Workshop Proceedings

Self-Consumption of Renewables:

The Role of Storage in Revolutionising the Grid Infrastructure

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IRENA Innovation and Technology Centre, Robert Schuman Platz 3, 53175 Bonn

Mr. Yasuhiro Matsuyama, Director of the New and Renewable Energy Division of the Ministry of Economy, Trade and Industry in Japan opens the IRENA Energy Storage Policy and Regulation Workshop on 7 November.

1. Introduction

The International Renewable Energy Agency (IRENA) organised its second "International Energy Storage Policy and Regulation Workshop" on 7 November 2014 in Tokyo, Japan. The workshop took place immediately after the Energy Storage Summit Japan on the 6th November at the same venue.

The aim of this specific workshop was to identify key technology solutions, regulatory challenges and policies needed to support the accelerated deployment of renewables at a residential level, and to identify opportunities for international cooperation and exchange of best practices and lessons. Workshop participants consisted of policy makers, industry representatives, academia, as well as a large delegation of technical experts from the International Electrotechnical Committee (IEC). 50 people participated in the workshop.

1.1 Structure of the workshop

The workshop was opened by Mr. Yasuhiro Matsuyama, Director, New and Renewable Energy Division of the Ministry of Economy, Trade and Industry, Japan. Subsequently, Mr. Masaomi Koyama, Senior Programme Manager of IRENA Innovation and Technology Centre (IITC) provided some key insights regarding distributed solar PV deployment from IRENA's renewable energy roadmap, the potential market opportunities for residential electricity storage deployment, and IRENA's activities on energy storage so far. IRENA's activities include:

- Electricity Storage and Renewables for Island Power: A Guide for Decision Makers (May, 2012);
- IRENA and IEA-ETSAP Electricity Storage Technology brief (April, 2012);
- Smart Grids and Renewables: A Guide to Effective Deployment (November, 2013);
- IRENA's grid stability studies for islands;
- Storage discussions during IRENA's 2nd International Off-grid Renewable Energy Conference and Exhibition (IOREC, 16-17 June 2014).

The introduction presentations were followed by a panel discussion with inputs from five experts. The list of experts and their respective topics can be found in Table 1.

Table 1a. List of policy experts in panel discussion

Expert	Organisation	Topic
Axel Göhner	Embassy of the Federal Republic of Germany to Japan	Germany's subsidy scheme for electricity storage
Melicia Charles	California Public Utilities Commission	Renewables integration and electricity storage: Lessons from California
Riccardo Toxiri	GSE	The Italian net metering scheme – Scambio sul Posto

Table 1b. List of technical experts in panel discussion

Expert	Organisation	Topic
Miyamoto Katsufumi	Panasonic Corporation	How can residential battery applications be used to support the integration of renewables into the grid?
Christopher Hebling	Fraunhofer Institute for Solar Energy Systems	Towards a Renewable Energy Economy
Yumiko Iwafune	University of Tokyo	What economic, environmental and social dimensions need to be considered for residential battery storage applications for renewables?
Penelope Crossley	University of Sydney	The Legal and Policy Obstacles to the Deployment of Residential Battery Storage for Renewable Generation

The workshop concluded with four roundtables. Each roundtable was organised around specific application area for electricity storage for renewables. The reason for grouping the roundtables around application areas is that government policies for different application areas are likely to differ (see Table 2). Therefore, best practices and international cooperation activities are likely to depend on the different national policies that policy makers consider.

Table 2. Topics of roundtables

Roundtable	***Facilitator***	***Topic***
1	Ruud Kempener	Technical challenges and solutions for residential RE grid integration through residential battery storage
2	Masaomi Koyama	Cost and finance models for residential battery storage for solar PV systems
3	Penelope Crossley	Regulatory challenges associated with residential electricity storage and renewables integration
4	Iosif Spyrides	Targets and Subsidies: Best practices for policy support on residential electricity storage

In each of the round tables, the participants addressed the following five questions:

- *Question 1: What are current best practices?*
- *Question 2: What are future objectives to be achieved?*
- *Question 3: Which key activities are needed to achieve these future objectives?*
- *Question 4: Who are the key stakeholder to drive these activities?*
- *Question 5: Based on the answer above, what are the three key areas where IRENA members can support the electricity storage for renewables through* ***international cooperation*** *activities?*

These proceedings will first provide the background for IRENA's activities in electricity storage (section 2), followed with a discussion from the insights of the expert panel (section 3). Section four will discuss the insights of the four roundtables, and the conclusions of each of the discussions. The final section will provide the conclusions from the workshop for IRENA's electricity storage roadmap.

Workshop participants are working in four roundtables to discuss the technical, financial, regulatory and policy challenges for residential electricity storage systems for renewables integration.

2. IRENA and energy storage

In January 2014, IRENA launched its global renewable energy roadmap towards 2030 (REmap 2030). This roadmap identifies a number of pathways to double the share of renewable energy in the period from 2010 to 2030. The roadmap is based on an in-depth analysis of existing national renewable energy plans and additional renewable energy options in 26 countries across the globe. Together, these 26 countries account for 75 percent of global energy consumption.

