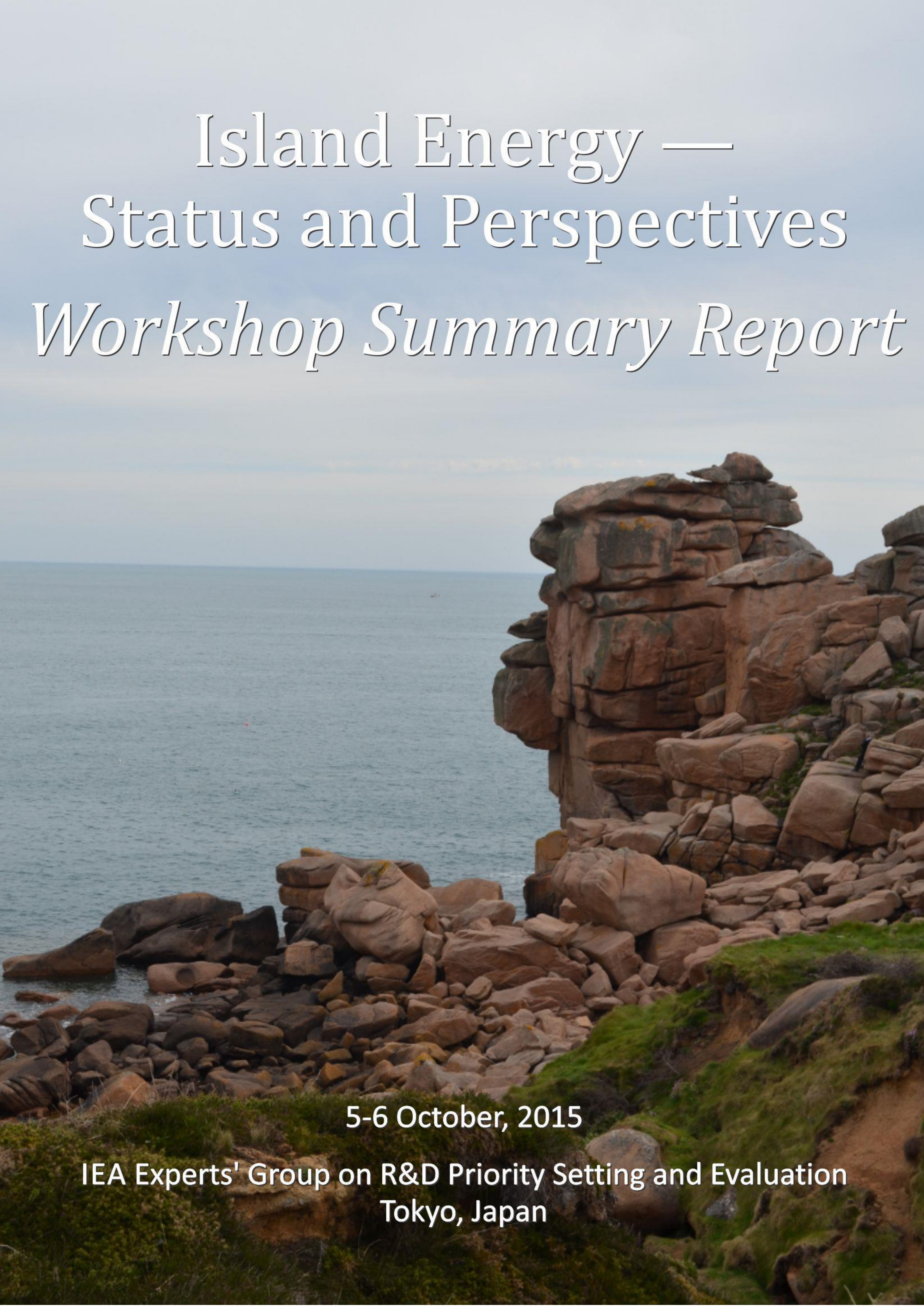

Island Energy — Status and Perspectives

Workshop Summary Report

5-6 October, 2015

IEA Experts' Group on R&D Priority Setting and Evaluation
Tokyo, Japan

International Energy Agency Committee on Energy Research and Technology

EXPERTS' GROUP ON R&D PRIORITY SETTING AND EVALUATION

Island Energy –

Status and Perspectives

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5 and 6 October 2015

Institute of Applied Energy

Tokyo, Japan

International Energy Agency

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its mandate is two-fold: to promote energy security among its member countries through collective response to physical disruptions in oil supply and to advise member countries on sound energy policy. The IEA carries out a comprehensive program of energy cooperation among 28 advanced economies,[1] each of which is obliged to hold oil stocks equivalent to 90 days of its net imports.

The Agency aims to:

- Secure member countries' access to reliable and ample supplies of all forms of energy—in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context, particularly in terms of reducing greenhouse gas emissions that contribute to climate change mitigation.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organizations, and other stakeholders.

IEA Experts' Group on R&D Priority Setting and Evaluation Research (EGRD)

The capacity of countries to apply sound tools in developing effective national research and development (R&D) strategies and programs is becoming increasingly important. The EGRD was established by the IEA Committee on Energy Research and Technology (CERT) to promote development and refinement of analytical approaches to energy technology analysis, R&D priority setting, and assessment of benefits from R&D activities.

Senior industry and policy experts engaged in national and international R&D efforts collaborate on topical issues through international workshops, information exchange, networking, and outreach. Nineteen countries and the European Commission participate in the current program of work. The results and recommendations provide a global perspective on national R&D efforts that aim to support the CERT and feed into analysis of the IEA Secretariat. For further information, see: http://www.iea.org/aboutus/standinggroupsandcommittees/cert/egrd. For information specific to this workshop, including agenda, scope, and presentations, see: http://www.iea.org/workshops/egrd-island-energy---status-and-perspectives.html.

This document reflects key points that emerged from the discussions held at this workshop. The views expressed in this report do not represent those of the IEA or IEA policy nor do they represent consensus among the discussants.

[1] Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States; the European Commission also participates in the work of the IEA.

The Island Energy Workshop

The *Island Energy – Status and Perspectives* workshop was held on 5-6 October, 2015, in Tokyo, Japan. The event was organized by EGRD and hosted by the Institute of Applied Energy (IAE).The workshop is part of a series organized within the EGRD's three-year mandate (2014–2016) as granted by the CERT.

This workshop summary provides an executive summary, the meeting rationale, and summaries of the experts' presentations and discussions.

On behalf of the EGRD,

Rob P. Koo*l, EGRD Chair, RVO.nl*

Astushi Kurasawa*, Director of Global Environmental Program, IAE*

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Executive Summary

Small island communities and remote, sparsely populated areas are particularly vulnerable to the impacts of climate change. Despite significant renewable energy resource potential, such regions are often highly dependent on imported fossil fuels to meet their energy needs. This reliance often leads to high electricity and energy costs, vulnerability to oil price fluctuations, supply interruptions, and environmental degradation. In recent years, an increasing number of island and remote communities are seeking to transition to a more sustainable energy system in which improved energy efficiency and renewable energy play important roles.

The *Island Energy – Status and Perspectives* workshop, organized by the Experts' Group on R&D Priority Setting & Evaluation (EGRD) and hosted by the Institute of Applied Energy (IAE) in Tokyo, Japan, on 5–6 October 2015, focused on the energy challenges, strategies, and technological solutions on islands and in remote, sparsely populated areas. The workshop explored the similarities and differences in a variety of cases to summarize lessons learned. Participants also explored which experiences and lessons learned are transferable between densely populated areas, such as compact cities, and islands and other isolated areas.

Some basic factors must be considered when studying an island's energy network.[2] The first is whether the island is part of a continental country, like the Spanish Island El Hierro, or not. Those that are part of a mainland nation often have the disadvantage of national legislation based on mainland market conditions that do not apply locally (e.g., unbundling), which presents legislative barriers for sustainable development. On the other hand, the island may benefit from economic ties to a mainland nation that can afford investments.

