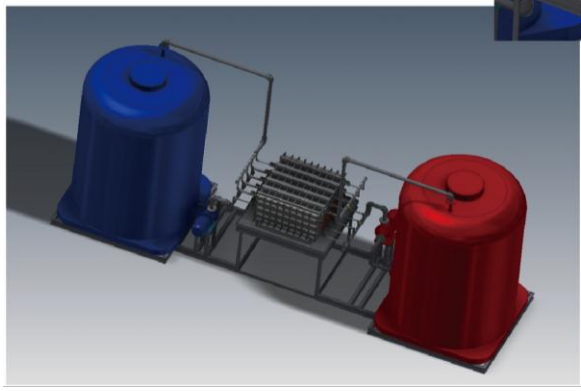
RFB upsizing

Three-dimensional graphics image

Redox flow battery 25kW



The output and amount storage can be freely adjusted by adjusting the number of cells and amount of the electrolyte.

RFB Structure

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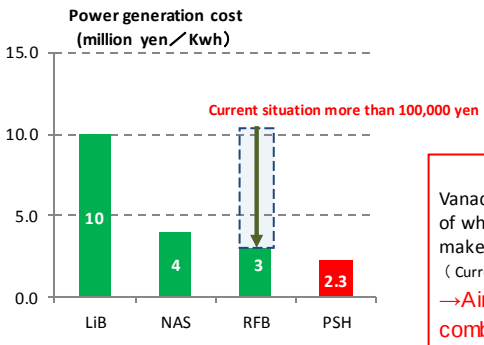
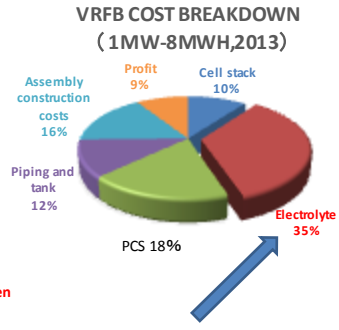
Cost of vanadium RFB

The vanadium redox flow battery (VRFB) has high generation cost compared to the other batteries





Vanadium electrolyte cost 35% of whole battery cost, it is important to make it cheaper.

（Current situation 400,000 yen / ㎥ →target 200,000 yen / ㎥）

→Aiming into 30,000 yen/kWh by combining it with mass production of a high output cell and an electric equipment

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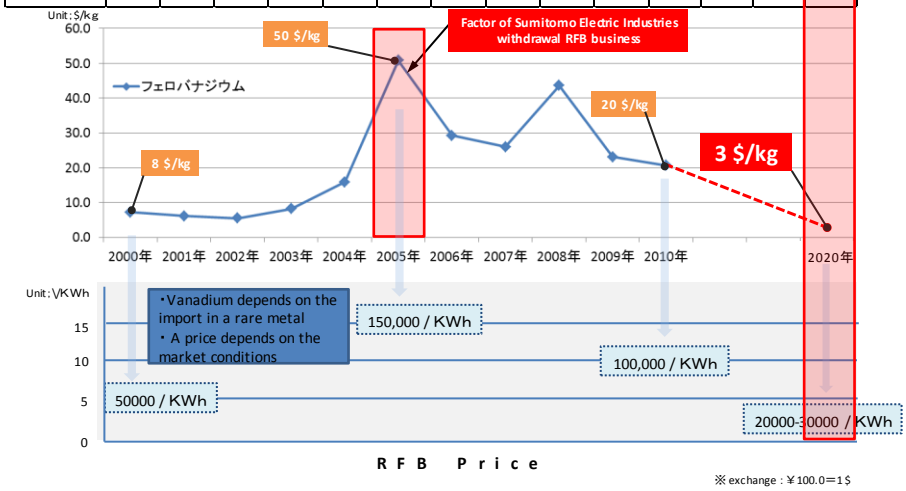
V (Fev) Market price trend

Vanadium import price

Unit:$/kg

	2000年	2001年	2002年	2003年	2004年	2005年	2006年	2007年	2008年	2009年	2010年	…	…	Target 2020年
Ferrovanadium	7.2	6.1	5.5	8.2	15.9	50.8	29.2	26.0	43.6	23.1	20.7			3.0



※exchange：¥100.0＝1$

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■Petroleum coke

PC (petroleum coke) is a by-product produced in petroleum refining (FIG. 1). PC is a residue of the process where primary fuels such as gasoline or heavy oil are purified, vacuum distillation residual oil is subjected to coking unit and then kerosene and diesel oil is extracted from gas. The improvement of purification in recent years techniques will facilitate the production of PC.

