# EV Installation Design for Okinawa Green Island Project

Kenji Tanaka

The University of Tokyo, JAPAN

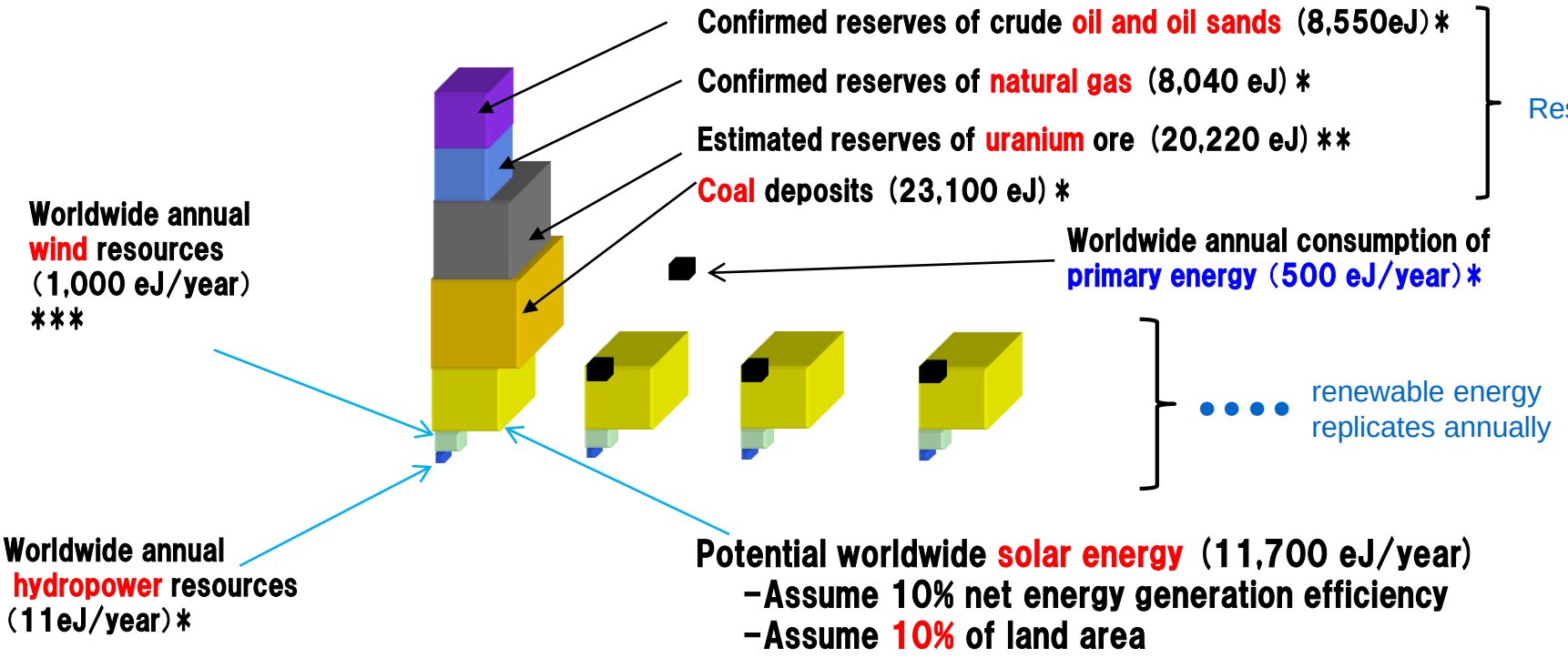
- Okinawa Project

- Power Grid Digitalization !

# Renewable Energy is Abundant and Sufficient in Scale for 100% of Needs

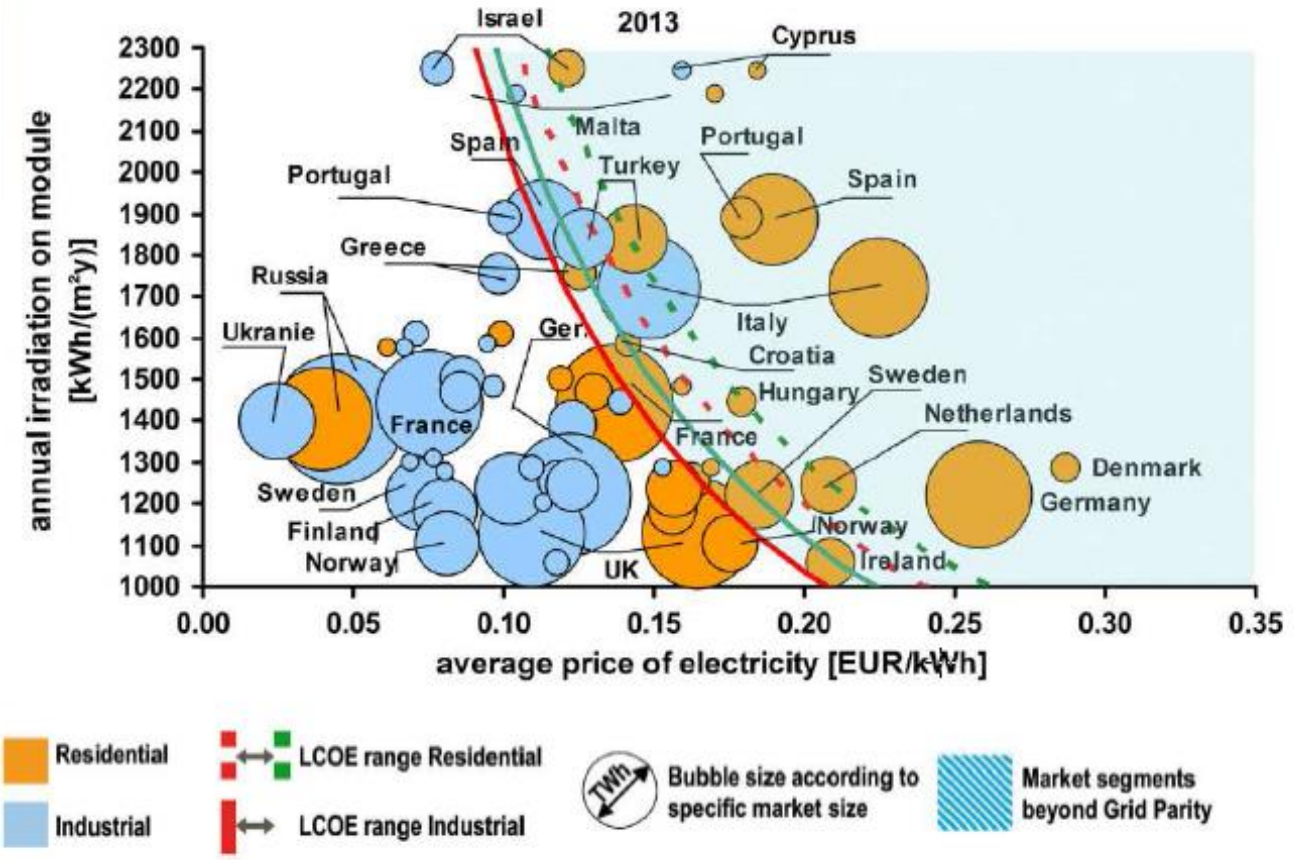
digital grid

- **Solar Energy is Abundant when Compared to Energy Reserves**




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

# “SOLAR PV reached the Grid Parity” by Dr. Pavan at ICCEP 2013




Breyer C, Gerlach A. **Global overview on grid parity**
Progress in photovoltaic: research and applications 2012. John Wiley & Sons, Ltd. DOI 10.1002/pip.1254



Source: Dr. Alessandro Massi IEEE ICCEP 2013, Algero

Breyer C, Gertach A, Global overview on grid parity, progress in photovoltaic, research and applications 2012

# THE ENERGY ISSUE


危机

The Stone Age didn't end because we ran out of stone…

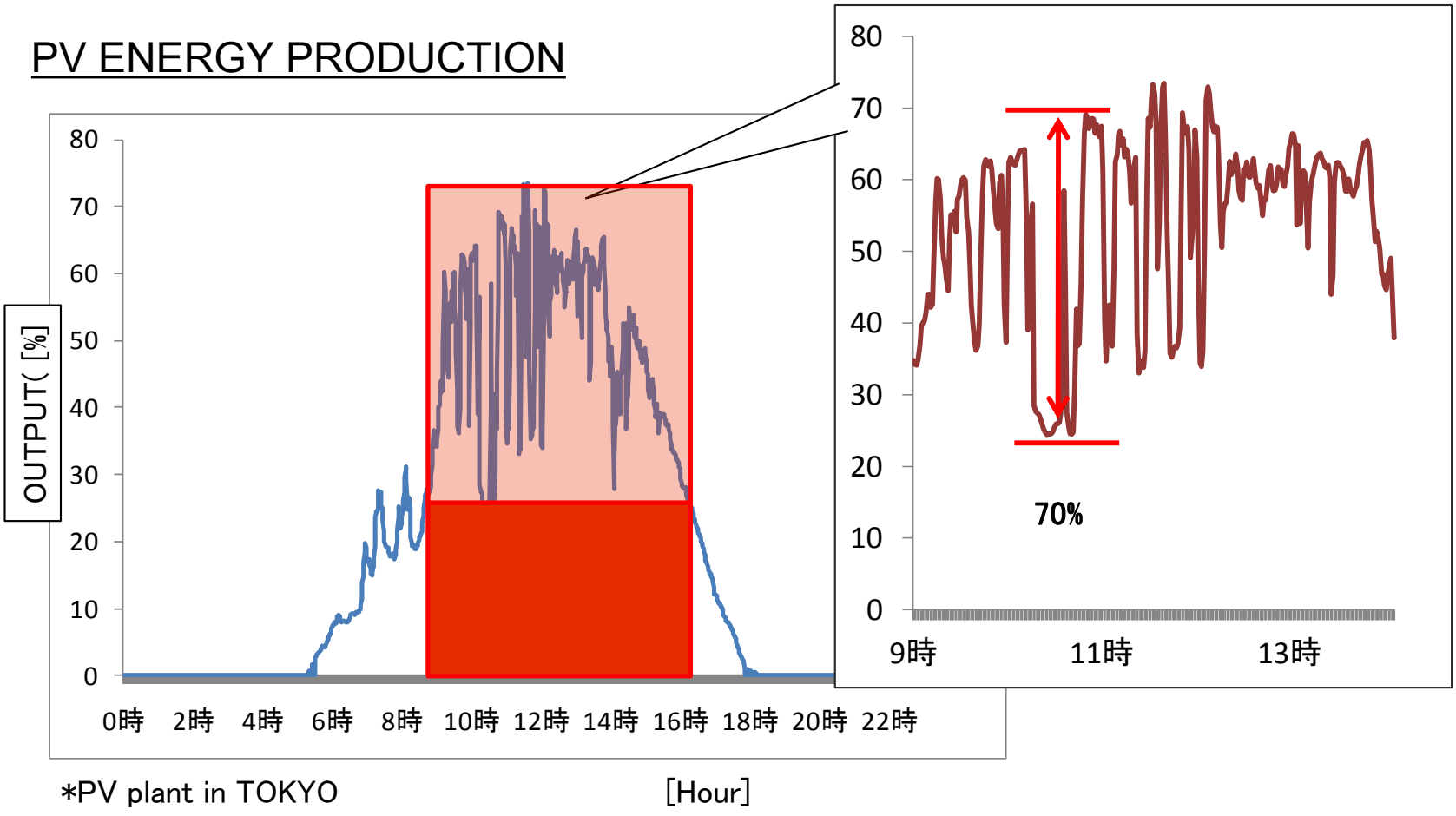
The Oil Age won't end because we run out of oil!

*Don Huberts, Shell Hydrogen*

IEEE ICCEP, Alghero (Italy), June 12th 2013
ALESSANDRO MASSI PAVAN

Source: Dr. Alessandro Massi IEEE ICCEP, Algero

# Renewable Energy is not Reliable Enough




*PV plant in TOKYO

# Power Storage to increase flexibility

## Power Flow

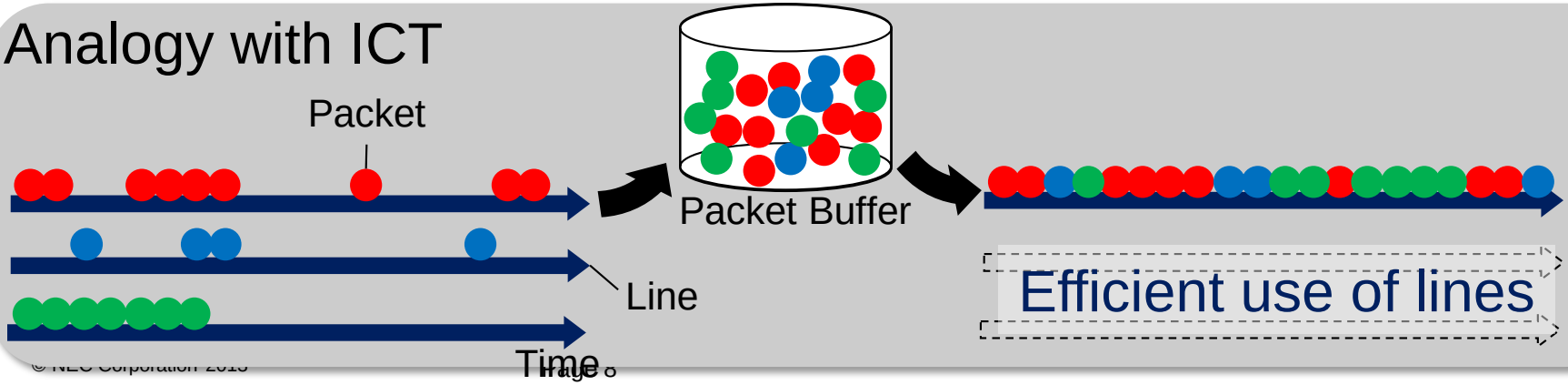
Uni-directional power flow from supply to demand sides

## Power Stock

Multi-directional power flow with flexibility (amount, timing)