The second consideration is market size. Islands range from small, remote territories to large island states with millions of inhabitants. The latter generally have well-developed grids and often interconnection between the major islands. Some of these big island states, such as Japan and the United Kingdom, are developed countries that can invest in an energy transition. However, even these major nations share vulnerabilities with the smaller islands, as showed by the Great East Japan Earthquake and resulting tsunami. Natural disasters can have an enormous impact on island nations' economies.

The third consideration is the presence and prevalence of fossil fuel. If an island had local access to fossil fuels during the industrial revolution, the economy could develop relatively quickly, as could a regional grid. However, domestic fossil fuel resources and industrial development does not guarantee rapid economic development. For example, Indonesia faces an ongoing dilemma: sell fuel to finance the national budget or use the fuel domestically to generate energy and boost the economy.

Energy transition planners must consider these three characteristics and tailor solutions for a location-specific strategy. There are many options available to create a sustainable energy system;

[2] For a much more detailed report on the differences between Island states and territories, see Irena, *Pacific Lighthouses Report,* Abu Dhabi, 2012.

the main challenge is determining how to combine them in the most suitable way for a specific territory. Some strategic components are discussed below.

Energy Efficiency

Islands are often exceptions when it comes to mining the first fuel, energy efficiency. In a number of cases, like in major parts of the Southern Pacific, building codes and labelling of appliances are not yet in place and a programme like the Pacific Appliance Labelling and Standards (PALS) helps to implement these codes and thereby helps contribute to limit the dumping of old technology.

Awareness is another element of mining the first fuel. There are several examples of a community approach, which includes all parties on an island and could serve as example elsewhere. These examples include Kumejima (Japan), Bornholm[3] (Denmark), the Faroe Island etc.

Technology

Most sustainable technologies are already available, including solar, wind, biomass, hydro and geothermal. However ocean energy (both tidal and ocean temperature conversion) needs more research to be fully deployed. Nevertheless, it remains a challenge to install the right equipment to achieve sustainable solutions on islands. Furthermore, additional research is needed create more robust renewable options that can withstand the harsh conditions that occur on numerous islands (e.g., hurricanes, monsoons, and extremely cold winters). Studies that examined climate readiness identified one common strategy: placing energy systems in better-protected areas.[4] However, this is not an option on the majority of islands.

For many islands targeting an energy transition, the first choice is a smart grid with distributed generation. Storage must be a key element in smart grid design. Including demand response and demand-side management can reduce necessary capacity. Smart grids based on direct current (DC) might be more efficient, but appliances are presently almost exclusively available in alternating current (AC). A DC grid would thus necessitate the use of AC/DC converters, which results in energy loss. Examples of successful smart grid island installations include those of the Faroe Islands and Miyako-Jima.

As with other solutions, the ability to implement energy storage is determined by the island's circumstances, i.e., what is both feasible and affordable. Natural storage—such as pumped hydro or heat storage—might be cheaper in the long run, but these solutions require high initial investments. For the most part, the Pacific islands use batteries, which have undergone fast technological development to improve storage capacity and battery lifetime. (As has been presented in previous workshops, including the EGRD storage workshop in 2014). The latest developments in compressed air (CAES) [5]were not discussed during the workshop.

As island-based technological solutions often have to be tailor made, standards to integrate grid components could be of considerable help on the route to sustainability. Regardless of the solutions chosen, electrification is an integral part of island societies becoming self-sufficient.

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[3] Bright Green Island: Bornholm, http://brightgreenisland.com/.
[4] IEA, RD&D Needs for Energy System Climate Preparedness and Resilience Workshop, November 2013, https://www.iea.org/workshops/rdd-needs-for-energy-system-climate-preparedness-and-resilience.html.
[5] http://energystorage.org/compressed-air-energy-storage-caes

Financing

There are sound financial reasons to invest in sustainable islands, including high fuel prices, high transport cost, inefficient diesel generators (currently in use), and climate change-induced indirect costs. Investment is more easily attracted when planning and design indicates that solutions will provide multiple benefits, such as sustainability, health, environmental issues, cost-effectiveness and employment opportunities.

The U.S. Department of Energy has developed the "Islands Playbook", a guide to help islands with design and financing.[6] The International Renewable Energy Agency (IRENA) also addresses this topic:

> *An energy development initiative for small island developing states (SIDS), such as SIDS-DOCK,[7] could help to overcome problems, provided funds are managed through the unified programme and not cut into many small projects with different decision makers.*

Despite some successes, financing and business models concerning the EGRD advices that energy transition should be explored in a wider scope than discussed in this workshop. Presenters provided examples from remote, sparsely populated areas, but these few examples alone cannot be the basis for solid conclusions. The challenges are similar to those of off-grid scenarios, so successful island implementations may be used as inspiration.

Crosscutting Issues

Society at large must also be engaged if sustainability efforts are to be effective, as was demonstrated by a number of projects.

Governments have to address regulations that are obstacles to sustainable paths forward. Grid connections, system operations, load management, baseload demand, etc. usually need modifications to be appropriate for an individual island. Long-term planning and political commitment are necessary to secure solutions. There is also a necessity to attract private sector investment in renewable energy deployment..

Islands share some crosscutting issues not only with each other but also with big cities. For example, some design elements of island projects are translatable into big city sustainability planning. Similar challenges include space limitations, while differences include energy network interconnections and market size. Circumstances differ too much for lessons learned to be largely applicable, although islands' efforts to transition can be inspiring for those who are promoting a more sustainable and efficient society.

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[6] *Energy Transition Initiative: Islands* website http://www.eere.energy.gov/islandsplaybook/
[7] SIDSDOCK (website), http://sidsdock.org/

Rationale

Small island communities and remote, sparsely populated areas are vulnerable to the impacts of climate change, and despite significant renewable energy resource potential, such areas are often highly dependent on imported fossil fuels to meet their energy needs. This need can greatly increase electricity and energy costs, vulnerability to oil price fluctuations, supply interruptions, and environmental degradation.

However, an increasing number of island and remote communities are seeking to transition to a more sustainable energy system, with improved energy efficiency and renewable energy playing important roles.

The workshop focused on the energy challenges, strategies, and technological solutions associated with such areas. The workshop explored the similarities and differences in a variety of cases and identified lessons learned, not least in terms of technological solutions. Further, participants explored whether there is value in islands' and isolated areas' exchanging experiences and lessons learned with densely populated areas such as cities.

Key Questions

- How do islands and remote, sparsely populated areas address the energy challenges, i.e., access to energy at affordable prices and with minimum impacts for the environment and climate?
- What are the similarities and major differences between islands and remote, sparsely populated areas? What are the lessons learned?
- Which technological solutions are available to address the energy challenges on islands and remote, sparsely populated areas?
- Can these technological solutions be scaled up and used in densely populated areas and vice versa?
- What are the similarities and differences between technological solutions for islands, remote areas, and densely populated areas?

Report Structure

This report summarizes the workshop findings, providing summaries of each presentation. Following this section, the report follows the agenda from the workshop, with five session chapters:

- Session 1 – Introduction
- Session 2 – Sustainable Islands
- Session 3 – Sustainable Cities
- Session 4 – Island States
- Session 5 – Discussion and Conclusion

Appendices to the report provide a list of acronyms, workshop participants, additional source information, and the workshop agenda.

Presentations are available at https://www.iea.org/workshops/egrd-island-energy---status-and-perspectives.html.

Session Summaries

Session 1: Introduction

Welcome

Atsushi Kurosawa, Director of Global Environmental Program, Institute of Applied Energy, Japan

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/0Kurosawa_IAE.pdf

The workshop was hosted by the Institute of Applied Energy (IAE), a not-for-profit organization with expertise in energy technology assessment. The Global Environment Group does modelling and analysis that covers 15 global regions, as well as technology assessment.

