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# Developing networking functions for ENE-FARM residential fuel cell cogeneration systems

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## 1. Abstract

In April 2014, Osaka Gas launched a new model of “ENE-FARM”, a residential fuel cell cogeneration system. Osaka Gas also developed smartphone application for ENE-FARM (“ENE-FARM App”). “ENE-FARM App” enables users to control fully automated bath unit and hot water floor heating system. With the application, users can also check the energy information.

Smartphone is connected to the remote control panel of ENE-FARM through the wireless LAN router. The application is also communicate with the server of Osaka Gas in order to improve not only the smartphone application but also the services related to ENE-FARM.

The major specifications and characteristics are described in this paper.

## TABLE OF CONTENTS

## 2. Introduction

ENE-FARM, a residential fuel cell cogeneration system, is the environmentally friendly energy system that produces electricity and heat at the same time from chemical reactions driven by hydrogen in natural gas and oxygen in air.

The system launched in 2009 for the first time in the world and since then, about 72,000 units had been installed by March 2013. A residential fuel cell cogeneration system which generates electricity and useful heat is energy-saving system in comparison to conventional systems.

The system is expected to spread because this leads to reducing residential energy consumption in Japan. Japanese government set a cumulative target of 1.4million residential fuel cell units by 2020, rising to 5.3 million units by 2030 (Figure1).

Gas companies and manufactures have been evolving ENE-FARM continuously and a new model of ENE-FARM was released in April 2014. The new ENE-FARM not only offers performance improvement and cost reduction but also provides additional value to customers with a function of smart phone connection.

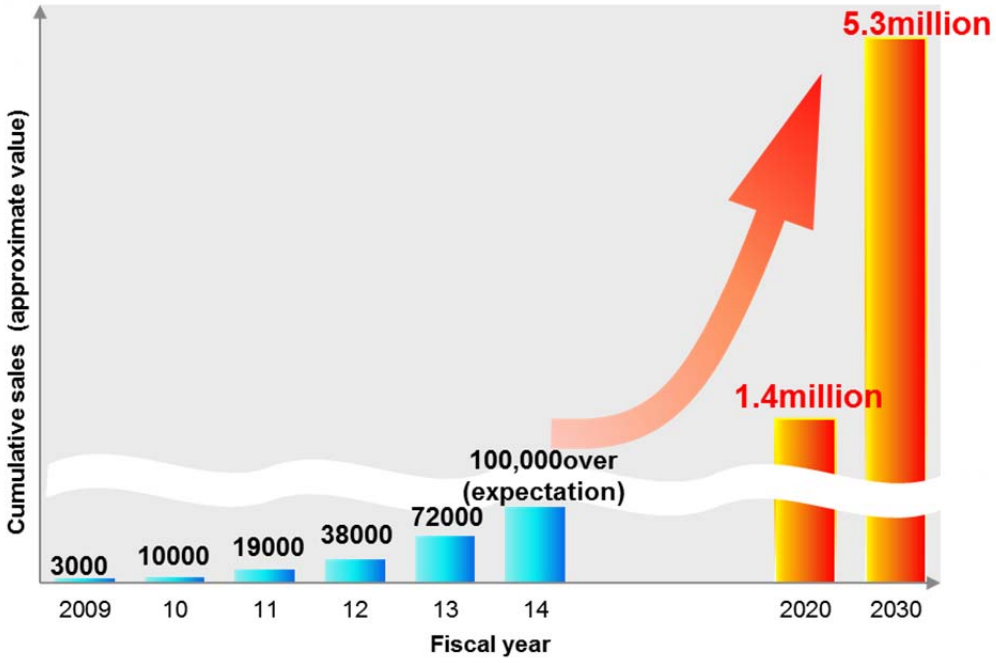


Figure1. Cumulative sales (2020 and 2030 is target) of the residential fuel system in Japan

## 3. Developing networking function of ENE-FARM

### 3.1 Back ground

Recently in Japan, several “Smart House” projects have been carried out. The definition of “Smart House” varies, but in general, it is a house aimed for the energy management such as saving energy by visualization of energy consumption, and controlling appliances. As mentioned

previously, fuel cell is able to realize a high level energy saving in houses. So fuel cell is expected to spread as the important component of “Smart House”.

As smart phone and the wireless LAN (Wi-Fi) became commonplace in people, household appliances which can connect to the internet or smartphone have launched and penetrated the market

Figure2 shows the penetration rate of smart phone and wireless LAN in Japan. The penetration rate is expected to be over 50% now, and increasing continuously.