The results suggest that existing national renewable energy plans would increase the RE share from 18 percent in 2010 to 21 percent in 2030. However, there are a large number of additional renewable energy options that can be pursued within these countries to achieve a RE share of around 36 percent. The power sector is one of the sectors where the growth of renewables will be largest reaching around 44 percent of power generation in 2030 (IRENA, 2014).

The largest growth for renewable power generation will be from wind energy and photovoltaics. Governments expect the installed capacity from wind power to triple from 318 GW today (GWEC 2014) to 1000 GW in 2030, and to quadruple for solar PV with 141 GW today (BNEF, 2014) and 400 GW in 2030. However, the analysis of additional RE options suggest that there is a substantial potential to grow these two sources even further, up to 1600 GW for wind and 1250 GW for solar PV (IRENA, 2014).

Both wind and solar PV are so-called variable renewable energy sources (vRE), which means that they will only be able to produce electricity when the wind is blowing or the sun is shining. This is different from conventional technologies like nuclear power or fossil fuel power generation which produce electricity continuously or can be switched on upon demand.

At the global level, the share of vREs is still very small – less than 3% of electricity production came from wind and solar PV in 2013. In most cases, grid operators can handle vRE shares up to 45% of annual production without significantly increasing the power system costs in the long run (IEA 2014a). For example, pumped hydro has been used for many years in most countries to support load shifting from electricity production at night time to support peak hours during daytime. However, for some countries the variable nature of wind and solar PV is already creating a new paradigm for managing and operating grids. In the month of December 2013, for example, Denmark produced 55% of all electricity generation from wind power.

Another characteristics of wind and solar PV is that they are modular – their size can be tailored and expanded as demand for electricity grows. Producing electricity close to demand centres means reduced need for costly transmission lines and it can provide electricity for small islands, remote locations, and for local communities on the spot. On the other hand, in some cases the wind and solar resources are far away from demand centres, and additional transmission lines are needed to connect wind turbines in windy locations across demand centres a country.

Combined, these two characteristics – variability and modularity – create new technical opportunities and challenges for planning and operating the future power system. For emerging economies – where around 80% of the estimated 10 billion dollar of grid investments will take place – wind and solar PV provide new means to accommodate the rapidly growing demand for electricity. For isolated states, it will even allow leapfrogging to new grid systems that are more decentralised, more variable, and run without marginal costs. Regardless of the pathway, it is clear that electricity storage will open up new opportunities and challenges.

2.1 Context, scope and timeline

IRENA is developing two separate roadmaps to examine the consequences of the rapid growth of variable renewables onto the grid infrastructure. The first technology roadmap will examine different strategies for renewable energy grid integration. In this roadmap, energy storage is only one of many options for the integration of renewables. Other options that will be discussed in this roadmap include the development and strengthening of grids and interconnectors, demand side management, and the use of dispatchable power plants and markets to balance supply and demand.

The second technology roadmap – and the focus of this workshop - will look specifically at electricity storage, because the recent advances in this technology are creating possibilities for a new paradigm of operating, managing, and building grid infrastructure. The current deployment of electricity storage technologies remains limited. Only 150 GW of electricity storage capacity is installed, compared to 5500 GW of installed electricity generation. Furthermore, more than 99% of this storage capacity is pumped hydro (140 GW). Other storage technologies are compressed air (CAES), batteries (lead-acid, NaS, Li-ion, NiCd, redox-flow), and flywheels (IEA, 2014b). Except for the use of lead-acid batteries, most electricity storage technologies are at a pilot scale.

In the last two years, IRENA has already developed a number of analyses for specific electricity storage markets. IRENA's electricity storage technology brief provides an overview of the different electricity storage technologies (IRENA-IEA-ETSAP, 2012a). For islands, IRENA has developed a guide for decision-makers that outlines possible strategies for electricity storage (IRENA, 2012b). For off-grid applications, IRENA organises the bi-annual International Off-Grid Renewable Energy Conference and Exhibition (IOREC) featuring storage solutions.

Building on these projects, the objective of IRENA's roadmap is to identify international cooperation opportunities for electricity storage to achieve a doubling of the share of renewables in the global energy mix, as outlined in IRENA's global renewable energy roadmap (IRENA, 2014). This roadmap includes both accelerated deployment of renewable energy options as well as energy efficiency improvements.

The roadmap will specifically focus on the role of electricity storage. The roadmap recognises that thermal applications for integrating variable renewable energy into the systems will be an important and in many cases the cheapest options for coping with variable renewables. For example, residential electric boilers are already used effectively to reduce peak capacity in France, combined heat and power (CHP) plants can be used to provide a more flexible generation mix, longer-term thermal storage facilities can provide seasonal flexibility, and thermal cooling technologies can free other generation sources to provide balancing services. However, the scope of this roadmap will be on electricity storage technologies that are immediately reversible, so can be used to both store and supply electricity when needed.

The geographical scope of IRENA's roadmap is global. IRENA recognises that there are already a large number of roadmaps on electricity storage available, including the recent development of the Energy Storage Roadmap of the International Energy Agency (IEA, 2014b). Most roadmaps focus on a specific geographical area, on specific milestones for technology deployment (costs, efficiency, capacity), or on research, development and demonstration priorities for storage deployment. Therefore, the specific aim of IRENA's roadmap is to focus on the identification of international cooperation opportunities for electricity storage for renewables across both developed and developing countries. In this context, deployment opportunities for electricity storage for renewables in developing countries and islands will receive special attention. Another area that will be of interest to IRENA members is electricity storage for self-consumption of renewable power generation. This is of particular interest in both developed economies with high electricity prices as well as emerging economies were reliable and uninterrupted electricity generation is required.

