Connecting the grid:
the way forward for renewable energy in Asia and Europe

The Digital Grid Concept

The First Step towards Realization of the "Internet of Energy"

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THE UNIVERSITY OF TOKYO

Presidential Endowed Chair,
"Electric Power Network Innovation
by Digital Grid"

digital grid

Digital Grid Consortium Inc.,

Digital Grid

- Digital Grid is proposing new technology direction, which will be "Grid of grids" via asynchronous, addressable digital grid routers and controllers, advocated by the University of Tokyo and Digital Grid Consortium.

- Digital Grid Vision
  - A world which makes wide use of abundant natural, renewable energy and is free from conflicts over energy resources.
  - A world with revolutionary efficient energy use by distributed heat and power generation which does mitigate the damage of environment.

- Digital Grid Mission
  - To realize the above Vision through Digital Grid technology and free market mechanism, resulting in "Internet of Energy" to the world.

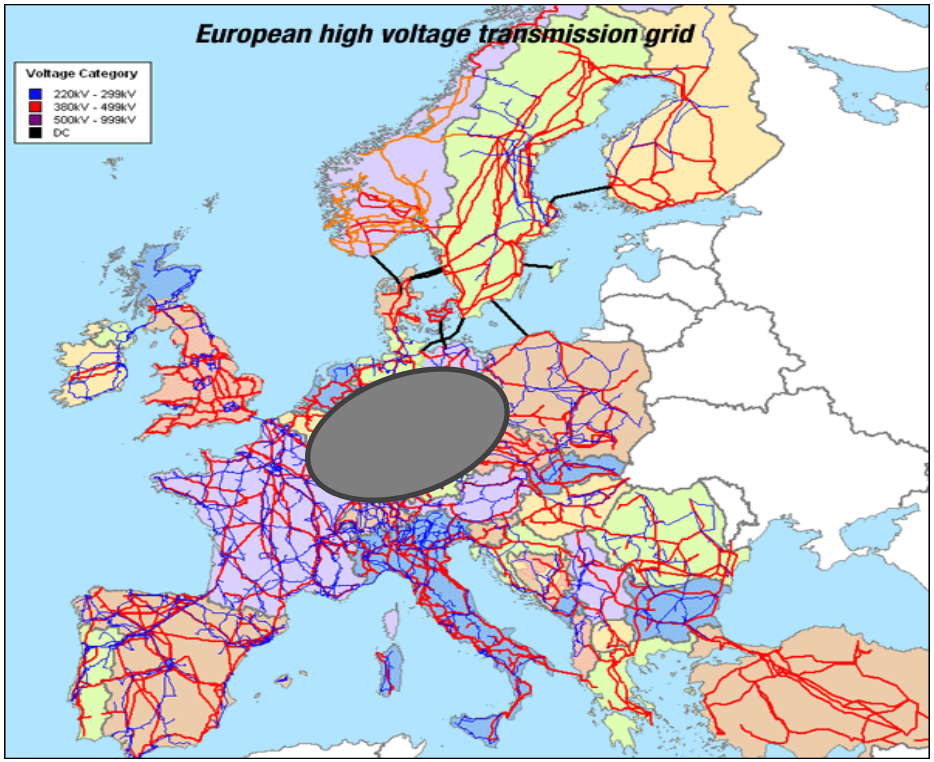
What's the problems with conventional grid?

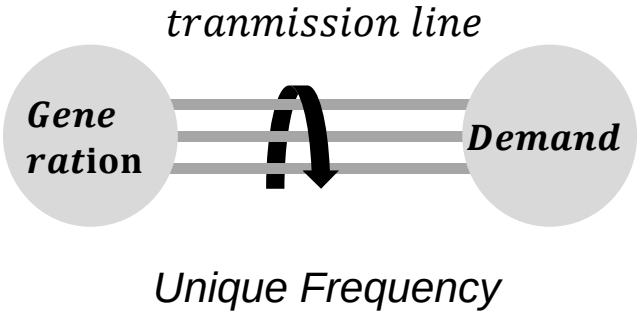
As the speed and scale of intermittent renewable generation increases, we will find two major problems in the conventional grid system:

1. **Technical problem**
2. **Business model problem**

1. Technical Problem:
One, Large, Rigidly Connected Grid

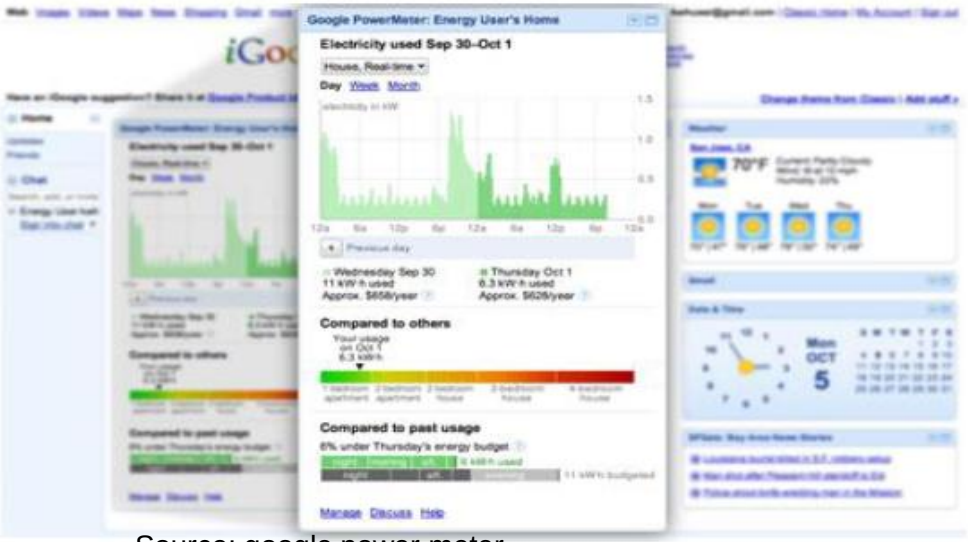
- One, Large, Rigidly Connected Grid has been very efficient with **the centralized control system.**
- It has **limit to control** to accommodate distributed, variable renewable energy.
- It's efficient but there is increasing risk of cascading failure





Technical Problem:
Smart Grid is not enough

- Smart grid tries to watch from generation to demand to have better control of the grid.
- Demand may be controlled by smart meters to match the generation.
- But it is **too slow**, compared to electric system behavior.