Introduction to the Workshop and the EGRD

Rob Kool, Chair of the EGRD**;** **E**nergy **E**xpert and **I**nterim **M**anager**,** Netherlands Enterprise Agency RVO.NL, Government of the Netherlands

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/0Kool_EGRD.pdf

The Experts' Group on R&D Priority Setting and Evaluation (EGRD) is part of the International Energy Agency's (IEA's) Technology Network. The EGRD examines analytical approaches to energy technologies, policies, and research and development (R&D). The group's recommendations support the Committee on Energy Research and Technology (CERT) and can:

- Support the methodology of priority setting and evaluation, contributing to theory
- Evaluate results: discuss IEA theoretical output with the "practitioners in the field" like roadmaps (always in collaboration with IEA secretariat)
- Support cross-cutting efforts by combining IEA fields of expertise to accelerate processes or identify blind spots

The EGRD Island Energy Workshop is part of a three-year programme that covers six different topics. This workshop addresses territory with several energy-related challenges and opportunities. There are more and more technological options to balance the electricity net, and production of renewable energy is on the rise. Despite significant renewable energy potential, however, such isolated areas are often highly dependent on imported fossil fuels. The resulting high electricity and energy costs make these areas vulnerable to oil price fluctuations and lead to supply interruptions and environmental degradation.

An increasing number of island and remote area communities seek transition to a more sustainable energy system, with energy efficiency and renewable energy playing important roles. Recent presentations at EGRD workshops showed the potential of an island approach e.g. the Danish Island of Bornholm.[8]

Results, report and presentations would be available on the EGRD page of the IEA website.

Key Note: IEA's Energy Technology Network and Implementation Agreements: A "New Era"

Toshiro Okada, Vice Chair of CERT; Senior Energy Advisor, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry, Government of Japan

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/1Okada_ANRE.pdf

The IEA's Energy Technology Network and Implementing Agreements will enter a new era after 40 years of operational experience.

The global community is moving forward on energy and climate. The IEA's work—both that of the secretariat and the Technology Network—informed the Group of 20 (G20) energy ministers meeting that was held 2 October 2015. In November–December 2015, the 2015 United Nations Climate Change Conference (COP21) will become the venue to negotiate the United Nations Framework Convention on Climate Change (UNFCCC). This event will underscore the importance of future IEA activity, especially when viewed against the ambitious goals likely to be adopted.

Figure 1. Toshiro Okada, Vice Chair of CERT.

Energy technology plays a pivotal role in achieving such goals, making research, development, demonstration, deployment and dissemination (RDDD&D) crucial. The CERT can support efforts to re-vitalize the network and facilitate collaborations among related parties. Fatih Birol, the IEA's new executive director, has called Implementing Agreement delegates together to brainstorm on ways to build up energy technology activities and to discuss new technology initiative procedures. CERT will hold the meeting in Paris.

The EGRD is developing a new strategic plan for 2017–2019. This plan is expected to provide new insights into IEA activities through CERT.

[8] Business Center Bornholm (2013), *Bornholm, Bright Green Island*, Business Center Bornholm, Denmark.

Policy Change in Japan and the Asian Energy Trends

Toshiro Okada, Vice Chair of CERT; Senior Energy Advisor, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry, Government of Japan

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/1Okada_ANRE_EnPolJpn.pdf

Japan has a high dependence on fossil fuels for power generation. After the tsunami caused by Great Eeat Japan earthquake, nuclear plants underwent long-term shutdown, and nuclear power underwent a significant decrease to 1% of domestic power generation. Thermal power has increased to 90%. In 2013, liquid natural gas (LNG) alone accounted for 43%. The overall cost of LNG imports to Japan increased from 3.5 trillion yen in 2010 to around 8 trillion yen in 2014. As a result, 2011 marked Japan's first trade deficit in 31 years. The deficit is growing, having reach 12.8 trillion yen in 2014.

The high energy costs in Japan have a negative impact on the competitiveness of energy-intensive industries. Thus Japan's Strategic Energy Plan focuses on diversification. The plan is in accord with both global and domestic agendas. From the international perspective, Japan is developing energy policies in line with international movement, as well as internationalizing energy industries by facilitating business overseas. The plan also focuses on domestic economic growth, activating Japan's energy market through energy system reform. The strategy focuses on "3E + S": **E**nergy security (stable supply), **E**conomic efficiency (cost reduction), **E**nvironment, and **S**afety.

The Strategic Energy Plan lays out a multi-layered, diversified, resilient, and flexible energy demand–supply structure. Multiple energy sources are balanced to allow Japan to leverage each source's advantages and minimize each source's drawbacks. The flexible structure will allow various players to participate, and system reforms can enable a range of alternatives as needed. The plan also calls for developing domestic resources. The plan aims to achieve increased self-sufficiency, lower electricity costs, and reduced greenhouse gas emissions. Figure 2 shows the targeted levels per energy source. This represents Japan's first comprehensive electricity and gas market reform in 60 years.

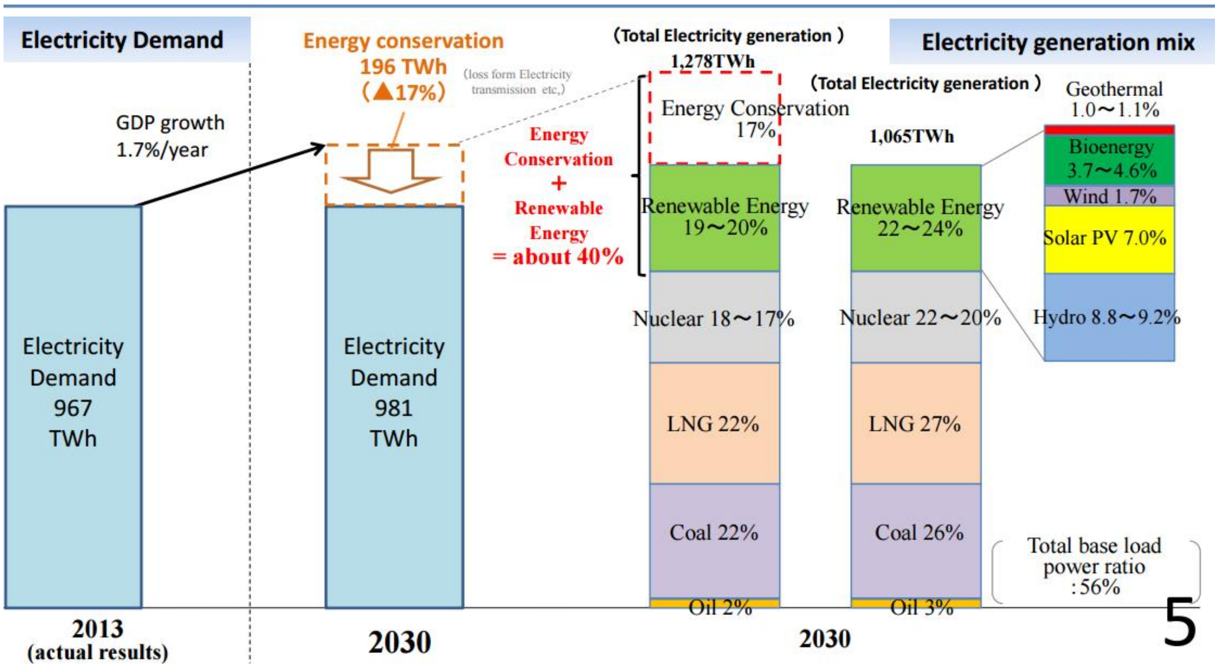


Figure 2. Japan's projected energy mix.

The total energy use in the Association of Southeast Asian Nations (ASEAN) region is expected to increase considerably over the next two decades. Electricity demand in Southeast Asia will increase about 140% by 2035, requiring a cumulative investment of $990 billion (see Figure 3). On the current trajectory, fossil fuels will continue to make up a significant percentage of the energy mix.