Battery


## Analogy with ICT

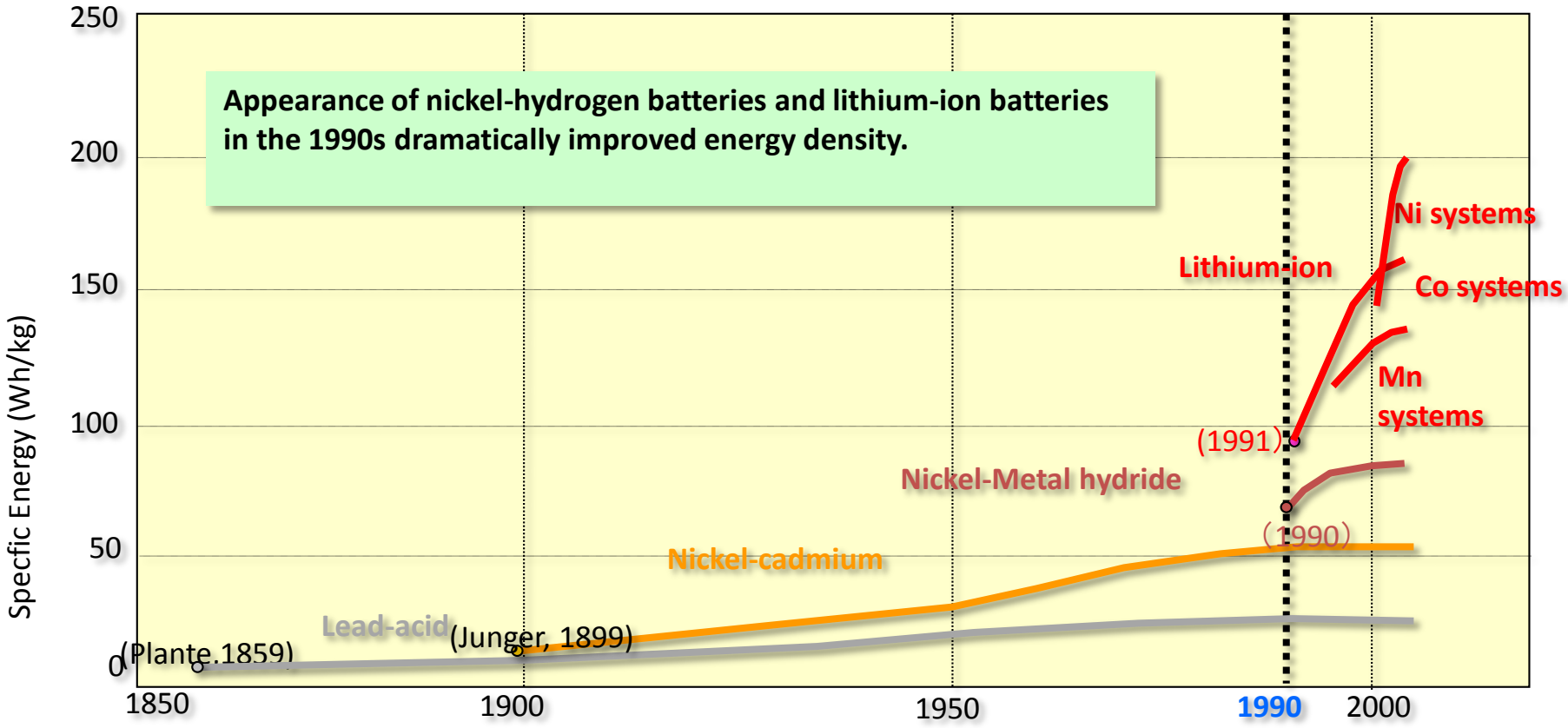






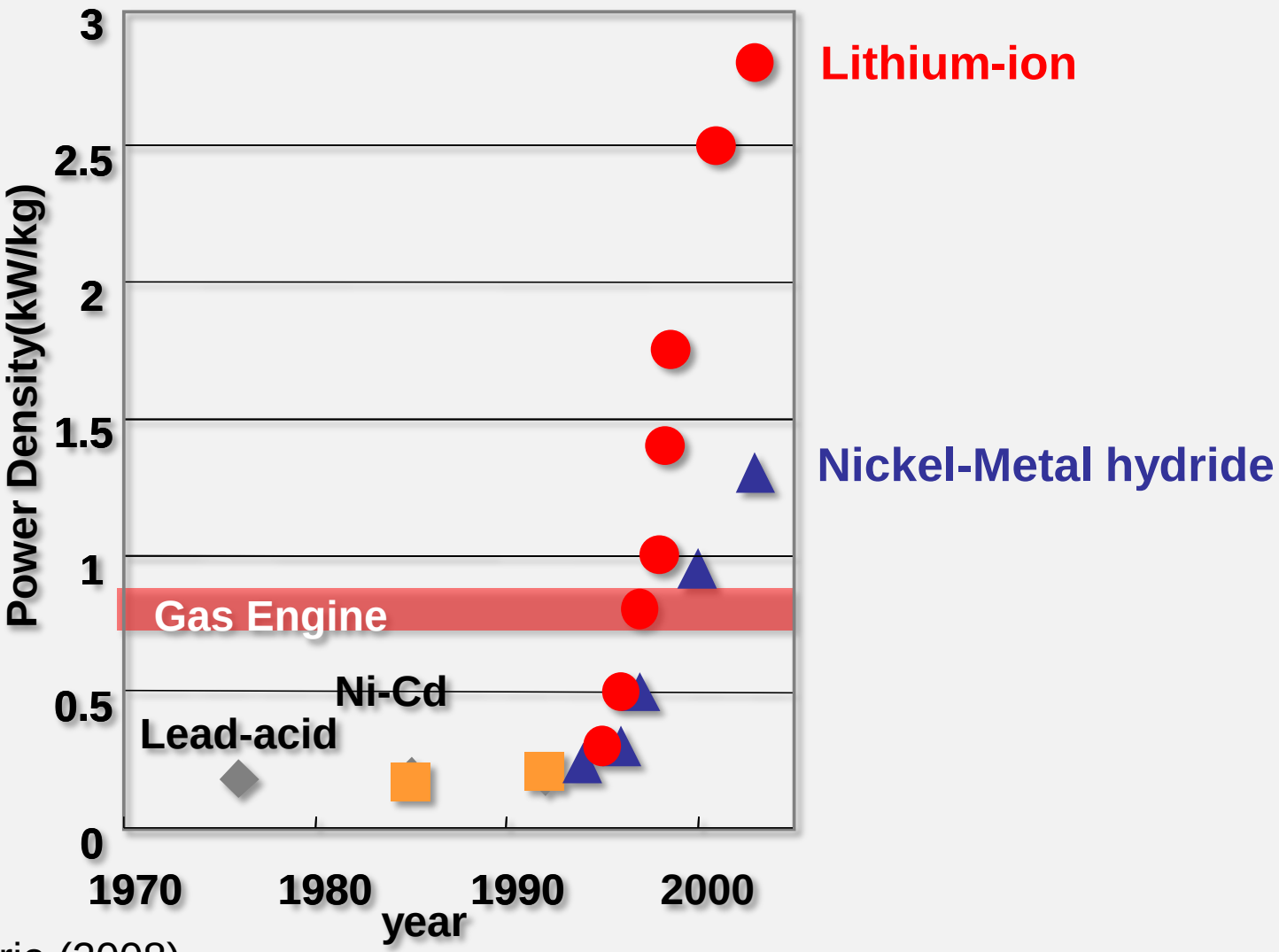

Source: NEC Dr.Emura et al, UTokyo Forum 2013

# Improvement of Battery technologies




Shimamura et al, WEVA journal vol.1 pp.251-257 (2007)

# EVs perform better than a gasoline engine in terms of the power output since 1990s




Source : H.Horie (2008)

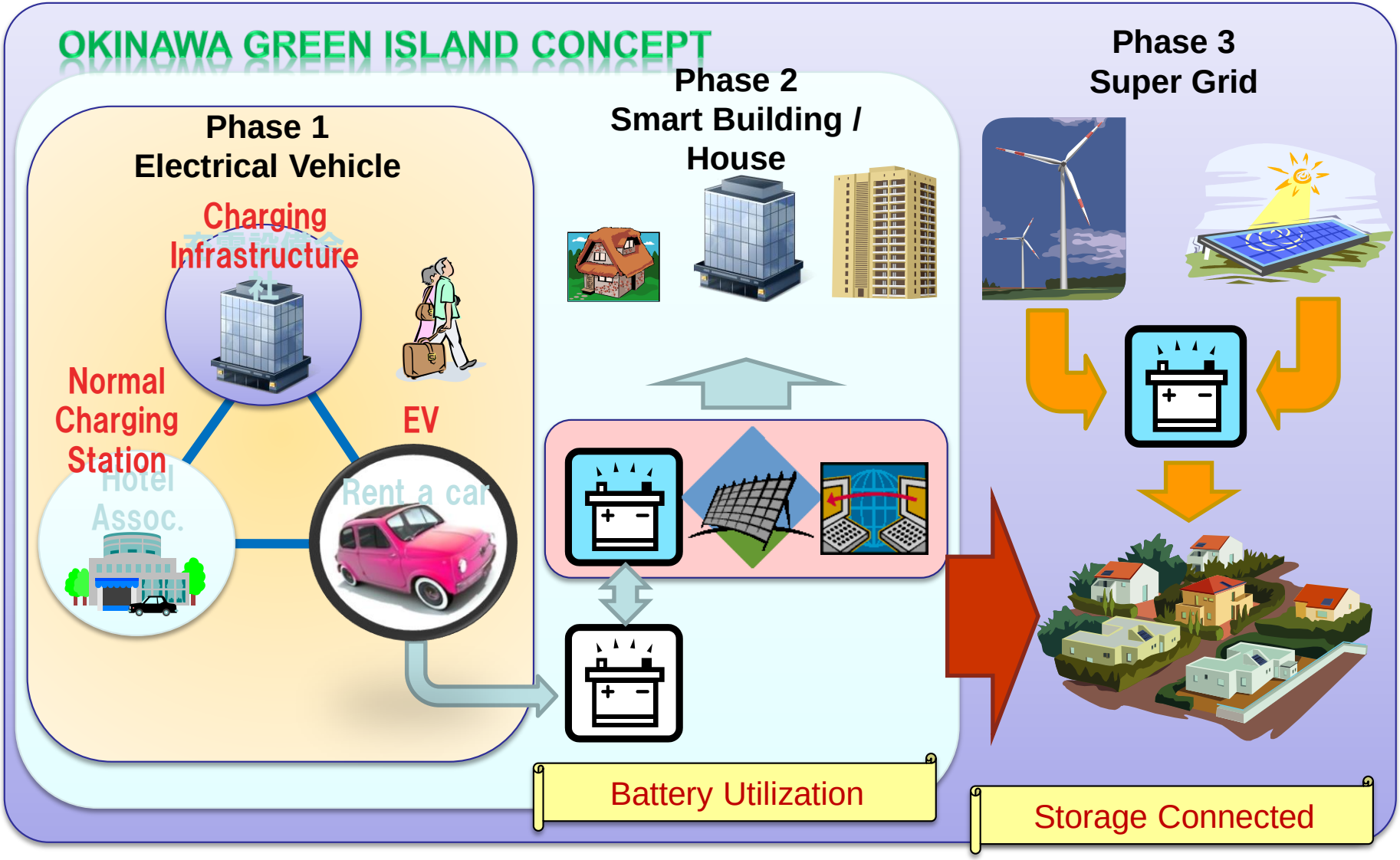
# Green Island Project
# EV Installation Design for Okinawa

# Okinawa Green Island Project

There are about 60 million tourists fascinated by its natural beauty. This project considered to strengthen the green image of Okinawa, and attract their tourist.
The green island project of Okinawa aim to build a sustainable and ecology friendly society with secondary batteries. The chamber of Commerce in Naha-city decided to promote it.
As a first stage of this project, the plan to introduce EVs as rental cars is organized.

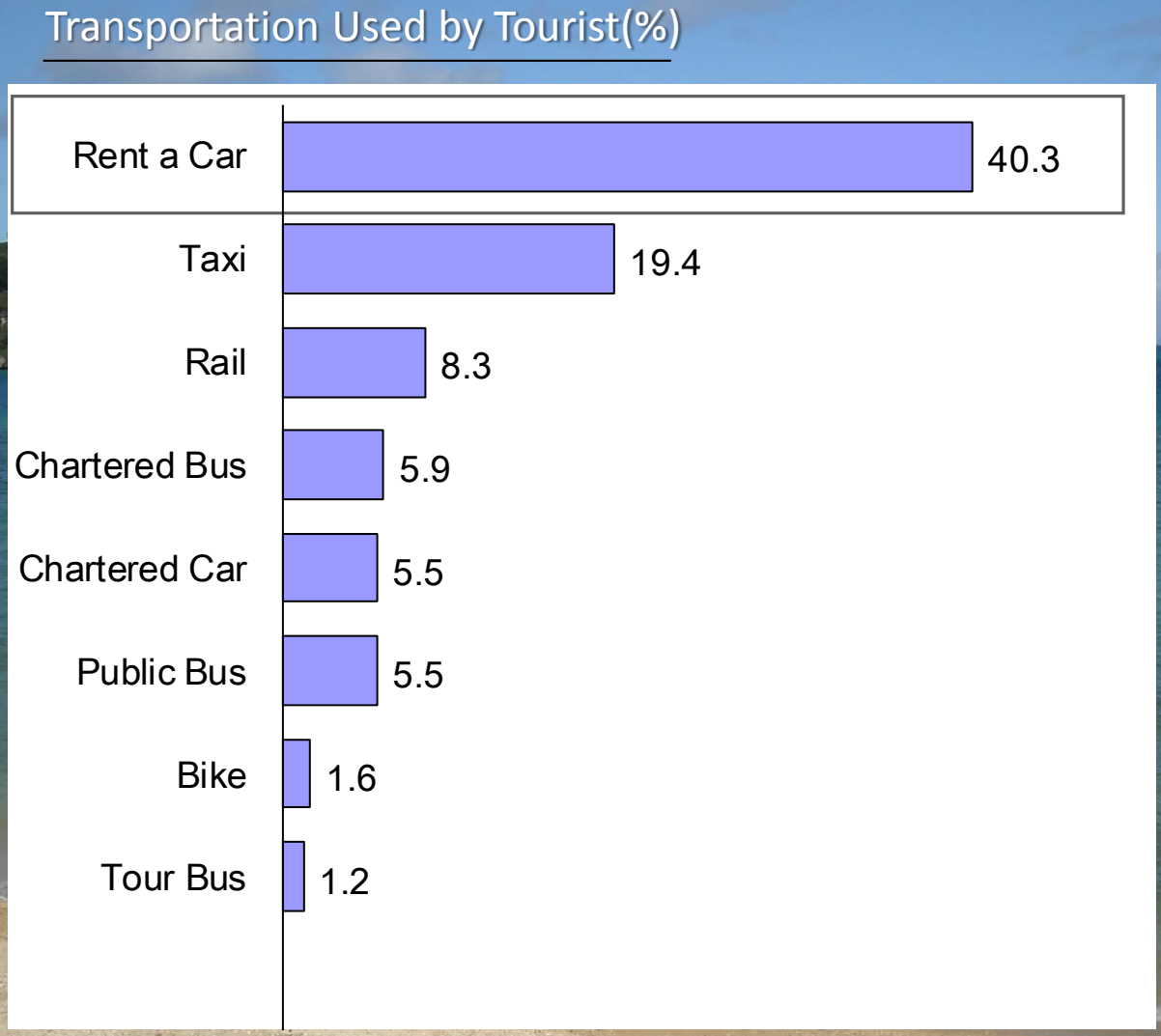

| | |
|---|---|
| 2009 Spring | EV car rental service concept Offering by Univ. of Tokyo |
| 2009 Autumn | The Chamber of Commerce in Naha-city decided to promote it |
| 2010 Spring | Establish EV infrastructure service company (AEC) |
| 2010 Autumn | Build the Charging Infrastructure by AEC |
| 2011 Spring | EV rental service started with 220 units of EVs |

# Okinawa Green Island Project




Source: Matsumoto AEC Company

# Many Visitors uses Rent a Car in Okinawa






Source : Okinawa Prefecture

## Charging station network in Okinawa is required

It is important to evaluate the specific electricity consumption of EVs based on traffic conditions in Okinawa

# To obtain the traffic conditions in Okinawa, The drive test is conducted

## Traffic Conditions in Okinawa (Drive test in 2009)

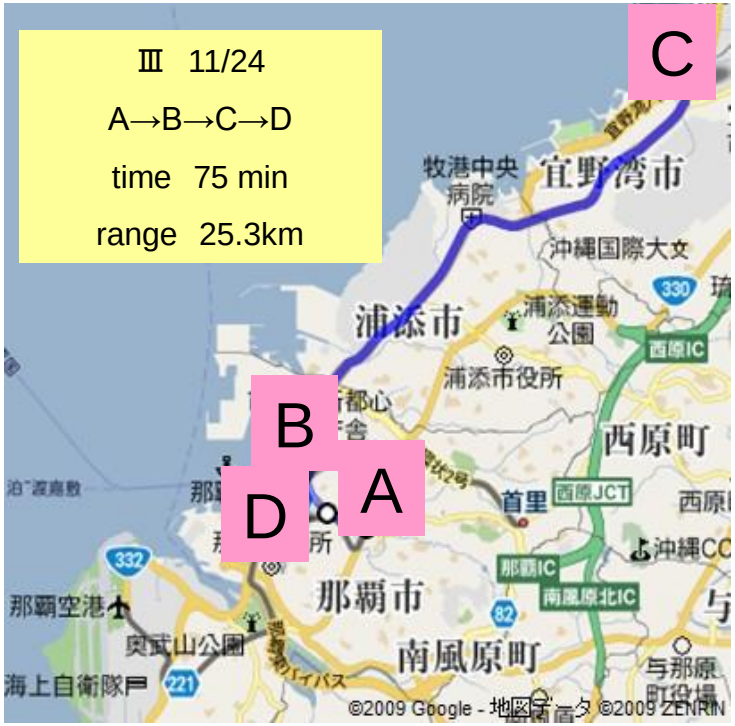
City

Highway

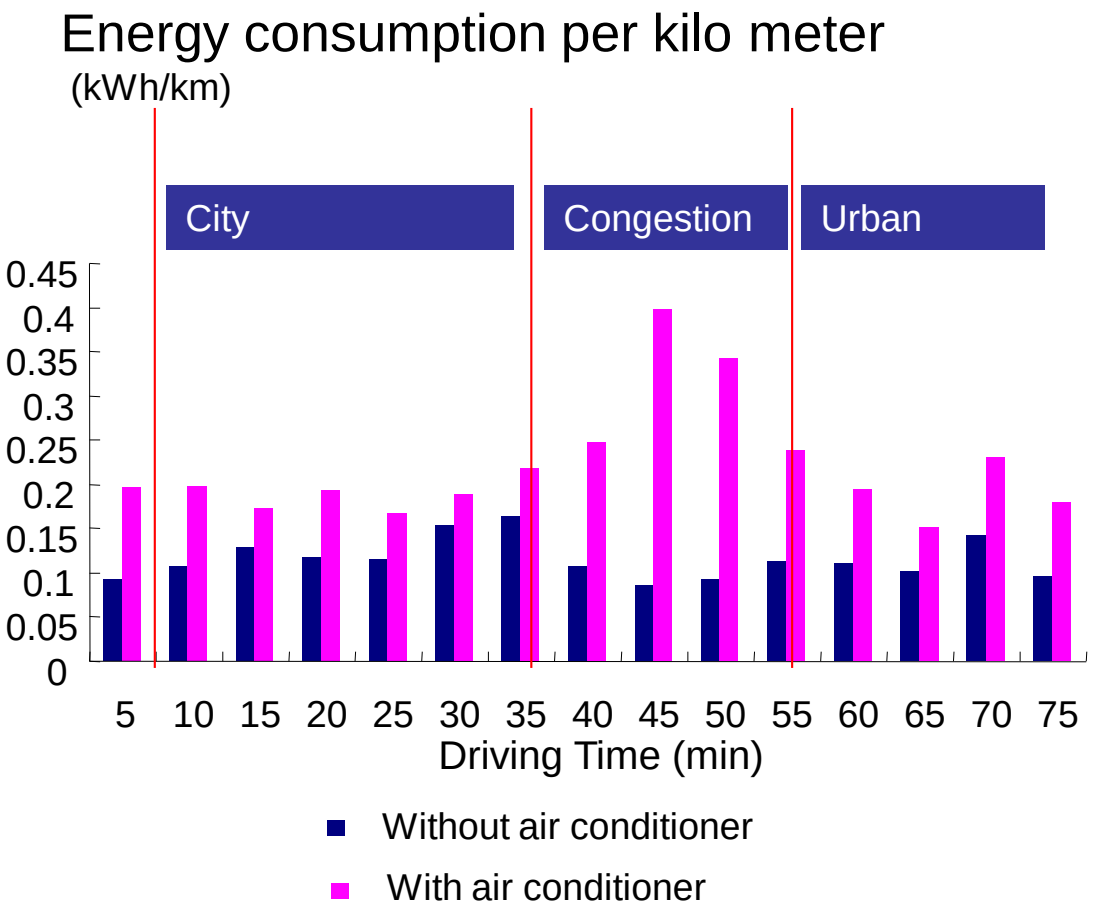
Country

Congestion

# Example of Drive Test




Route Ⅲ



# Modeling the energy consumption of EV: Drive Power

Output Drive Power of EV can be obtained by the equation (1)
The integral of time-series *P* is the energy consumption of vehicles.