The intention is to present a draft roadmap report by March 2015. This roadmap will be critical in identifying how countries can benefit from this emerging paradigm.

2.2 Residential electricity storage for renewables deployment

This workshop was the second in a series of International Energy Storage Policy and Regulation Workshops to inform IRENA's technology roadmap on electricity storage. The kick-off meeting for this roadmap took place on 27 March in Dusseldorf, Germany, and brought together representatives from 13 IRENA countries, industry representatives, academia, and other relevant stakeholders to identify key areas where electricity storage can support the deployment of renewables.

One of the key areas for renewables deployment that was identified in the first workshop was the use of where electricity storage could potentially start to revolutionise the grid infrastructure is residential electricity storage for residential applications.

With decreasing costs of rooftop solar photovoltaics (PV) systems, there are already a number of countries where the levelised costs of solar PV are lower than residential electricity prices. This includes countries like Australia, Chile, Denmark, Germany, Italy, Portugal, Spain and many islands and island states (BNEF, 2014). Large countries like Brazil, France, Japan and the UK are expected to follow shortly.

As the price differential between solar PV power production and residential electricity prices are increasing, the economic case for residential electricity storage becomes interesting. In most cases, a storage system can increase self-consumption of solar PV production from 30 to around 60%. In some locations, like Australia, Denmark, and the South of Germany, residential electricity storage technologies are already viable. If the deployment of residential electricity storage systems becomes more widespread, there is the potential for **negative network effects**. In principle, this would mean that the fixed transmission and distribution network costs would have to be allocated to small base of customers. This would mean that residential electricity prices would increase, and the economic case for residential electricity storage stronger. Although it is not expected that large shares of consumers would disconnect from the grid (so called grid defection), the economics and operations of the existing grid infrastructure could be dramatically affected and changed by these technological developments.

With this as background, IRENA organised its 2nd International Energy Storage Policy & Regulation workshop on "Self-Consumption of Renewables: The Role of Storage in Revolutionising the Grid Infrastructure". The workshop took place in Japan, because Japan is one of the first countries in the world to have policies in place to support the residential deployment of batteries for renewables integration. Furthermore, many Japanese companies are developing technologies for residential electricity storage.

Box 1. Definition of residential electricity storage

One of the outcomes of the roundtables was a discussion on the definition of residential electricity storage, especially in terms of how this definition might affect relevant policies. Based on this discussion, the participants suggested that:

- A residential electricity storage connected to a rooftop solar PV system in a single households is only one possible configuration;
- Electricity storage systems in apartment blocks and/or office buildings;
- An aggregation of residential electricity storage systems at a community level;
- Electricity storage systems at a community level serving other residential households;
- Distributed batteries within a given household, including telephones/laptops;
- Electric vehicles connected to residential households and/or neighbourhoods;
    - However, electric vehicles are often not connected during working hours.

3. Insights from the expert panel

The aim of the expert panels was to provide a status update on the latest technology and policy developments for residential electricity storage for self-consumption of renewables. The discussion and presentations throughout the panel will form the basis for the group discussion and the roundtables.

The expert panel was divided into two groups. The first group consisted of a number of country experts and provides a country overview of the latest developments. The second group of expert consists of industry and researchers to discuss different technological, systemic, socio-economic, and regulatory aspects of residential electricity storage for self-consumption. Following the presentations by both groups, the expert panel will be followed by a group discussion with Q&A from the workshop participants. The full set of presentations can be found at:

http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=30&CatID=79&SubcatID=475.

Mr. Yasuhiro Matsuyama, Director of the New and Renewable Energy Division of the Ministry of Economy, Trade and Industry - Japan's subsidy scheme for residential battery usage

Mr. Matsuyama opened the workshop, and provided an overview of Japan's current situation regarding renewable energy deployment, its current challenges regarding the integration of renewables into the grid, and the frontrunner role that Japan is playing in the development and deployment of electricity storage systems. Through its feed-in tariff (FiT) for renewables projects, Japan catapulted to one of the frontrunner countries of renewable energy deployment in less than two years. From July 2012 to the end of June 2014, more than 11 gigawatts (GW) of renewables were installed and an additional 60 GW of renewable projects have been approved. In comparison, Japan's total installed power generation capacity equates to around 280 GW.

This rapid growth has resulted in a drastic change in the Japanese grid infrastructure, and five utilities have stopped to process new applications for renewable grid connection until they ensure that both supply and demand can be balanced adequately. The challenge is, however, not only technical. Japan's Diet passed the Electricity Business Act on 11 June. This Act fully opens the retail electricity market to so-called Power Purchaser and Supplier in 2016. This means that any company is now allowed to sell electricity, including to households. This opens up a whole new market for companies like real-estate companies, IT suppliers, gas suppliers and other service providers to 84 million customers. Together with the rise of independently owned generation capacity, this means that utilities will have to deal with both technological changes as well as a completely new market.