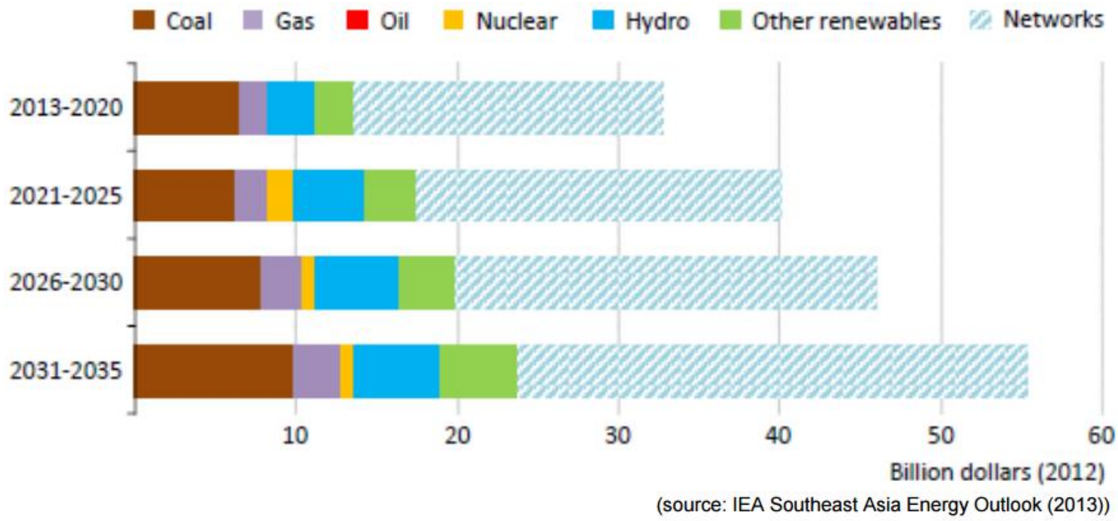


Figure 3. ASEAN average annual investment in power generation capacity.

Japan's situation sheds light on the island energy scenario. A high dependence on fossil fuels has negative impacts on the global climate, and a high dependence on imported fossil fuels is detrimental to the local economy. There are numerous options for building a more effective energy infrastructure.

Clean Energy Systems for Islands: Insights from IEA Analyses

Eric Masanet, Head, Energy Demand Technology Unit, International Energy Agency

- Link to presentation slides:
  https://www.iea.org/media/workshops/2015/egrdoct/2.Masanet_IEA.pdf

Past IEA activities have focused largely on densely populated areas and large countries and regions; there has been no specific focus on islands or sparsely populated areas.

The energy network of the future will be intelligent and integrated, organizing the sources of and requirements for energy from all parts of the energy system (see Figure 4). The energy technology portfolio to achieve the IEA's ETP 2°C scenario[9] includes energy efficiency, fuel switching, and various energy supply and conversion technologies. Energy efficiency, often described as the "first fuel", is the most significant opportunity and, when fully exploited, has a broad range of potential positive impacts (see Figure 5). With new, more energy-efficient processes, energy can often be saved at net negative costs.[10]

The multiple benefits of energy efficiency improvements, and opportunities for net negative cost energy technologies was also mentioned[11].

Energy efficiency can significantly reduce final energy use for space heating and cooling, although regional priorities in the building sector vary because of local differences in technology and policy. For example, the European Union prioritizes heat pump technology, whereas Mexico and Brazil are more focused on solar thermal. Appliances are also targets for energy efficiency, and many regions have seen great progress in this sector.

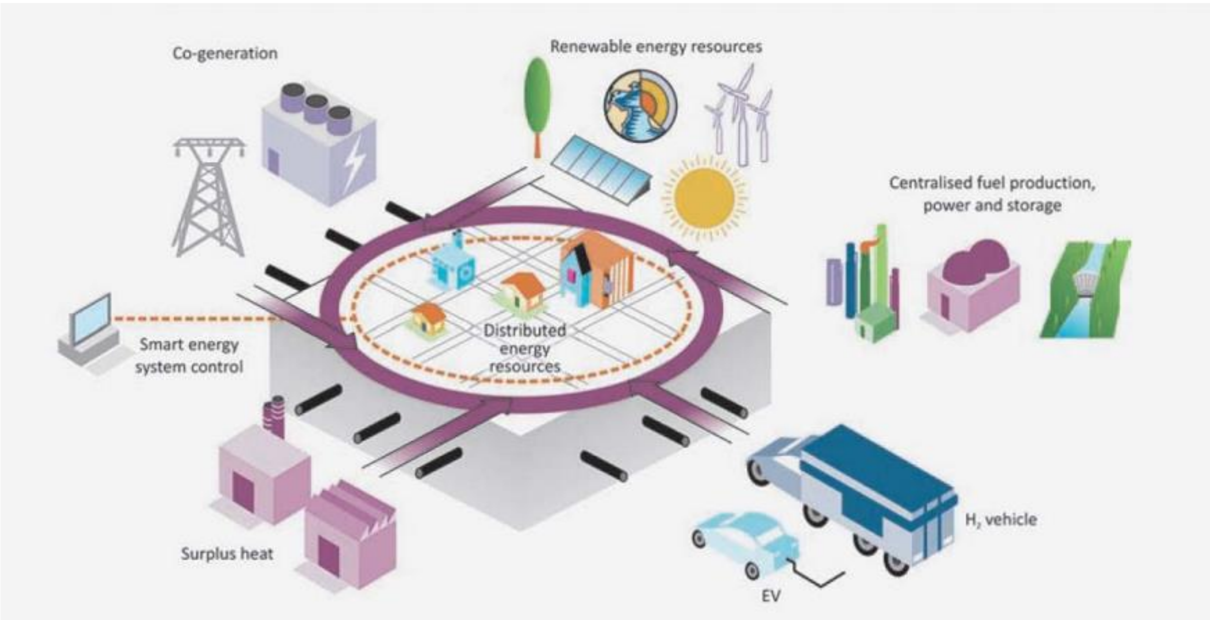
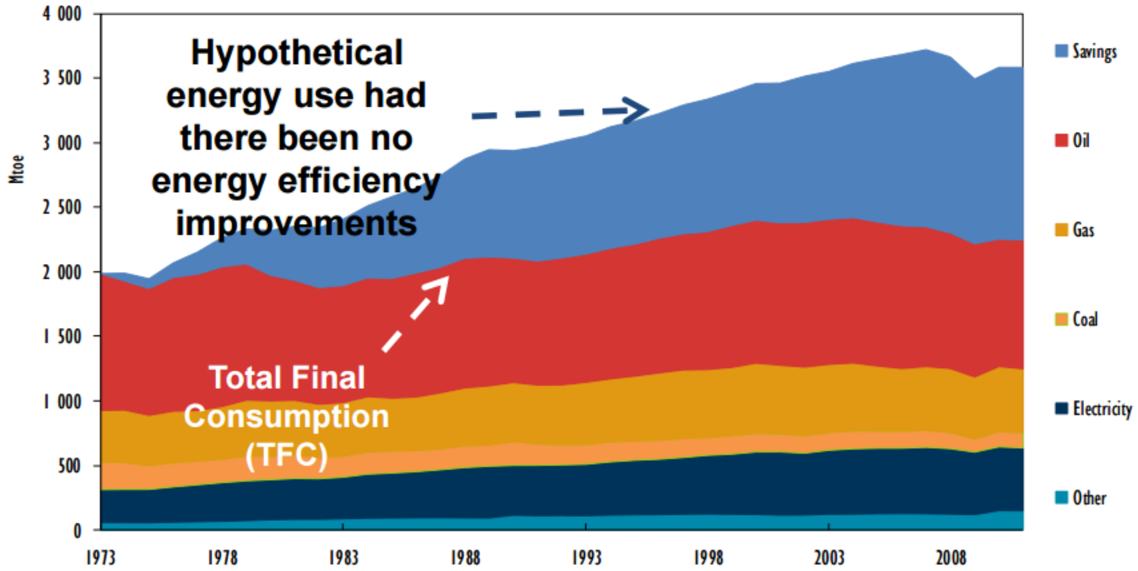


Figure 4. Intelligent and integrated system of the future.