Table 1 shows a comparison of bituminous coal and VR. PC has a heating value of ca. 1.24 times that of bituminous coal. In estimating the amount of heat generated, for the same amount of power generation, PC requires only 80% of bituminous coal (1/1.24). It also contains more heavy metals than general fuel and there are less volatile materials during the combustion in the boiler. In general, fuel costs are lower than bituminous coal. Thus, even with regard to power generation costs, PC is quite competitive with the bituminous coal powered plant.

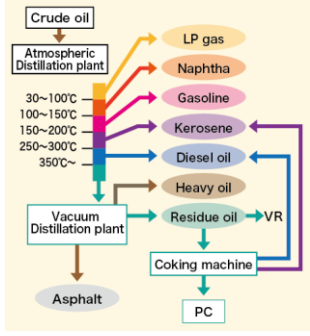

Fig.1 PC Production Process

Table 1.
General Characteristics Comparison between the PC and other fuels

	PC	Bituminous coal	VR
Higher calorific value (air-dried) (kJ/kg)	34893	28180	41850
Volatile content (air-dried) (wt%)	9.9～13	26.2	—
Fixed carbon (air-dried) (wt%)	87～90	56.3	20～30
Sulfur content (anhydrous ashless) (wt%)	＜6.5	0.40	4.0～6.0
Vanadium (ppm)	＜1500	—	＜300

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■Kashima-Kita Power Plant

12 companies that operate the plant such as Mitsubishi Chemical, Kashima Oil and Kashima Electrolytic at Kashima coastal industrial zone were invested and established the Kashima-Kita Electric Power Cooperation (KEPC) which is managing the power plant and supplying the power and steam to the each company.

Besides Kashima south co-generation Kashima south joint power plant, there are Tokyo Electric Power Kashima thermal power plant, Kashima co-fired Kashima joint power plant and Nippon Steel Sumitomo Metals Kashima thermal power plant in the vicinity.

These plant are utilized inexpensive heavy oil matter (such as Orinoco Tar and Petroleum Coke).Although it have many impurity materials, they have been completed the acceptance system and the recycling technology of impurities.

Power generation facilities
Total output: 605,000 kW

Unit 1 rated output: 95,000 kW Fuel: petroleum coke

Unit 2 rated output: 125,000 kW Fuel: heavy oil

Unit 3 rated output: 165,000 kW Fuel: heavy oil

Unit 4 rated output: 150,000 kW Fuel: petroleum coke

Unit 5 rated output: 70,000 kW Fuel: petroleum coke

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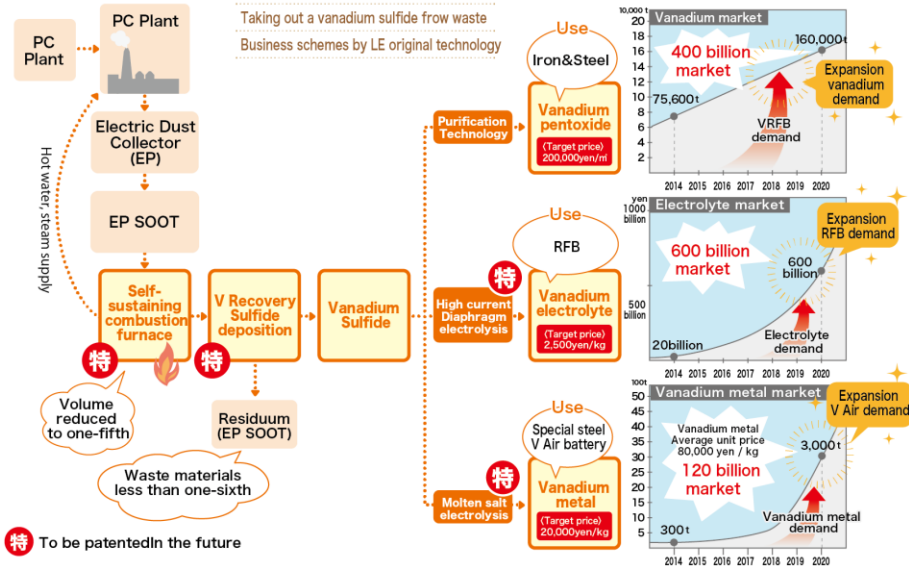
Vanadium Recovery Scheme