Drive Power [W]

$$P = \left(\frac{1}{\eta \cdot \varepsilon}\right) \cdot u \cdot F$$

$$= \left(\frac{1}{\eta \cdot \varepsilon}\right) \cdot u \cdot \left\{ g \cdot r_{Roll} \cdot M + \frac{1}{2} \rho \cdot C_d \cdot S \cdot u^2 + g \cdot M \cdot \sin\theta + a\left(1 + k_{Rotat}\right) \cdot M \right\} \quad (1)$$

Mechanical Friction factor

Rolling Friction Resistance

Air Friction Resistance

Gradient Resistance

Acceleration Resistance

Mechanical Loss

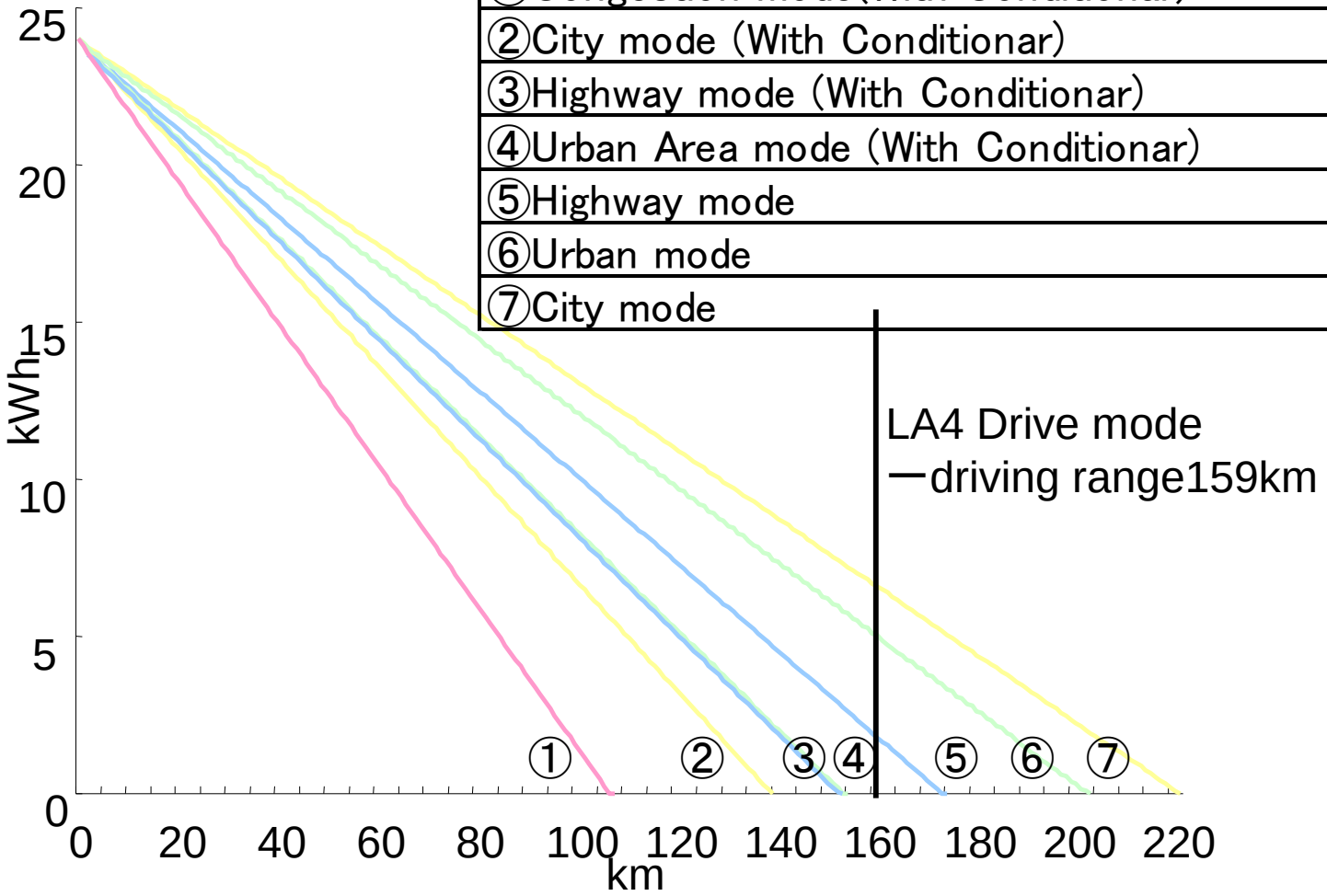
Friction Resistance Loss

Brake Loss .

# Drive range differ from 108km to 222km according to driving patterns

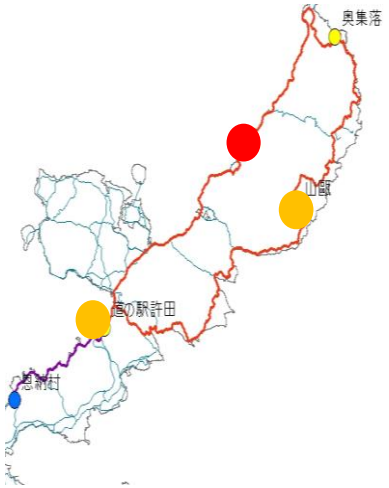
## Driving range of each driving pattern

| Drive Mode | Drive range |
|---|---|
| ①Congestion mode(With Conditionar) | 108km |
| ②City mode (With Conditionar) | 140km |
| ③Highway mode (With Conditionar) | 154km |
| ④Urban Area mode (With Conditionar) | 155km |
| ⑤Highway mode | 175km |
| ⑥Urban mode | 204km |
| ⑦City mode | 222km |



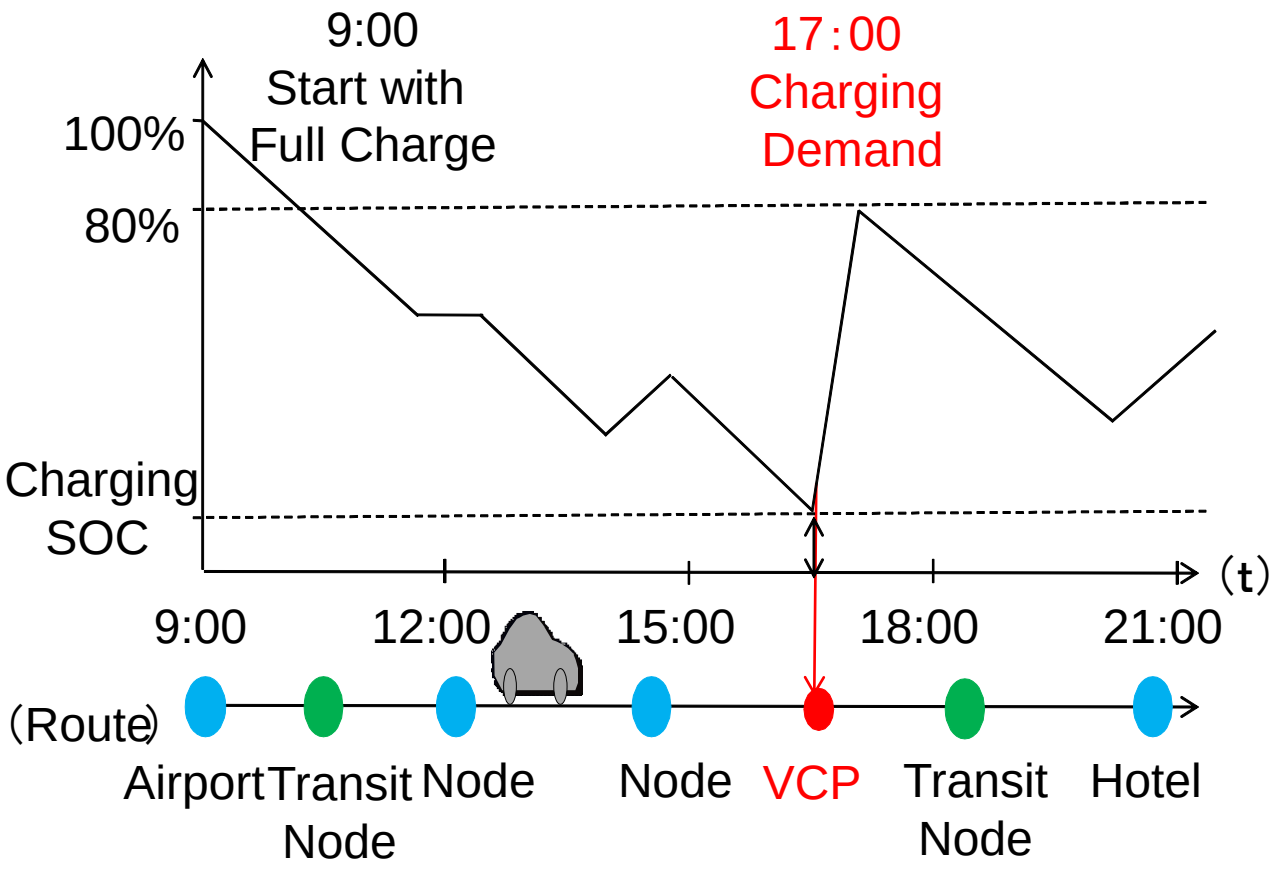
# Location Arrangement Planning based on driver's behavior simulation

Generate each one of EV tourist based on statistics



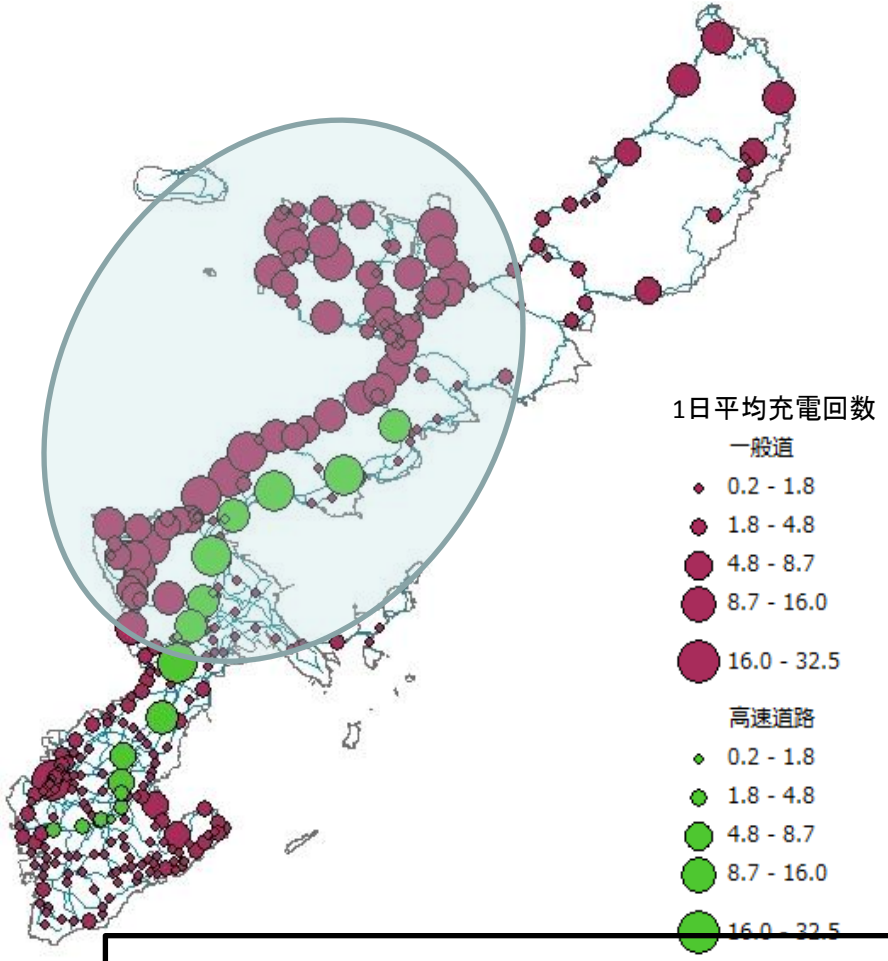

Monitoring batteries status of Charge (SOC)

**Driver's behavior simulation by time-marching steps**



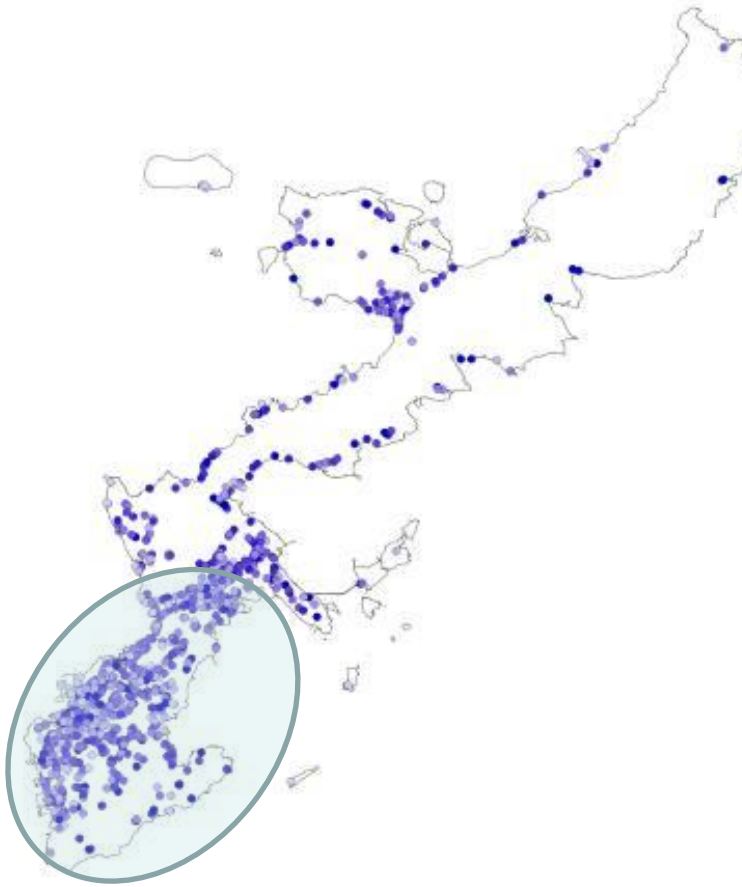
# The result of charging demand is different from the allocation of existing gas station.

## Result of charging demand




Average charging times per trip : 0.26

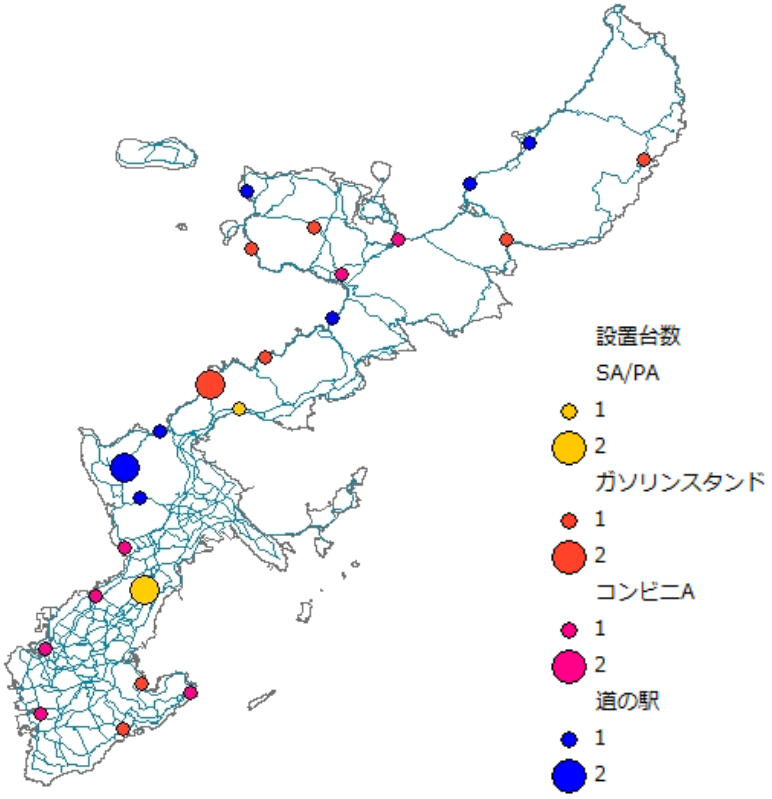
## Existing gas station



# Recommended arrangement plan

The demand distribution is aggregated to practical sites where the charging stations can be set , and the plan was adopted.