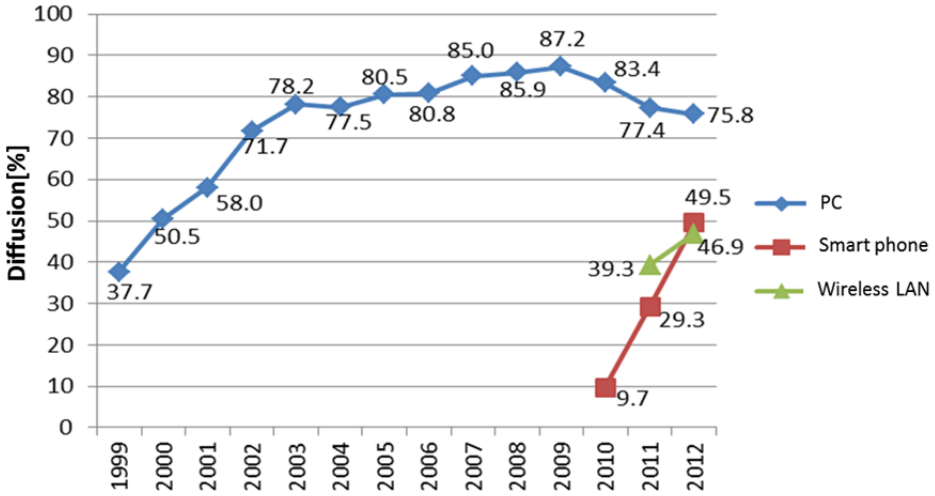


Figure2. Diffusion of smart phone and wireless LAN in Japan

The followings are some examples of household appliances that can connect to the network.

① Networked printer

It enables users to print pictures directly from smart phones.

② Video recorder

It enables users to control video recording and play recorded programs with smart phones even outside.

③ Health-care products(digital blood pressure monitor, body fat scale and others)

These products make it easier for users to manage health-care data.

④ Home-use game console

Connecting to the Internet enables users to play online game and download games instead of going to the shop to buy it.

Other than those above various home appliances such as air conditioners, toilets, refrigerators, ovens, washing machines, robotic cleaners, are connected to smartphones and the Internet and provide new additional values to customers. Their features, such as “convenient”, “fun to use”, “easy to handle” or ”cool” directly intensify customer’s desire to buy. As a result, considerable number of products is used in ordinary home.

In addition, the manufacturers of these products are able to collect various kinds of data, so called “BIG DATA”, from these products through the Internet. “BIG DATA”, such as the use for the products, condition of consumable supplies and customer preferences, are utilized for marketing and product development.

We think that it is more important to improve the attraction of the product by using smart phone which became popular and providing the new values. Therefore, we developed the function that cooperates with smart phone and added it to ENE-FARM launched in April 2014.

### 3.2 System configuration

#### 3.2.1 System configuration of ENE-FARM

The system configuration of ENE-FARM is illustrated in Figure3.

The basic concept of ENE-FARM is described as follows.

ENE-FARM consists of a fuel cell unit, a hot water storage tank unit, a remote control panel and a hot water heating installation for floor heating, a bathroom drying and heating, etc.

The fuel cell unit generates electricity and exhaust heat by hydrogen from natural gas and oxygen from air. Electricity generated by ENE-FARM is grid-connected and supplied to electronic appliances. On the other hand, exhaust heat recovered as hot water is once stored in a storage tank in tank unit, and then used for domestic hot water. The tank unit is equipped with a back-up boiler in case the amount of hot water in the tank is not sufficient. The back-up boiler is also used for hot water heating system.

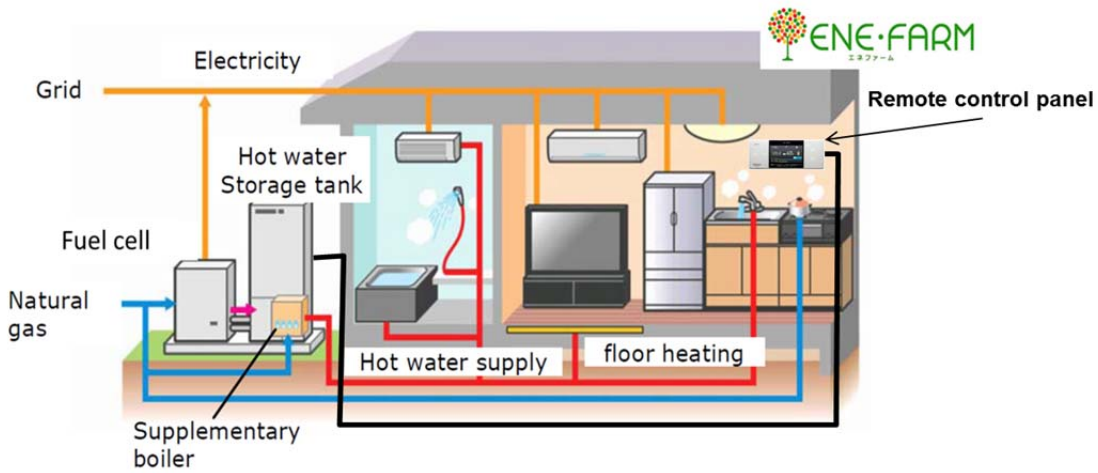


Figure3. ENE-FARM system

Figure 4 shows a remote control panel of ENE-FARM.