Regarding electricity storage technologies, the Japanese government established a Storage Battery Strategy Project Team to formulate and implement integrated strategic policies for storage batteries, including a certification system, as early as 2012. The strategy assumes that the storage battery market will consist for 35% out of large scale batteries for storage applications, 25% out of residential or industrial use applications, and 40% out of vehicle use. In 2013, the New Energy and

Industrial Technology Development Organization (NEDO) released an updated technology roadmap for stationary batteries with targets for both grid and demand side applications in terms of life span and costs. Major challenges are cost reduction, enhanced safety, discharge/charge efficiency, durability, recycle technology, and resource restrictions. The Japanese government has established a number of major subsidy programmes for 2012-2013, provides guidelines to secure electrical quality, and has simplified procedures to promote battery deployment. Examples of electricity storage projects for renewables are the Wakkani Mega Solar Project, the Miyakojima Remote Island Microgrids, a large-scale battery energy storage system by Tohuku Electric power Co. Inc., and a multi-purpose grid storage project with Hokkaido Electric Power Co. Inc.

In 2014, the Japanese government opened a subsidy programme for lithium-ion battery-based stationary storage applications. The programme has a budget of around USD 100 million, and subsidies are available up to USD 10000 for individuals and USD 1 million for businesses for installations with 1 kWh capacity or more.

Alex Göhner, Embassy of the Federal Republic of Germany to Japan - European Energy Storage Technology Development, Roadmap towards 2030.

Mr. Göhner showed Germany's ambitious plans for renewables expansion, which would result to around 124 GW of wind and solar photovoltaics capacity by 2030. Consequently, it is expected that renewables will be satisfying peak demand by 2020 and much greater flexibility will be required from conventional power plants. Storage options is one of four flexibility measures that is under consideration[1]. Demand for energy storage is subdivided into short-term needs to increase flexibility, decrease electricity prices, and deal with self-consumption and electric vehicles. In the long run, storage would be needed for security of supply, high fluctuations of spot market prices, and deal with electricity overproduction.

Germany has two programmes for energy storage. The first programme is a market incentive programme introduced by the German parliament. The programme started in May 2013, and provides low-interest loans plus repayment bonus for battery storage systems combined with solar PV (max. 30 kW). The repayment bonus is maximum EUR 600/kWpv and maximum 60% of the power produced can be fed into the grid. Finally, the programme requires an interface technology for remote parameterisation and remote control. As of July 2014, the programme provided 5200 loans with a total volume of EUR 85 million averaging a repayment bonus of EUR 3000.

The second programme "Support Initiative Electricity Storage" provides EUR 200 million for funding of RD&D projects. 250 projects have been accepted under this programme, including wind-hydro coupling, batteries in distribution grids, thermal storage, alternative pumped hydro storage, and compressed air storage.

[1] Other options are expansion of the grid, more flexibility in generation, and demand response.

The German government sees energy storage as one of the four options to support the integration of variable renewables, and considers more RD&D pivotal to reduce the cost and make energy storage options more competitive to the other solutions.

Melicia Charles, Californian Public Utilities Commission - Renewables Integration and Energy Storage

California has a renewable portfolio standard to procure 33% of electricity production from renewable energy resources by 2020. In 2014, the large investor owned utilities served 21% of their retail electricity load from renewable energy resources. On the customer side, nearly 1.6 GW of rooftop solar PV and 23 MW of wind power has been installed.

In 2010, the CPUC was directed to adopt procurement targets for energy storage to optimise the grid, integrate renewables and reduce greenhouse gas emissions. In 2013, the CPUC developed storage procurement targets for the largest three investor-owned utilities resulting in a total mandate to procure 1325 MW of storage capacity by 2020. Non-utilities generators are targeted energy storage capacity equivalent to have 1% of peak load by 2020. Pumped storage more than 50 MW is not eligible, and the storage facilities have to be in operation by 2024.

For 2014, the energy storage procurement targets for the three largest utilities were 90 MW for Southern California Edison, 90 MW for Pacific Gas and Electric, and 20 MW for Sand Diego Gas & Electric. These targets were subdivided by transmission, distribution and customer. In November 2014, Southern California Edison announced that they procured 261 MW of energy storage for 2014, which is much more than the required target of 90 MW (see table 3).

Table 3. Procurement of energy storage by Southern California Edison in 2014.

Seller	Resource type	MWs
Ice Energy Holdings, Inc.	Behind-the-Meter Thermal Energy Storage	25.6
Advanced Microgrid Solutions	Behind-the-Meter Battery Energy Storage	50
Stem	Behind-the-Meter Battery Energy Storage	85
AES	In-Front-of-Meter Battery Energy Storage	100

Following these mandates, the CPUC is developing an Energy Storage Roadmap together with the local transmission system operator CAISE and the Energy Commission, and the will open a rulemaking to address outstanding issues in 2015.

Riccardo Toxiri, GSE Ltd – The Italian Net Metering Scheme Scambio sul Posto.

Mr. Toxiri provided an overview of Italy's net metering scheme called Scambio sul Posto (SSP) that was established in 2009. Instead of physical compensation in terms of kWh consumed and fed into the grid, the scheme provides economic compensation based on differentiated prices depending on what time the electricity is consumed or fed into the grid. As such, the SSP scheme acts as a virtual energy storage system for electricity produced but not consumed in the same period.