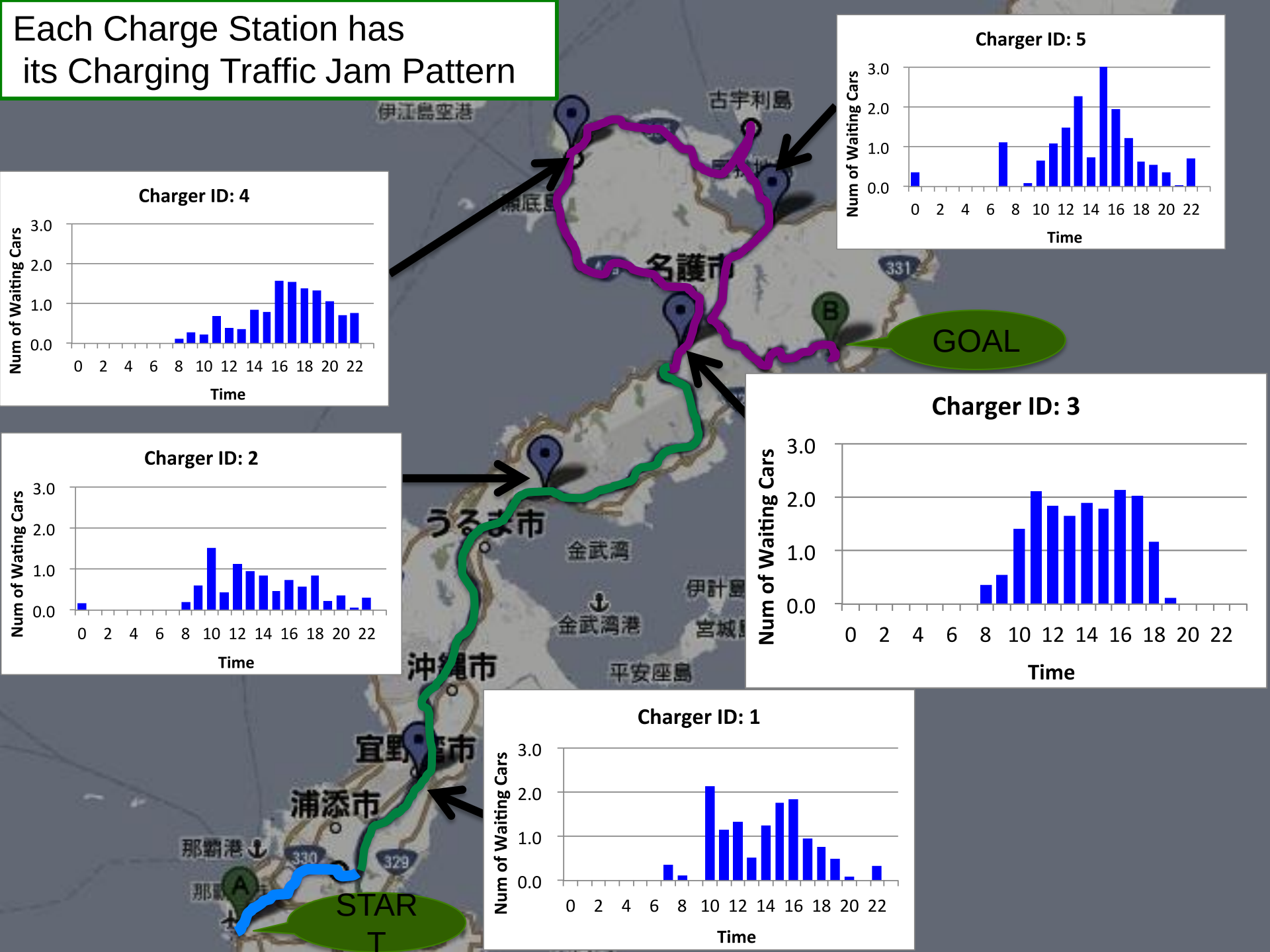
Recommended Arrangement Plan
27 units at 24 sites




Adopted Arrangement in 2011 Feb.
27 units at 18 sites

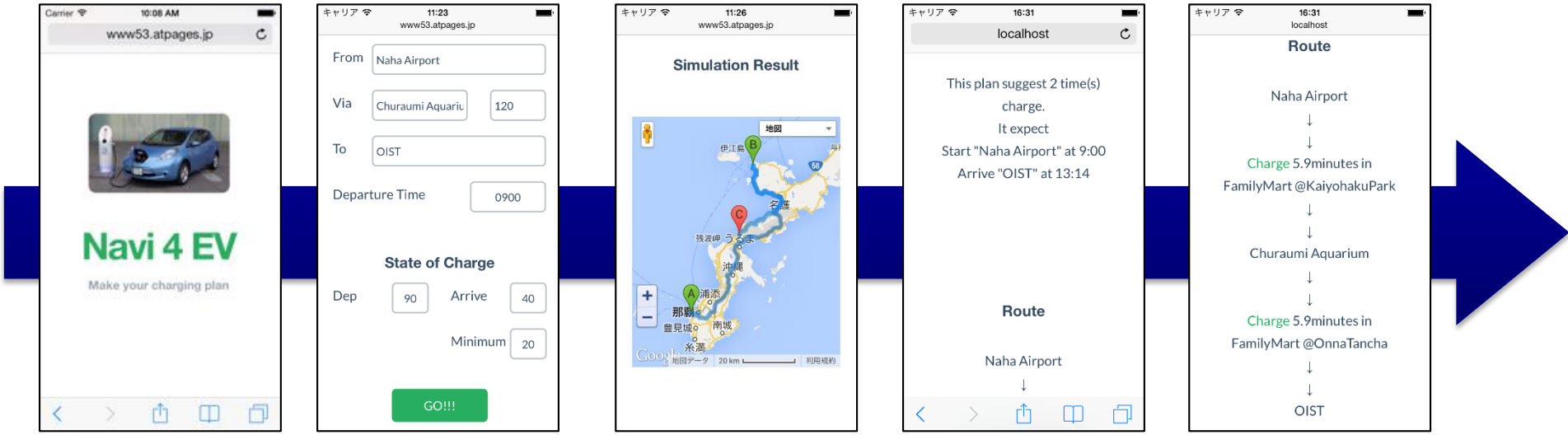
# EV car rental service is now on service in Okinawa

# Each Charge Station has its Charging Traffic Jam Pattern



# Demo Site

Make optimized charging plan for EV

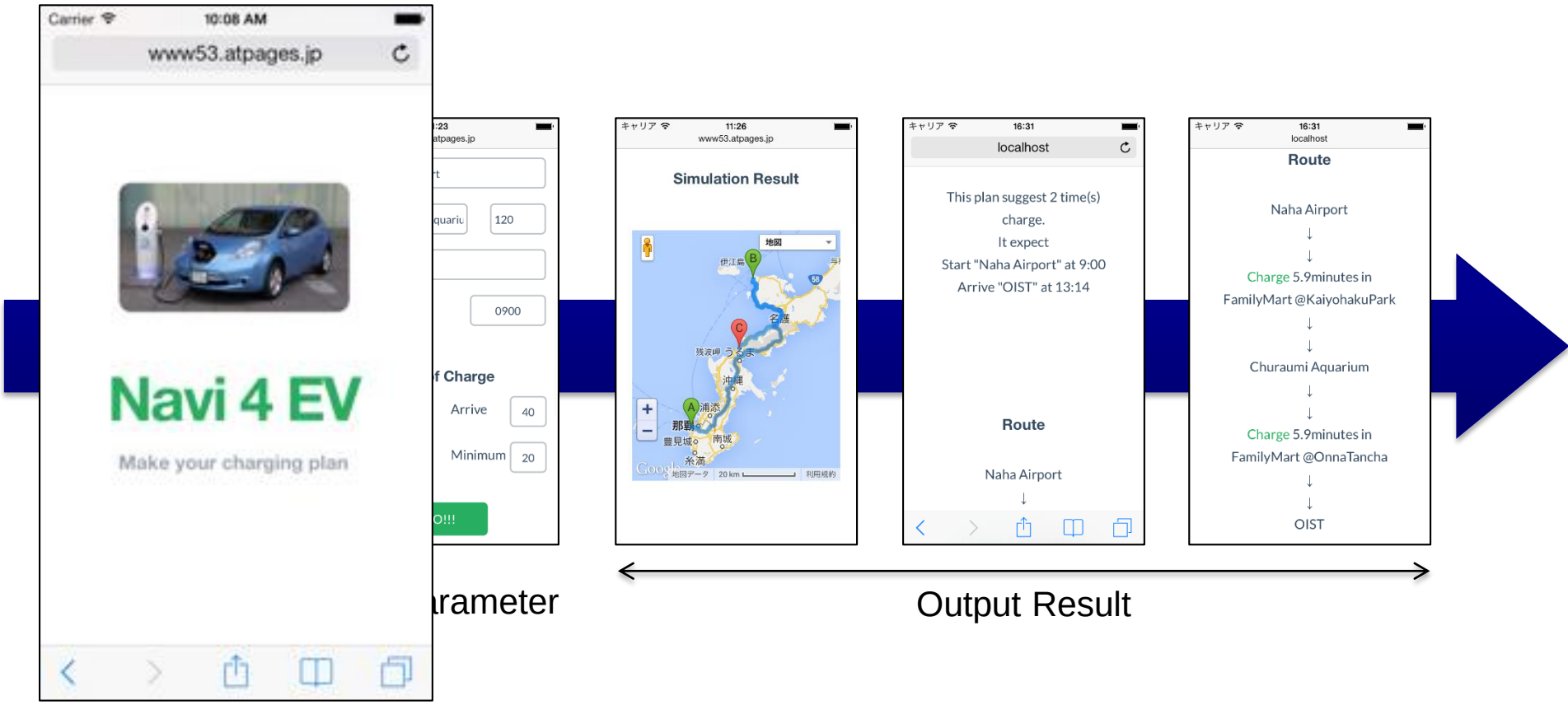



Input Parameter

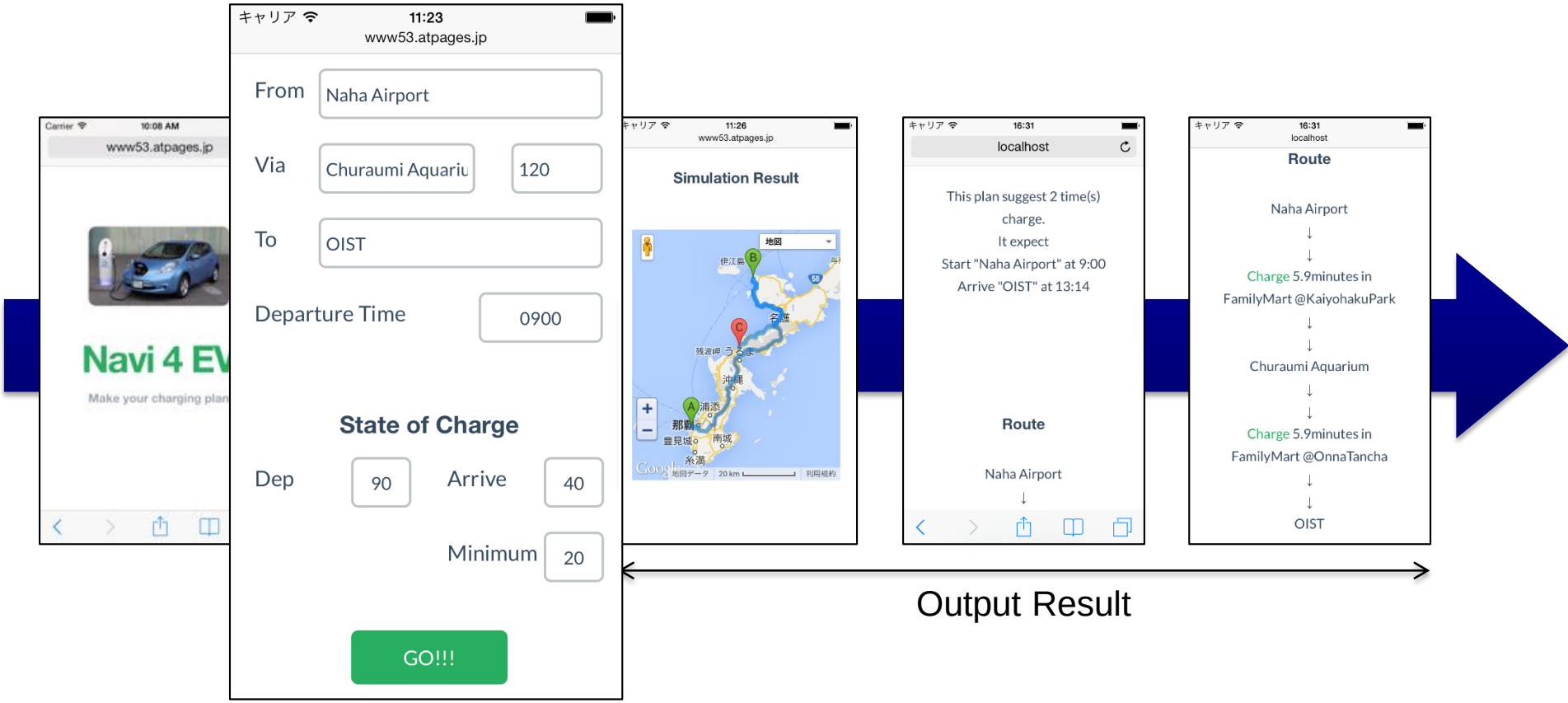
Output Result

# Demo Site

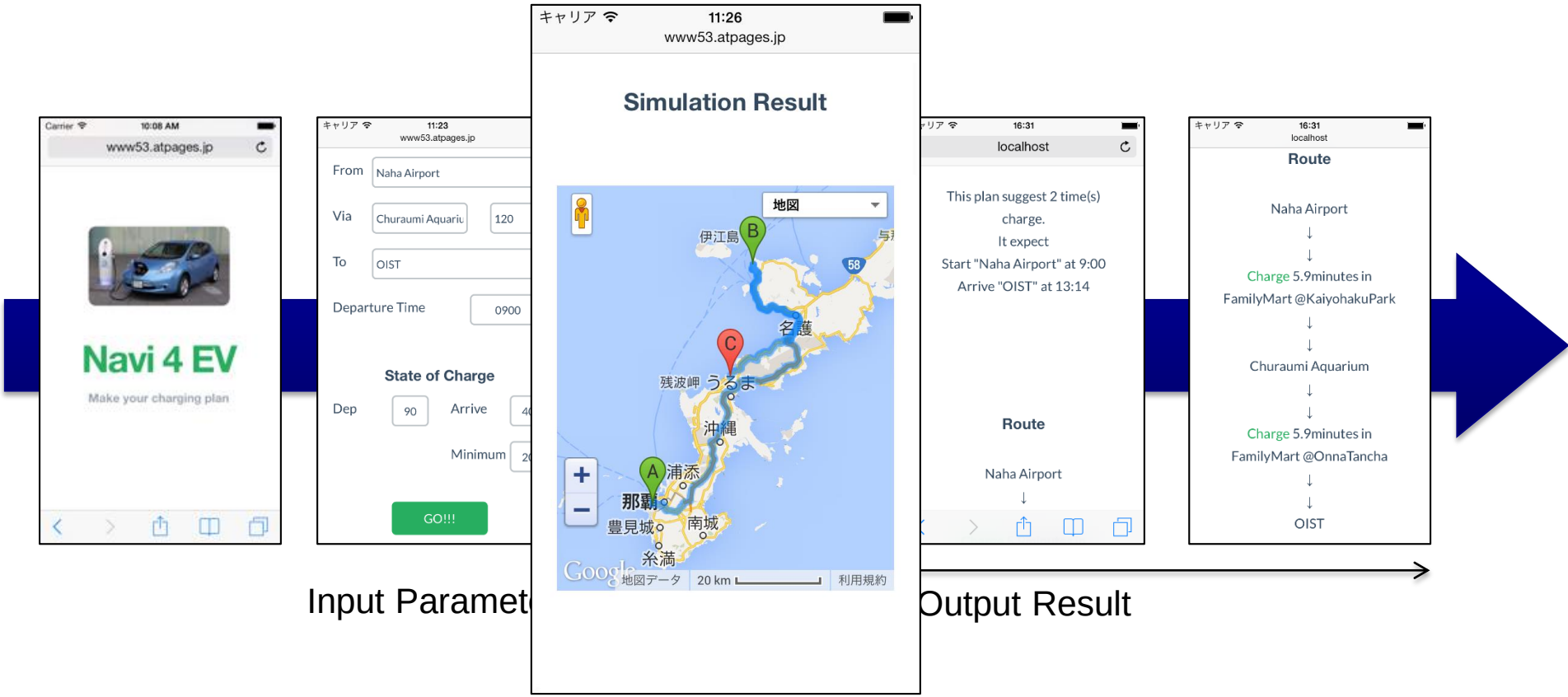
Optimized charging plan for EV



# Demo Site


www53.atpages.jp
Navi 4 EV
Make your charging plan
キャリア 11:23
www53.atpages.jp
From
Naha Airport
Via
Churaumi Aquariu
120
To
OIST
Departure Time
0900
State of Charge
Dep
90
Arrive
40
Minimum
20
GO!!!
11:26
www53.atpages.jp
Simulation Result
16:31
localhost
This plan suggest 2 time(s) charge.
It expect
Start "Naha Airport" at 9:00
Arrive "OIST" at 13:14
Route
Naha Airport
16:31
localhost
Route
Naha Airport
Charge 5.9minutes in FamilyMart @KaiyohakuPark
Churaumi Aquarium
Charge 5.9minutes in FamilyMart @OnnaTancha
OIST
Output Result

