Case Study: Smart Community Demonstration Project in Greater Manchester, UK

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1. Introduction

During the period between 2014 and 2016, there had been a smart community demonstration project held as a UK-Japan joint project in Manchester, U.K. The main objective was to confirm the validity and feasibility of an aggregation business that creates load adjustment power by controlling residential power consumption using Japanese ICT in the UK, which is an advanced country in terms of efforts including introduction of renewable energy to realize low-carbon societies.

This demonstration was conducted as an "International Energy Consumption Efficiency Demonstration Project of Technology and System" as well as an "Overseas Smart Community Demonstration Project" of NEDO. Under a cooperation agreement to promote the demonstration concluded between the Greater Manchester Combined Authority (GMCA) and NEDO, the project was carried out jointly by local players including housing corporation and universities and the Japan Consortium consisted of NEDO, Hitachi, Daikin Industries and Mizuho Bank. (Figure 1)

The project included introduction of heat pump (HP) technology to insulated public housing, provision of demand response (DR) technology in consideration of residents' living environment and development of an aggregation system that responds to electricity market in the UK followed by the verification of the effects, providing important suggestions during the process.

This case study summarizes the implications of smart community related technologies obtained from and the social significance of the demonstration.

2. UK's approach to reducing carbon

The UK lead the world in low carbon trend by enacting "The Climate Change Act" in 2008 and declaring to reduce greenhouse gas emissions by 80% of 1990 levels by 2050. The UK emissions were 42% below 1990 levels in 2016. Its approach has become a role model for countries struggling to tackle climate change.

Promoting carbon emissions reduction from heating is what is considered as the next area of focus. In the UK where climate is severe in winter, about one third of the total UK greenhouse gas emissions come from the heating in the domestic and commercial sectors. The main heat source is gas boilers, which are used for heating and hot water supply for residential customers, accounting for about 40% of the total UK gas consumption. In order to achieve the 2050 target, it is being considered to replace these gas-powered boilers/heating systems with electrified appliances such as heat pump. In 2014, "Renewable Heat Incentive (RHI)" was launched for the domestic sector to provide government's support including subsidies for the introduction of renewable heating systems e.g. biomass boilers, heat pumps and solar panels.

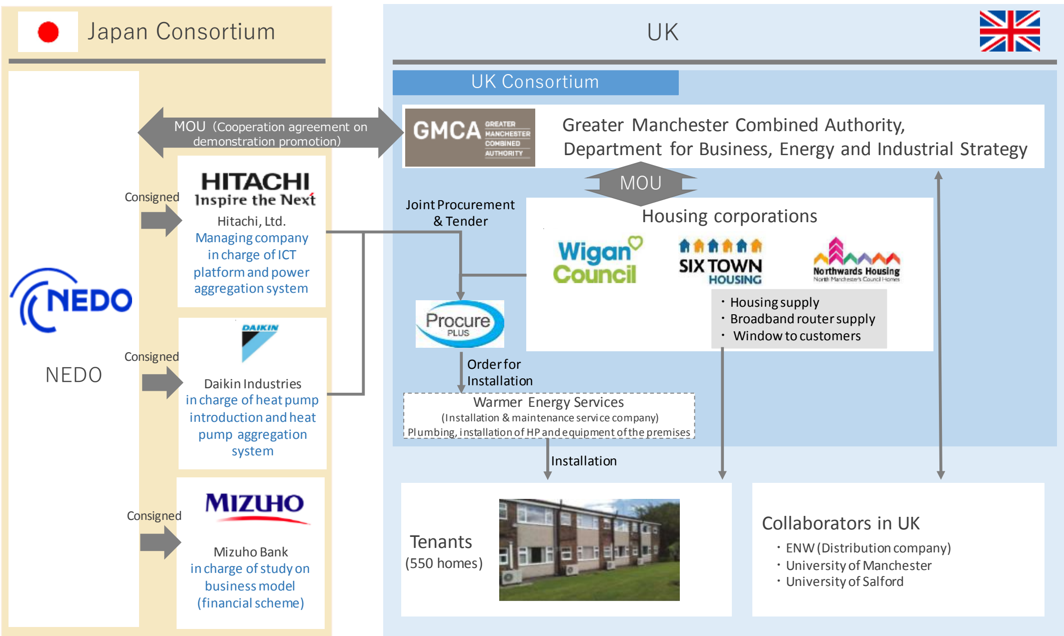

Figure 1 Overall structure of the demonstration

In this demonstration, carbon reduction was realized by replacing the gas boilers/heating systems of public housing with HPs, which however resulted in an increase of power consumption in the domestic sector. Especially during the morning and evening hours when power consumption of HPs is high in winter, the demand for electric power peaked, raising concerns of imposing strains on electric transmission and distribution network. In future, further electrification is expected such as the spread of EVs. Therefore, the shifting and leveling of power demand during peak hours when greater load is placed due to electrification is viewed as an important issue that needs to be discussed to meet the carbon reduction target.

3. Demonstration overview

The demonstration was conducted in three areas of Greater Manchester: Manchester, Bury and Wigan. (Figure 2)

Figure 2 Demonstration sites in Greater Manchester

Under the UK energy policy, efforts to reduce carbon emissions in hot water supply and heating energy in the domestic sector are underway in Greater Manchester. Replacement of gas boilers by HP is now in full gear backed by the government subsidies and mandates to promote the efforts to local government and industry. On the other hand, measures against an increase in and an over-emphasis on electric power load that would be posed by the spread of HP have emerged as a new issue. For that reason, more and more attention is being paid to DR service for enhanced balancing of supply and demand, aggregation of electricity demand on customer side and electricity aggregation that implements collective energy trading and operation.