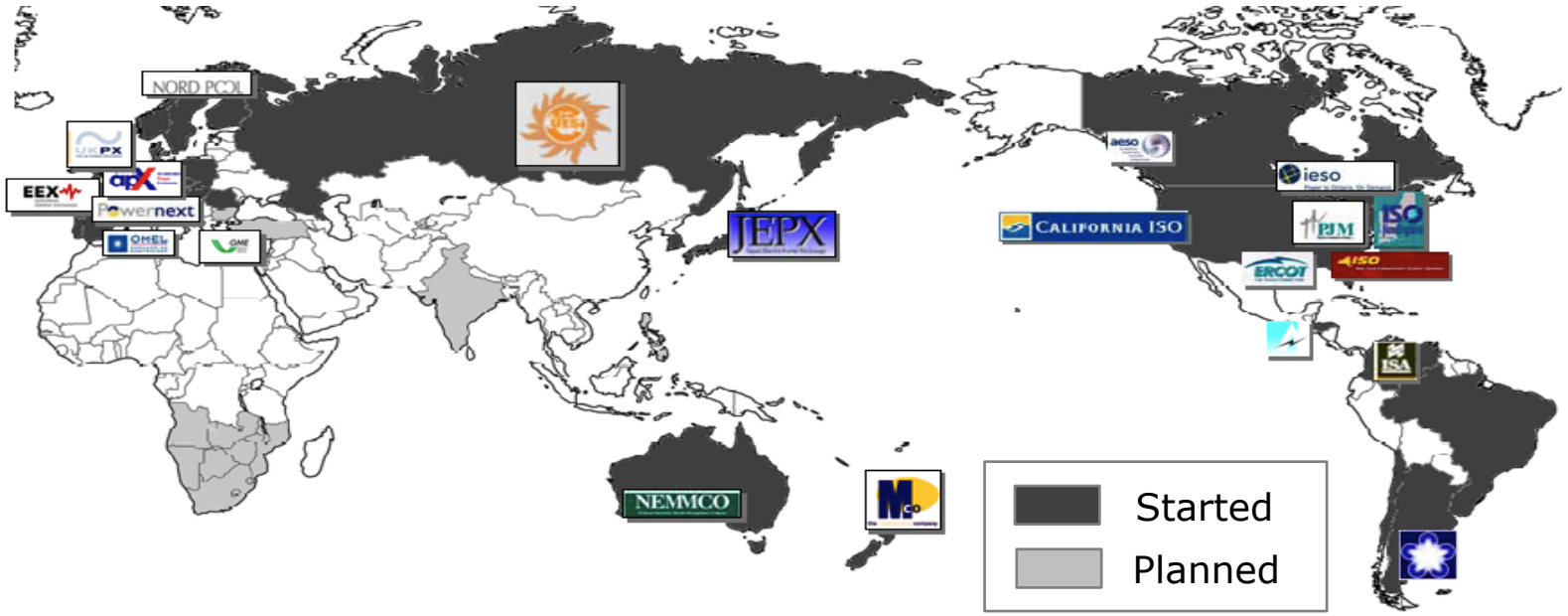


Source: google power meter

Source: Trilliant

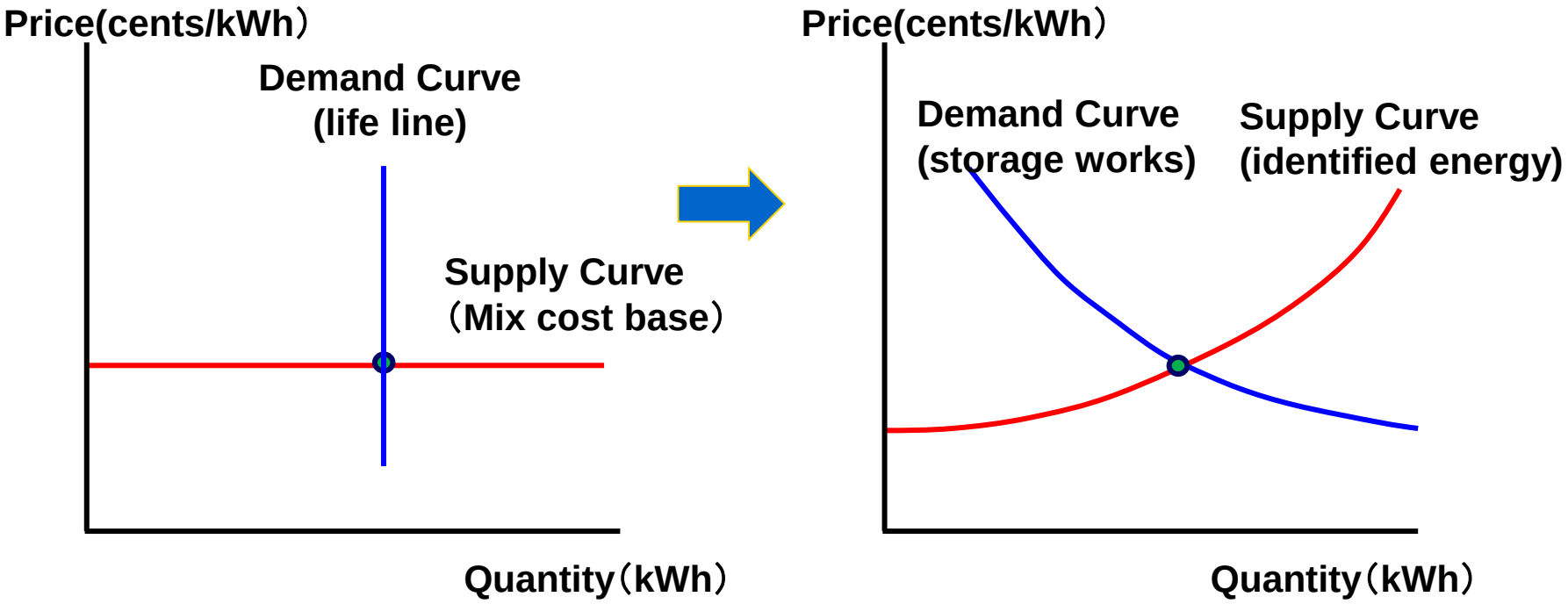
2. Business Model Problem:
Conventional model to market model

- Conventional utility business is based on investment recovery model for 15-20 years period under regulated circumstances.
- Under deregulation movement, a number of electric power markets started, however, they have to accommodate with electrical constraints in power grid, such as power flow limitation, voltage requirement, frequency regulation, etc.
- Therefore, limited, knowledgeable players are only allowed to join in the market.



Business Model Problem:
Free market needs a huge number of players

- To create a free market we need to bring in huge number of new suppliers and purchasers who will compete without price regulation.
- But this will require an administrative ability for the supplier to "address" his "energy product" and the purchaser to "identify" his "energy purchases."
- Furthermore, new players will be required to mitigate electrical constraints of the grid.



Digital Grid Solutions:

The Digital Grid is proposing the following solutions.

1. Technical Solution:

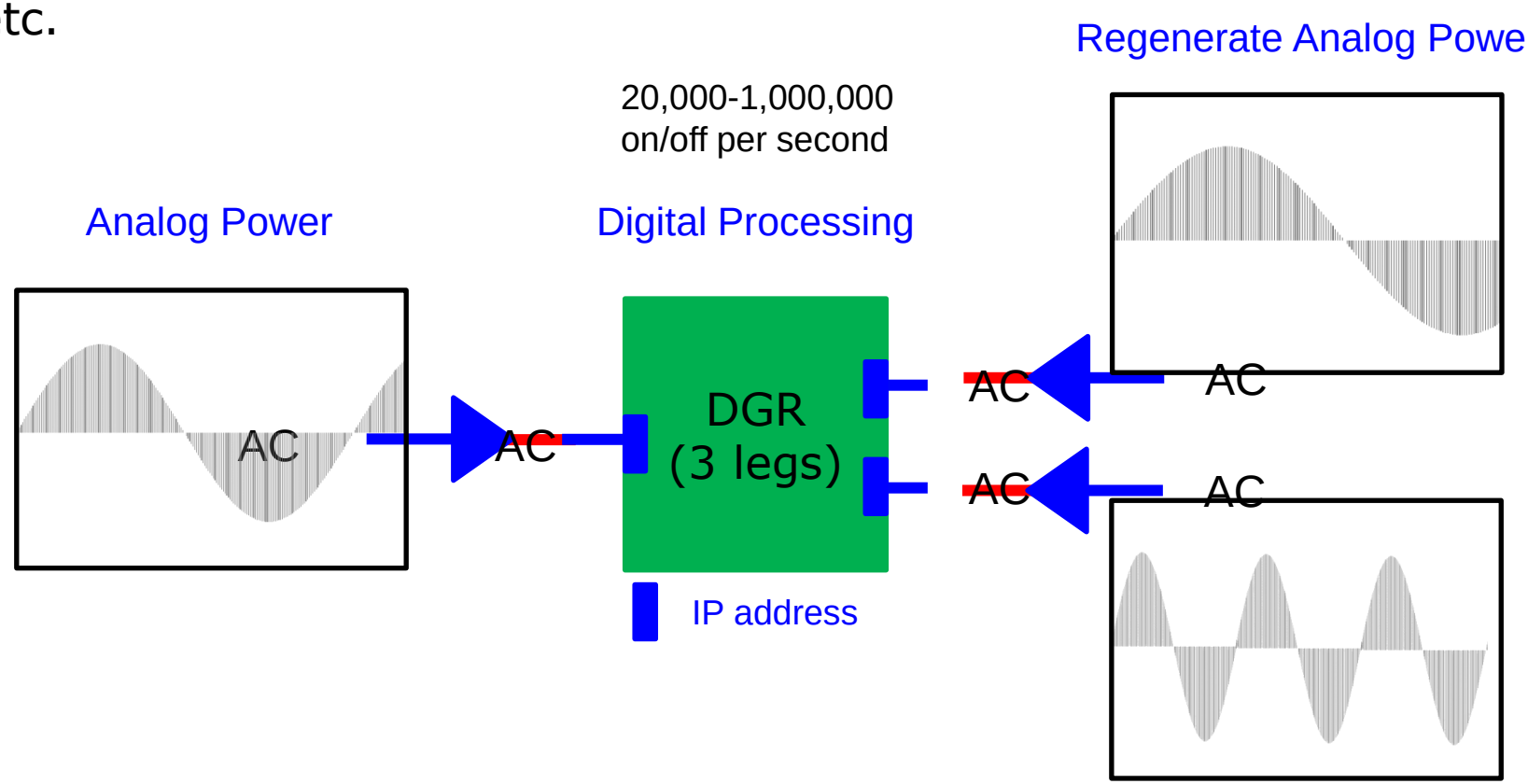
- It allows the shift from the centralized control to decentralized control through **smaller, multiple and flexible power flow controller and energy storage.**