GSE Ltd. is the central actor in this SSP scheme. GSE obtains data regarding the electricity fed in and consumed from the grid by renewable power generators, and collects data on distribution costs and electricity prices. With this information, GSE calculates the value of the electricity fed into the grid and the costs of the electricity consumed. If the value of the electricity fed into the grid is larger than the costs of electricity consumed from the grid, the renewable energy power generator is paid the difference (minus administration costs) or can use this economic credit to buy electricity at a later point in time. GSE also pays the grid operator for the dispatching costs associated with balancing the grid. In other words, the grid operator is paid for its services to allow the electricity system to be used as a virtual energy storage system.

From the 1st January 2015, all renewable power generation plants up to 500 kW are eligible for the SSP scheme, including high-efficiency combined heat and power plants up to 200 kW and hybrid plants with non-renewable power generation < 5%. In 2013, almost 400000 plants were covered by the scheme with a total installed capacity of 3.7 GW.

From a government perspective, the SSP scheme has been alternative model for the incentive scheme, has fostered distributed renewable energy power generation, and has provided a clear view of energy prices. For the user, the SSP scheme it provides a clear system to determine the economic credit of feeding into the network. As such, it will also allow consumers to determine whether self-consumption through electricity storage systems is economically more attractive than feeding into the grid. On the downside, SSP has a high administrative burden for both the government and the users.

Miyamoto Katsufumi, Panasonic Corporation – How can residential battery applications be used to support the integration of renewables into the grid?

Mr. Katsufumi presented Panasonic's residential battery storage batteries, which can be used to manage demand for energy within the home. The same batteries can also be used to reduce the stress on the grid to control supply and demand.

At the moment, Panasonic provides Li-ion battery storage units of 5 and 10 kWh that can be coupled to rooftop solar PV systems. The batteries can be charged with solar PV power generation or with cheap electricity during the nighttime, and is discharged during peak demand during the morning and evening. The battery storage and solar PV systems can also be coupled to a home energy management system (HEMS) to control loads of appliances and light. The value of these systems is mainly for the residents.

Panasonic is currently running a trial to run residential battery storage systems in community microgrids installed in houses/buildings with multiple households. In this case, there is a communal battery storage system that can communicate with the home energy management systems located in the individual apartments. This allows for energy sharing and value creation among a group of households. Such systems would not only reduce the energy bill for single homes, but could also be used to increase demand side flexibility, optimise procurement and balancing processes, support grid stability, manage loads, and avoid grid infrastructure investments.

From a technology development perspective, Panasonic is examining the use of artificial intelligence for forecasting both demand and solar PV generation. This would allow the community energy management system to plan ahead and make the management system more effective and responsive. Furthermore, enhanced communication systems will be able to support grid services better.

In conclusion, it is important for the deployment of residential storage batteries that it creates value for individual households, for groups of households or communities as well as creating value for the grid.

Christopher Hebling, Fraunhofer Institute for Solar Energy Systems – Towards a Renewable Economy

Mr. Hebling presented the current situation in Germany and the role that Fraunhofer ISE plays in examining pathways to achieve German's energy objectives of 80% renewables and increased energy productivity by 2050. Such a renewables-based energy system would lead to lower costs in the medium to long term, but energy storage technologies will be a crucial part of such an energy system.

Energy storage systems can be subdivided into four categories:

- Power to power through technologies like pumped hydro & batteries
- Power to heat through heat pumps and electrical heating
- Power to gas through electrolysis
- Power to fuel through bidirectional chargers and hydrogen fuelling stations.

Residential homes will be one of the sectors where both energy efficiency as well as the use of renewable energy has to be improved to achieve the German greenhouse gas emission targets. This would include 147 GW_e of solar PV systems, increased use of solar thermal at both a household level (42 GW_{th}) and at a community level (40 GW_{th}), and increased use of heat pumps. From a storage perspective, a transition towards renewables would require about 24 GWh of stationary batteries (e.g. 8 million units of 3 kWh each), heat storage tanks in buildings of about 320 GWh (e.g. 7 million units of 800 litre each), as well as community heat storage systems of about 350 GWh (e.g. 150 units of 50 million litre each). Besides deployment of both renewable energy and storage at a household and community level, you would also require large scale deployment of wind, electrolysers to convert electricity into gas connected to transmission and distribution system, and pumped storage.

Yumiko Iwafune, University of Tokyo – Economic, Environmental and Social Dimensions to be considered for residential battery storage applications for renewables

Ms. Iwafune provided an overview of the key considerations for residential battery storage applications in Japan, which include cost savings and electricity security. One possibility for the use of residential battery storage application is to store cheap electricity at night (with 1/3 of the price of daytime electricity), however current costs for battery storage systems are too high to simply reduce the electricity bill at a residential household level. Furthermore, the feed-in tariff for solar PV is higher than residential electricity prices, so there is no economic incentive to use storage for self-consumption. From a security perspective, Japan's power sector has shown high resilience with restoration rates up to around 90% within four days after the East Japan Earthquake in 2011. The economics of residential battery storage applications as part of an electric vehicle are more promising.