With such background, the demonstration was conducted based on the following three themes (Figure 3):

- Theme 1: Demonstration of HP introduction
- Theme 2: Demonstration of aggregation system
- Theme 3: Development of business model

Theme 1 aimed to introduce multiple types of HP systems to 550 homes that took part in the trials, have them use the system for a long term and provide them with sufficient maintenance and repair services, in order to demonstrate the validity of HP. In the UK where HP is not yet well known at the current moment, there are various issues and constraints such as the regional difference in the structure of target houses and the power capacity and resident's awareness about HP. Based on these conditions, the demonstration was carried out through development and operation of a system to introduce HP systematically

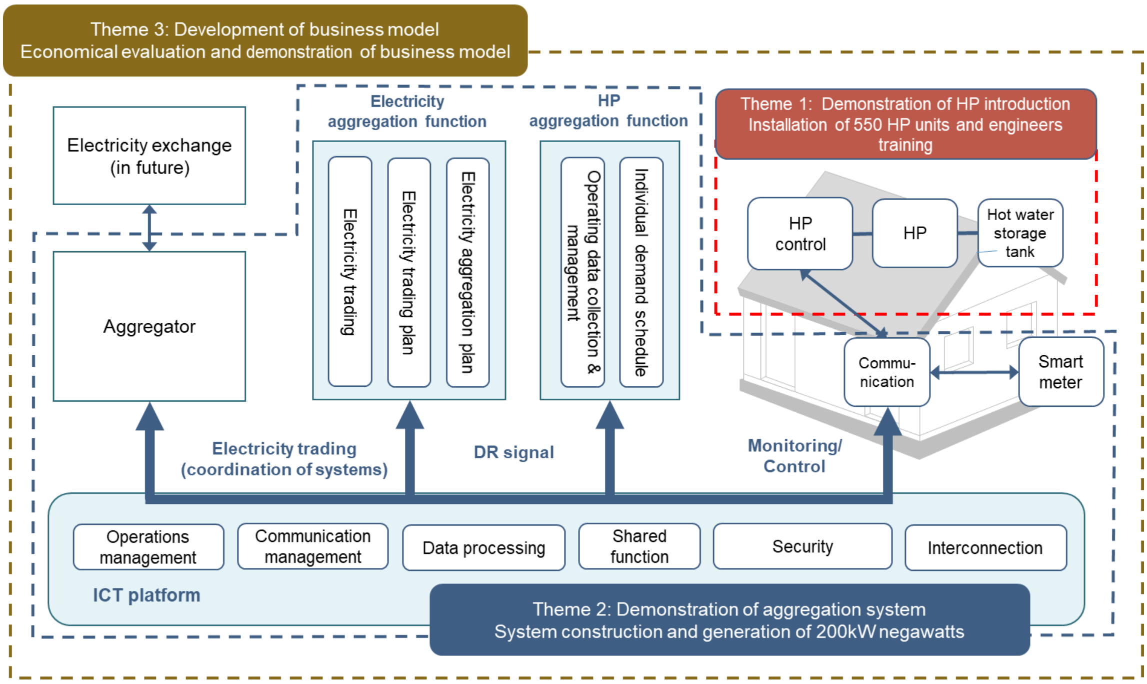

Figure 3 Whole picture of the demonstration

and fostering engineers with skills to install different types of HPs, giving consideration to the spread of HP after the project.

For Theme 2, electricity aggregation system that takes account of trading in the UK electricity markets was constructed in addition to the HP aggregation system to perform centralized control of 550 HPs introduced under Theme 1, demonstrating that load adjustment power obtained from controlling and aggregating small customer's HPs can be provided as available supply-demand balancing capacity in the UK electricity market.

Specifically, whether the load balancing power by aggregation can be operated to the extent that it meets the electricity market's trade requirements or not was confirmed by the actual data collected from aggregated 550 HPs for each of the use cases (1 to 7) assumed in actual operation.

Upon understanding the situation and characteristics of the UK electricity market, evaluation and determination of possible business models to commercialize small aggregation business demonstrated in Themes 1 and 2 and simulation of operating revenue for each model were conducted under Theme 3.

In the following chapters, implementation contents, demonstration results and accomplishment are summarized.

4. Theme 1: Demonstration of HP introduction

In Theme 1, it was able to clarify the issue of actually introducing HPs to social housing properties in three areas in Greater Manchester and obtain valuable implications for full-scale popularization of HP.

Introduction of HP was implemented in partnership with three housing corporations: Wigan Council (hereinafter, "WALH"), Northwards Housing (hereinafter, "HWH") and Six Town Housing (hereinafter "STH"). (Table 1)

Table 1 Housing corporations and their assigned area and the number of HP units installed

Housing corporation	Area	Number of HPs
WALH	Wigan	307
NWH	Manchester	153
STH	Bury	90

4.1. Structure of HP system

A total of 550 HP units, 10 from Hitachi Air Conditioning Europe and 540 from Daikin Industries, were used in the demonstration. All the Hitachi's units were LT Split type that separates the heat source and the refrigerant/boiler heat exchange unit. HPs provided by Daikin included 231 units of LT Split type, 169 of Monoblock type that integrates heat source and heat exchange units, 117 Gas Hybrid type that uses HP in combination with gas and 23 of those with heat storage tank added to each of the types.

Each of the social housing was installed with heater radiator, broadband router (hereinafter BBR), DR controller, etc. in addition to the HP system consisted of outdoor unit, heat exchanger, etc. (Figure 4)

When DR is activated, control signal is sent from HP aggregation server to DR controller over broadband lines to operate ON/OFF of the HP.

In addition to the configuration shown in Figure 4, in practice, special equipment known as a home gateway (hereinafter, "HGW") which monitors and transmits the home's power consumption status to ICT Platform (hereinafter, "ICT-PF") server and a smart meter will also be installed.