2. Business Model Solution:

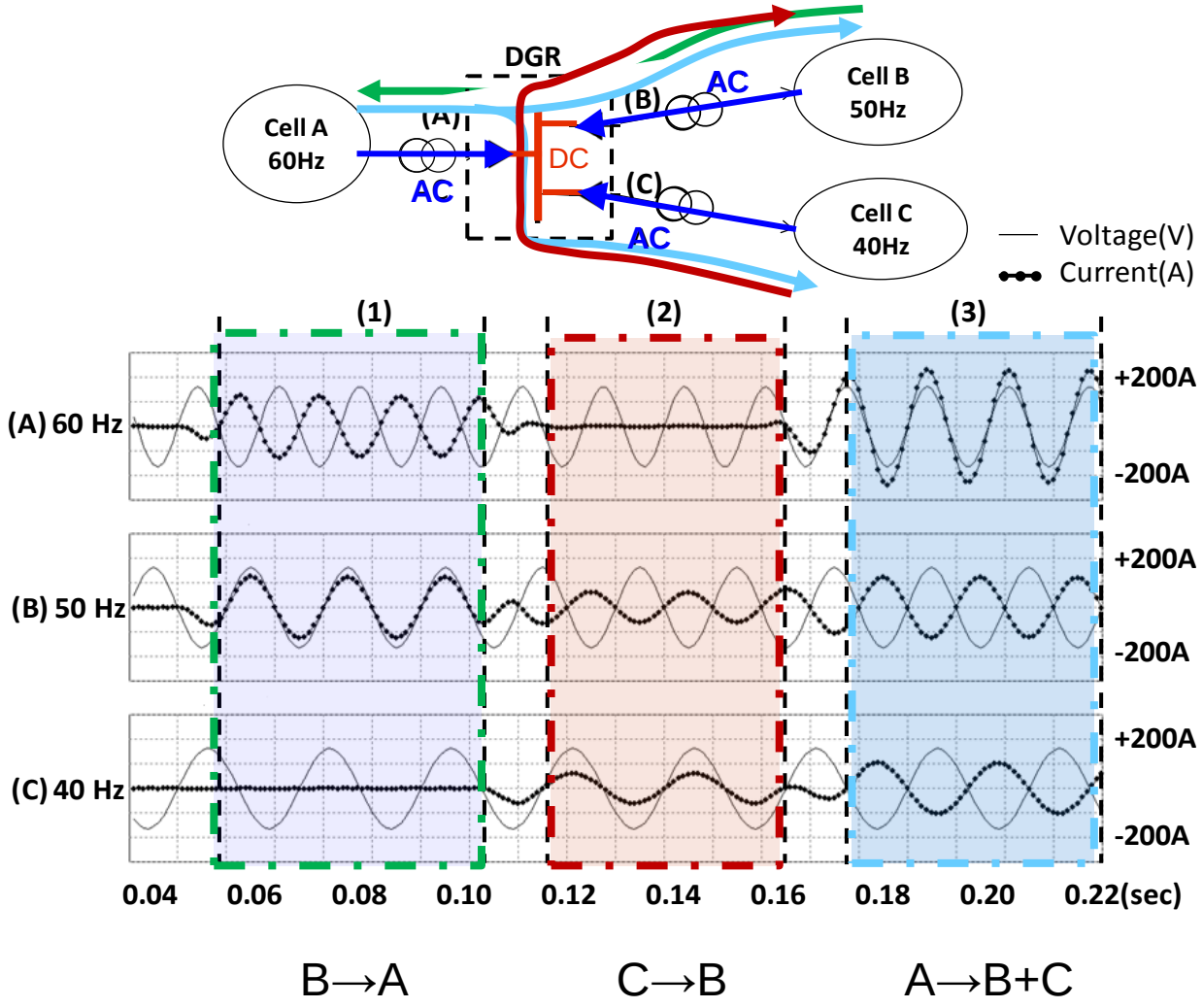
- It uses **addressable power flow controllers** which allow supplier to address his energy product and the purchaser to identify his energy purchases.

Digital Grid Router (DGR):
Addressable, Flexible Power Flow Controller

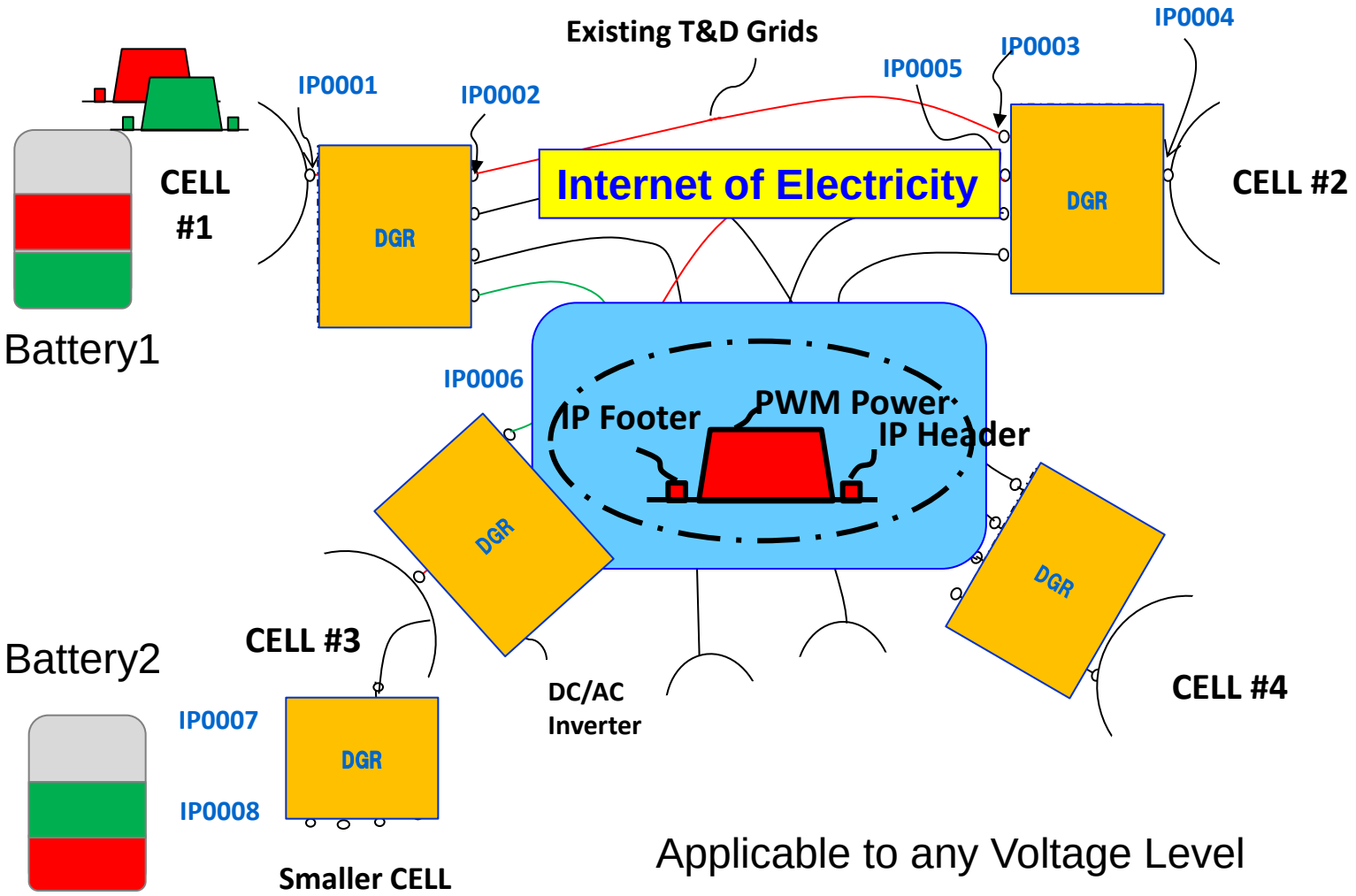
- DGR can control electrical voltage & frequency via digital processing.
- DGR can send discrete power packets over existing transmission lines to any location by using IP Address.
- Each energy transaction can be recorded along with additional properties, such as, location, time, generation source, price, CO_2 credit, etc.