Overall development scheme

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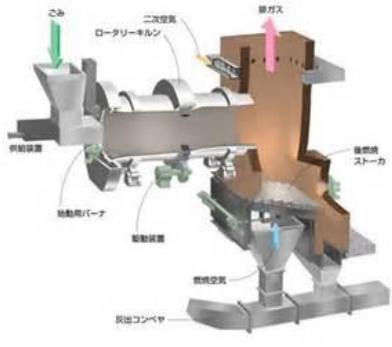
Compared to the rotary kiln, energy-saving and low-cost
- Simple, compact and low-cost structure
-low-temperature combustion and auxiliary fuel unnecessary
-Exhaust gas treatment is easy
- Easy to control the reaction of alkali roasting

The conventional model (rotary kiln)



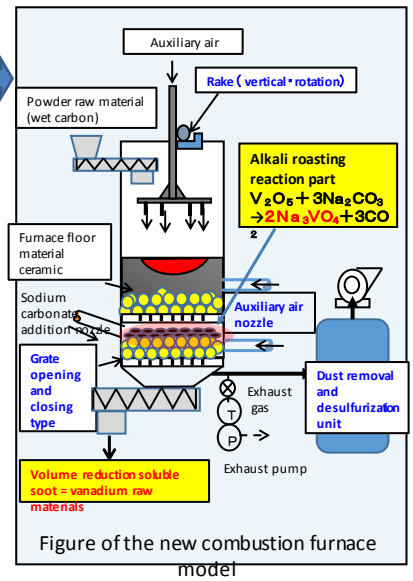


Figure of the new combustion furnace model

Self-sustaining Combustion Furnace for Vanadium Recovery

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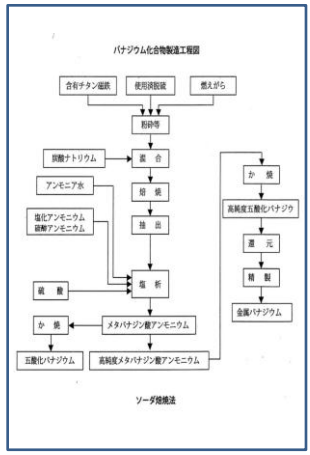


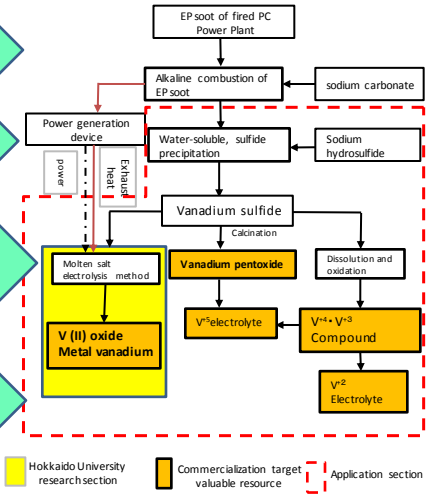
Conventional vanadium recovery method

Cost reduction by using the unused waste

By self-combustion furnace, the energy recovery from PC soot.

By wet processing, work environment improved energy-saving and low-cost to generated electrolyte

By molten salt electrolysis method, Generate energy-saving and high-purity metal V



V Recovery System

The comparison of conventional method for vanadium recovery

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Alkali roasting of EP soot

- volume reduction of unburned carbon
- Solubilization of vanadium (V)

Water dissolved and sulfide precipitation

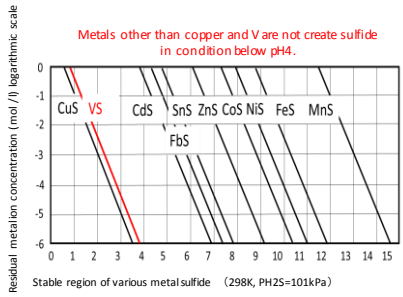
・Dissolve the V salt in water.
・Separation removal of such as Ni,Fe,Cu that not made the Na salt.
・Highly purified and solidified precipitation of sulfides under acidic conditions
・Soluble Mg, Na, the Ca are eliminated.

V electrolytic solution produced from the vanadium sulfide

・In an aqueous solution of VS precipitation, oxide dissolved
・Thiosulfate, oxidized to sulfate ion. Until the final V2O5
・V is reduced and become tetravalent electrolytic solution.
・Electrolytic reduction to trivalent divalent liquid produced.
・Tetravalent electrolyte becomes pentavalent electrolyte.