4.2. Installation/construction of HP

For the HP installation work, Warmer Energy Services (hereinafter,

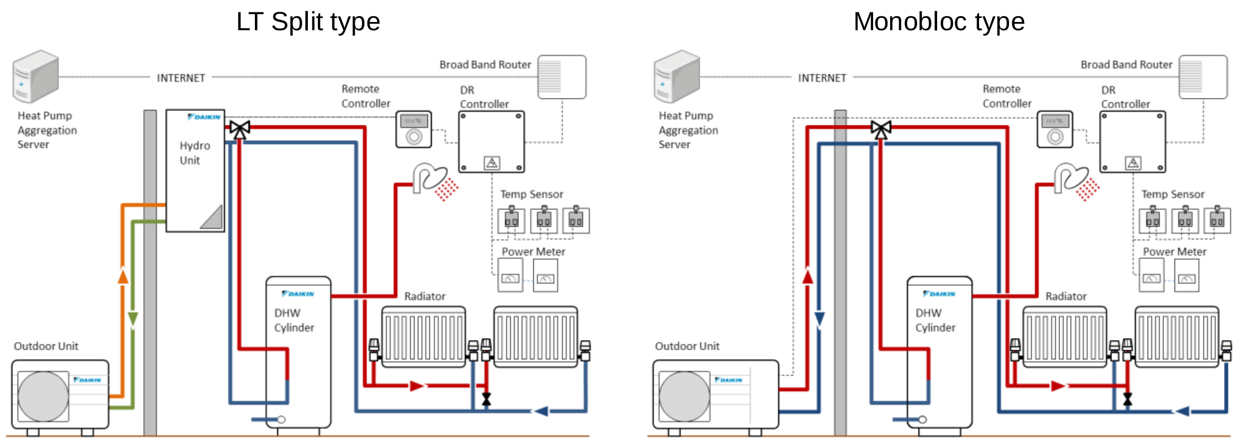

Figure 4 System configuration for LT Split type / Monoblock type

"WES") was selected as a construction company as a result of bidding based on the EU directives for public projects.

Daikin UK provided WES with training on the installation and commissioning of HP. A total of 35 engineers took the training consisted of 9 lessons in a classroom or a training room. (Figure 5) There are not enough engineers who can install HP in the UK where HP has not been fully popularized yet. In this sense, it is considered as a great achievement that as many as 35 engineers received training not only for the demonstration but also for the future deployment of HP.

Figure 5　Training of engineers at Daikin UK Office

It was housing corporations that served as the window for the selection of target homes and negotiation with tenants. Having good communication with tenants was extremely important for the negotiation. Because most of the tenants did not have previous knowledge, they spent enough time and visited the residents a number of times to explain the purpose and significance of the demonstration. Figure 6 shows a descriptive brochure used by a housing corporation.

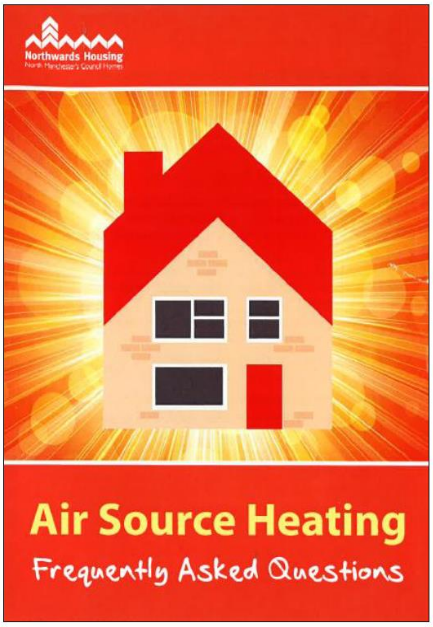

Figure 6　Descriptive brochure prepared by NWH

Despite these activities, it was very difficult to attract project participants because of a lack of understanding of tenants about HP and DR. Eventually, 550 homes that can provide sufficient DR results agreed to take part in the project thanks to the support by Daikin UK engineers, etc. Ingenious attempt and knowhow of communicating with tenants are detailed later in the Key Findings section.

For the housing properties of the tenant who agreed to be part of the trial, a field survey was conducted to know the insulation property, number of rooms, volumetric capacity, number of residents, etc. to design the appropriate capacity of a heating equipment. As it was necessary to properly confirm the heating effect of HP, HP was implemented only to the housing properties that maintained a certain level of insulation efficiency.

Based on the design resulted from the field survey, equipment was supplied by Hitachi and Daikin Industries and the installation started. (Figure 7)

Figure 7　Installation of outdoor unit

It was planned to spend 2 to 3 days per house to install the equipment. After the installation by WES, commissioning by Daikin Industries was performed to complete the introduction. Although there were unfavorable cases occurred (e.g. cancellation incurred due to unexpected circumstances, installation did not complete by the due date; defective work was found in the commissioning stage, etc.) from time to time, the 550 HP units were finally installed safely.

～ Key Findings ～

Case Study of HP introduction in UK

Because it was the first case where HP was introduced on a large scale in the UK, various awareness was raised and lessons were learnt throughout the demonstration in which 550 HPs were installed.

First, it was realized how important it was to share information with DNOs (Distribution Network Operators). Although the tenants' consent to participate in the demonstration was gained, some houses were found inappropriate for the project because of the concern for security with distribution network, which was a result of prior checking with Electricity North West (hereinafter, "ENW"), the DNO of Manchester. Importance of collaboration with DNO can be seen in the comment by Mr. Hiroei Mikami of Daikin Industries.

Comment by Mr. Hiroei Mikami, Daikin Industries
The DNO was concerned about the capacity of distribution network being tight if the number of HP installation increases in the short

term. After repeating investigations on this matter on both sides based on the characteristics of HP equipment, ENW decided to cooperate on a preferential basis in the introduction of HP in this project. But still, we were concerned with an occurrence of a possible problem like blackout because of the installation of so many HPs in a specific area, so we installed all of the 550 HPs after getting 'permission.' Similar interests must be found in other areas, but I believe such an in-depth communication with ENW in this project will certainly serve as a first step forward for the promoting the widespread use of HPs in the UK.

The second lesson was the adoption of technology adapted to resident's living. Wired internet line was used in the project for the collection of power consumption data and the control of HPs, but there were incidents like LAN cable unplugged by tenant and BBR's power turned off. One reason is that elderly people were particularly not familiar with the operation of BBR and LAN cables. Therefore, for those who repeatedly unplugged the cable despite cautions, a LAN connector with removal prevention function was adopted. Demonstration of smart city or DR often generates much interest focusing on the introduction of state-of-the-art technology. In order to actually implement it to the site, however, it was found that the ingenuity and technology appropriate to the living of tenants as mentioned above were necessary. Mr. Mark Atherton of GMCA mentioned as follows:

Comment by Mark Atherton, GMCA

High-tech is not the only thing that is necessary for the services for the domestic sector. For example, there were instances that a resident unplugged LAN cable, but for them, especially the elderly, it is the habit to pull out all the wiring before they go to bed, which is hard to change. In such a case, it is important to adopt a LAN connector that is technically hard to pull out in addition to persuade the tenants. Thus, it was observed that the combination of the advanced technology and the technology that supports resident's periphery was important, and that the service must be designed appropriately so that technology and residents do not disturb each other.