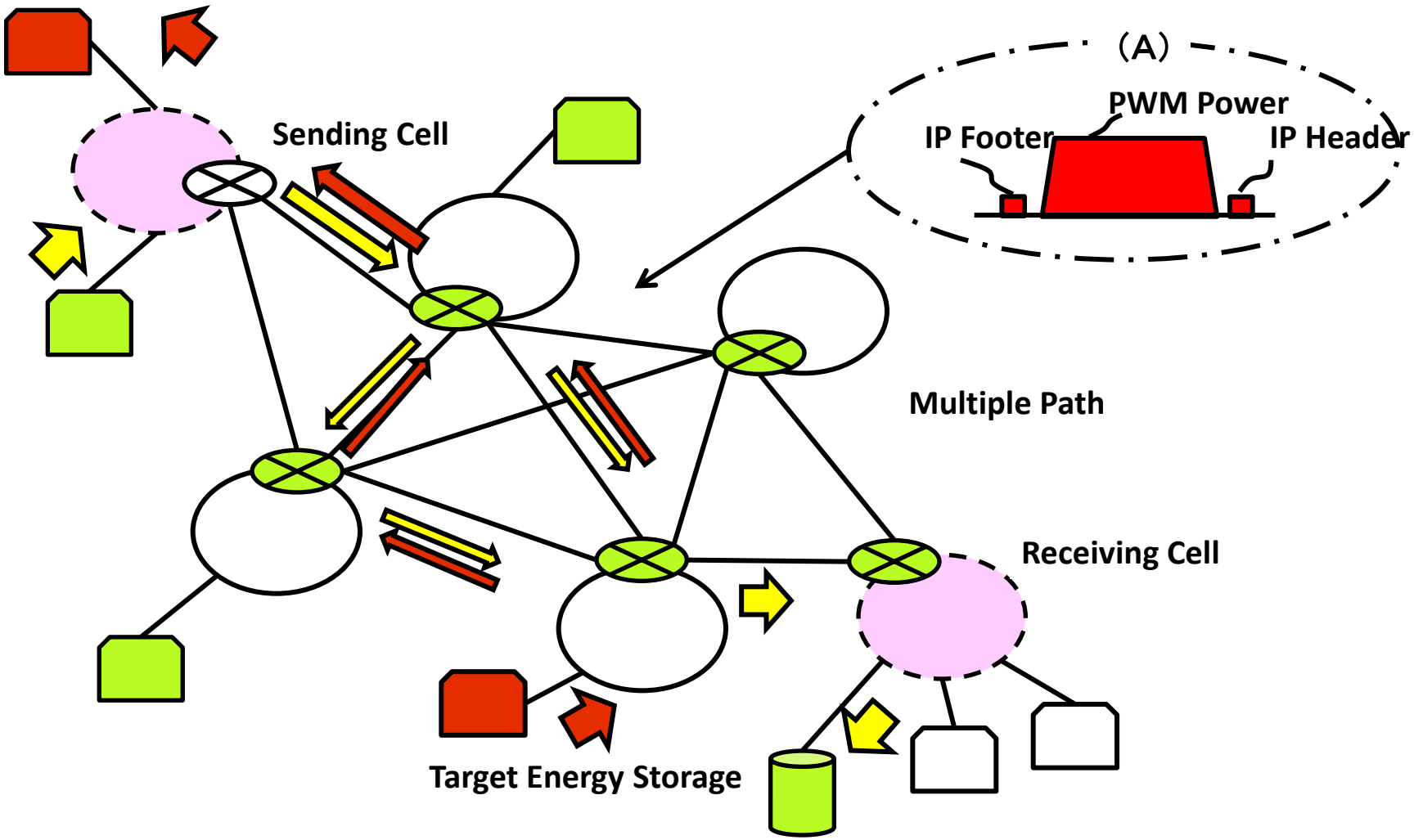
Smooth switching of the power without transient spike



Internet of Electricity



Power Flow Netting



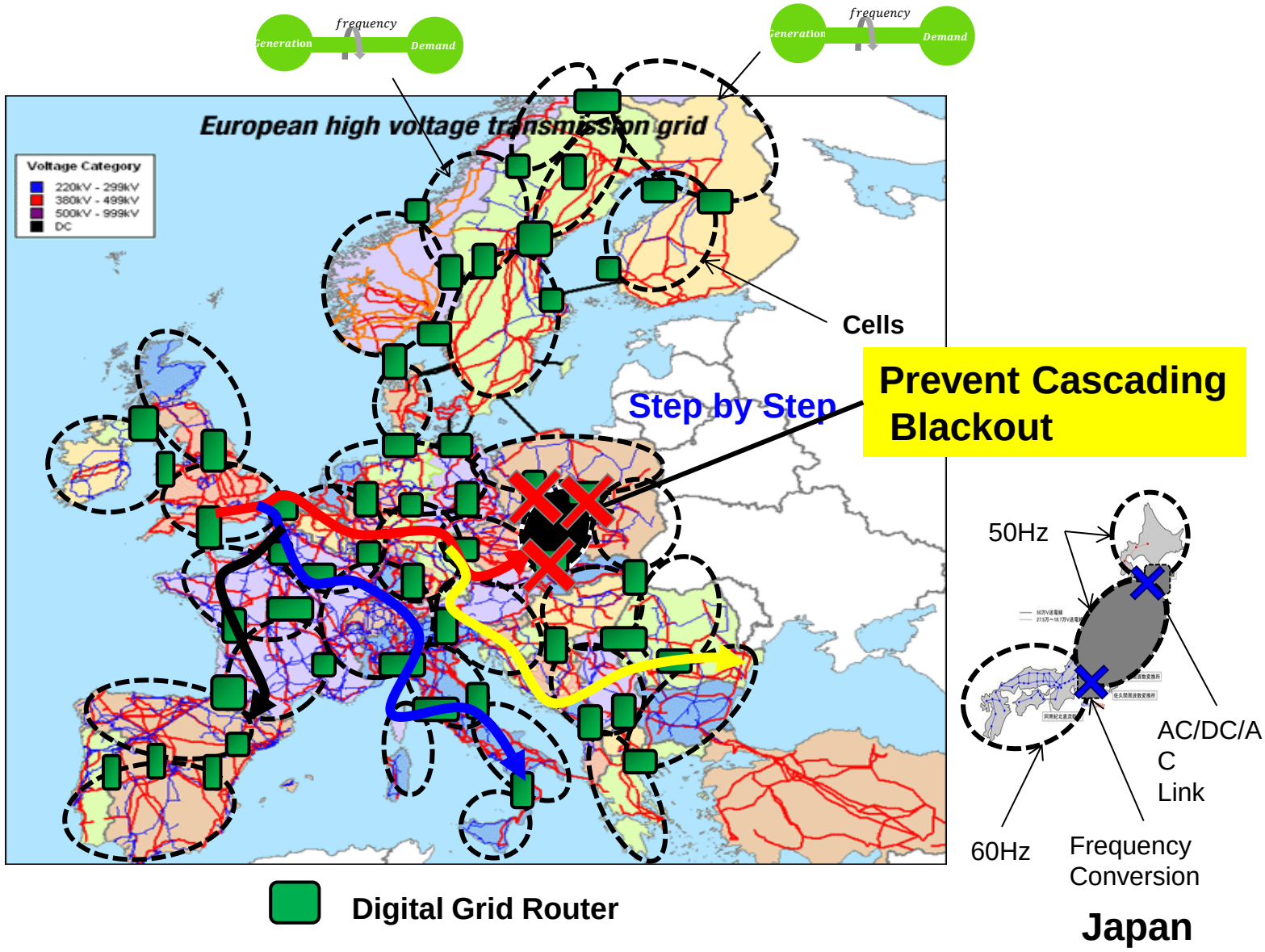
Identify every transaction without electrical constraints

- If it is possible to identify the source, storage and consumption of energy, it will encourage the development of new, innovative energy market.

Date	Start	Stop	From	Buy	To	Sell	Balance
12, May,' 99	02:15:40	08:17:20	Grid A9806	2890kWh			10299kWh
14,May,' 99	03:07:10	08:55:56			Grid W962	7600kWh	3699kWh
17,May,' 99	18:40:12	23:40:12	Grid B547	3455kWh			7054kWh
20,May,' 99	10:20:32	16:35:44	Int. PV003	456kWh			7510kWh

- Electricity Transaction will be recorded in Digital Grid Router as bank book
- Authorized organization to certify those record
- Many features will be add such as CO_2 credit, RPS value, Green value, etc.