# Demo Site




Input Paramet

Output Result

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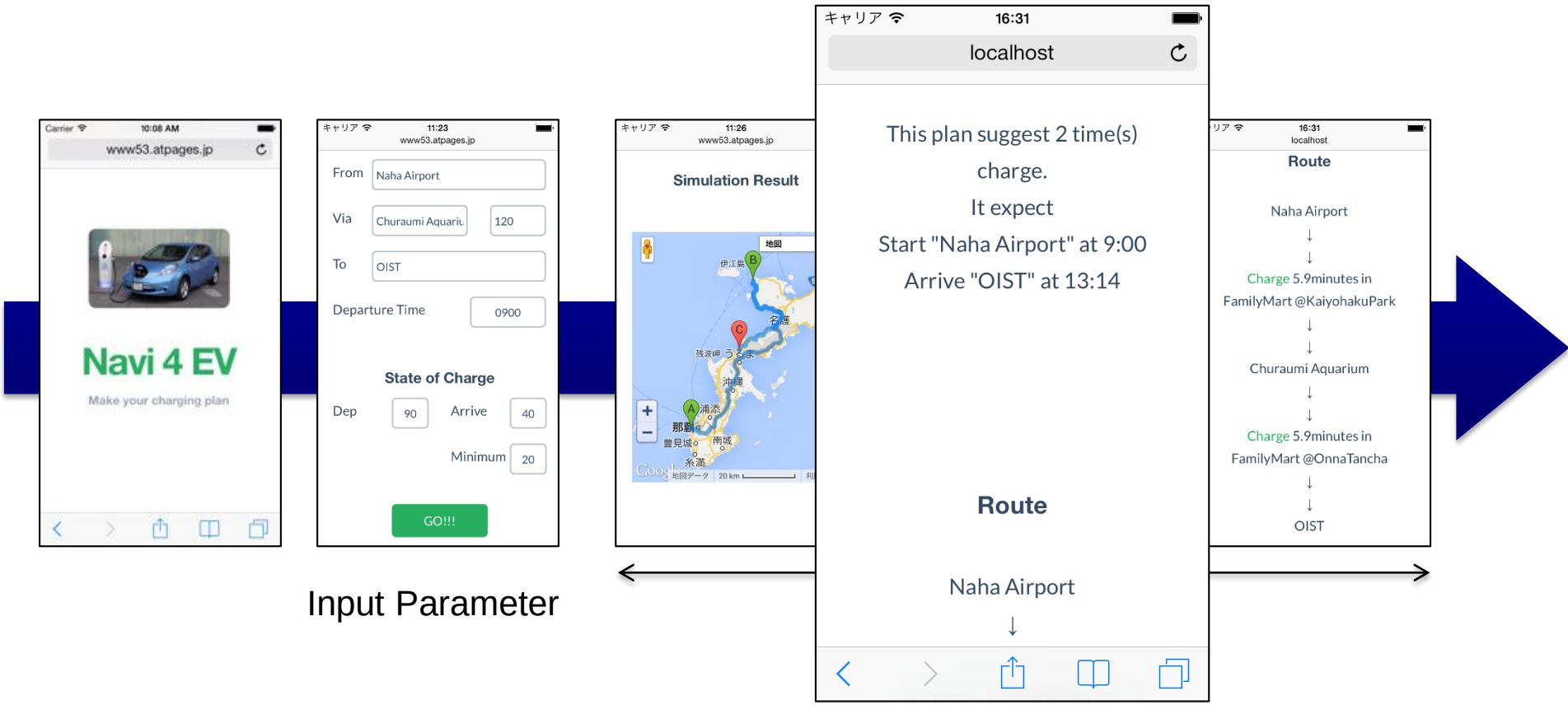
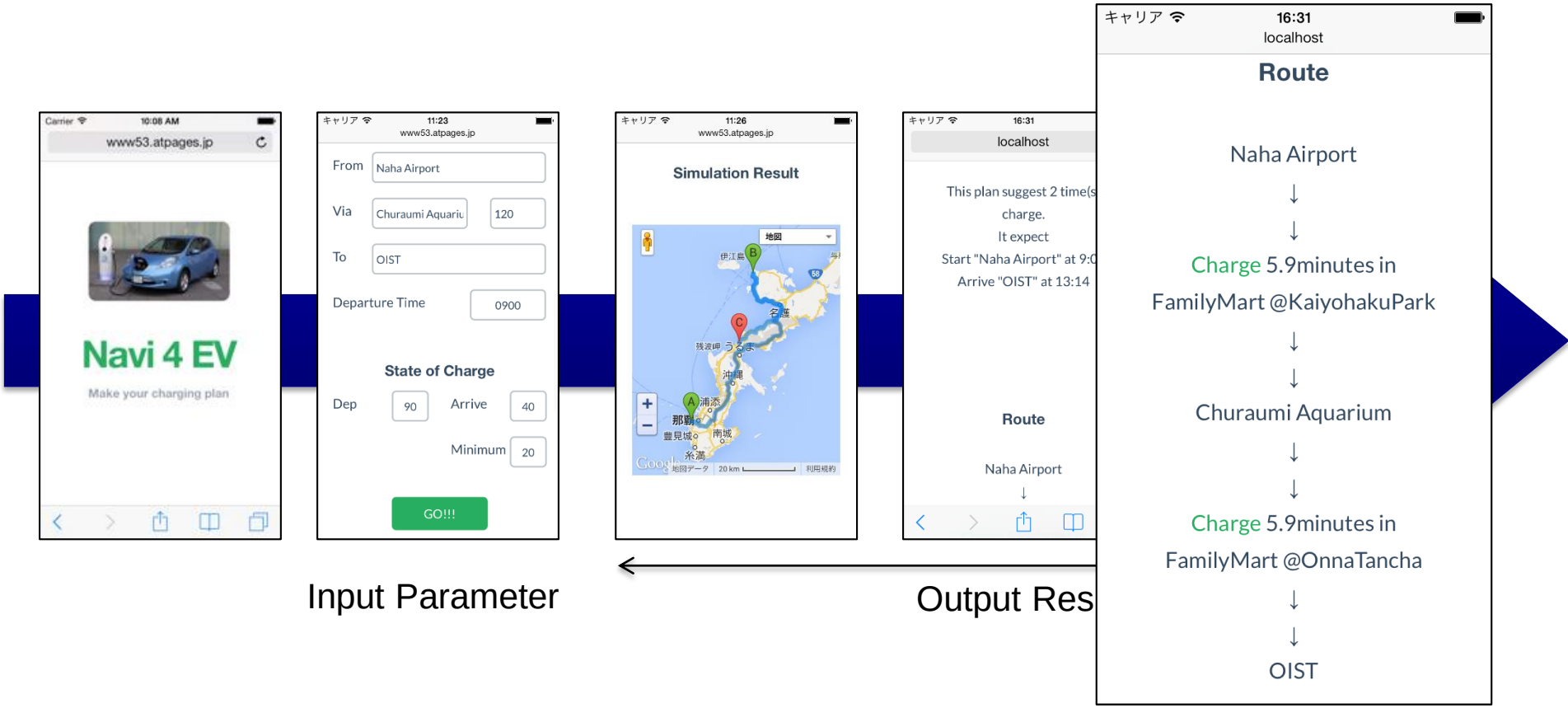



Input Parameter

# Demo Site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Naha Airport
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Charge 5.9minutes in
FamilyMart @OnnaTancha
OIST
Input Parameter
Output Res

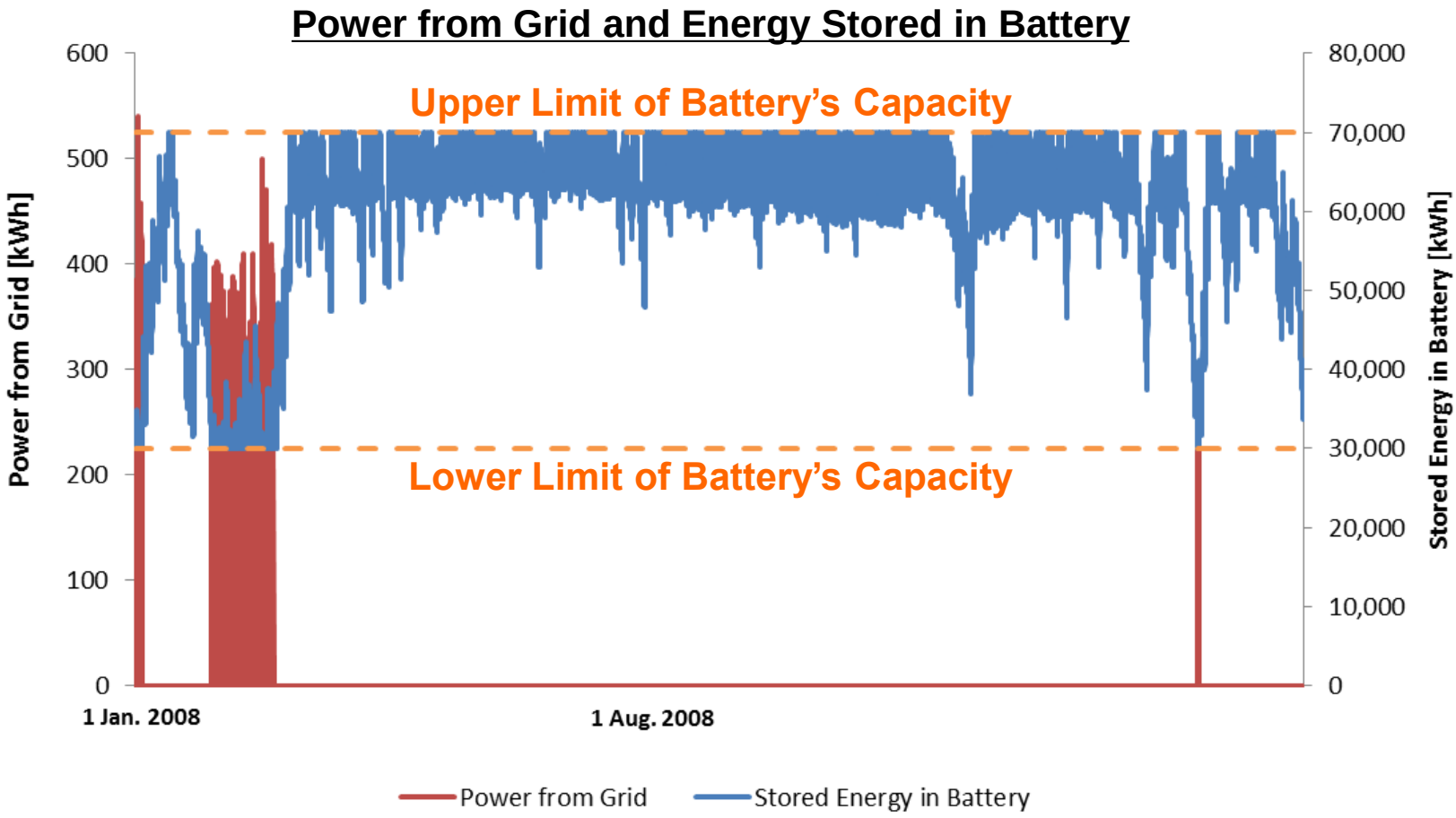
# Simulation Energy Storage Micro-grid Design


Time-series

Forecasting

# Enable to verify the performance beforehand

PV : **9.71** MW ← Power generated by PV is **150 %** of annual demand

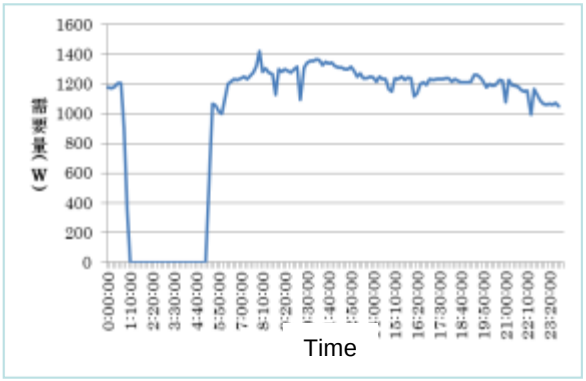



**There is a critical period during winter season in Okinawa**

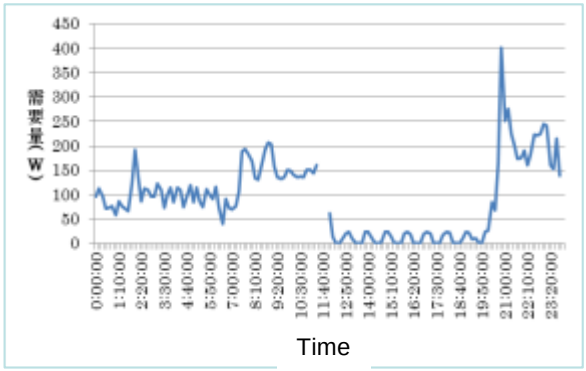
Battery Capacity : **540 %** of daily demand

# Managing the Uncertainty of Demand and Supply with Storage System is One of the Key Researching Area

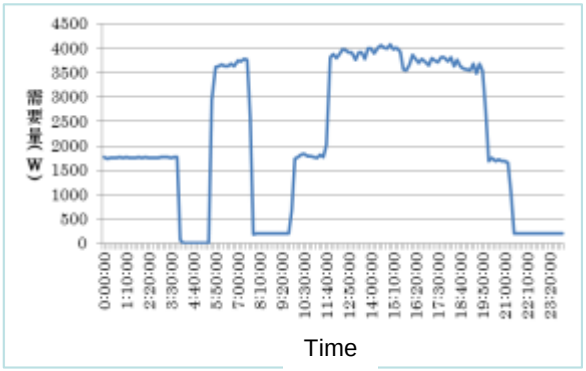
**Restaurant Building**




**Room Building**

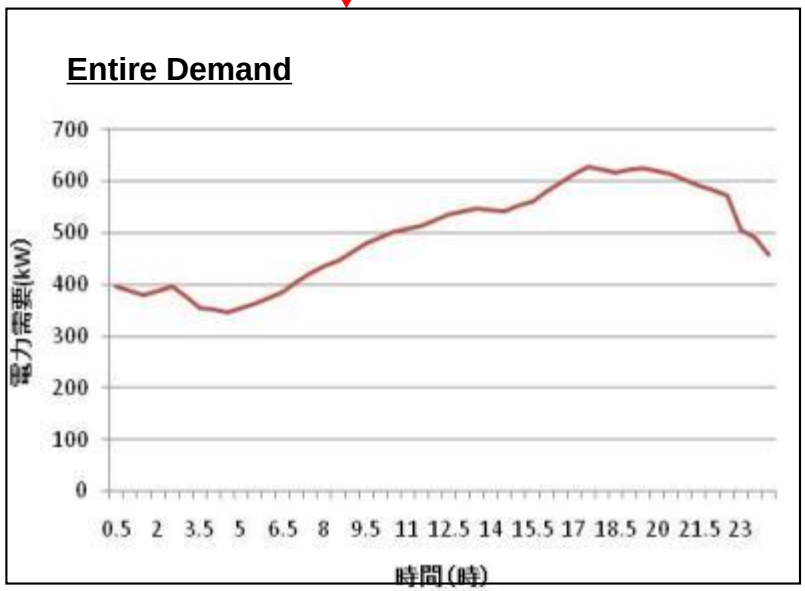


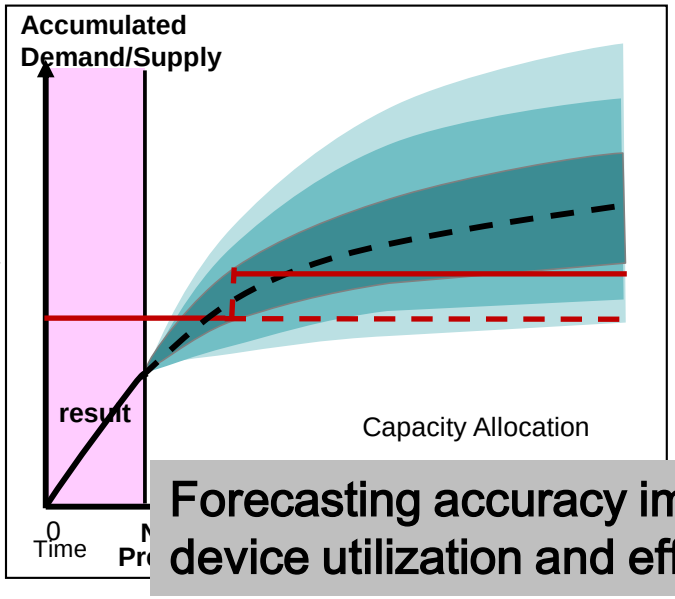

**Lobby Building**

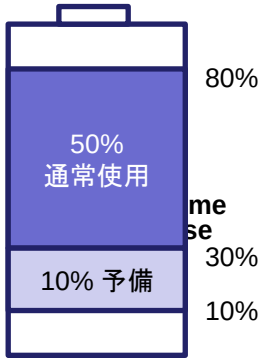



...