Thirdly, the importance of persuading and educating the residents was recognized. As mentioned above, DR and HP are not familiar for many tenants, therefore it was hard to have them understand the purpose of the demonstration and agree on the participation. Because the method of using HP differed greatly from conventional gas boilers, even those who had participated in the trial before could not understand the proper way of using the equipment and repeated the switching on and off, resulting in insufficient heating performance and higher energy bills. Figure 8 shows the result of customer satisfaction survey on the HP system by installation period. There is a tendency that tenants who set up HP system earlier is more satisfied with the system. This indicates that a certain amount of time is required to have people develop a better understanding about and learned an appropriate method for using HP.

Raised from the residents who acquired the proper method of using HP were some positive opinions on HP such as savings on utility costs, enhanced comfort, etc. The comment by Deborah Stevens (Figure 9) who is introduced in the case study prepared by Daikin UK was very impressive therefore introduced below. By installing Daikin Industries' gas hybrid type HP and solar panels to the house, she was able to cut her monthly gas bill by more than half while maintaining comfort.

Comment by Ms. Deborah Stevens

I wanted my house to be always warm so I wasn't prepared to sacrifice comfort for cost. I was shocked how much I have saved. I knew nothing about renewables or HP beforehand. Now I can tell all my neighbors, friends and family about them and their benefits.

Figure 9 Ms. Deborah Stevens

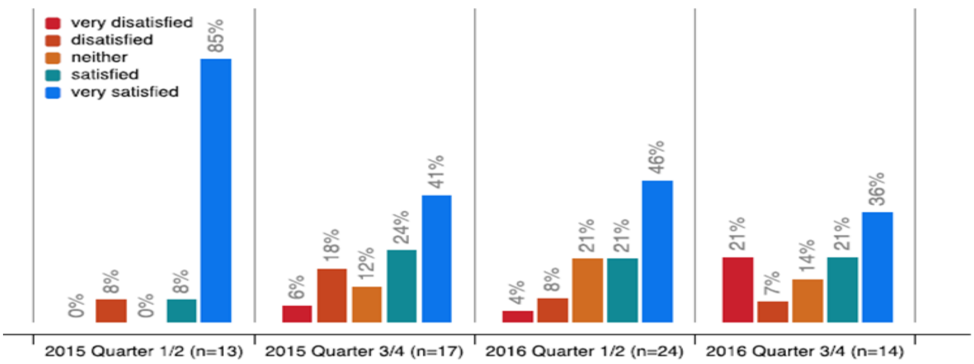

Figure 8 Tenants' satisfaction level with HP system by installation period

As described above, this demonstration provided an opportunity for valuable simulation to promote a full-fledged spread of HP in the UK. Mr. Elliot Simm of NWH commented on expectations for future HP penetration as follows:

> ***Comment by Mr. Elliot Simm***
> *It's certainly be a lot of hard work but produced a great result. The next step will be to showcase the results and feedback of the project and highlight the benefits to tenants. With the right data and feedback, it will allow us and other housing associations to push for more heat pump installations in other regions in future.*

5. Theme 2: Demonstration of aggregation system

Under Theme 2, HP aggregation system that integrates and control 550 HP units introduced under Theme 1 (of which 10 HP units by Hitachi Air Conditioning Europe were controlled through HEMS aggregation system), an electricity aggregation system that deals with electricity market, etc. with aggregated load adjusting power and an ICT-PF serving as the overall basis for running each system were constructed. (Figure 10) In addition, seven use cases assumed for actual operation were verified as to whether load adjustment power can be provided at a tradable level.

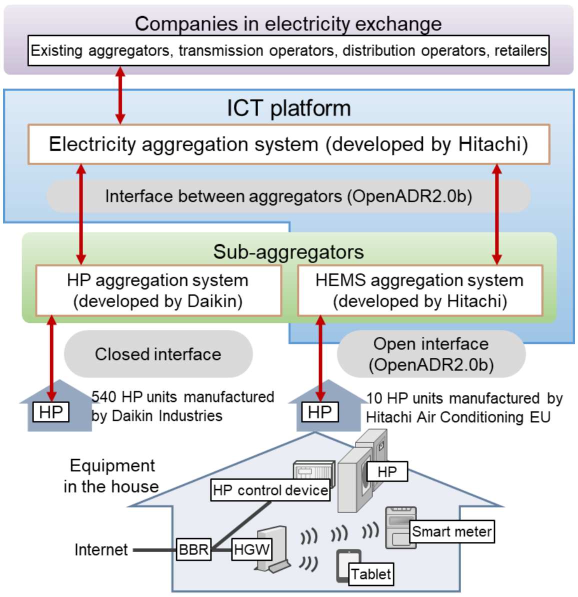

Figure 10 Overall picture of aggregation system

5.1. Building aggregation system

Regarding the development of aggregation systems, Daikin Industries took charge of HP aggregation system and Hitachi other systems. The two companies carried out the actual work while sharing information. The DR's de-facto protocol of OpenADR 2.0b, which is also used in Japan, was used for the communication between systems. The systems are designed with the specifications assuming actual operation after the demonstration, including, for instance, compliance to General Date Protection Regulation (GDRP), the personal information protection regulation of the UK; addressing the specifics of connection with actual electricity market and aggregators; and enabling the system operation even when 9,000 HP units were connected given a possible future increase of HP introduction.

A single HP unit repeats ON-OFF action intermittently, but when multiple units are controlled in an integrated manner (aggregated) by an HP aggregation system, they were collectively confirmed to be effective as a stable DR resource. As shown in Figure 11, power consumption can be curbed through DR by aggregation at two peak periods in the morning and evening.

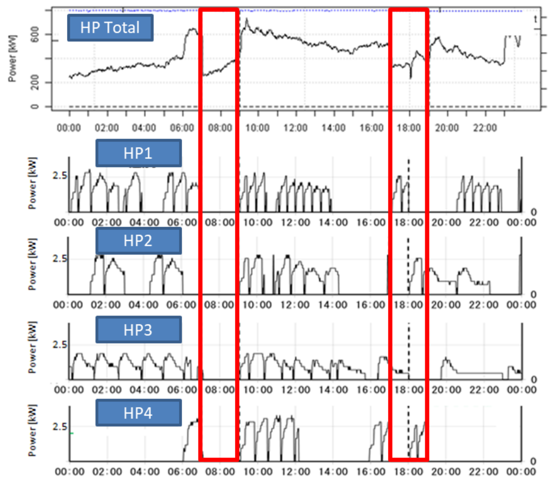

Figure 11 Image of the effect of aggregation

5.2. Use case of electricity aggregation

In the demonstration of electricity aggregation in which load adjustment power is traded at electricity market, etc., seven use cases shown in Figure 12 were examined if each can supply load adjustment power at a tradable level. Here, activities involved are cooperation and collaboration with the client and existing aggregator Flexitricity and demonstration of simulated trade for the trade with electricity market, etc. that were not linked this time.