Proposed Digital Grid in Europe



Proposal

- In order to accelerate digital grid solution, we propose to establish an **INTERNATIONAL ORGANIZATION** in Europe to realize;
  - From Analog to **Digital Grid world** that can absorb huge amount of variable, intermittent renewable energy without electrical constraints.
  - A **free market mechanism** with digitalized autonomous trading system can accelerate a big ban in power supply industry, which has happened in ICT industry.
  - The developing world that may skip conventional grid infrastructure which requires unstable fuel supply and **can directly jump into the grid of smaller scale grids with renewable resources everywhere.**

Thank you for your attention!

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This presentation was prepared by:

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As the speed and scale of intermittent renewable generation increases, we will find two major problems in the conventional grid system:

2. Business model problem

- Conventional Utility Business is based on long time investment recovery model with **monopoly economy.**
- As the shift to decentralized renewable energy, many competing suppliers and purchasers will join and prefer the **free market mechanism.**

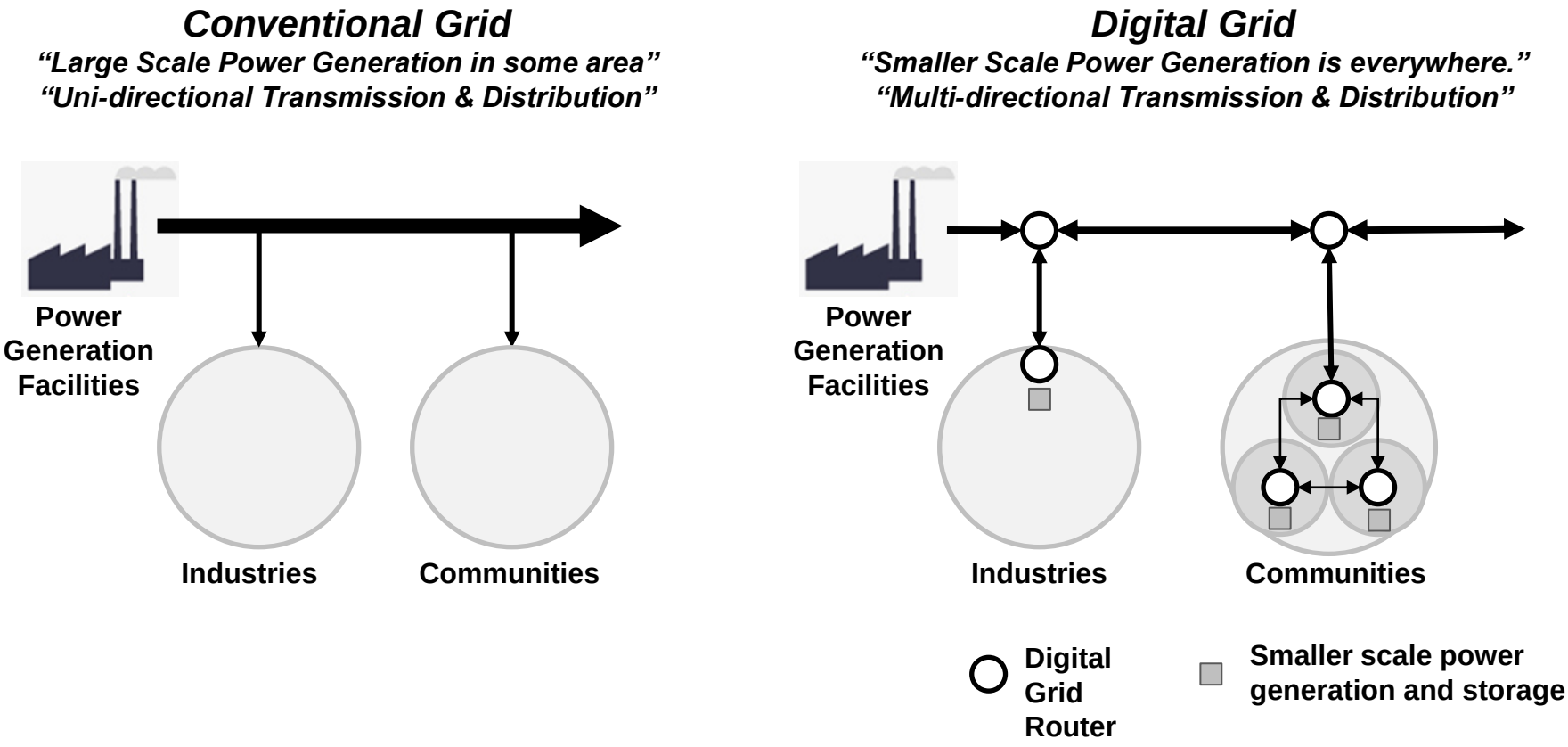
- The exponential growth of renewable energies during the last decade, they have become an ideal component in the energy mix to provide more energy security and fight climate change.

- Increasing renewable energy in the electricity mix poses to create a flexible grid that can transport electricity over vast variability and intermittency of electricity production.

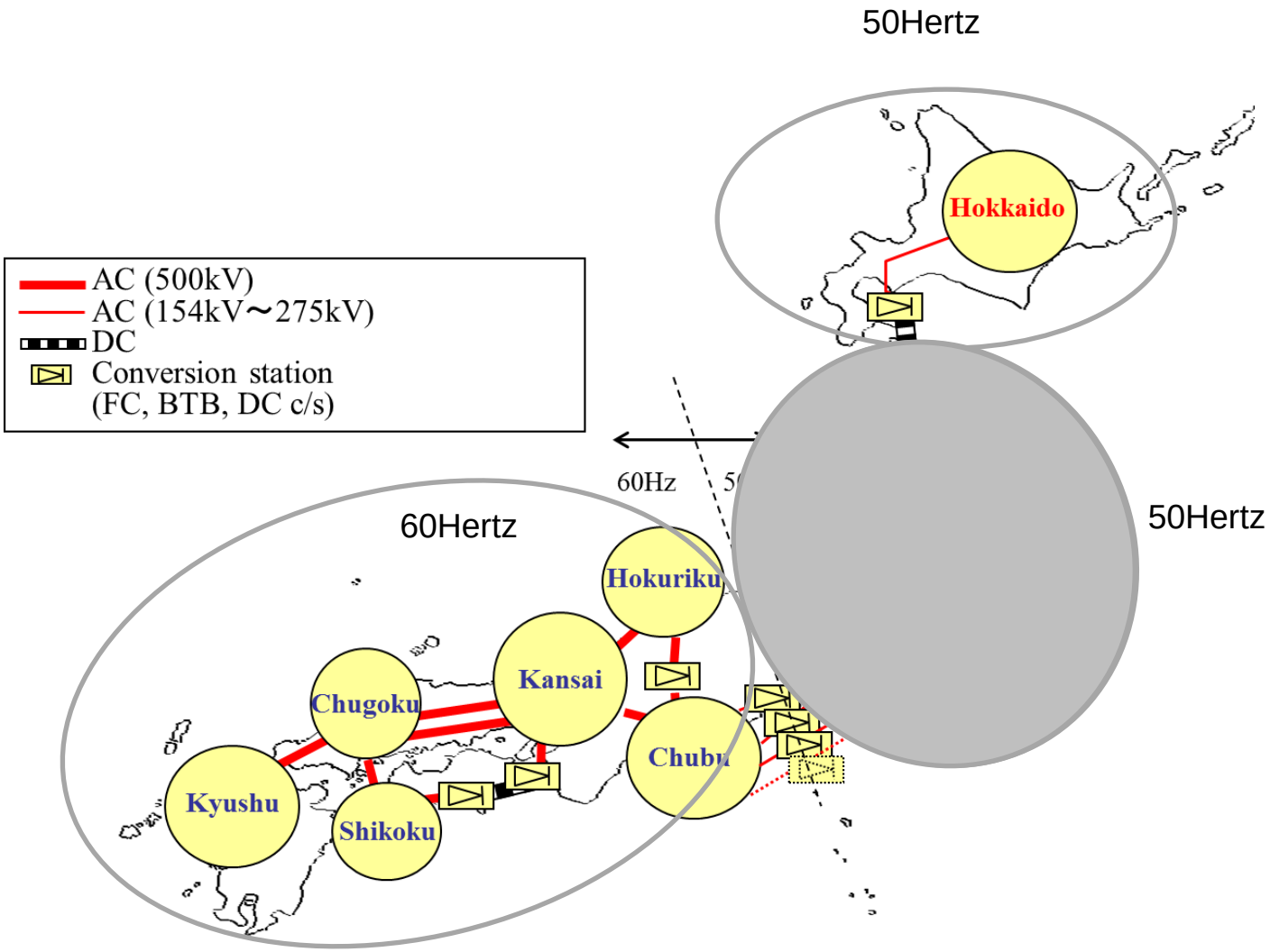
- Various smart grid technologies enable a more efficient flow of electricity. In addition, larger grid networks are under development, such as the North Seas Countries' Offshore Grid Initiative in Europe.