**Entire Demand**



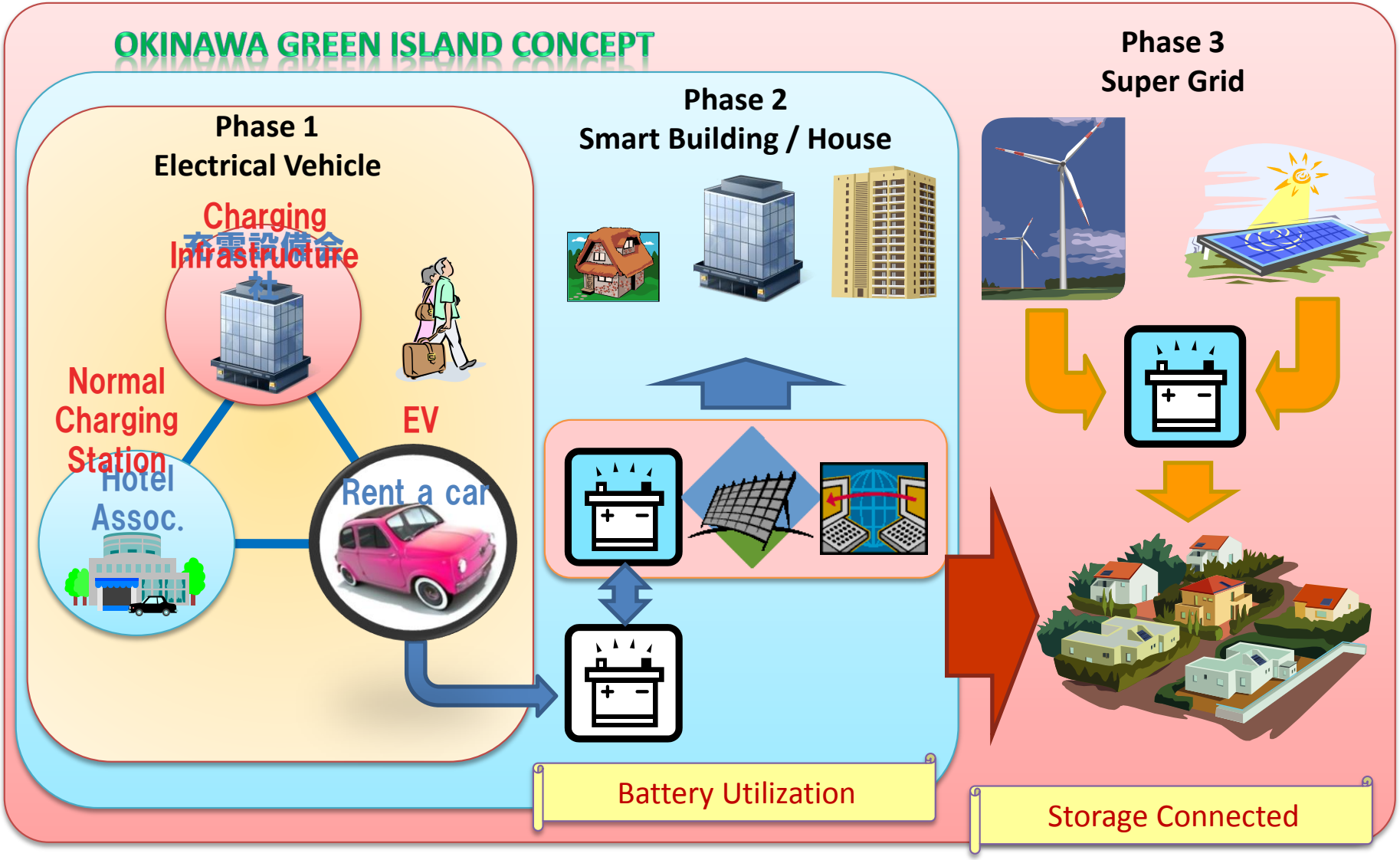

**Forecasting accuracy improve device utilization and efficiency**

# Hotel Installation Study of Micro-grid

| | |
|---|---|
| **Location** | Okinawa, Japan |
| **Annual Demand for Power** | 6,800 MWh (2008) |
| **Rooms** | 315 (max. 1,170 guests) |
| **Site Area** | 652 acre |


[Source] Resort A Website

# Power Grid network is next issue

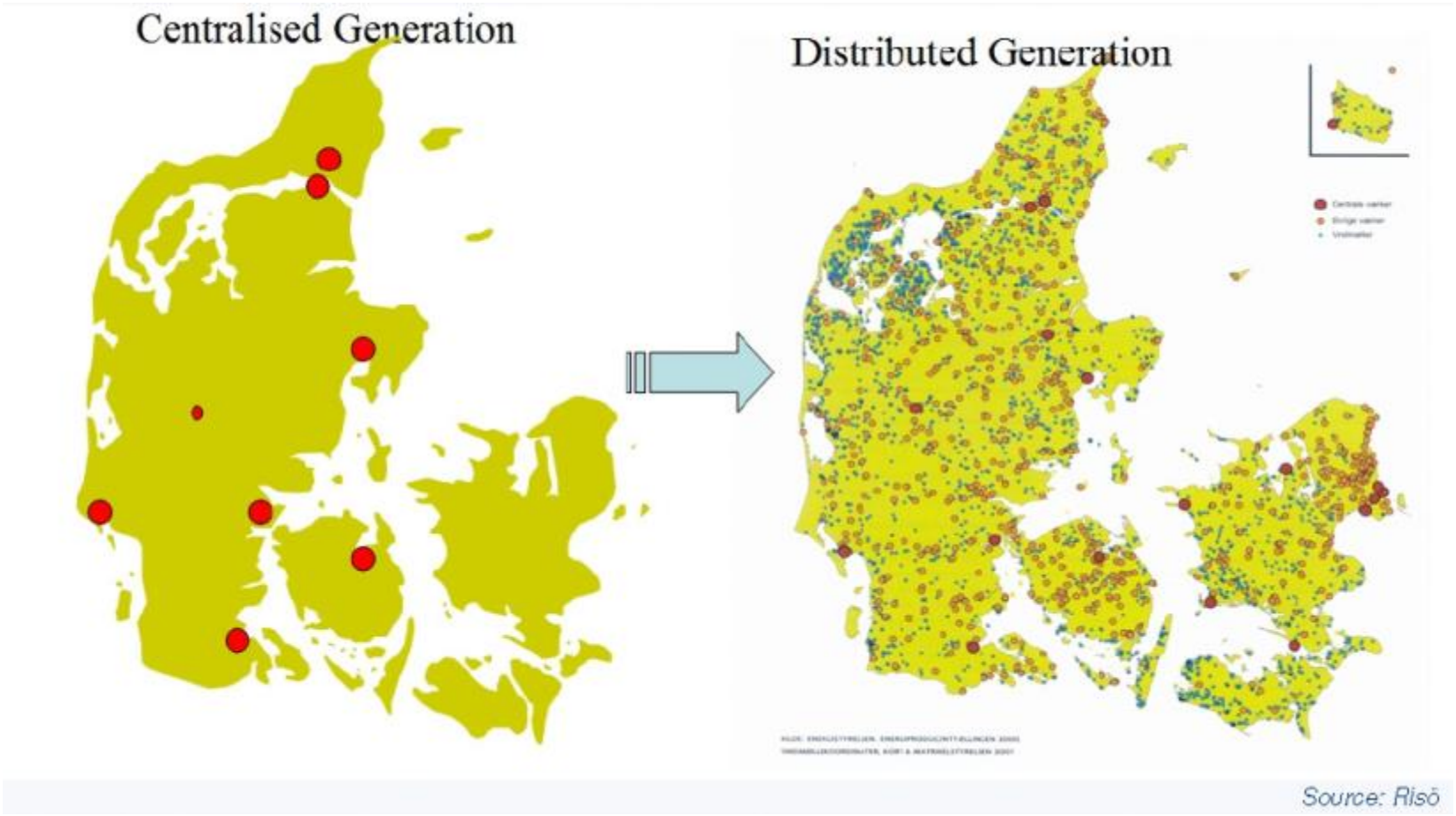



Source: M.Matsumoto (AEC)

- Okinawa Project

- Power Grid Digitalization !

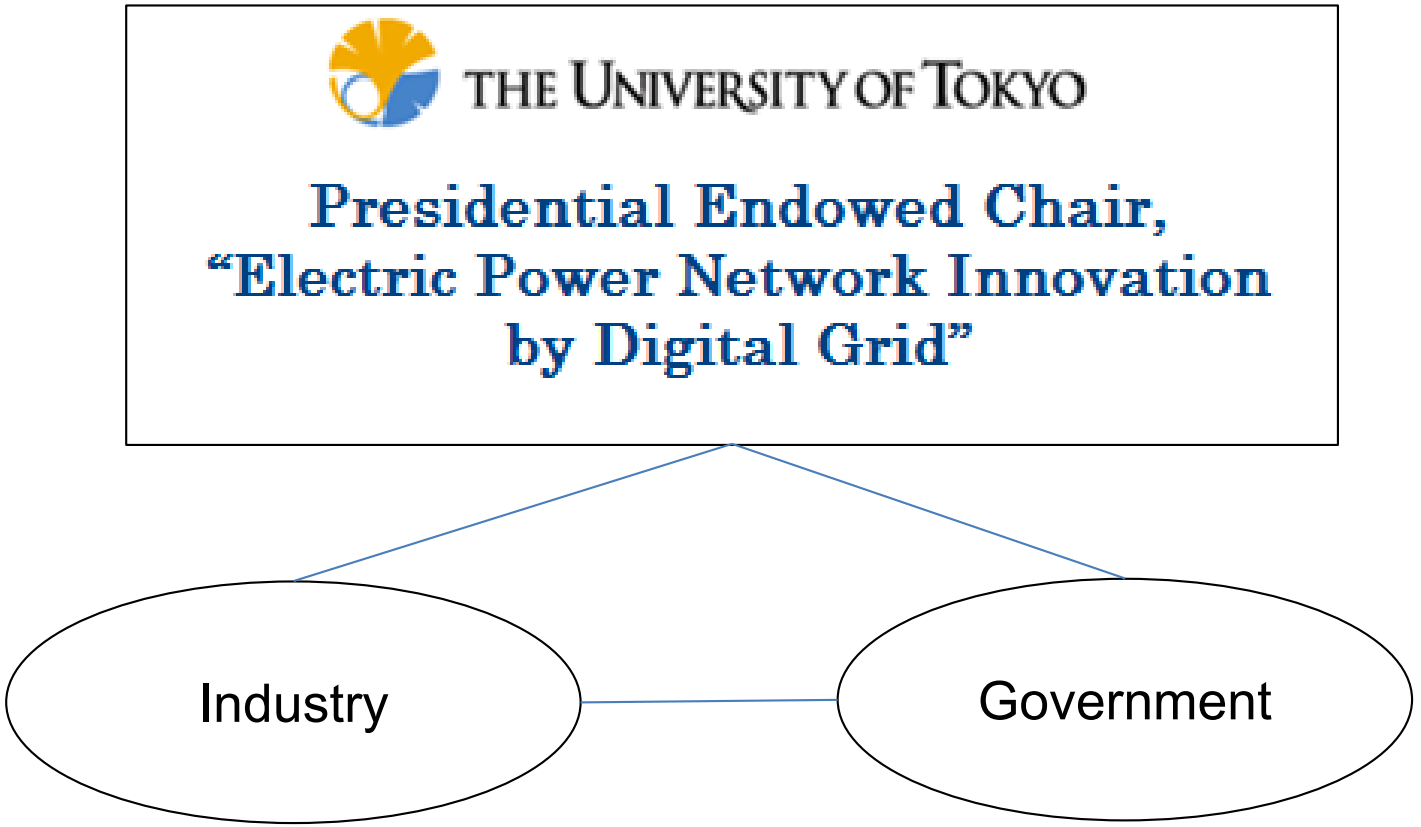
# The Power Network will be decentralized



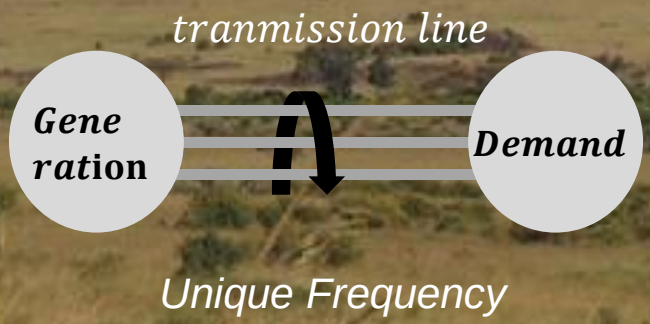

30 yeas ago
Denmark

Present
Denmark

# The Univ. of Tokyo decided to contribute Grid Issues



# Conventional Power Grid – mono grid

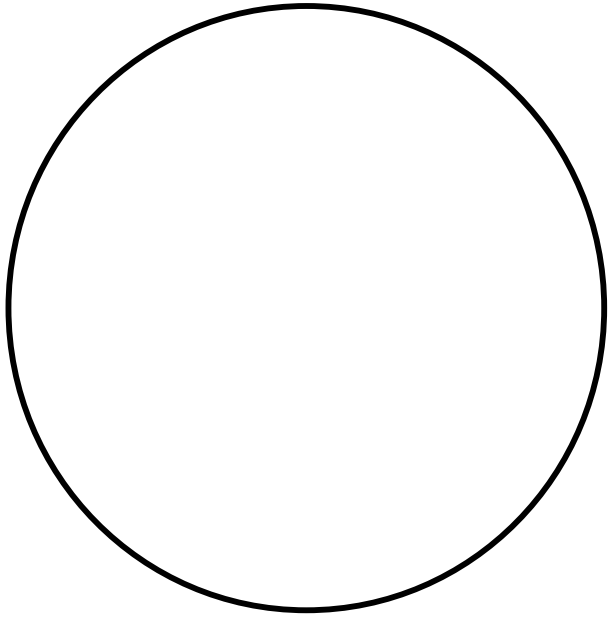



- One, Large, Rigidly Connected Grid has been very efficient with **the centralized control system.**
- It has **limit to control** to accommodate distributed, variable renewable energy.
- It's efficient but there is **increasing risk of cascading failure**

# Grid of multiple grids with flexible connection

# Mono Grid to Grid of Grids

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

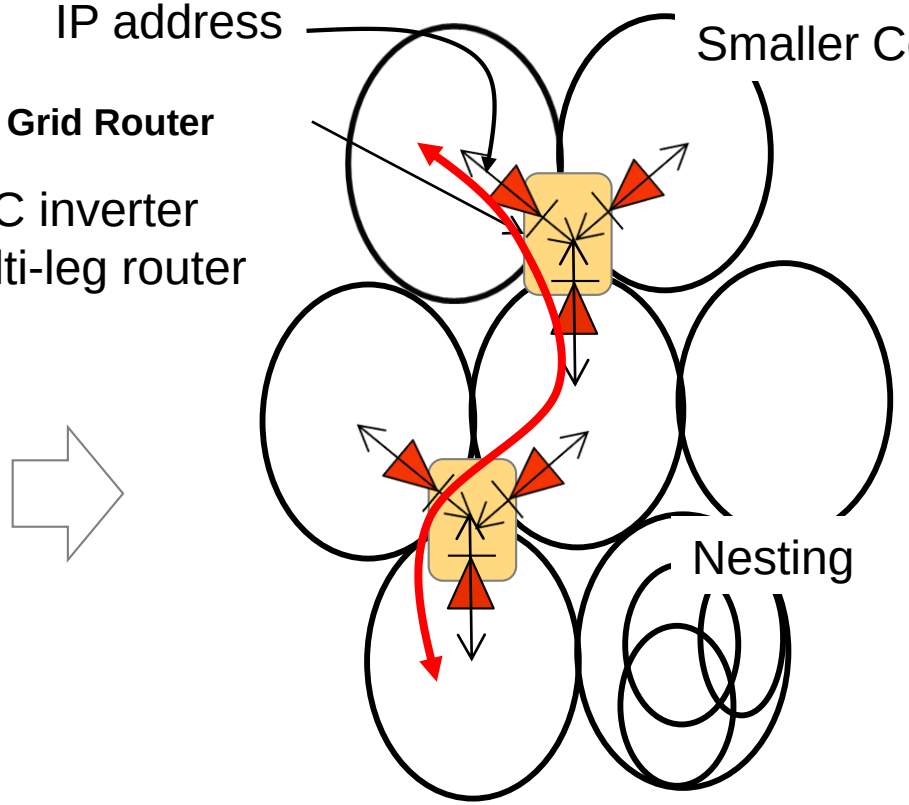


## Smaller standalone Cell Grids
(with asynchrous connection)

IP address

**Digital Grid Router**

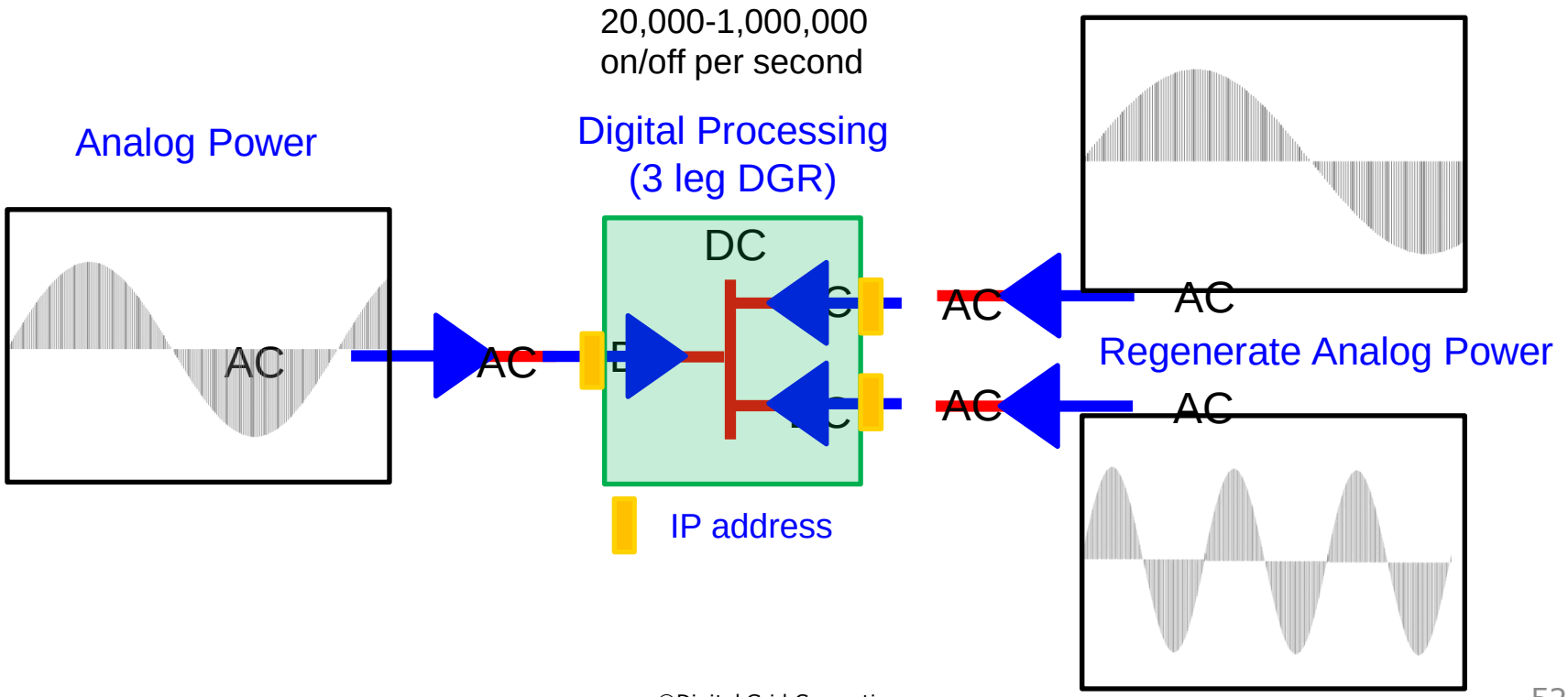
-VSC inverter
-Multi-leg router




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

# Digitalized Grid – Digital Grid Concept
## Addressable, Flexible Power Flow Controller

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



# Remodeling Current Energy Infrastructure

- Digital Grid will totally remodel energy infrastructure through digitalized electricity combining with digitalized ICT and digitalized economy.
  - **Retail market initiative**
  - **Demand side driven load profile (Demand Futures)**
  - **Time/resource/… premium service**
  - **Multiple access power line**
  - **Flexible/robust network**
  - **Best effort power supply**
  - **IP tagged energy transaction**
  - **Energy based economy**
- What has happened in digitalized technology?