For the use cases 1 to 7, PC which is commercially used by Flexitricity was brought in to connect with the system under the same circumstances as the actual condition. In the use cases 4 to 7, an emulator was developed to test pseudo-connection. In every use case, the objective was to check the connection as a demonstrative experiment, containing no actual deals that produce money transaction. It was confirmed that the DR volume, response time and duration had met the regulations of actual transaction in the system connection test with Flexitricity.

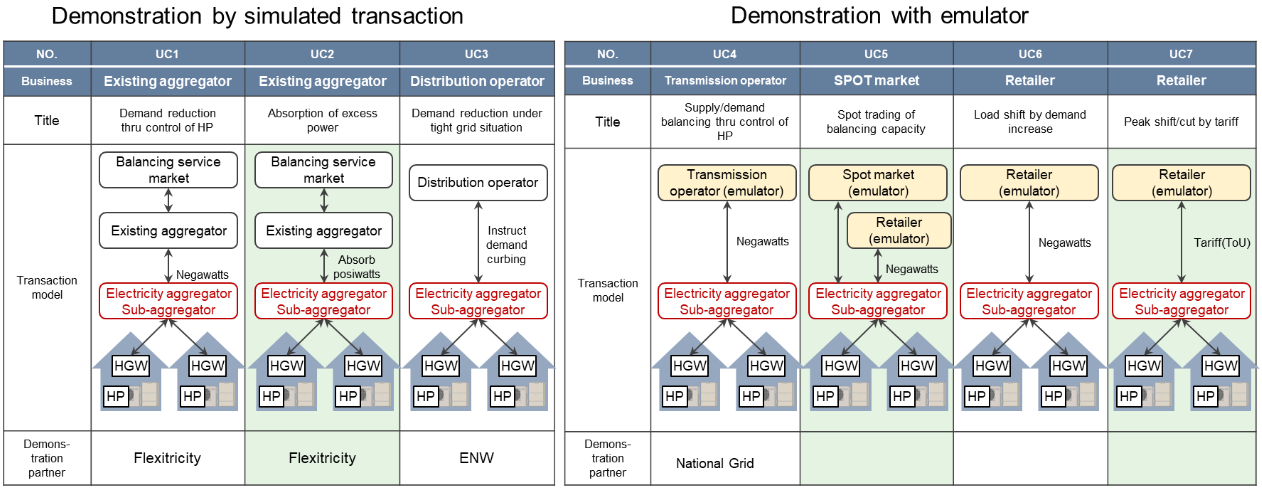

Figure 12　Electricity Aggregation Use Cases (UCs)

5.3.　Result of electricity aggregation

DR demonstration by electricity aggregation system was conducted 299 times in total for 7 use cases during 18-month period between October 2015 and March 2017. Assessment of each use case is summarized in Table 2.

Table 1　Assessment of each use case

UC	Indicator	Target	Assessment	Note
1	DR volume	200kW	○	More than 200kw of DR is achieved in 144 cases. Response and duration times are achieved in all cases, which are less than 6 min and more than 30 min respectively.
	Response time	12min	○	
	Duration	30min	○	
2	DR volume	(100kW)	△	Response and duration times are achieved in all cases. 100kW of DR volume is achieved in 26 cases. However, these cases have a problem in control method due to the bias in time distribution.
	Response time	(12min)	○	
	Duration	(60min)	○	
3	DR volume	(200kW)	○	More than 200kW of DR is achieved in 144 cases. 60 min of duration time is achieved in 92%, which is at practical level. 60sec of response time (required by DNO) is achieved only in 7 cases.
	Response time	(60sec)	△	
	Duration	(60min)	○	
4	DR volume	(200kW)	○	More than 200kW of DR is achieved in 144 cases. Since the actual transaction requirement is more than 3MW, it could be achieved with increasing number of households.
	Response time	10min	○	
	Duration	(60min)	○	
5・6	DR volume	(200kW)	○	More than 200kW of DR is achieved in 65 cases. 12min of response time is achieved in all cases. 120min of duration time is achieved only in 24%.
	Response time	12min	○	
	Duration	(120min)	△	
7	Shift time	(more than 60min)	○	Reduction of the operation hours of HP and more than 350Wh/house of shift volume are achieved. Cost differences are negative in all time zones, indicating that the cost is reduced with the peak shift.
	Shift volume	(350Wh/house)	○	
	Cost difference	Negative value	○	

Initial target indicators (DR volume, response time and duration) were achieved at least once in all use cases. In particular, the reference DR volume of 200kW was achieved 144 times in use case 1, which is regarded promising as the first business model.

The overall average response time was about 2.3 minutes, which was a noteworthy achievement as a DR case that controlled small demand of 550 residents. This clearly meets 12 minutes, the transaction requirement in use case 1, and is considered to be sufficiently available for actual transactions. For use case 3, further improvement is needed because DNO requires the response time to be within 60 seconds, however, discussion with DNO on whether 60 seconds is appropriate or not for response time will be necessary.

Regarding duration, 100% of cases achieved 30 minutes, about 92% achieved 60 minutes, and about 8% achieved 120 minutes, indicating realistic duration for transaction in actual operation is within 60 minutes. (Figure 13)

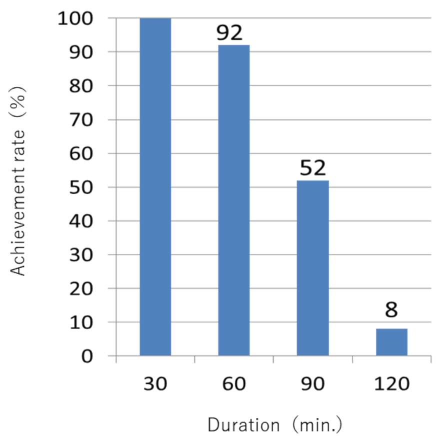

Figure 13　Achievement rate by duration

～ Key Findings ～

Development of aggregation system corresponding to actual power trading

One of the significant results of the demonstration is that DR effects that meet the requirements of actual power trading were achieved by installing small resources like HP to 550 houses and controlling them in an integrated manner. The results were reported in a debrief session held in Manchester in November 2017 by Mr. Hiroei Mikami of Daikin Industries and Mr. Takahiro Tsukishima of Hitachi, who made presentation using actual DR data.