A new power infrastructure paradigm

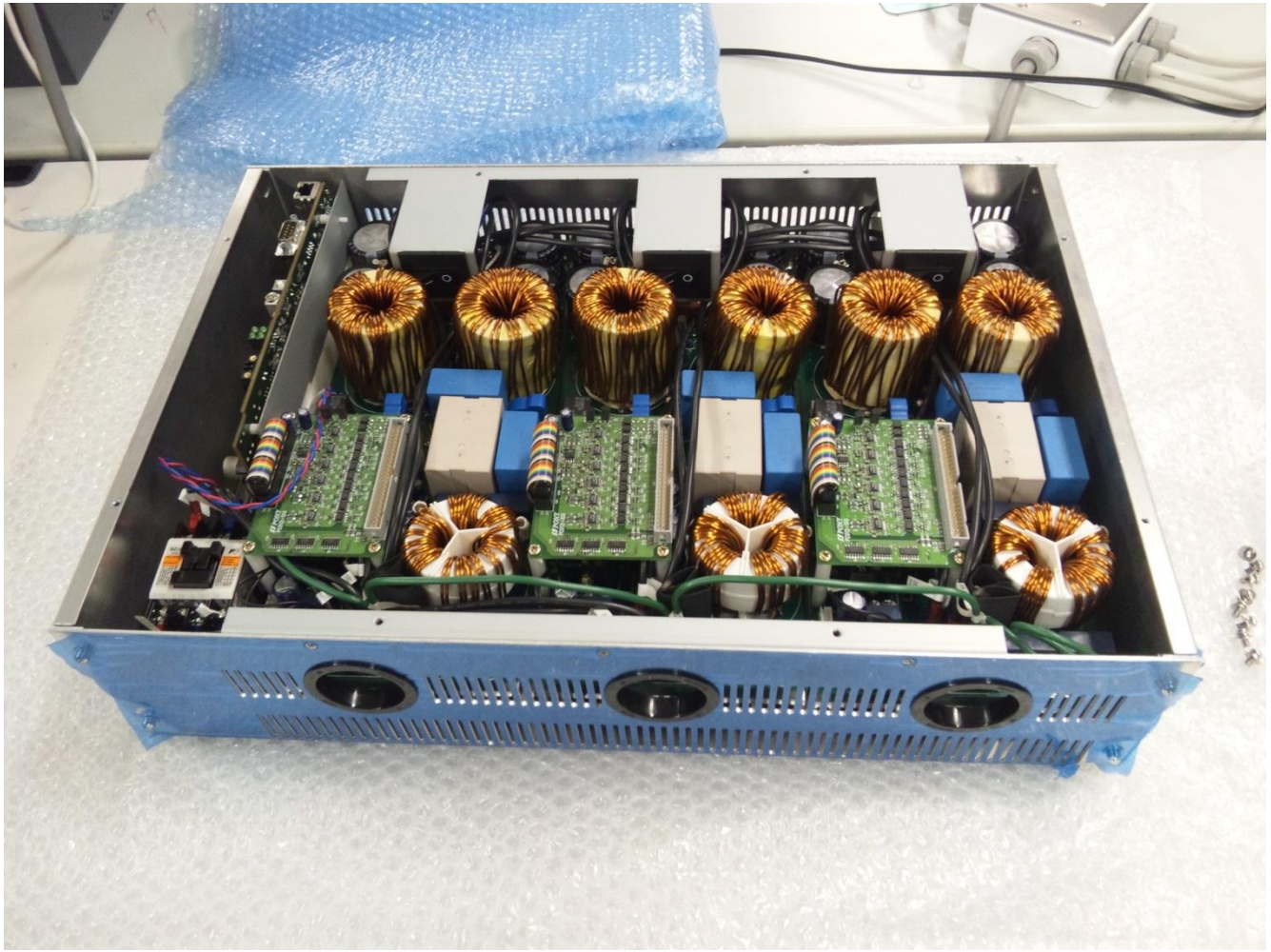
By using asynchronous connections and addressable power devices, **Digital Grid** realize "grid of segmented grids and multi-directional transmission & distribution".



Technical Problem:
Example) Japan's 3.11 Earthquake

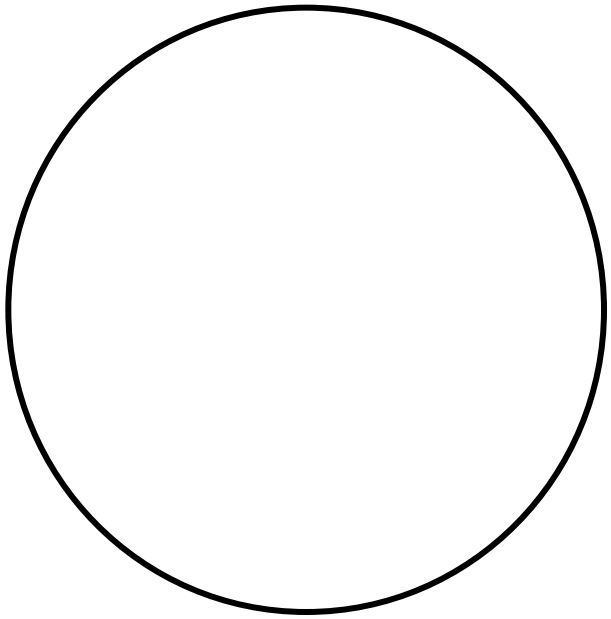


3-Leg Router(Mark I)：2kWx3



Concept of Digital Grid

Large synchronous grid
(all the generators and motors are synchronized to the grid frequency)

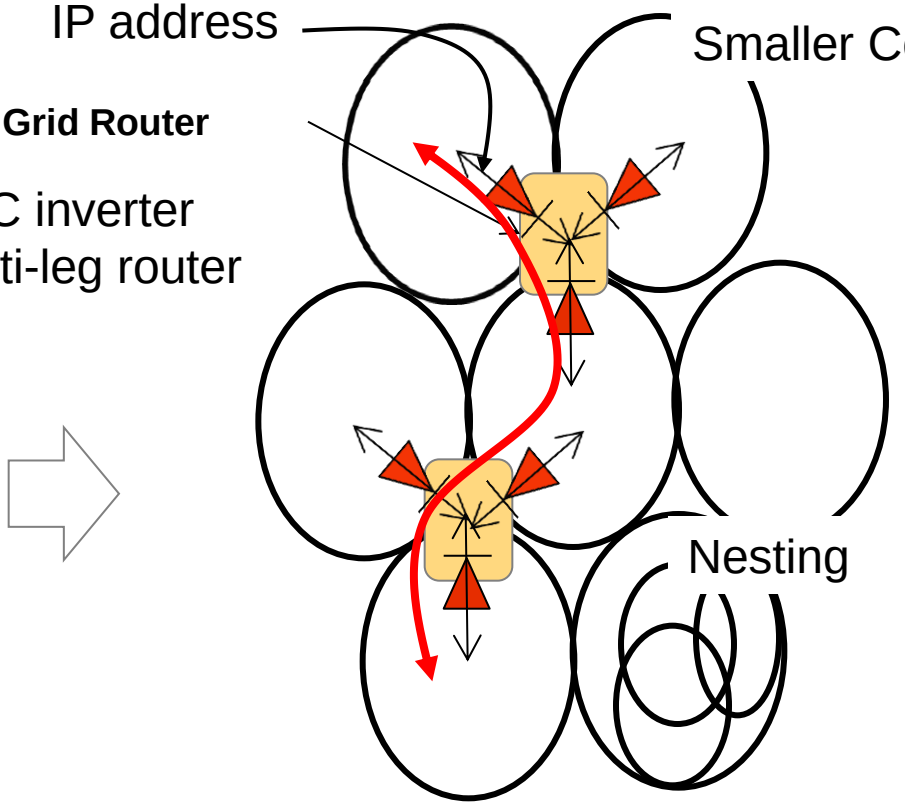


Smaller standalone Cell Grids
(with asynchrous connection)