Table 2. The composition of the PC-fired EP soot (concentration%)

	No washing	After washing with water
Moisture	29.05	25.91
Carbon	70.74	88.94
Ammonium sulfate precipitation	16.11	
Ash	11.53	5.7
V	2.02	0.61
Ni	0.59	0.36
Fe	0.42	0.28
Mg	1.01	0.05
Ca	0.2	0.09
Na	0.21	0.08
Lower calorific value kcal / kg	kg	3300～3,700



The principle of selective highly purified and solidified precipitation of VS

The Technology of Sulfide Combination

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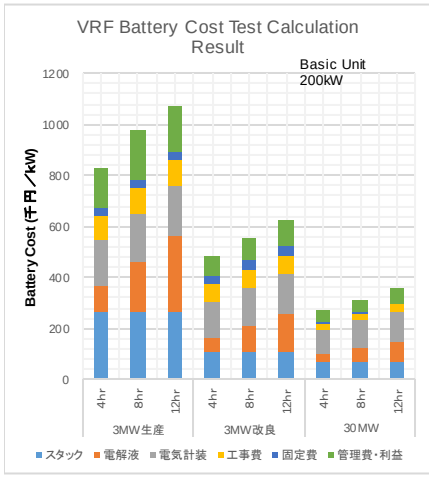

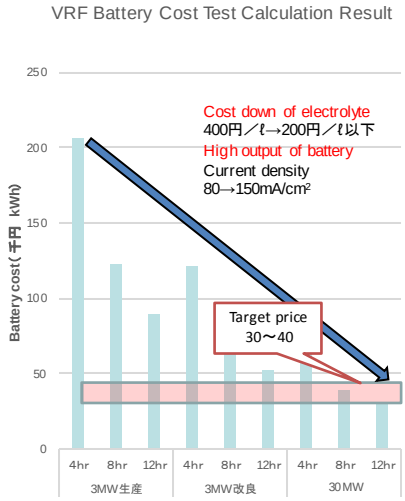

The Vanadium Battery Prospects

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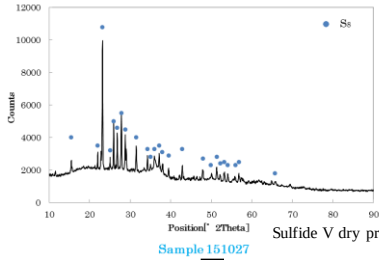
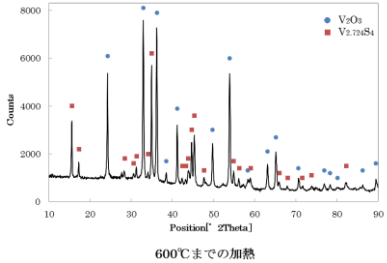
R&D Results



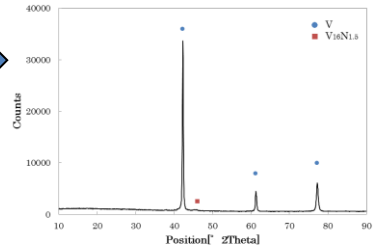
Sulfide V dry product

Sample 151027

Result analysis is V sulfide and sulfide of trivalent and tetravalent



600℃までの加熱



Sample 151126(151027を電解)

The Purity of Metallic Vanadium

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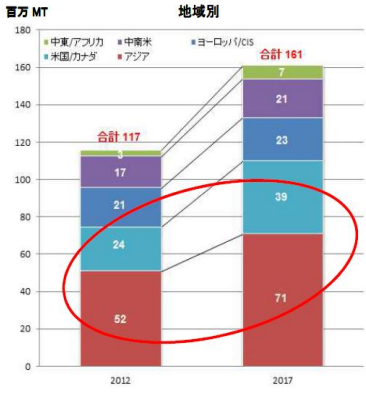

Source:MITSUBISHI co., Ltd

Production and supply is extended (preceding). On the other hand the growth of consumption and demand is limited (trailing)
Consumption and a lot of demand in Asia and North America , viewed as a raw material use (calcine), fuel use (cement and power generation)

The Trend of Petroleum Coke

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Vanadium RFB maker in the world

VRFB Maker in the world

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The 12.5kW VRFB In Container

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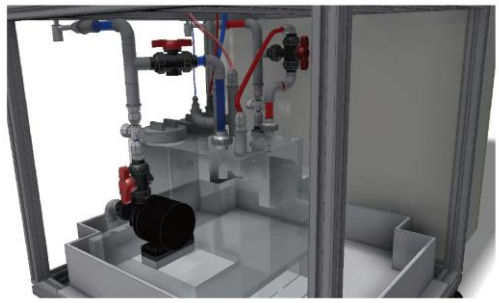
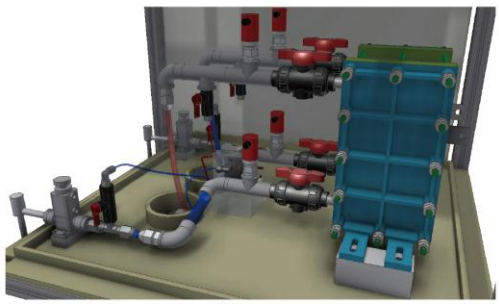
250W VRFB