# Digital ICT Big Bang

- ICT Analog Technology

- Reliable
- 1:1Direct Connect
- Limited Market

- ICT Digital Technology

- Best Effort
- N:N Indirect Connect
- Unlimited Market

# Digital Grid Big Bang?

- Analog Grid

- Reliable
- Direct Connection
- Limited Market

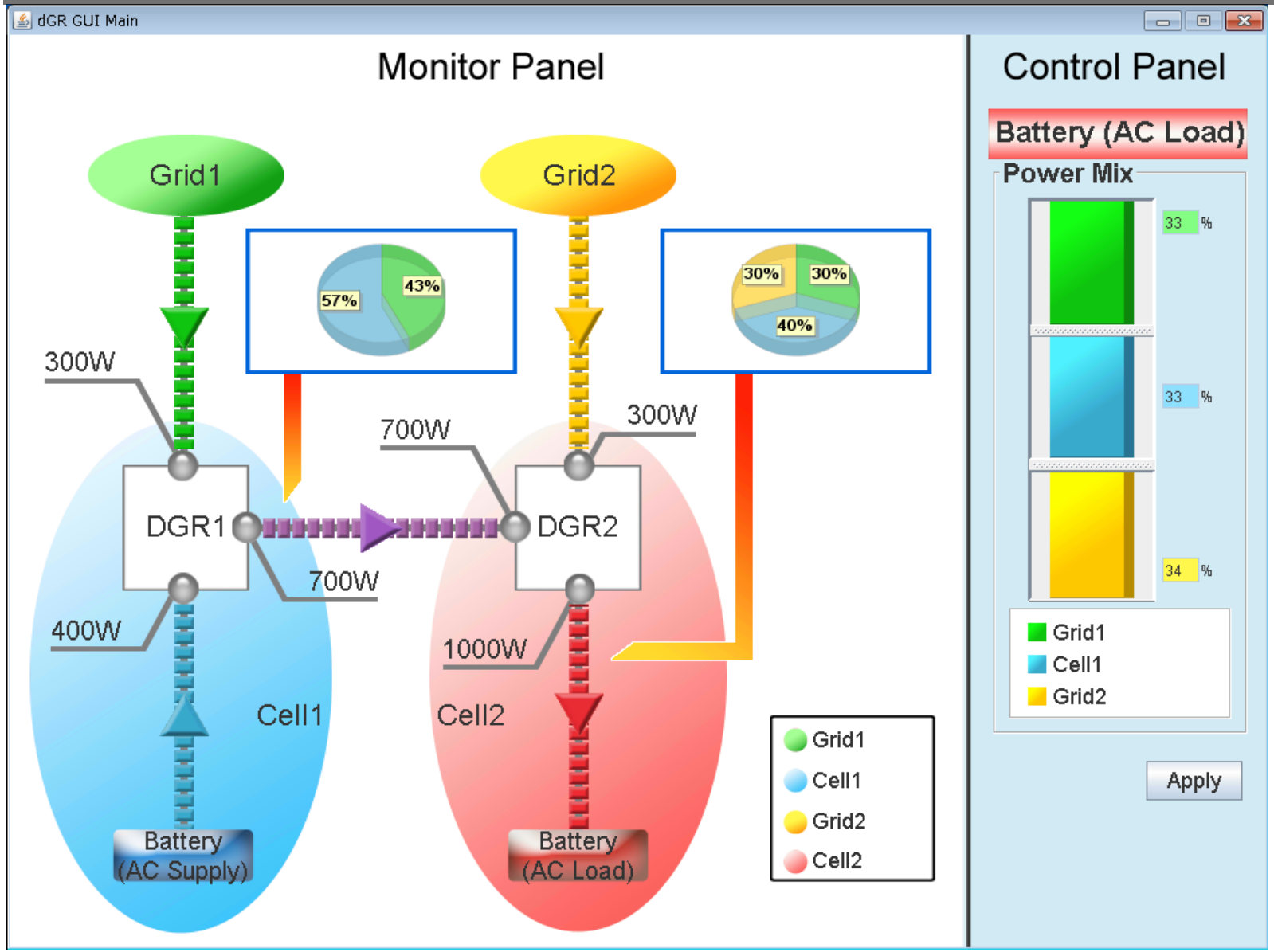
- Digital Grid

?

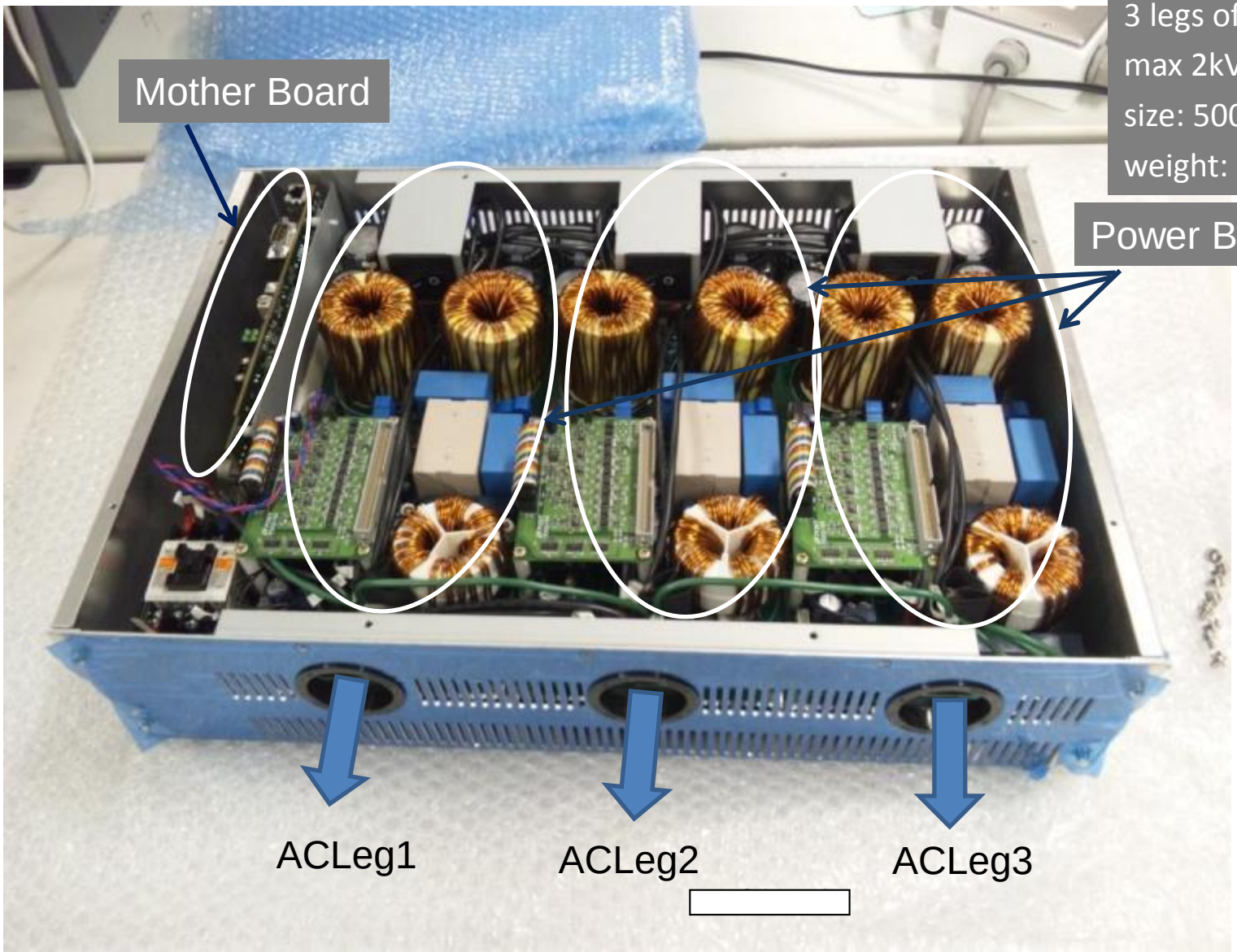
- Best effort?
- Indirect Connection?
- Unlimited Market?

# SOFTWARE Designed Grid Network

- Design power and direction at each leg
- Enable user to change ratio of power from 3 sources by Software



# We have developed the Digital Grid Router (DGR) Prototype




3 legs of AC 0-220V, 0-20A,
max 2kVA, 50Hz-60Hz
size: 500x330x120mm
weight: 12.5kg

# Application Model of Digital Grid

1. On Grid Model
2. Off Grid Model
3. Weak Grid Model

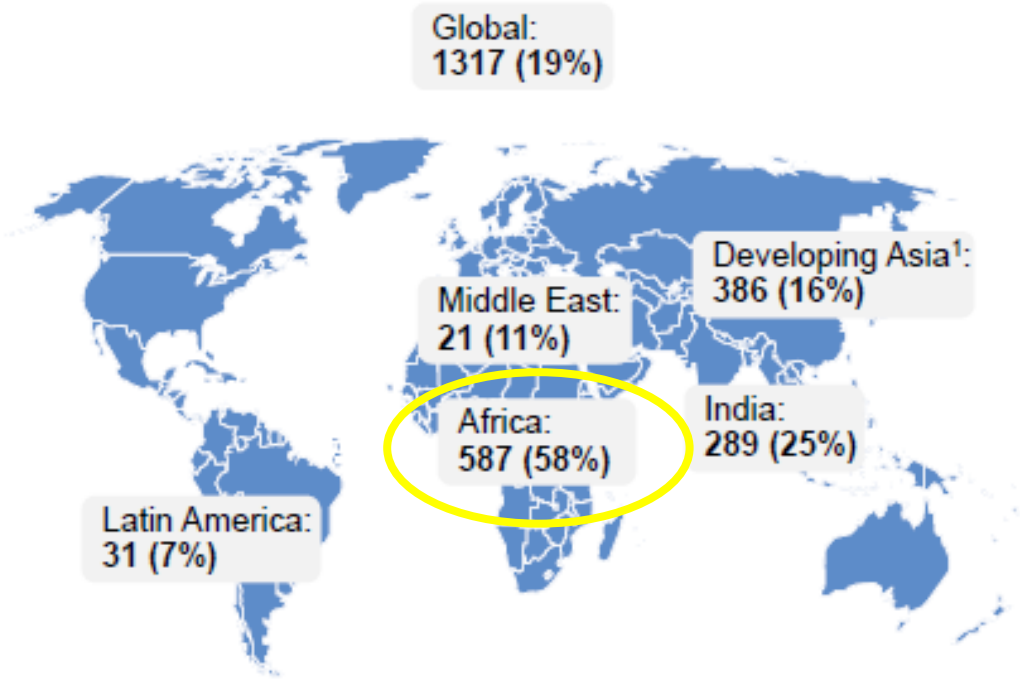
# Application Model of Digital Grid

1. On Grid Model
2. Off Grid Model
3. Weak Grid Model

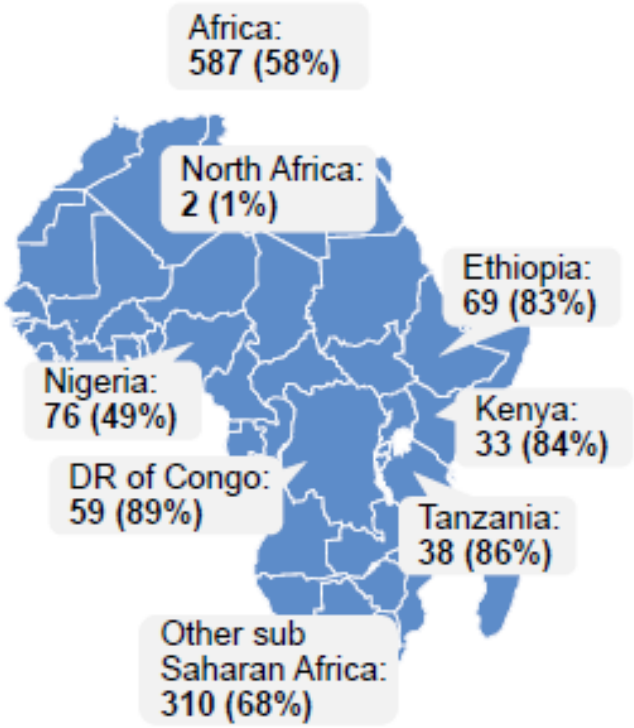
# In Africa 58% of the total population has no access to electricity

## People without access to electricity in 2009

**Global**
(population in mn and % of total)

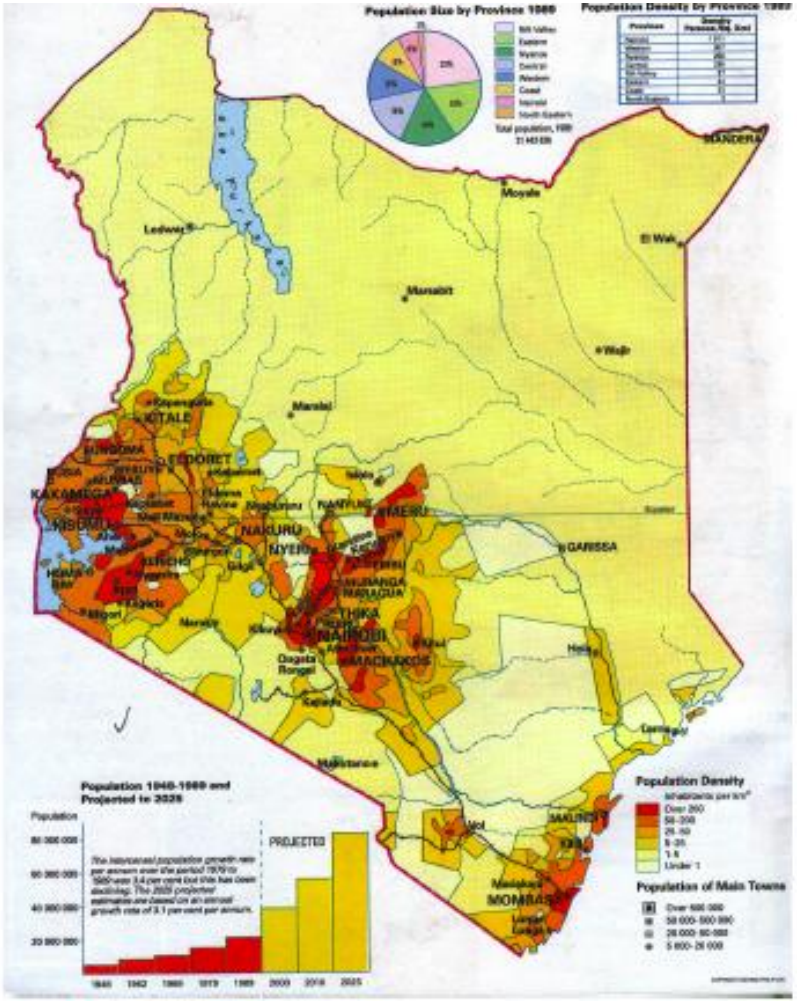



**Africa**
(population in mn and % of total)



# North Part of Kenya has Large Scale of Off-grid area

## Population in Kenya




## Electrification in Kenya


However, about 70% of people has mobile phone



Source) CAMCO (2012), Regulation and Governance Issues for the Off-grid Sector in Kenya

# On-grid power service is too expensive for users

# KPLC: Prepaid Solar Charging Station/Kiosk

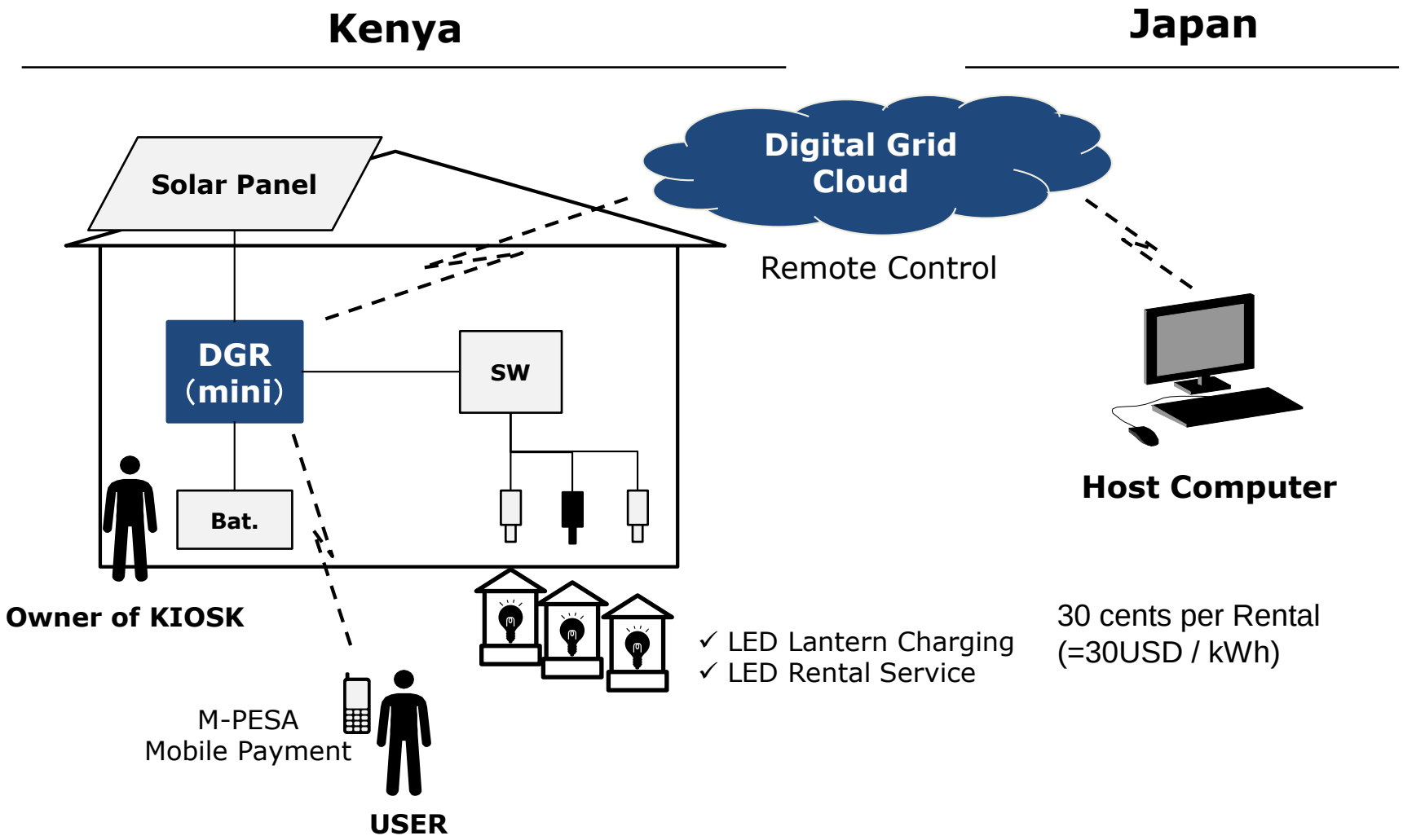
- KPLC's rural electrification program (budgeted)
- Hundreds of Station/Kiosk are placed in a few years.
- In a pilot study phase

***Solar Charging Kiosk***

***⇒ Providing ultra-low-cost M2M prepaid charging solution by Digital Grid.***

# Final Concept Model: Prepaid Solar Charging Kiosk

Lantern Rental Service is now trying.
Instead of Using Power Line, Human walking network is embedded to the Power network.