IP address

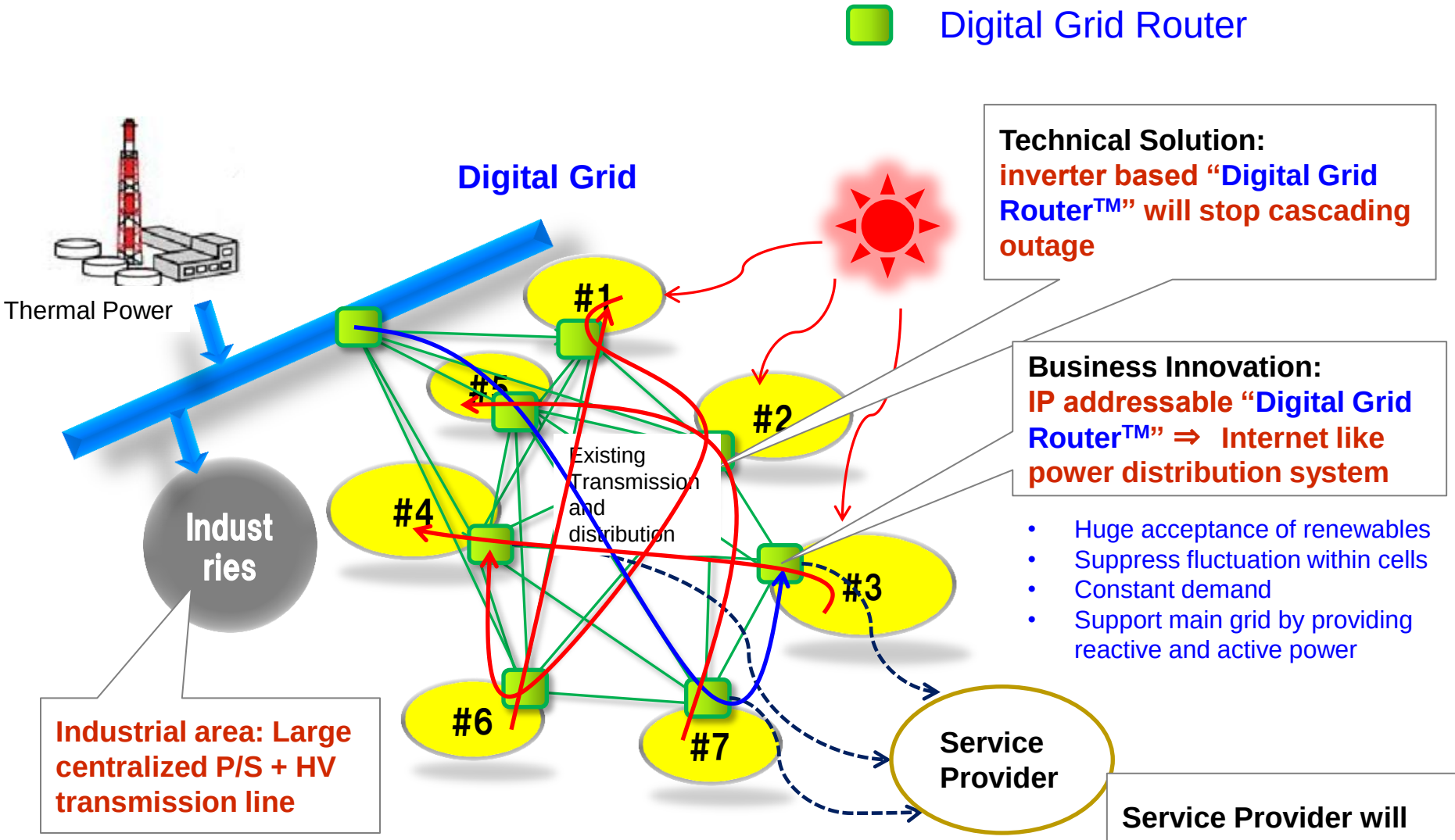
Digital Grid Router

-VSC inverter
-Multi-leg router



Cell Size; State, City, Town, Village, Factory, Building, House, etc.

Digital Grid Solution



Technical Solution:
inverter based "Digital Grid Router™" will stop cascading outage

Business Innovation:
IP addressable "Digital Grid Router™" ⇒ Internet like power distribution system

- Huge acceptance of renewables
- Suppress fluctuation within cells
- Constant demand
- Support main grid by providing reactive and active power

Industrial area: Large centralized P/S + HV transmission line

Service Provider will act as a certified bank

Potential

- With distributed control of energy, it becomes possible to identify the source of energy and will encourage the development of new, innovative energy services.

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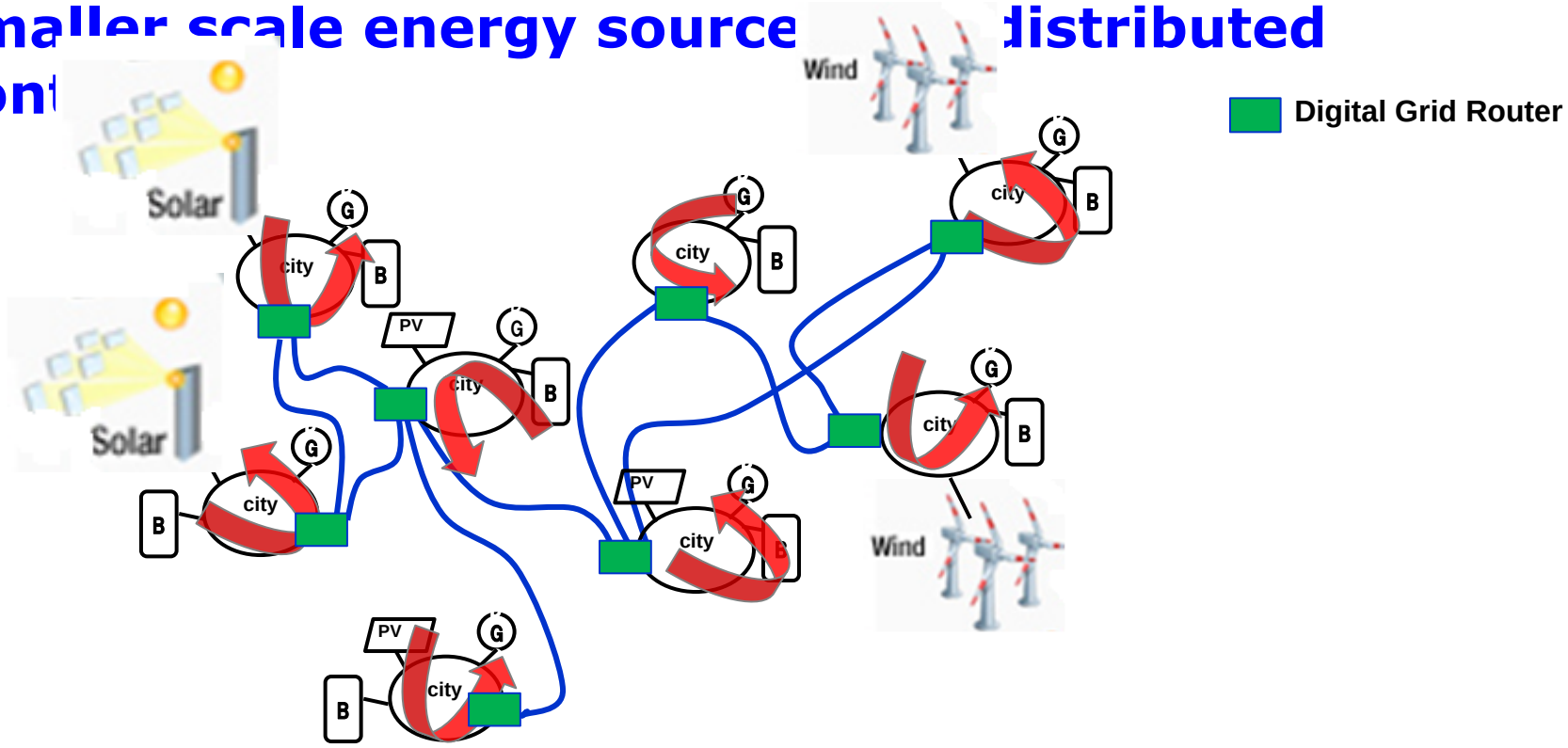
Developing countries may choose different path

- Just as developing countries have skipped the use of fixed line phones and have jumped directly to cell phones, it will be possible for the developing world to skip the stage of centralized, one way power generation with large investments in infrastructure and **jump directly to smaller scale energy source distributed cont**



Who we are

- The Digital Grid Consortium (DGC), founded in 2011, is a not-for-profit corporation based in Tokyo, Japan. Its mission is to develop the next generation grid system.
- DGC is operated by member companies in collaboration with Presidential Endowed Chair for "Electric Power Network Innovation by Digital Grid" in the University of Tokyo.