Comment by Mr. Hiroei Mikami & Takahiro Tsukishima

We were able to identify a clear reduction of power consumption on a chart (Figure 11). It was quite unusual that a DR effect was made explicit this much. Having achieved not only the target volume of 200kW stably but also met the National Grid requirement for response time by realizing 2 to 3 minutes on average, we can say that we are at a feasible level for actual power trading.

Another achievement is that information which would be useful in the actual operation phase e.g. technical information including connection specifications, maintenance and operation knowhow, etc. could be obtained by connecting the equipment which will be used by Flexitricity (existing aggregator) in actual transaction with the aggregation system as a simulation of actual power trading.

This demonstration was designed in consideration of international standardization, providing communication framework based on OpenADR2.0b as the communication standard between aggregation systems and with clients. The use cases received a high valuation as they correspond to commercial trading in the UK, and can be considered to contribute to international standardization that have been discussed at SGTEC (Technical Committee for commercialization of Smart Grid for demand facilities), IEC (International Electrotechnical Commission), etc.

DR Control without imposing stress on residents

The aggregation system has a distinctive feature - Fail Safe function which is designed not to make a sudden drop of the room temperature by DR control. Specifically, when the room temperature is lowered by 2℃from the start of DR control the system automatically breaks away from DR (OptOut). If the room temperature is less than 18℃at the start of DR control the system will not perform DR control (i.e. withdraw from DR with the DR event start), and when the system is remotely controlled by a tenant, it will break away from DR and prioritize the remote control operation. Here is a comment by Mr. Takahiro Tsukishima of Hitachi, ltd. on the effect of this function.

Comment by Mr. Takahiro Tsukishima

Thanks to the function which enables an automatic break-away from DR, about 90% of the tenants did not even realize that DR was performed. A total percentage of break-away was about 10%, mostly caused by automatic safety stops due to low outside temperature. There were few cases that a tenant voluntarily withdrew from DR.

Tenants can break away from DR control using remote control, and in houses equipped with HEMS they can restart HP by operating a display screen on the tablet (Figure 14).

Figure 14　Display screen for Opt-Out from DR control

Figure 15 shows a transition in the number of break-aways from DR event conducted in the morning of January 27, 2017. There were 364 participants at the event start, but ended with 151 withdrawals during 120 minutes of duration. Most of them were automatic Opt-Outs by Fail Safe function. A break-away occurred within 5 minutes after the DR event start is likely to be an automatic Opt-Out which is triggered by outside temperature being below 18℃.

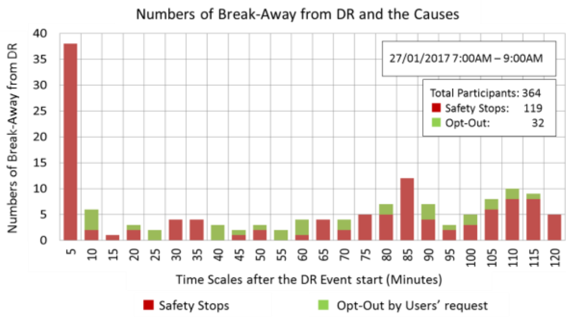

Figure 15　Nos of Break-Away from DR in the morning of Jan. 27, 2017

Thus, by providing the Fail-Safe function linked with the temperature, the stress generated by a DR event on tenants can be reduced. Mr. Mark Atherton of GMCA believes the Fail-Safe function is a major factor that DR had high tenant satisfaction.

Comment by Mark Aterton

I realized that the tenants who understood the purpose of DR, did not try to operate the controller by him/herself and could leave the control up to the system had higher satisfaction with DR. Another reason for high tenant satisfaction was that the tenants had the right to break away from DR by his/her own choice and not only being controlled.

The system may automatically break away from DR event when the room temperature drops. About 70% of tenants were completely unaware of DR event during the demonstration period (Figure 16). There were concerns among tenants about DR before the demonstration. However, in practice, Demand Response applicable in actual power trading could be demonstrated successfully without imposing too much stress on tenants, thanks to the effective Fail-Safe function. This brought about substantial results for the demonstration.

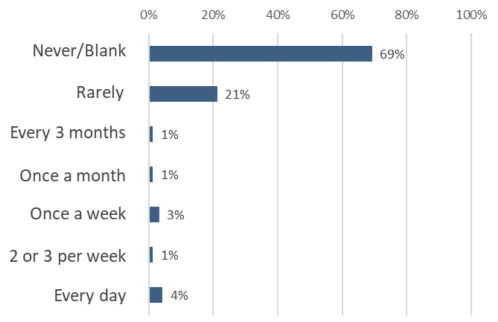

Figure 16　Frequency that tenants notice DR event

6. Theme 3: Development of business model

Theme 3 covered the evaluation and examination of business profitability performed by reflecting the data obtained in actual operation of HP and DR under Themes 1 and 2 in the economical evaluation included in the feasibility study that was carried out beforehand, led by Mizuho Bank who played a central role for this theme. Upon understanding the situation and characteristics of UK electricity market, the evaluation and determination of possible business models (including responsible entity, finance scheme, etc.) to commercialize small aggregation business demonstrated under Themes 1 and 2 and the simulation of operating revenue, etc. for each model were conducted under Theme 3.

6.1. Study on the spread of HP

The biggest challenge for the widespread use of HP is expensive introduction cost. Together with equipment/installation costs, the required cost becomes two or three times greater than that of conventional gas boilers (GB), bringing about delay in the diffusion of HP.