[9] IEA, *Energy Technology Perspectives (ETP)*, IEA Paris, 2015.
[10] Hannah Choi Granade, *Unlocking energy efficiency in the US economy*, McKinsey & Company, 2009.
[11] IEA, *Capturing the Multiple Benefits of Energy Efficiency*, IEA Paris, 2015.



*IEA-11: Australia, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Sweden, United Kingdom, United States

Figure 5. Energy efficiency-based savings.

Knowledge from the residential and transport sectors is applicable to island energy systems.

Road transport share is highest among transportation energy modes, mainly fuelled by oil. IEA's concept of transport policy is avoiding unnecessary trips, shifting modes, and improving vehicles through efficiency improvements and low carbon fuels.

The IEA is drafting the 2016 ETP. Likely topics include integrating local and national energy policies to target sustainable energy transitions, informed urban planning that incorporates sustainable buildings with low-carbon heat supply, and low-carbon urban mobility options.

Session 2: Sustainable Islands

Moderator: Atsushi Kurosawa

A large number of small islands around the world had developed into great showcases for the energy system of the future, implementing a range of promising solutions to energy challenges. Session 2 explored the driving force behind these ambitious cases and assessed the technological solutions, including their reliability and costs. Experts discussed what were the lessons learned for the overall energy system, as well as to densely populated areas.

Figure 6. Workshop participants.

Japanese Island Grid Experience

Satoshi Morozumi, Smart Community Department Director General, New Energy and Industrial Technology Development Organization, Japan

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/3MOROZUMI_NEDO.pdf

The New Energy and Industrial Technology Development Organization (NEDO)[12] has been promoting microgrid-related activities since the early 2000s. There have also been private projects in the market. Three such projects include *JUMPSmartMau*i in Hawaii (a Nedo project), the Miyako Island Mega-Solar Demonstration Project, and the Okinawa Smart Grid Energy Island Project—island projects—and the New Mexico microgrid demonstration in Los Alamos County (a Nedo project) —a remote, sparsely populated area.

Hawaii's incentive to investigate microgrids is clear: of the 50 U.S. states, Hawaii has the highest dependence on fossil fuels, as well as the highest electricity retail price at around 40 cents/kWh. Maui, an island in the state of Hawaii, has peak demand around 200 MW. Renewables installed include 70 MW wind and 40MW photovoltaics (PV), and 30% of demand is supplied by renewables. ces; Maui's aggressive target is to become a 100% renewable energy island within 30 years. The State of Hawaii is aiming for 40% of all of energy consumption to be from renewable energy sources.

The *JUMPSmartMaui* project goal is to establish a world-leading remote island society with a top-level energy management system with individual optimization, electric vehicle (EV) charging, transformer control, batteries, water heating, and a PV power conditioning system. NEDO joined the Maui smart grid demonstration under the Hawaii–Okinawa clean energy memorandum of cooperation. Figure 7 shows the demonstration facilities supporting this project.

Japan's Ministry of Economy, Trade and Industry (METI) conducted the Miyako-Jima project (2009–2014) and the Cabinet Office of Japanese government conducted the Okinawa Smart Grid Energy Island Project (2011–2016). The Miyako project demonstrates the use of a small independent grid to employ renewable energy on off-grid islands. Installing PV on the island produced a duck curve on sunny days (see Figure 8); the demonstration project used batteries to stabilize power output.

The Okinawa project aims to contribute to secure energy supply and to reduce CO_2 emissions. The project constructed a model utilizing maximum (100%) renewable energy. Energy sources include existing wind in Miyakojima and new solar panels and batteries installed at the customer locations.

The New Mexico project employed a 3 MW microgrid energy management system. The energy source was a PV system, and a stationary battery system provided grid stabilization through PV output control. The project created a duck curve artificially to test battery operation, aiming for flat power flow (see Figure 9).

The projects shared one conclusion: high PV penetration can result in loss of revenue from power sold. Similar situations have been observed in California, Italy, and Germany.

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http://www.nedo.go.jp/english/

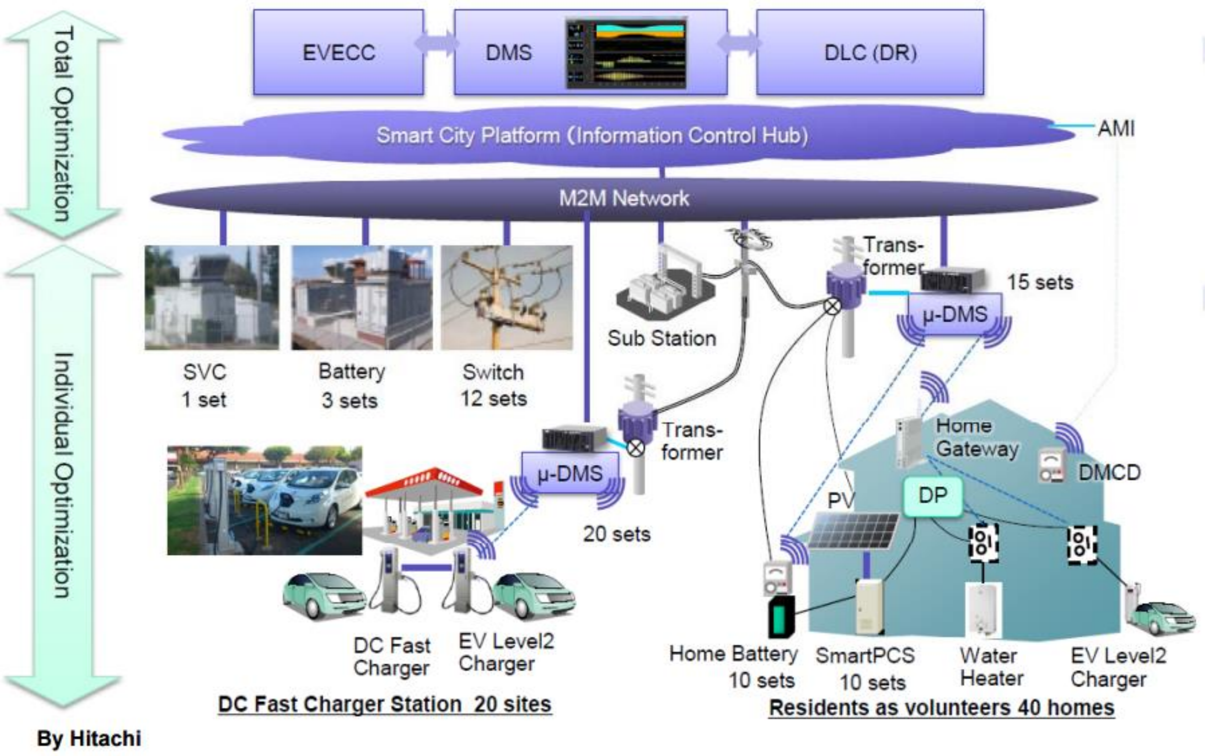


Figure 7. Demonstration facilities on Maui.