The Digital Grid Consortium

Member Companies:

NEC
HITACHI
ORIX
SEKISUI
KEL
KANEMATSU ELECTRONICS LTD.
NATIONAL INSTRUMENTS

Partners

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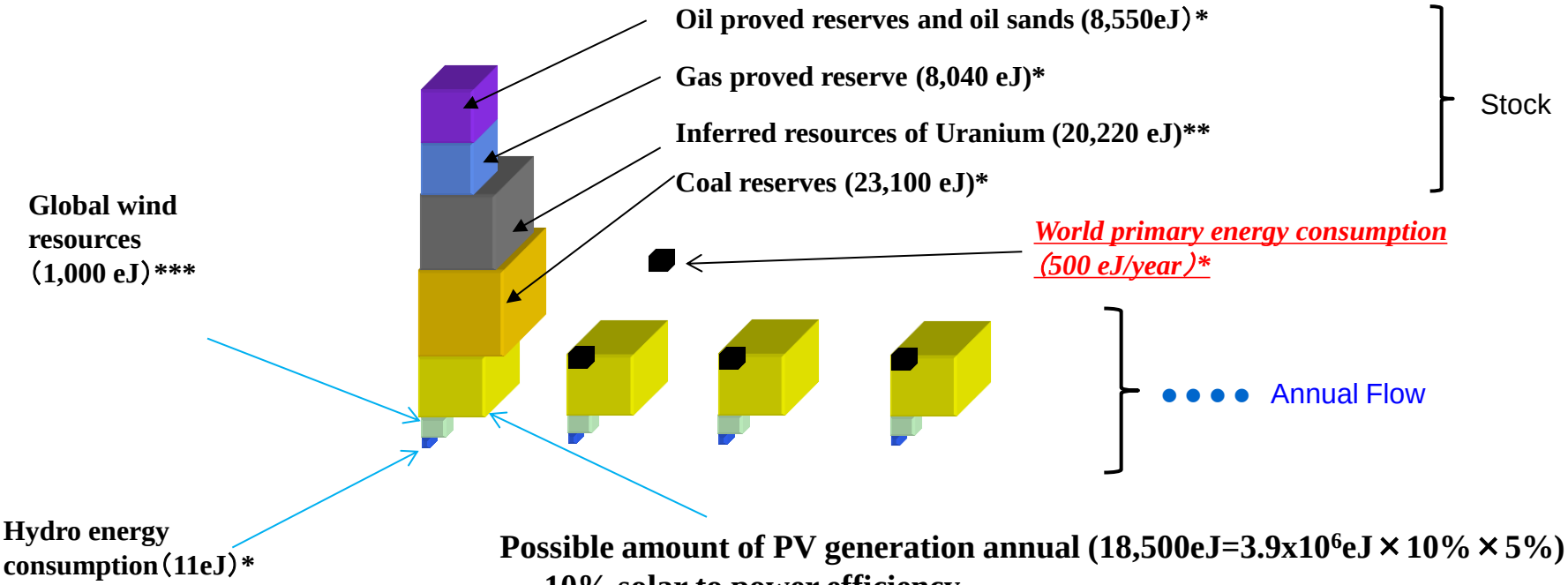
FREEDM systems center

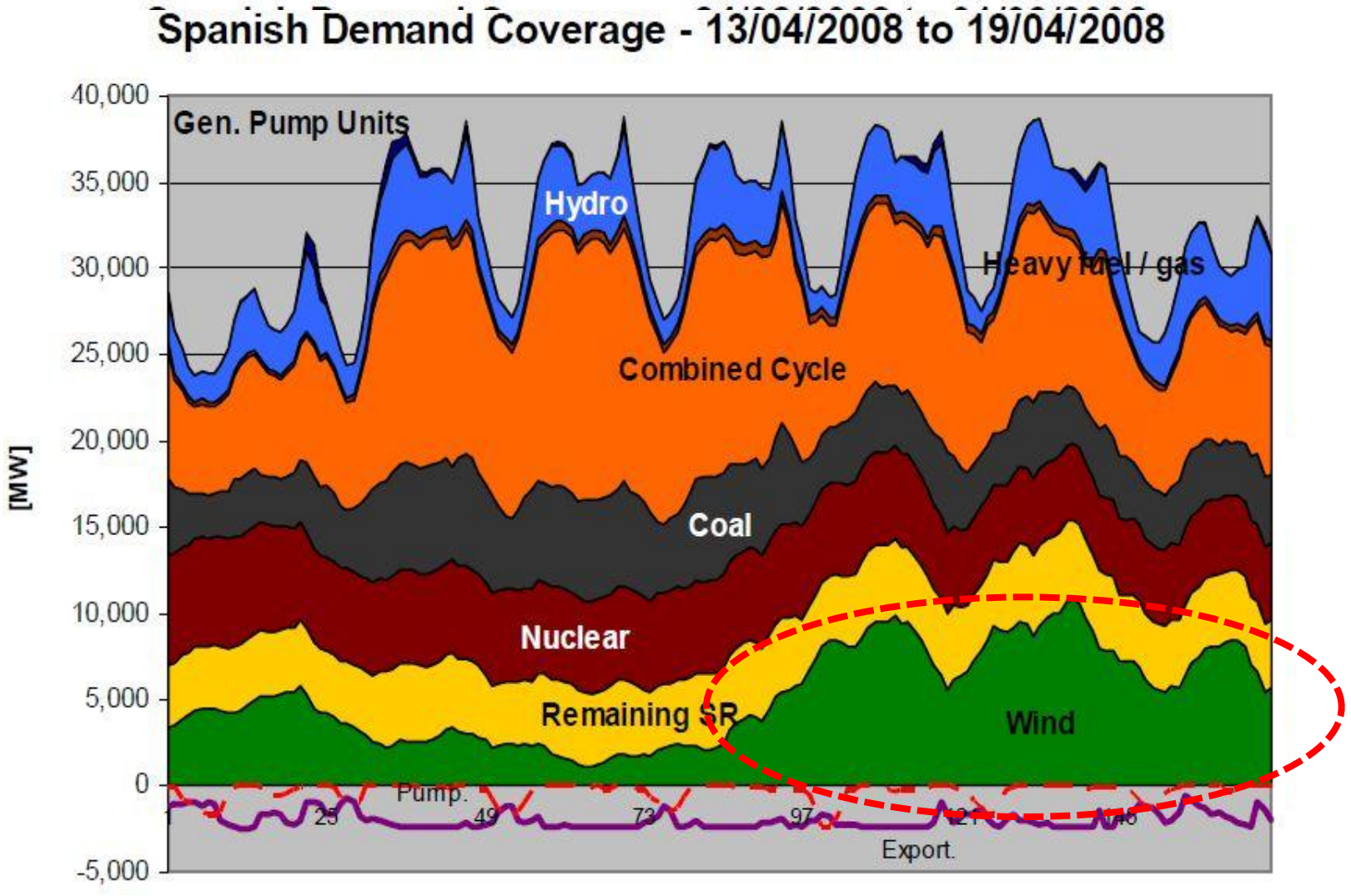
Solar potential is huge and sustainable



Possible amount of PV generation annual (18,500eJ=3.9x10^{6}eJ×10%×5%)
-10% solar to power efficiency
-5% of land area

* : BP world energy 2009
** : OECD nuclear energy data 2008
*** : World energy council survey of energy resources 2007
eJ : exajoule (10^18 J)

Difficult to use in conventional power grid



Paradigm Shift is required

A new flexible power grid infrastructure

Flexible Sized, Flexibly Connected, Flexibly Powered

FROM: Very Large, Rigidly Connected, One Grid