In order to evaluate the introduction cost of HP, it is necessary to consider the subsidy provided under Renewable Heat Incentive (RHI) program intended to encourage a shift to renewable heat system in the domestic sector. The cost of introducing HP was still higher than that of GB including RHI subsidy until recently, but with RHI's purchase price of renewable heat increased by about 33% in April 2017, it was found that, for electric type HP, one can recover the difference from the GP introduction cost in a total amount of seven years with subsidy (Figure 17). Gas hybrid type HP has less purchase volume compared with electric type HP, therefore, even with the new renewable heat purchase price, the introduction cost of gas hybrid HP will become higher than that of GB by about 1,000GBP.

This provisional calculation does not include the effect of reducing energy bill through introduction of HP. About 60% of tenants said that they could make savings.

A major reduction in equipment/installation costs cannot be expected when the number of HP installed is not so big, therefore it is necessary to provide political approach including RHI to popularize HP. With RHI closing application in 2020, extension of RHI and creation of other supportive measures will be essential for continued widespread deployment of HP.

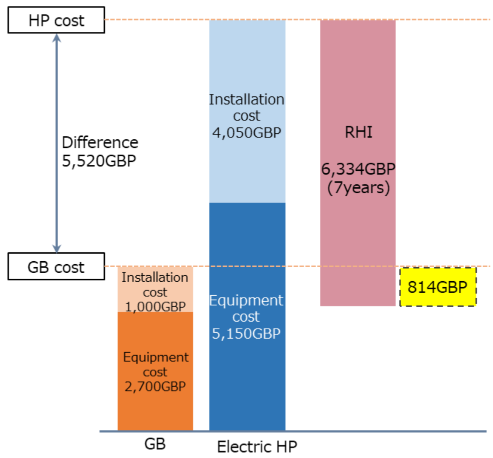

Figure 17　Comparison of introduction cost with gas boiler (Electric HP)

6.2. Study on DR aggregation business for the domestic sector

With an objective of reducing the grid load associated with expanded introduction of renewable energy, the DR-based power trading is already being implemented in the UK. According to aggregators and electricity retailers, the DR market is expected to grow further. On the other hand, current DR resources are present in the industrial and business sectors, and DR for the domestic sector's small resources such as HP are considered to take more years to reach commercialization in terms of economy. For that reason, when considering further spread of DR aggregation business for the domestic sector, it is important to pay close attention to the penetration of DR for the industrial and business sectors as well as the trend of energy related services for the domestic sector.

Looking at the sectoral breakdown of electric consumption in the UK winter peak hours (15:00-19:00), domestic sector accounts for almost half (Figure 18). This implies a big potential of DR for the domestic sector. As identified in this study, there are challenges in the briefing session, awareness raising and follow-up for tenants in addition to the issues of installation costs of aggregation related equipment necessary for the development the DR aggregation business for the domestic sector. In practice, it is essential to collaborate with local partners including local governments and accumulate the knowhow starting with a small area. It is also effective to consider the proposed electricity market reform to increase the trading volume of small DR resources, for instance, lowering the minimum trading volume (currently 3MW) of Short Term Operating Reserve (STOR).

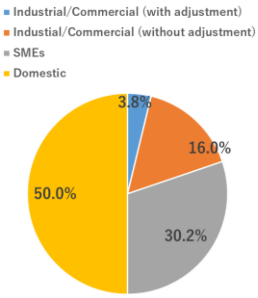

Figure 18 Sectoral breakdown of electric consumption in winter peak hours (2010)

6.3. Overall evaluation of the business model

Regarding the timing of introducing DR aggregation business for the domestic sector, many of the aggregators, electricity retailers, etc. who were interviewed said that a proposed target could be around 2020 when the installation of residential smart meters is expected to complete. In considering the development steps of the business, therefore, it is assumed to start from DR aggregation of public housing and facilities where it is easier to acquire customers and expand to general households. For the use cases besides UC1 and UC4 (STOR only), it is considered difficult to discuss about the possibility based on the results of demonstration of electricity aggregation and interview with persons involved. For this reason, the balance of payments model of the above two UCs was adopted as the basic data in the economic evaluation.

Figure 19 shows the revenue forecast based on this introduction scenario. The key to establish aggregation business for residential HP is to incorporate many HPs in the DR program. The number of household that can introduce HP would be limited with an area of Greater Manchester (GM) only. In order to secure the break-even point of 55,000 to 60,000 HPs, it is found to be useful to expand the business to areas outside GM and increase potential households to install HP to move into the black as soon as possible. Based on this estimate, a single-year profit can be achieved by 2025.

As discussed so far, it is assumed to launch the business in GM first in close cooperation with GMCA and other local governments, and deal with upper level aggregators and National Grid (STOR market) with New Co. to be built as the primary entity to implement DR aggregation business for residential customers.

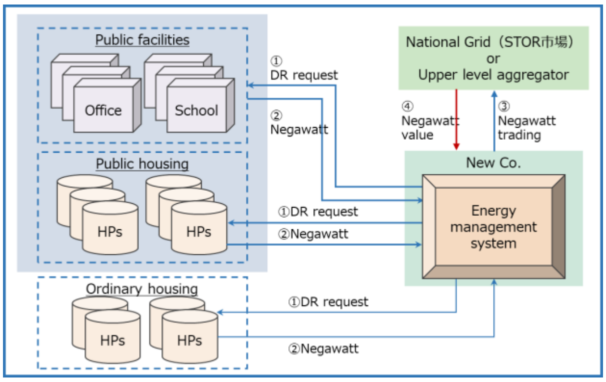

Figure 20 Overview of business model

Participation of public housing and facilities in DR program should be based on the collaboration with the local government, and it is also important to promote the business and relationship-building with ordinary housing together with the local government. Because of a public goal to help reducing GHGs in the longer term, it is inferred that a clarification of involvement in the business is desirable also for the local government. This leads to a possible joint investment with the local government in the foundation of New Co.

Another significant point in assessing the business model is the dissemination speed of HP. In the calculation shown in Figure 19, the HP introduction cost is assumed to be covered by general households, therefore not included in the result. With the current introduction cost, HP will not be popularized unless there is a subsidy (RHI) as shown in Figure 17. In order to secure more than 55,000 to 60,000 units of HP participating in the DR program, the spread of HP itself must be accelerated. Therefore, continuation of HP introduction incentive program equivalent to RHI even after 2020 would be a key milestone.