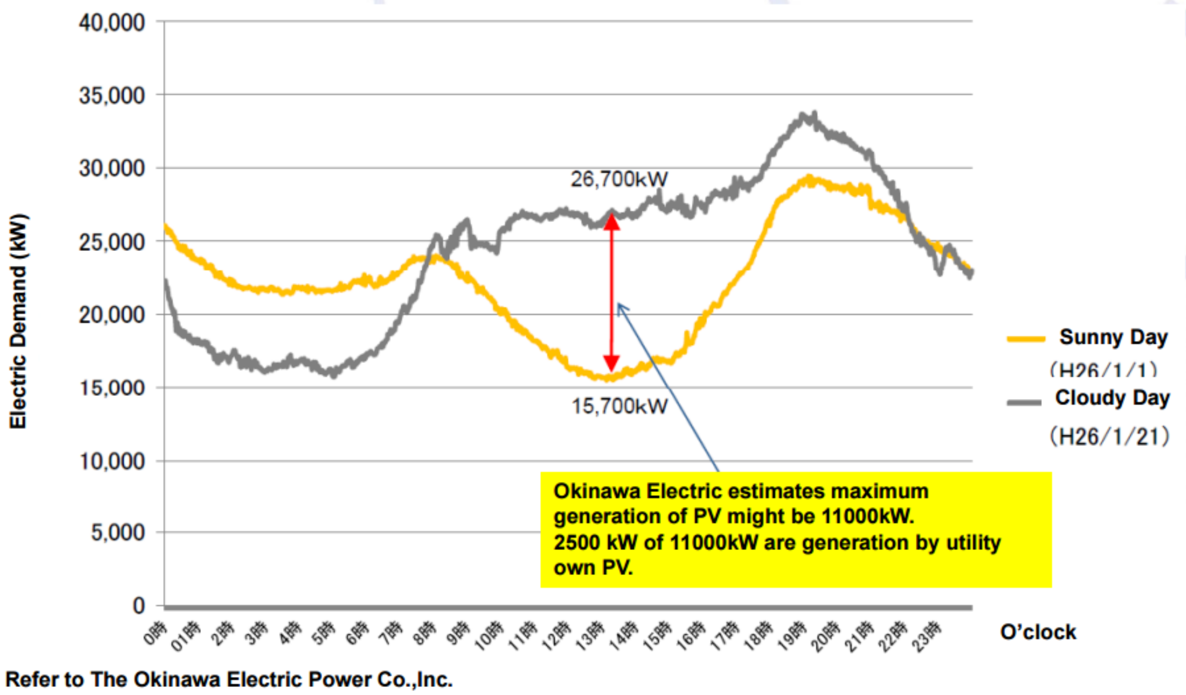


Figure 8. Renewables penetration in Miyako-Jima.

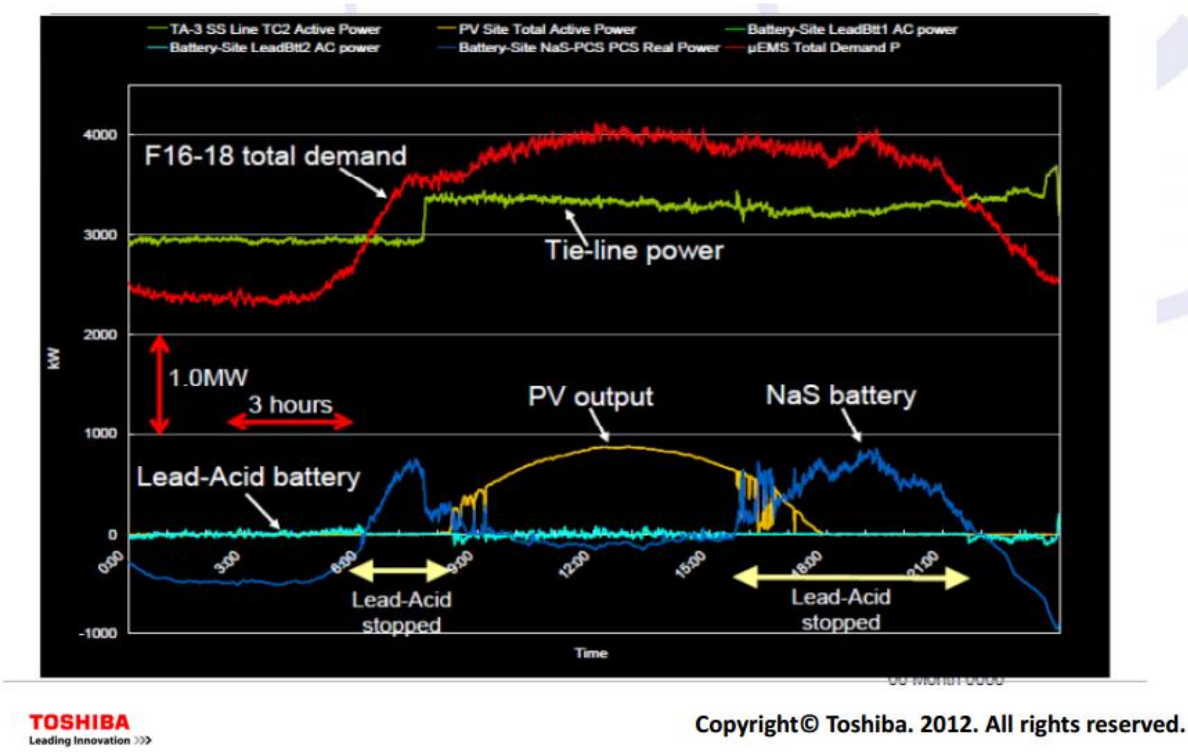


Figure 9. Daily operation of Los Alamos microgrid feeder.

DC-Based Open Energy System: A Bottom-Up, Distributed Power System for Self-Sustaining Islands

Mario Tokoro, Founder & Executive Advisor, Sony Computer Science Laboratories, Inc., Japan

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/4Tokoro_SONYCSL.pdf

Sony Computer Science Laboratories aims for future energy systems that are sustainable, dependable, and affordable. Their approach constitutes open energy systems (OESs) that use distributed energy sources, local production, and an exchange network rather than a distribution network. The system generates, stores, and shares electrical energy in a bottom-up manner to provide renewable energy to communities.

Sony's direct current (DC)-based Open Energy System(DCOES) project involves an energy system that serves 19 inhabited houses at the Okinawa Institute of Science and Technology, so the system has been tested in a real environment. Each house is equipped with PV panels, batteries, and an energy exchange subsystem that handles the power transfer between houses via a private DC exchange network, i.e., a 350 V bus line (see Figure 10). The system has been operational since December 2014.

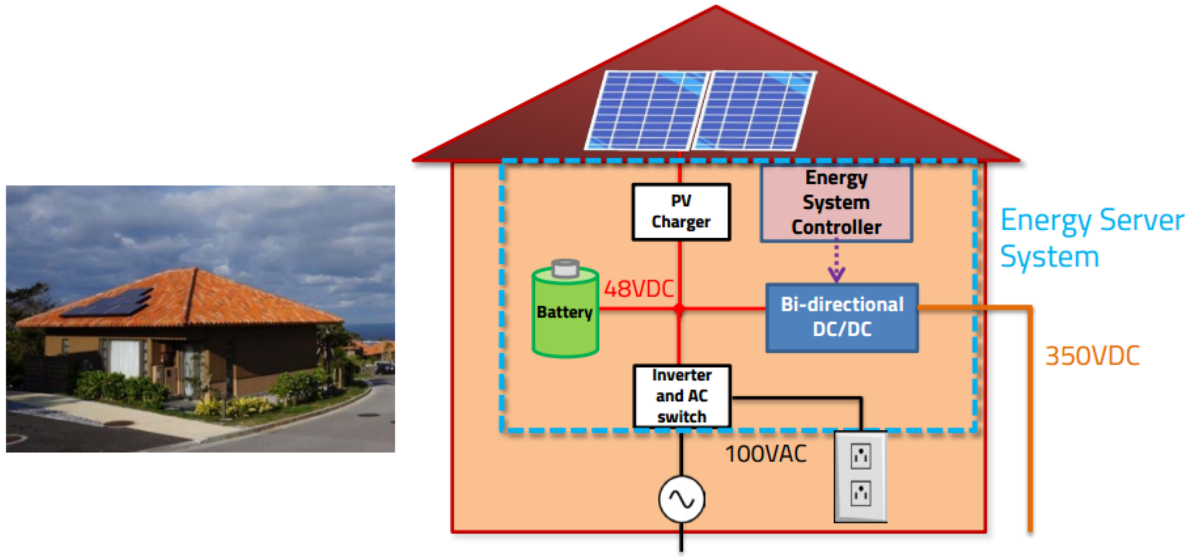


Figure 10. Configuration of an individual house in the DC-based OES project.