The remote control panel is placed in the kitchen and connected with tank-unit by wires. Users can browse the status of ENE-FARM and energy’s use (electric generation, electrical

consumption, purchased electrical charges, gas consumption and hot water usage) Multiple devices including energy measuring equipments are also connected with ENE-FARM. Therefore, it is convenient to have one remote control panel with multiple functions such as displaying energy information and operation system of electric generation, hot-water supply, heating the bath water and floor heating. The simple system configuration that multiple functions to operate ENE-FARM are integrated in one controller, is also useful when adding communication function with smartphones


Figure4. Remote control panel and a display example (energy monitor)

### 3.2.2. System configuration of ENE-FARM linked up with smart phone.

Figure5 shows system configuration of ENE-FARM linked up with smart phone.

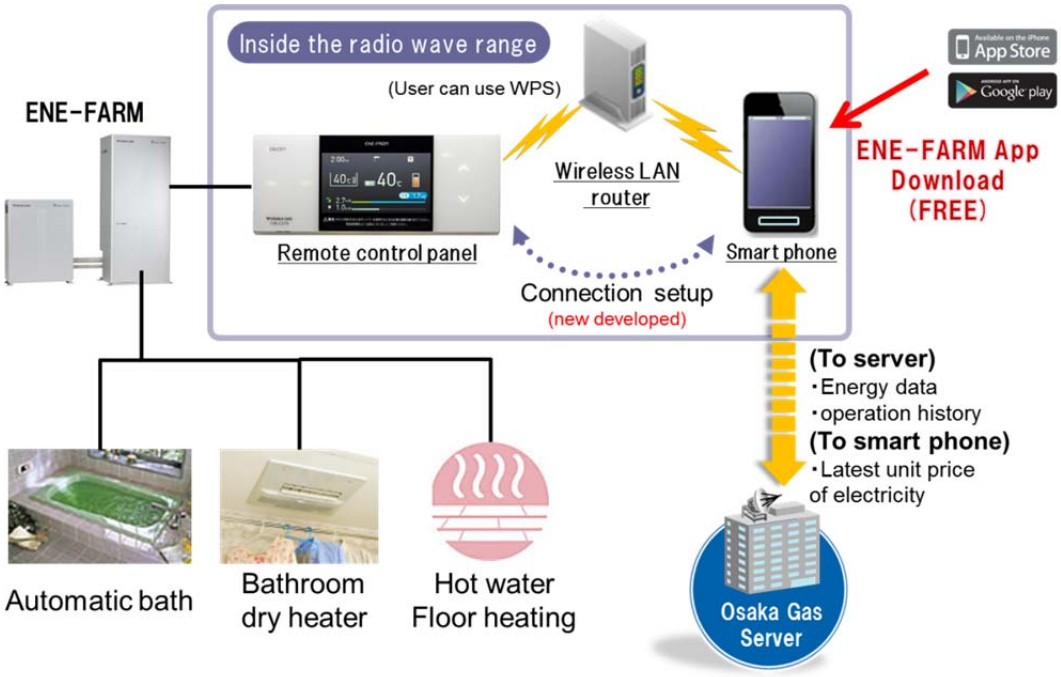


Figure5. System of ENE-FARM with networking function

When users start application, users' smartphone communicate with the kitchen remote control panel via wireless LAN router. Users can also look electric generation and control the automated bath system. Moreover, when users initiate application, smartphones send or receive information to server of Osaka Gas through the Internet.

### 3.3 Wireless communication

#### 3.3.1 radio function to control panel

We decided to equip a wireless LAN module in the kitchen remote control panel.

The reasons are as follows.

1. The fuel cell unit, the hot water storage tank unit, and many other functions are able to operate with the kitchen remote control panel. Therefore, a simple connection between the smartphone and the kitchen remote control panel enables user to access almost all functions of ENE-FARM
2. The kitchen remote control panel and wireless LAN router are both installed indoor and therefore the communication between smartphone and the remote control panel is relatively stable.

#### 3.3.2 Adoption of wireless LAN

Generally speaking, the communication methods with the smart phone include following three.

- Wireless LAN (Wi-Fi)
- Bluetooth
- NFC

We adopted wireless LAN in this case. Because, wireless LAN has longer communication range than other two methods and users seem to be able to access the ENE-FARM with their smart phones wherever they are in houses. Bluetooth or NFC can't be used unless the smartphone is used near the remote control panel.

Wireless LAN has several standards (Table1), ENE-FARM supports IEEE802.11 b, g and n.