Category		Precondition
Participating HP	Social housing in GM	About 15% (about 40,000 housings) out of 260,000 social housing in GM introduce HPs by 2030. All introduced HPs participate in DR and acquire 100% share.
	Ordinary housing in GM	20% of all ordinary housing introduce HPs by 2030, 30% of which participate in DR and achieve 50% share.
	Throughout the UK	About 8.5%(2.3 million houses) of all houses will introduce HPs by 2030, 30% of which will participate in DR and acquire 30 % share.
Electricity trading	Availability	365times/year, 2h/time, ￡0.00387/kWh
	Utilization	Winter: 155 times/year, 1.7h/time, ￡0.16978/kWh Other seasons: 98 times/year, 1.5h/time, ￡0.16978kWh

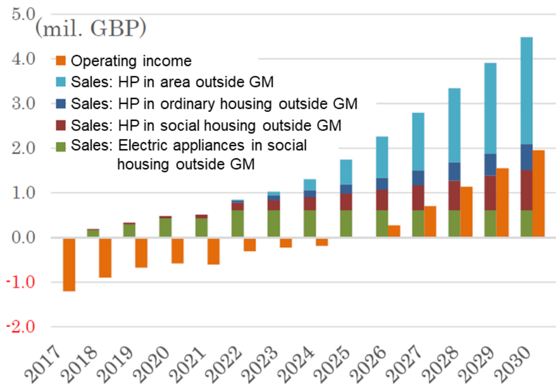

Figure 19 Revenue forecast of DR aggregation business for domestic sector

～ Key Findings ～

Challenge in DR aggregation business for the domestic sector

The results of the study on the business model indicated that the DR aggregation business for the domestic sector would get into full swing after 2020. In the process of acquiring and analyzing actual aggregation related data and identifying the needs of aggregators, electricity retailers, etc., various challenges facing the embodiment of the DR aggregation business for the domestic sector were clarified.

The first challenge is the expansion of DR resource. A model to forecast the DR volume obtained by HP was developed in the demonstration, which included a simulation resulted in a revenue decrease due to reduced DR volume especially in summer time (Figure 21). It is therefore considered beneficial to promote the diversification of DR resource to advance the business.

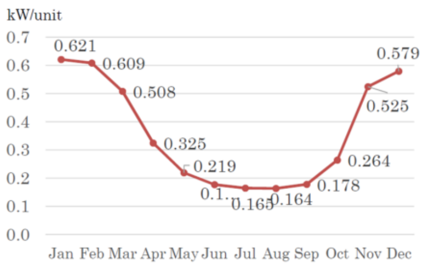

Figure 21 DR volume obtained from a HP (estimated figure)

Promising DR resources are storage battery and EV. Batteries have been attracting attention in combination with residential PV system and some operators are trying to do aggregation business with batteries as the DR resource. EV, on the other hand, has not become popular yet and may prevail at a much later timing than batteries and HPs. The UK, however, announced the ban on the sale of new petrol and diesel vehicles from 2040, indicating a high possibility for EV to become a good DR resource.

Also, expanding the business in cooperation with the provider of service utilizing these DR resources can be an option. Mr. Yasuharu Funabashi of Mizuho Bank, who was in charge of the study of business model, commented on the possible expansion of DR resource as follows:

Comment by Mr. Yasuharu Funabashi
We have to consider collaboration with local operators when trying to promote the actual business. To get the DR business on track, it is important to have a synergy effect through combination of services instead of doing DR business alone. In the UK where the major electricity retailers have 90% share of the market, mid and small sized retailers can develop the DR business as the differentiating strategy. Retail operators will be the promising partner.

The second challenge lies in the study on the business model for DNO. As mentioned in the description of Theme 1: Demonstration of HP introduction, DNOs pay attention on the spread of electrification including introduction of HP and EV to stably operate distribution network, and have started examining possible collaboration with DR aggregators on the investment and the postponement of investment in distribution network enhancement. For the future stance of DNO, Mr. Paul Bircham of ENW, the DNO of Manchester, made a comment as follows:

Comment by Mr. Paul Bircham
Power demand pattern will change as an electrification advances with HP and EV. It was a valuable experience that we could make a simulation of the effect of HP introduction on distribution network. In future, DNO will be asked to play an operator's role to make 100% efficient use of the whole distribution network. We are considering aggressively providing an incentive for DR as well as HP.

In New York state, there has been a DR demonstration performed by distribution operators, verifying how much the reduced demand at peak hours could contribute to the postponement of investment in distribution network. The demonstration this time falls under the business model of UC3. If such business is materialized, it can be a good factor to further improve the profit of DR aggregation business for the domestic sector. Mr. Yasuharu Funabashi of Mizuho Bank expressed his opinion on the possibility and challenge of the business models for DNOs as follows:

Comment by Mr. Yasuharu Funabashi
As electrification being promoted, load adjustment by DR is an important factor for DNA. On the other hand, I think a bit more time is needed to form a consensus on how to allocate the economic benefit gained from the investment postponement among DNO, aggregator and general residential customers.

7. Summary

The implementation content, results achieved and key findings for each of the three themes conducted in this demonstration have been summarized. It was very impressive to see all the demonstration participants working in close cooperation with each other to foster much discussion and continuous ingenuity for the realization of new business models like the 'aggregation of HP of 550 homes' and the 'DR aggregation business for the domestic sector.'

To conclude the demonstration project, Mr. Alex Ganotis of GMCA expressed appreciation to those involved in the demonstration in his comment on the prospects.

> ***Comment by Alex Ganotis***
> *I would like to express my sincere appreciation to everyone involved in this demonstration, through which we were able to prove that DR can be realized through aggregation of a number of small resources of public housing. This has a great implication for the realization of low carbon society. In order to take the next step, we should properly evaluate what we could do and what we couldn't do, instead of just completing the project. GMCA is going to put out Manchester to the world as an advanced ecocity, and for this purpose we will make continuous effort utilizing the achievement of this demonstration.*

The demonstration included introduction of state-of-the-art technology such as aggregation system. However, it was confirmed that ingenuity and non-technological activities such as promotion to and education of residents for the technology were extremely important to realize a smart community involving residential customers. Study on DR aggregation business for the domestic sector will be proceeded not only in the UK and Japan but in many countries. We strongly hope that the knowledge and knowhow obtained by this demonstration will be widely shared and utilized by people all over the world.

8. Acknowledgment

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