Residential electricity storage systems seems to be most viable as part of a cooperative energy management system, especially as it pertains to smoothing both load and generation. Such a system would consist of a number of stakeholders and technology groups. Within residential households, batteries would be one of many components (including electric vehicles, smart appliances, and heat pumps) which cooperate through a controller. Residential homes would be aggregated into dispatch areas that would communicate with the utilities. Furthermore, the residential controllers would be communicate with weather stations to provide information on production and consumption to the utilities.

The deployment of residential electricity storage applications would require dynamic pricing mechanisms to account for the difference in costs prices during the day, as well as capacity or ancillary service markets to be able to use electricity storage applications for frequency and voltage control.

Penelope Crossley, University of Sydney – The Legal and Policy Obstacles to the Deployment of Residential Battery Storage for Renewable Generation

The key theme of Ms. Crossley's presentation was that there is significant regulatory and policy uncertainty in electricity markets internationally, which is affecting the deployment of residential battery storage systems.

The uncertainty is partly due to the current market structure in most countries, which assumes power generation to take place at large-scale centralised power generation stations transmitted and distributed to the consumer. Furthermore, in many countries the utilities have been privatised and unbundled into generation/transmission/distribution/retail, which means that both generators and suppliers are competing on the market for customers.

Renewables and electricity storage are challenging the current status quo. Renewables allow for distributed generation, which competes with centralised power production but does not require a large transmission network. However, renewables are also variable sources of power generation so require back-up capacity or storage to balance supply with demand. Energy storage allows for the latter, but does not fit into existing market structure as it can be seen as a generator technology if electricity is supplied, a transmission & distribution technology if it is used to operate the grid, or an electricity consumer if it stores electricity.

This situation is complicated even further due to the different ownership models that are possible. Households may purchase their storage technology outright, or lease the system. However, the system might also be owned by the grid operator or the solar PV company.

Consequently, there are five key policy and regulatory barriers that are hindering the deployment of residential battery storage systems:

1. There is a lack of deployment incentives for residential battery storage. Furthermore, alternative back-up capacity – like diesel generators – are often subsidised.
2. There is a lack of reliable, publically available, and independent information. Many of the technical datasheets and performance evaluations are not easily comparable to one another. Furthermore, the performance indicators are often not relevant for the specific situation in which the battery storage technology is applied.
    a. The lack of comparable information will impact those residential owners relying on bank loans.
3. There is limited availability of contractual warranties for the performance or life of residential battery storage systems. In many cases, it is limited to a number of years.
    a. Again, the lack of warranties may impact any finance institutions that provide funding for electricity storage systems.
4. In the future, the use of residential battery storage systems might not only be to promote self-consumption of solar PV power generation but also to support the grid functions. In that case, third parties may seek to remotely control the operation of storage systems. The models and/or procedures for third party usage are not clear yet.
5. The role of liability. Network operators generally, by contract, exclude all liability. This means that households could be held responsible for any damage caused to the network through their solar PV cells or battery storage systems. Since this might have large economic consequences, this means that households would take on high risks.
    a. Such risk profiles might also affect other stakeholders, such as insurance companies for battery storage systems.

In conclusion, there are quite a number of regulatory challenges that have not been addressed yet.

4. Roundtable results

The roundtable took 1.5 hours, and workshop participants were free to choose one of the four roundtables. Each roundtable consisted of around 8-10 workshop participants. The discussion was subsequently summarised according to the five questions outlined at the start of the workshop. At the end of the discussion, the groups would prioritise their recommendations for international cooperation activities and present the results back to the workshop.

In these workshop proceedings, the results of the roundtable discussions are combined and presented according the questions.

4.1 Current best practices for residential electricity storage applications for renewables

There is a large variety of technologies available for residential electricity storage applications with different performance characteristics in terms of energy density, power density, number of cycles, efficiency, life time, maintenance, costs, safety, etc. There is no single electricity storage system that scores high on all criteria.

Instead, the right technology depends on the application. If electricity storage systems are only used to be charged and discharged once a day, then an established and relative cheap technology like lead-acid batteries will be able to serve this purpose. However, if residential electricity storage systems will be used for additional services – including home energy management systems and/or support to distributed grid operators – then technologies with higher cycle numbers and higher efficiencies, like Lithium-ion, will be more beneficial.

Due to the large variety in electricity storage systems and system configurations, however, the most important factor in choosing the right electricity storage system is correct dimensioning and correct assessment of the total cost of system ownership, including possible cooling systems, inverters and any maintenance costs. Further considerations should be given to recycling after end-of-life. Safety is another important aspect that should be considered for residential electricity storage systems.

Any best practices should be considered in three separate categories:

- Off-grid and microgrid systems;
- Island grid systems;
- Grid connected systems.

Most experience on residential electricity storage applications for renewables deployment can be found in off-grid and microgrid systems. For example, countries like Morocco and Bangladesh have extensive programmes rolling out solar home systems connected to batteries (currently, around

70,000 systems per month are installed in Bangladesh). Also, a company like EcoNet is installing different solar home system solutions coupled to battery storage systems.

For island systems, Hawaii will likely become a best practice example. In New Zealand, the electricity network operator Vector is running a trial to lease customers a rooftop solar PV system coupled to a battery storage system for the same costs as retail electricity prices[2].