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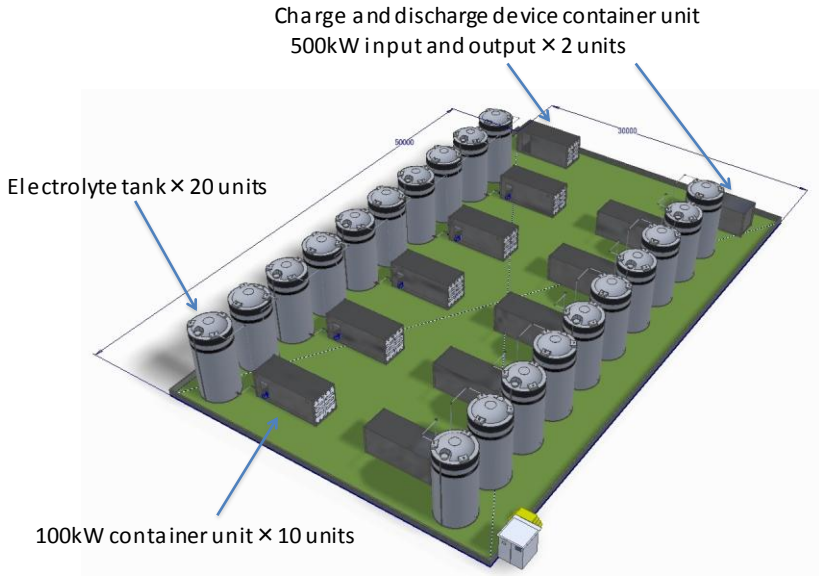
1MW 5MWh RFB installation image



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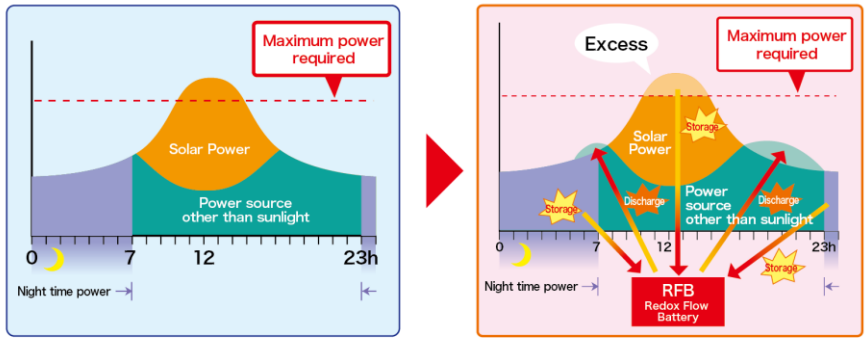
The Utilization Plans of Day and Night Electricity

Urban Pumped-storage Power Generation



- Increase in the percentage of renewable energy
- Increase of demand as the base power
- Combine with a storage battery as the power generation amount is unstable
- Peak cut in the storage battery use as urban pumped-storage power generation

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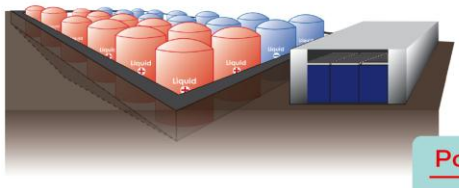
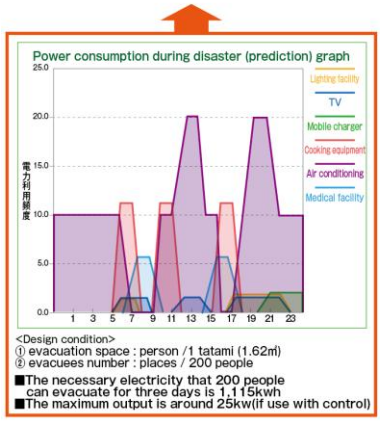
Backup during a disaster



RFB is possible to adjust the scale of the quantity of storage electricity as needed.



Power supply during disaster

Generator
Fossil fuel (Heavy oil and light oil)
Retrograde in CO_2 problem

Fuel battery
hydrogen
requires storage and transportation facilities of hydrogen

Storage battery
Electricity
It can be stored directly to renewable energy

- ■NaS battery
  difficulty in safety and running cost
- ■Lithium-ion battery
  Life is limited, high cost
- ■Lead battery
  Life is limited, and an energy density is low
- ■Redox flow (RF) battery
  Safe and can be installed anywhere.Large-capacity, and life is long

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