The project employs stock-based, asynchronous load–supply balancing that considerably lessens the storage need. Existing batteries cannot store all the energy produced by PV. The project's energy exchange technology enables an exchange of DC-type energy among batteries. The system leverages differences in usage patterns—e.g., the energy needed to light a room versus the energy needed to recharge an EV—to maximize the use of PV panels and subsystems.

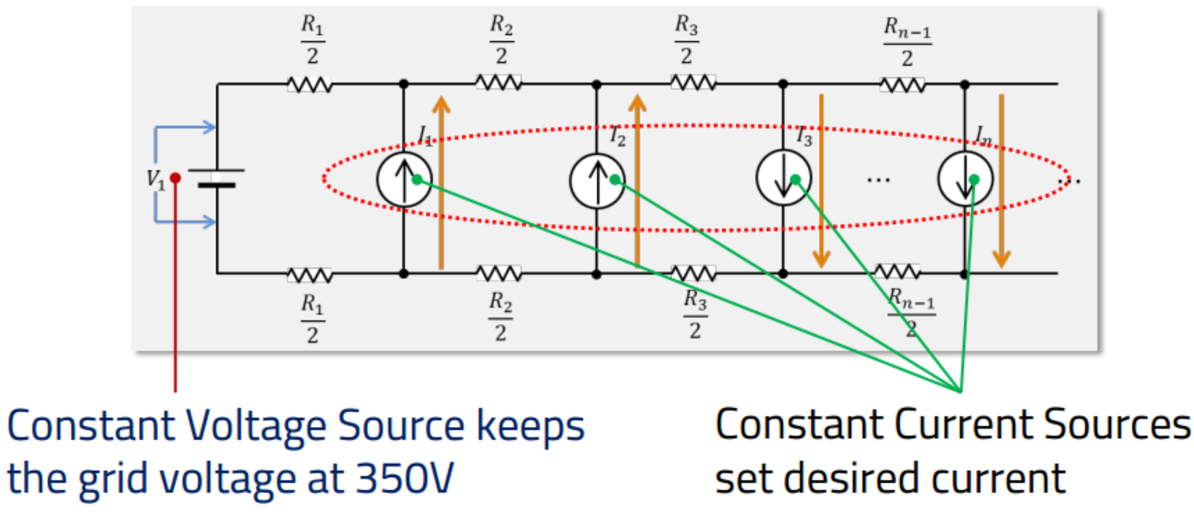


Figure 11. Base theory: one voltage source and n current sources with durable and flexible distributed control.

The technology is designed to support various renewable energy sources and was proven efficient in the use of renewable energy.

The project compared the new DC-based distributed system with a top-down centralized system. The bottom-up OES was shown to be flexible in size and variety with incremental costs, and one failure does not result in total system outage. The top-down system was fixed in size with high initial costs, and a single failure could cause outages across the system. However, the distributed system may not be as efficient overall as the centralized system.

Bottom-up architecture can be applied to various locations, from very small, isolated communities to ones that grow by incorporating hierarchical architectures. In the demonstration project, most energy exchanges take place at the lowest layer—from household to household—so there is very limited dependence on a large grid. These findings indicate that this solution could support sustainable island energy systems.

Connection between communities with 1kV DC line, expansion to large buildings would be next steps.

Electricity Storage for Island Transitions: A Strategic Niche?

Ruud Kempener, Analyst, **IRENA**

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/5Kempener_IRENA.pdf

Electricity storage technologies are developing rapidly but are at various stages, with some facing challenges in development and others already in use (see Figure 12). Some of the more successful, such as lithium-ion and vanadium redox flow, are experiencing drastic cost reductions and increased installed capacity. Others are in the "trough of disillusionment," and expanded R&D is needed to address inflated expectations.

With the variety of technologies in development, decision makers for island communities must consider the local value chain and system characteristics.[13] Hybrid storage concepts use more than one technology option, which could provide multiple grid functions such as load shifting, operational reserves, regulation, and primary control. Minigrids have their own subsets of storage functions and suitable technologies.

Several islands have conducted energy storage projects to support renewables integration. The Auwahi Wind Farm in Maui employed an 11 MW battery system for ramp rate management. Kodiak Island in Alaska employed advanced lead acid battery storage and a flywheel for power smoothing. Tokelau in the Pacific Islands also deployed a battery-based system. Gorona del Viento in El Hierro, Spain, implemented hybrid storage to support a hydroeolic power plant comprising a 11.5 MW wind farm and 11.3 MW pumped hydro.

Island projects can face challenges beyond technology-based needs. The following are, according to Irena, critical needs to support development on islands and remote areas:

- Facilitate financing
- Create local value chains
- Develop a global database with practical examples
- Guide policy makers through the required tools

[13] For more details on storage technologies, see EGRD, *The role of Storage in Energy System Flexibility – Summary Report*, IEA-Paris, 2014.

In conclusion, the following was stated that electricity storage technologies were rapidly developing, and reducing in costs. Still R&D should broaden and we should address inflated expectations. System considerations and local value chain were more important than individual characteristics. Hybrid functions could be interesting options for providing multiple grid functions. In this contribution one case study of the IRENA work was highlighted[14].

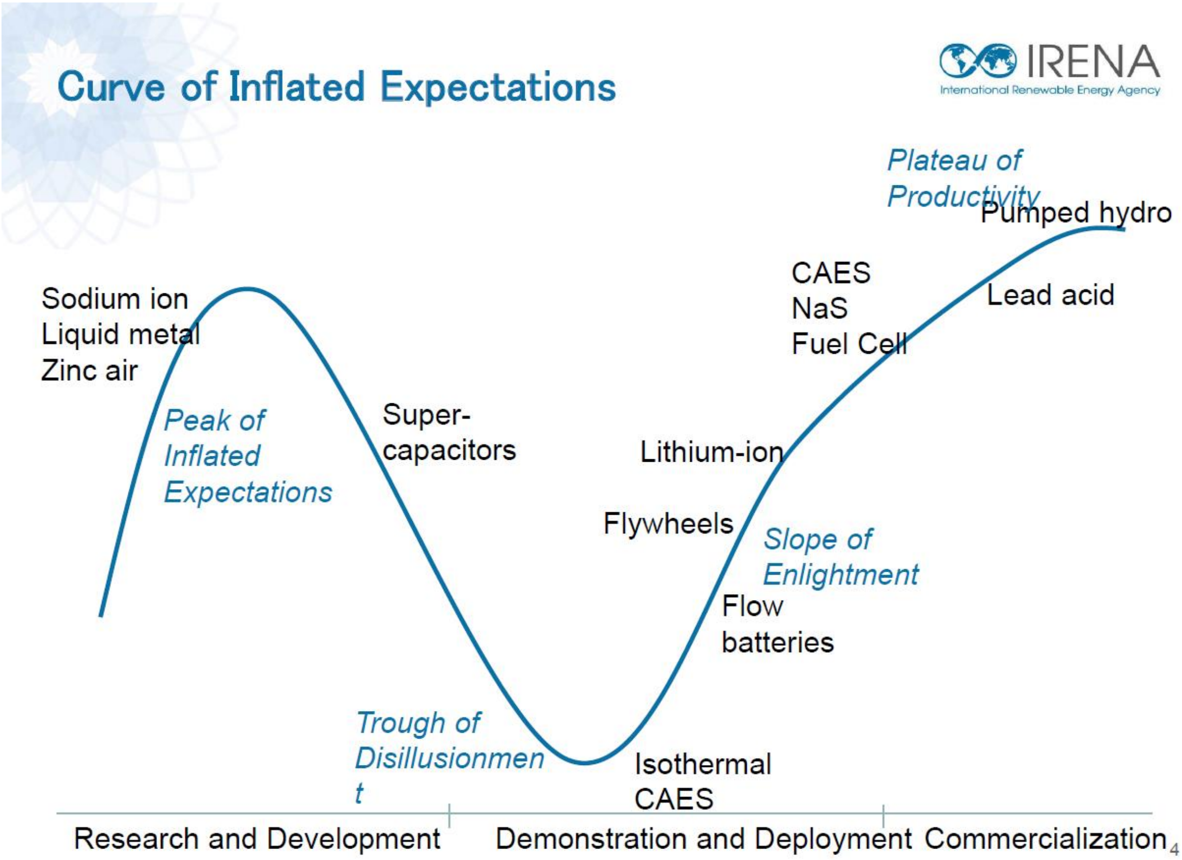


Figure 12. Storage technologies in the RDDD&D cycle.