In all roundtables, the participants agreed that grid-connected residential electricity storage systems aiding to grid operations are preferred over storage systems simply used for self-consumption. Any regulation that supports residential battery storage systems aiding the grid should be regarded as good practices, including policies that sees residential storage systems or electric vehicles as part of a move towards smart and more efficient grid infrastructures. For example, the German subsidy scheme for residential battery storage systems requires remote control and access to the storage system. Furthermore, policies and incentives should be introduced gradually as to allow markets to adjust. Finally, policies that are supporting experimentation of storage systems, including solicitation for storage paired with renewables, should be promoted as good practices.

More specific, California's mandated storage target is regarded as a good model to provide certainty and guidance for electricity storage systems, including a scheme whereby subsidies decrease as capacity is increased. Furthermore, electricity storage incentive schemes should have clear end dates. Also, Californian utilities that have been pro-actively identifying high value storage location is seen as a good practices.

4.2 Future requirements for residential electricity storage applications for renewables

Despite the relative high performance of existing residential electricity storage systems, there are a number of areas where these technologies should be improved:

- The costs need to be reduced;
- For grid support services, the number of cycles should be improved;
- User friendliness needs to be improved;
- Environmental performance;
- Advancements could be made in the battery management systems, including:
    - Improved harmonisation and compatability across system components;
    - Remote control and artificial intelligence;
    - Community and grid service support;
    - Reducing the costs for monitoring and metering;
    - Size reduction;

[2] The system consists of a 3kW PV panel array (Trina), inverter (Schneider) and a 10.7 kWh Li-ion battery (Kokam). More information can be found here: http://reneweconomy.com.au/2013/culture-shock-network-offers-solar-storage-leases-to-customers-91569

- Safety of the technology, safety for the installer, and safety for the grid.

Technology development is also needed in the existing grid infrastructures to deal with electricity storage systems. This would include the use of smart grids, but possibly also the development of super inverters to manage the disaggregated load and generation patterns. Furthermore, there is an opportunity to develop Direct Current (DC) grids. Solar PV produce DC, battery storage systems store DC, and consumption with LED and all other household electronics relates to DC. A DC system or DC minigrid would largely reduce transformation losses, especially with new DC/DC-converters. Island grids and grids in rural areas could also take a great benefit from development in DC grids.

From a finance and costing perspective, there is only limited information so far. In the future, more information needs to be gathered on the driving forces, including cost reductions for energy storage. Furthermore, more understanding is needed regarding the cost-effectiveness of storage, including value assessment of the contribution that storage can make to energy efficiency, demand response, renewables and grid support. Considering that storage can contribute to these multiple objectives simultaneously, this will also require methodology to rank the different value propositions for storage, and any incentives associated with supporting these functions. The finance sector and the public also needs to be more involved in the debate.

The majority of future requirements seem to be from a regulatory perspective. This would include:

- Development and use of standards for[3]:
  - Safety
  - Reliability
  - Interconnection
  - Contracts, warranties, output performance
  - Communication (universal and aggregation to support reliability, security, and privacy).
- Improved management systems and protocols for:
  - Networks and tariffs;
  - Energy storage for grid management benefits;

Finally, there is a need to properly define electricity storage in legal terms, and enable/recognise energy storage as a "multifunctional asset" that crosses traditional boundaries between generators, transmission, distribution, and retail. Furthermore, businesses and regulators need to rethink regulated asset prices and change their investment models to consider the value of storage.

[3] The International Electrotechnical Committee (IEC) Technical Committee (TC) 120 is working on standards for grid integrated electricity energy storage systems.

4.3 Key activities needed for residential electricity storage applications for renewables

The activities to support technology development can be categorised into four areas:

1. Support for technology development through R&D in businesses, and government funding for RD&D activities;
    a. This would include activities to develop smart artificial intelligence systems to support aggregated control of energy storage systems.
2. Standards need to be developed quicker, so that business development is not inhibited by lagging regulation;
3. Labelling of residential electricity storage systems to support the consumer in its choice;
4. An energy storage market needs to be created that better supports and compensates storage, including better recognition of the costs and value of energy storage, infrastructure support, and supporting regulation;

From a finance and costing perspective, a better understanding of the value proposition of energy storage and enhanced engagement of the finance sector and the general public can be achieved through:

- Demonstration projects like the development of smart cities;
- A communication strategy to inform the general public, including commercial advertisements on energy storage;
- Support for research on cost-effectiveness of energy storage.

To develop a supporting regulatory framework for residential electricity storage, activities needs to be undertaken at an international level and at a national level.

At an international level, energy storage requires:

- International safety standards group needs to be established;
- International communications protocol group;
- World standards for technical bankability;
- Outreach and collaboration between developed and developing countries.

At a national level:

- National committees of stakeholders to analyse barriers;
- National deployment of analytical toolboxes to measure costs and benefits of energy storage;
- National assessments of the risk of both utility- and residential scale electricity storage systems, and an assessment of how risks are deployed if storage is deployed at both levels;
- Education of stakeholders.