# Digital Grid Router for Off-grid Village

# Pilot Project Area: A Kiosk in Lodwar, North Kenya

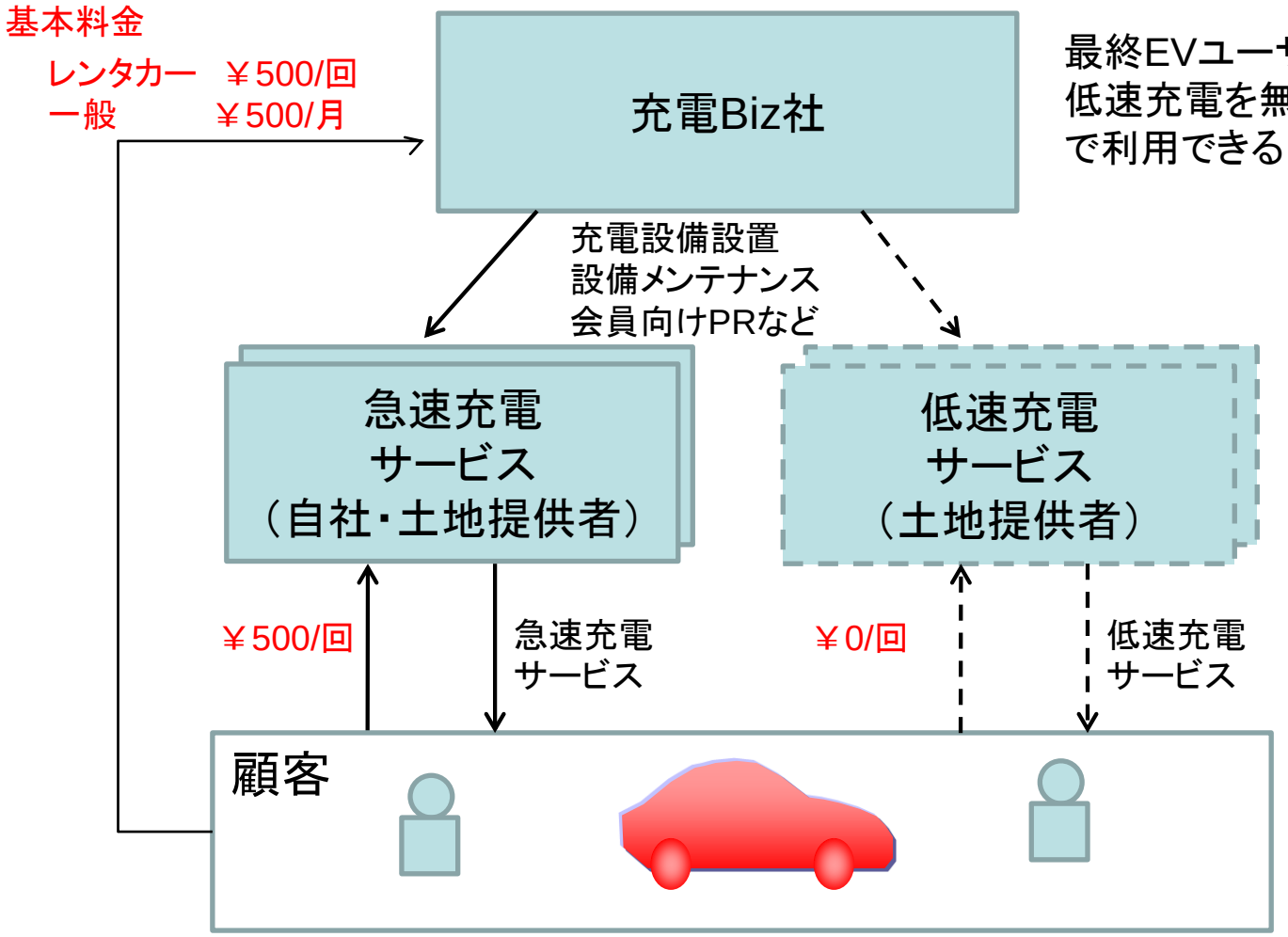
# Inside KIOSK


The President of TANZANIA @ African Fair 2013

THANK YOU

Kenji Tanaka
kenji_tanaka@sys.t.u-tokyo.ac.jp

# Proposed Business Model Design of Charging Service Company

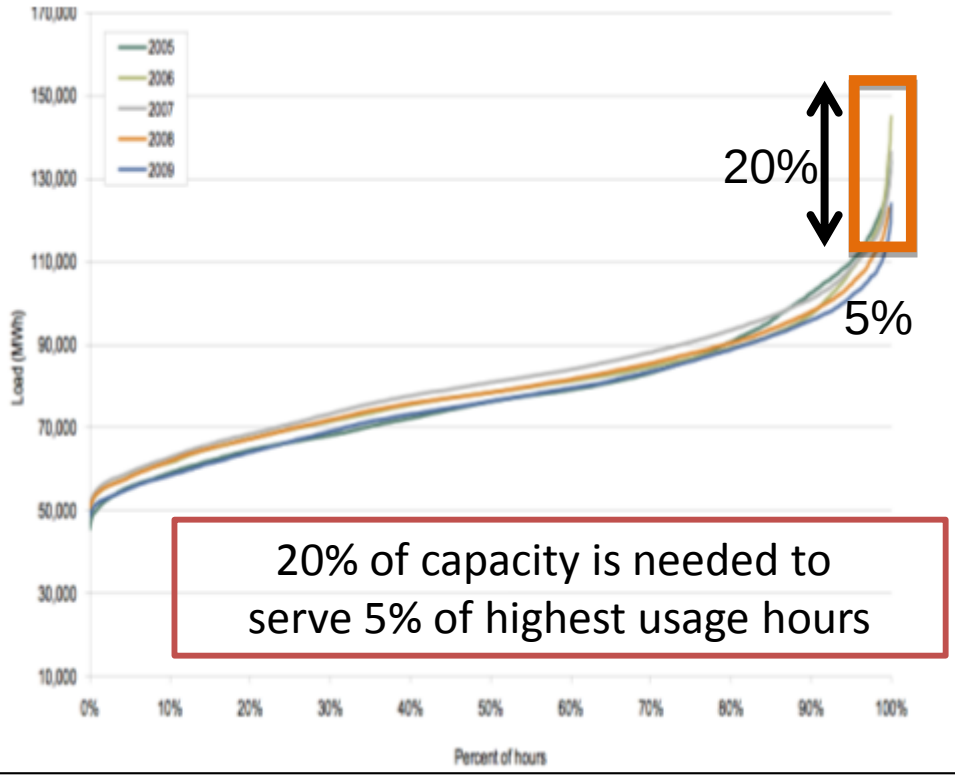



最終EVユーザーは基本料金を支払い、低速充電を無料で、急速充電を500円で利用できる。

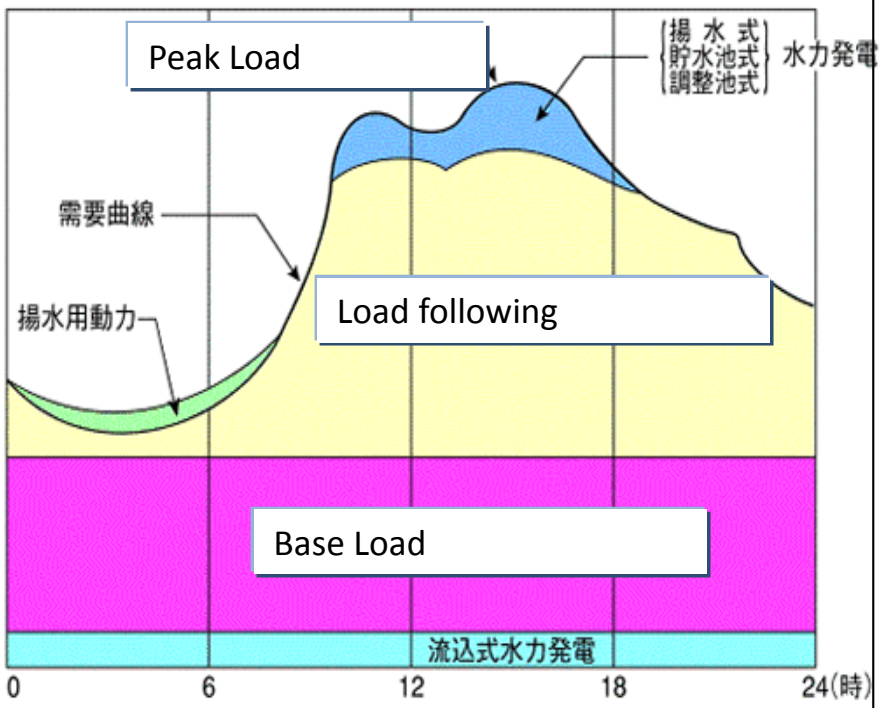
# Current Grid is Fragile

For avoiding the system down, we have to install more capacity than the peak load.

## Power Grid Load (US case)




## Load and Generation

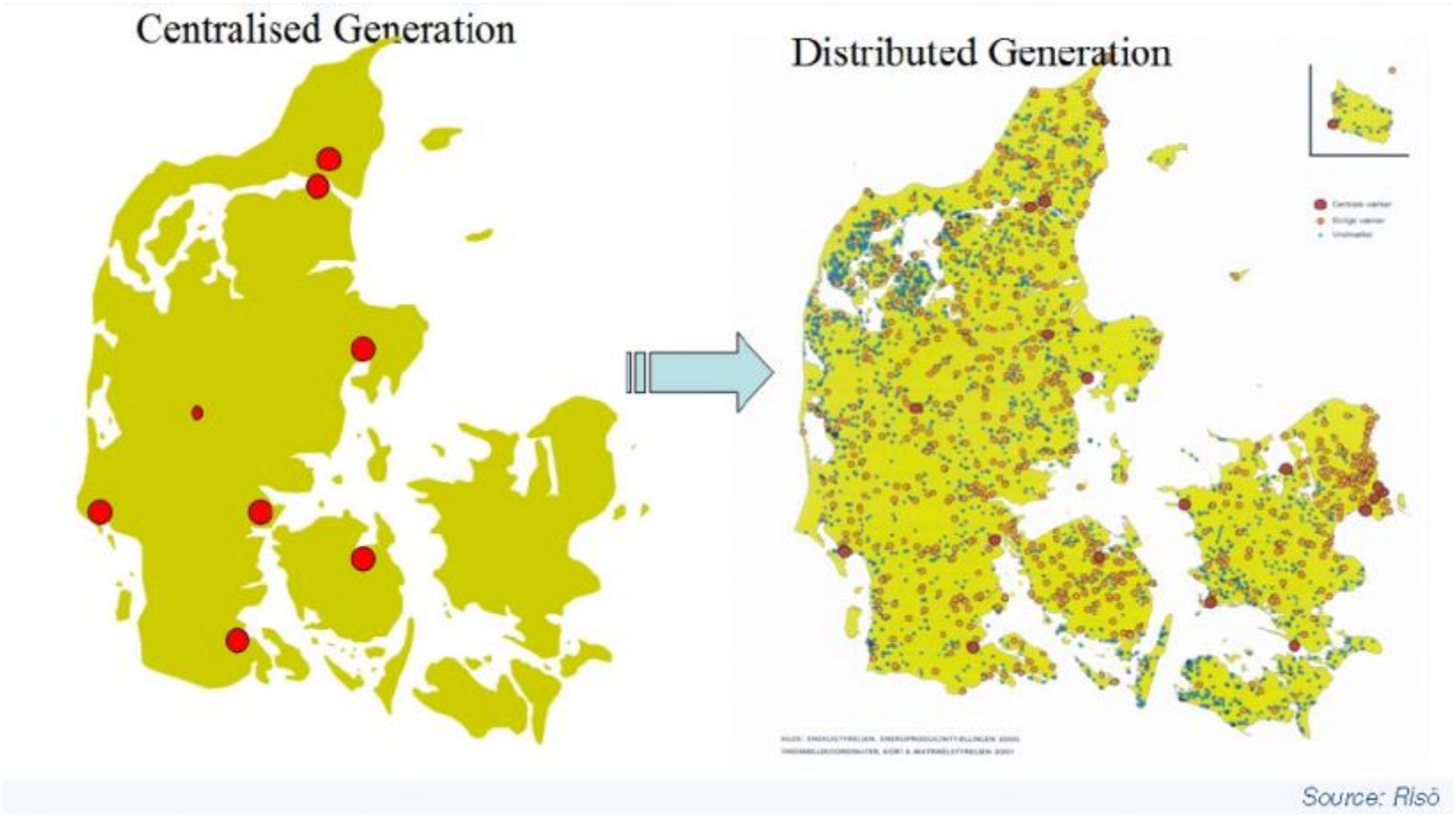



Source : NIST, Eric Simmon ,An Introduction to The Smart Grid (2010)

# Grid Resiliency is becoming the new driver

Source:EPRI

# The Power Network will be decentralized




30 yeas ago
Denmark

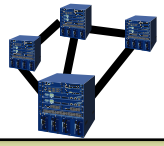
Present
Denmark

# Power Grid Digitalization

**Computer** Analog → Digital

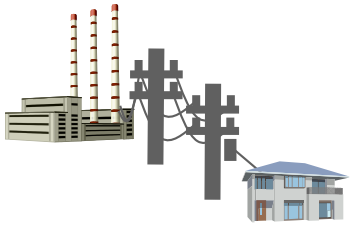
*) Mechanical Calculator

**Communication** Analog → Digital



**Power Grid** Analog → → → → → → → Digital

?



***Fxed power supply with reserved margin***

***Necessary amount of power supplied at anytime, anywhere***

Strict rule, i.e. balancing generation and demand at anytime shall be relaxed.

Source: Emura et al, UTokyo Forum 2013

# 技術要素をつないだ社会全体エネルギーシステムの研究

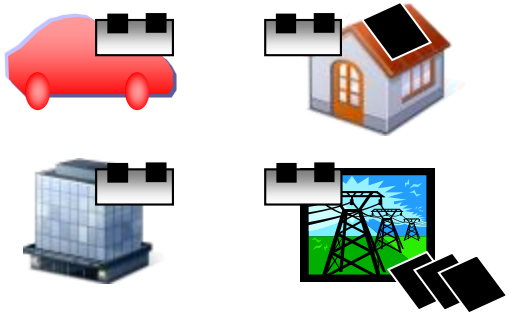
## Smart grid business service phases

Level 1

HW introduction Phase

EV

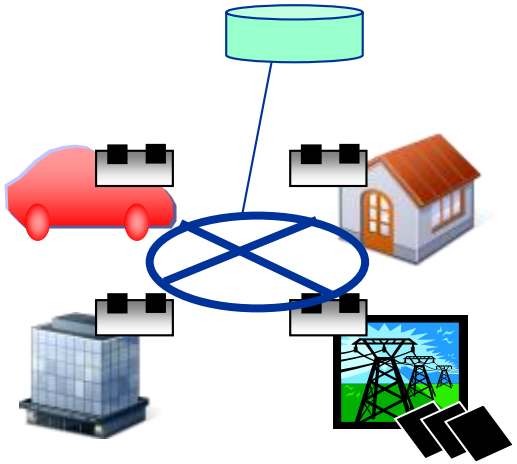
HEMS BEMS



Level 2

Networking Phase

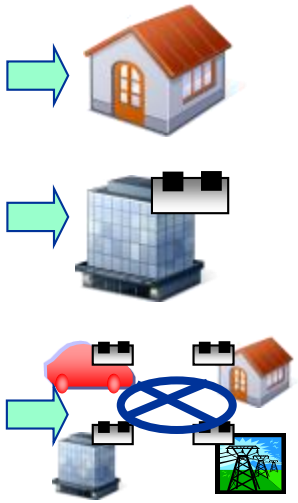
Passive data Monitoring service



Level 3

Service Providing Phase

Active business services with BigData



# Proposed Digital Grid for Developing Country

- ① Continuous Stable Electricity Power can be Supplied
- ② Decentralized Renewable Power can easily be installed
- ③ Main-grid can be supported by remote-controlled DGR
- ④ Remote Monitoring provides simple maintenance

To be designed for local needs

DG CELL for weak grid