Table1. The wireless LAN protocol

| 802.11 protocol | Frequency [GHz] | Data rate(Max) [Mbps] | ENE-FARM |
|---|---|---|---|
| b | 2.4 | 11 | ○ |
| g | 2.4 | 54 | ○ |
| a | 5 | 54 | × |
| ac | 5 | 6900 | × |
| n | 2.4/5 | 600 | ○（2.4GHz only） |

#### 3.3.3 Network configuration setup of ENE-FARM

It is users that set up for connecting the remote control panel to wireless LAN router and their smart phones. Therefore network configuration setup has to ensure sufficient security and easy for general users.

For connecting the remote control panel and wireless LAN router, we adopted WPS that Wi-Fi alliance provides. Most wireless LAN routers sold in electronic retail stores in Japan support WPS.

WPS enables users to connect the remote control panel to wireless LAN router easily. The only thing to do is to push the button of the router and the remote control panel once. Moreover, ENE-FARM adopts WPA2-AES as a wireless LAN encryption system that has high security performance.

After users connect the wireless router and the remote control panel, the smart phone is needed to be registered with the remote control panel. We developed an original process of pairing the smart phone with remote control panel, because there is no general process.

During the pairing process, users have to operate smartphone and the kitchen remote control panel at the same time. Therefore malicious third party cannot connect the remote control panel with their smart phone.

### 3.4 Application functions

(1) Visualization of energy information

The remote control panel of ENE-FARM has a function to display quantity of power generation or consumption of the energy. Users can also read information of energy on the smart phone application at hand

We decided to limit data shown in the remote control panel and the smartphone to electric information as quantity of generation and charges for purchasing electricity. The reasons are as follows:

1. The questionnaire survey showed that data above were browsed most frequently in the remote control panel.

2. It is difficult for users to understand everything if lots of information were shown rashly in the small display.

We spotlighted users' "joy of the power generation" which is one of the main solicitation points of the ENE-FARM, and made it easy for users to check the contribution of the generation by the ENE-FARM.

In addition, a relatively precise electricity bill is displayed by acquiring the power company's latest tariff from Osaka Gas's server, The former model of ENE-FARM also displayed an electric bill on the remote control panel, but users had to input electricity unit price by themselves, which made it difficult for users and they didn't see the information frequently.

(2) Operation of device

Using ENE-FARM app, users can control fully automated bath system, set a timer for filling hot water set operative temperature and timer of floor heating system. As for the floor heating, collective operation for up to six floor heating controls is possible. Users can also set floor heating

timer easily by simple operation using touch panel display. Therefore, the usability of floor heating system was improved in comparison with the existing remote control panels.

(3) Notification function

When the hot water filling, preparation for a bath mist mode, or bathroom heating cloths drying system is completed, the kitchen remote controller sends a notification to the smartphone. Thus users are able to know a situation in the bathroom even if they are in other rooms.

(4) Additional game mode for continuous use

For the purpose of application use promotion, it was equipped with a game function. With this application, users can get “bait” depending on the previous day’s amount of electricity generation by ENE-FARM, feed and bring up their characters. Recently “Gamification” that is the concept of applying game design techniques to motivate people to achieve their goals is adopted positively. In our application, we adopt this gamification and motivate users to use this application continuously

Some screen examples of the application is shown below.


Figure6. Display example of ENE-FARM App

ENE-FARM application supports two major operating systems of smartphones, iOS by Apple and Android by Google.

The following shows applicable versions.

iOS: version 6.1.3 or above

Android: version 4.0 or above

### 3.5 Cooperation with server

From the server in Osaka Gas, ENE-FARM app acquires a latest tariff of utilities that is needed for displaying the accurate energy bills and weather information used for the game function.

The remote control panel sends energy information at users’ houses and operation history to the server while smart phone application is activated. Information sent from ENE-FARM is used

for improving our services.

Especially, improvement of maintenance time and cost are important issues of ENE-FARM. In the case of trouble, it is needed time for cause investigation because ENE-FARM has a complicated system. And, in the scheme of fuel cell, it is needed hours for start or stop power generation. Therefore, not only the time burden on users is long, but also our maintenance costs are apt to increase.

In the future, using network function, we correct data from various sensors in ENE-FARM and usage history in case of trouble in order to try to specify failure cause in advance,. We think that this will be efficient to conduct ENE-FARM maintenance.

## 4. Conclusion

ENE-FARM provides new value for users with functions that are cooperated with the smart phone. Moreover, we acquire many kinds of data including energy related data, and took our first step to provide new information services to our customers.

Firstly, we are going to expand our sales of ENE-FARM for much more customers and increase ENE-FARM app users while improving the cooperation function with the smartphone and network.

We will continuously make an effort to add more values to ENE-FARM by developing new network functions, which will lead us to play a big role of energy saving and CO2 reduction in houses.

## 5. List of tables



## 6. List of figures