4.4 Key stakeholders for residential electricity storage applications for renewables

The key stakeholders that need to be engaged in residential electricity storage technologies for renewables can be broken down into two categories. The first category are those stakeholders that are involved in energy storage as a whole. The second category of stakeholders are those stakeholders that are specific to **residential** electricity storage.

Table 4. Key stakeholders for residential electricity storage for renewables

Electricity storage stakeholders	Residential electricity storage stakeholders
Power generators/ utilities Transmission system operators (TSOs) Distribution system operators (DSOs) Intergovernmental agencies Policy makers Grid planners Regulators Federal grid agencies State grid agencies Renewable energy developers Engineering companies Electric vehicle developers Trade organisations Storage associations Service and maintenance companies Research institutions Consultancy companies Finance sector Environmental sector	Home insurance companies Leasing companies Consumer groups Local communities Energy sharing communities (ZEH/ZEB) Home builders Emergency agencies Demand response aggregators

4.5 International cooperation activities to support residential electricity storage applications for renewables

Based on the prioritisation of international cooperation activities needed to support residential electricity storage, the following recommendations were provided:

The results of this workshop suggested the following:

1. International cooperation on RD&D is still fundamental for residential storage systems, in particular with regard to battery management systems, cost reductions, grid integration, and safety. Governments can support these activities by providing funds for international cooperation, support exchange of scientists and researchers, and funding for shared demonstration projects.
2. International cooperation activities to support the development of labelling of residential electricity storage technologies will support the consumer, create new markets, and help to move from high-level targets to actual deployment on the ground.
3. International cooperation to develop grid codes, ownership models, and cost models that will allow residential electricity storage systems to support the grid, otherwise problems will occur at a later stage.
4. There are limited best practices to date, so the focus should be on best experiments. Off-grid systems is one area where lessons could be learned for residential electricity storage systems. IRENA could develop a directory of energy storage with information on people, organisations, studies, regulatory rules, standards and other relevant information to support decision makers.
5. Residential electricity storage systems will inherently require the engagement of new stakeholders, like insurance companies, construction industry, installers and the general public. Site visits and more specialised international workshop can support education and engagement.
6. Finally, countries should work together to support the development of new analytical tools to understand how grid operations with storage might function, how to evaluate the cost-effectiveness of policies, and how to determine targets. These tools could be shaped into guidebooks that, together with the establishment of an international strategic taskforce, could help national policy makers to assess their national situation and facilitate the exchange of international experiences.

5. Conclusions

The aim of this workshop was to examine the role that residential electricity storage technologies may play in the deployment of renewables, and to identify what applications, best practices and lessons should be highlighted in IRENA's global technology roadmap for electricity storage. Based on these insights, the aim of the roadmap is to identify priority areas for action, and specify activities for international cooperation among different stakeholders, and provide a framework to monitor progress.

The conclusions of this workshop are that:

1. There is an array of residential electricity storage technologies available, including technologies that convert power into storable heat or fuel. In most cases, the most important criteria for choosing a residential electricity storage system is the correct dimensioning of the system, including a transparent assessment of the total system costs over the lifetime of the product.
2. There are a number of features that make residential electricity storage different from electricity storage deployment in other applications areas. These include:
    a. Households need to be better informed about the products on the market, and how they compare to one another;
    b. Standardisation of batteries, and system components will be an important aspect for large-scale deployment in the residential sector.
    c. There are a number of additional stakeholders, like insurance companies, home builders, installers, and emergency agencies (e.g. fire brigade) that need to be better informed and engaged in the discussion on residential electricity storage technologies.
    d. Safety, warranty, end-of-life policies, and comparable and understandable information sheets are an important and more pronounced aspect for residential electricity storage systems.
3. There is general agreement that policy makers should avoid large-scale deployment of residential electricity storage systems that are only used for self-consumption and cannot support grid services. The use of electricity storage systems for self-consumption will lead to so-called 'negative network effects' whereby distribution and transmission companies will face challenges in maintaining the reliability and cost-effectiveness of the grid.
    a. Large-scale deployment of residential electricity storage for self-consumption could happen in selected countries in the next five to ten years if the costs of solar PV systems and electricity storage systems continue to decline. This means that policy makers need to be pro-active in developing policies and regulation to will allow the use of these technologies for grid support.
    b. Future developments in the area of communication protocols and control systems with artificial intelligence are key area where more technological development is needed.

4. There is very limited experience and best practice on cost and finance models. More research is needed on understanding how residential electricity storage systems at a residential, community, or infrastructure level add value to energy efficiency, demand response, renewables deployment, and grid service support, and how deployment of electricity storage systems at these different levels might interact.
    a. The results of these analysis should be used to develop appropriate and cost-effective incentives and measures to support residential electricity storage deployment.
    b. The results can also be used to support and develop finance models, including technical bankability.
5. Regulation for residential electricity storage systems is lacking, and will be a serious impediment for future development. The development of appropriate regulation is further complicated by the different models (purchase, leasing, grid-owned systems) that are possible. Furthermore, the issue of liability needs to be resolved.
6. International cooperation can significantly contribute to the appropriate policies and regulation for residential electricity storage, because there are limited best practices at the moment (one should speak of best experiments). This includes the development of online directories, expert workshops, international taskforces, and international cooperation to support RD&D, the development of standards, and grid codes.