[14] Linus Mofor et al.(2013): *Pacific Lighthouses Renewable Energy Roadmapping for Islands*, Irena-Abu Dhabi

Integration of Hydro–Wind Power Generation on El Hierro

Gabriella Németh, Energy Directorate, Electric Energy Department, Spain

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/6Nemeth_CNMC.pdf

El Hierro Island traditionally has diesel-based power generation with limited wind (280 kW) and PV (≈5 kW). However, a recent project has established a hydro–wind power plant (HWPP), which could increase the share of renewable energy sources to more than 50%. The project goals were to offer a technical solution to integrate renewables, improve power generation efficiency, reduce the overall cost of resource exploitation, reduce greenhouse gas emissions, and reduce dependence on oil products with volatile prices.

The thermal diesel-based plant, Llanos Blancos, remains in operation and accounts for 11 MW of generation. However, the HWPP started operations in August 2014, increasing the share of renewable (see Figure 13). The plant combines 11.5 MW of wind with a hydro pumping station with 6 MW capacity and hydro generation plant with 11.3 MW (nominal) capacity.

The plant has only one connection to the network; wind and hydro are jointly operated. There are two operating modes: supply and storage. Figure 14 provides a rough schematic of the overall system, which implies joint operation and remuneration of the pumping station and the wind generator. Pumping can only be run on wind energy, thermal generation cannot be used for this purpose, due to regulation specific to this installation

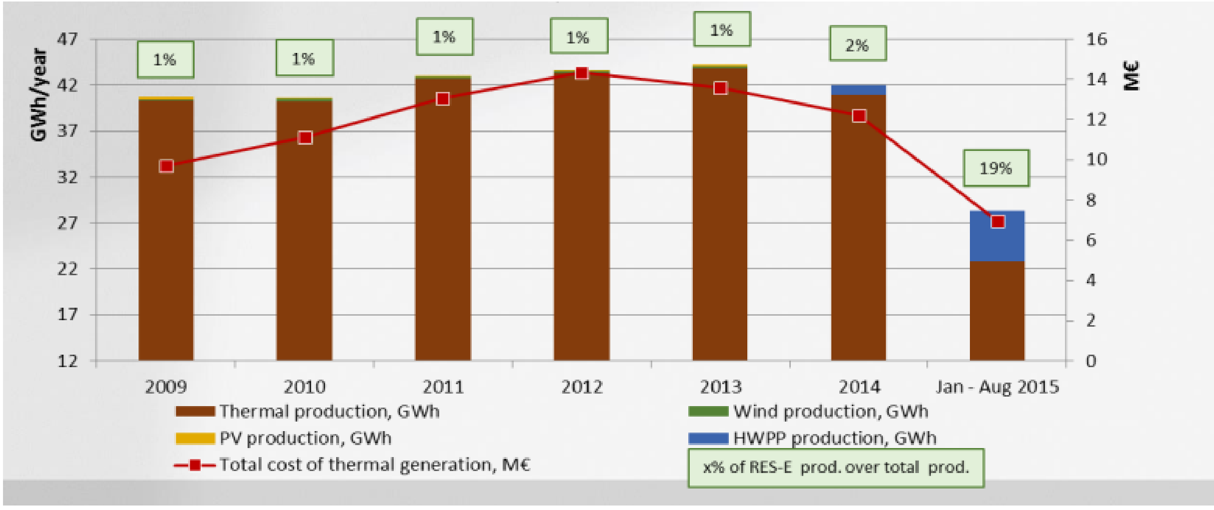


Figure 13. Power generation on El Hierro Island.

Figure 14. Hydro–wind plant schematics.

HWPP operation has priority access as other renewable power generation. Cost reduction for power generation is one of the most important issues for island communities. The relatively small power system of islands puts limitations on leveraging market conditions, so unbundling is not necessarily an effective cost reduction strategy. However, smart grid elements such as distributed generation and storage show potential to improve cost efficiency and integration of intermittent generation.

Islands and urban areas share certain features that could make lessons learned from island projects relevant to city planning. Both have densely populated areas with space limitations that encourage rooftop generation. In addition, developing distribution networks is difficult and expensive, and obtaining permits and authorizations can be its own challenge.

On the other hand, islands and urban areas are dissimilar in many ways. Islands lack interconnections via backbone transmission networks, while large cities are typically surrounded by high-voltage transmission rings. In addition, islands tend to have regulated conditions, while cities have market conditions.

Session 3. Sustainable cities

Moderator: Rob Kool

This session explored similarities and differences in technology and other solutions for cities and islands as well as sparsely populated areas.

Rapid global urbanization is challenging municipal governments to adapt to changing demands for energy, infrastructure, and space. As providers of energy services to the majority of the world's population, cities are uniquely positioned to accelerate the transition to energy efficiency and renewable energy. The goal of expanding renewable energy uptake is intertwined with other objectives in increasing efficiency and enhancing reliability.

The session was organized as a world café with inspirational speeches and a true workshop with interventions and discussions of participations.

Figure 15. Workshop participants in discussion sessions.

Yokohama Smart City Project: Large-Scale Demonstration and Future Implementation

Yuki Murai, Officer, Project Promotion Division, Climate Change Policy Headquarters, City of Yokohama, Japan

- (no link to presentation available)

Yokohama, Japan, has a population of 3,700,000 and is located near Tokyo. The city faced several challenges related to rapid population growth and global warming. The population is 3.5 times what it was 60 years ago and is expected to continue increasing until 2020, thereby increasing energy demand. The temperature has risen approximately 2.7°C over the past 100 years, and the impacts include local heavy rain that was difficult to predict and other extreme weather events, such as typhoons, that lead to floods. As such, there is a strong focus on reducing greenhouse gas emissions.

The Japanese government selected Yokohama as the location for *the* next-generation energy and social system demonstration area project. This project is designed to enable the building of smart grids and their promotion overseas as part of the country's new growth strategy, *Strategy to Achieve Global Leadership in the Environment and Energy through Green Innovation*. Strategic projects involve incorporating renewable energy into existing power networks, peak shifting, and peak saving. The public notice for proposals was issued in the winter of 2010. Twenty applications were submitted, and Yokohama was one of four selected. In August 2010, the master plan was announced, with duration from fiscal year (FY) 2010 to FY 2014; the Yokohama project schedule is shown in Figure 16. March 11, 2011, was the date of the Great East Japan Earthquake.

The project is a collaboration between Yokohama City, 34 businesses, and 15 sub-projects. It aims to promote the international standardization of related industries, advance them to the next generation, and improve competitiveness in the areas of energy and the environment.

The project has established an energy storage system (see Figure 17) and a regional community energy management system (CEMS) (see Figure 18), which was in place by mid-FY 2012, as well as operational models for next-generation tools and techniques such as demand response. Various forms of demand response were implemented on a trial basis in FY 2012 and the results studied in FY 2013 and FY 2014. Using demand response, home energy management systems (HEMS) led to a confirmed maximum peak shaving of 15.2% (based on the HEMS monitor). Using an integrated building energy management system (BEMS) resulted in maximum peak shavings of 22.8%.

Community energy management would be implemented strategically, based on the specific supply and demand scenario. Disaster preparedness would be improved through energy cooperation between the hospital and the ward hall. Energy cogeneration would be implemented, improving operational efficiency and effectively using waste heat, thereby reducing both CO_2 emissions and cost. Generated electricity would be supplied to specified partners with close ties. While electricity would be generated via gas engines, etc., the accompanying waste heat will be used to meet the demand for climate control. Old heat source equipment would be upgraded or replaced. A BEMS would provide effective utilization of waste heat and optimal control of local energy.

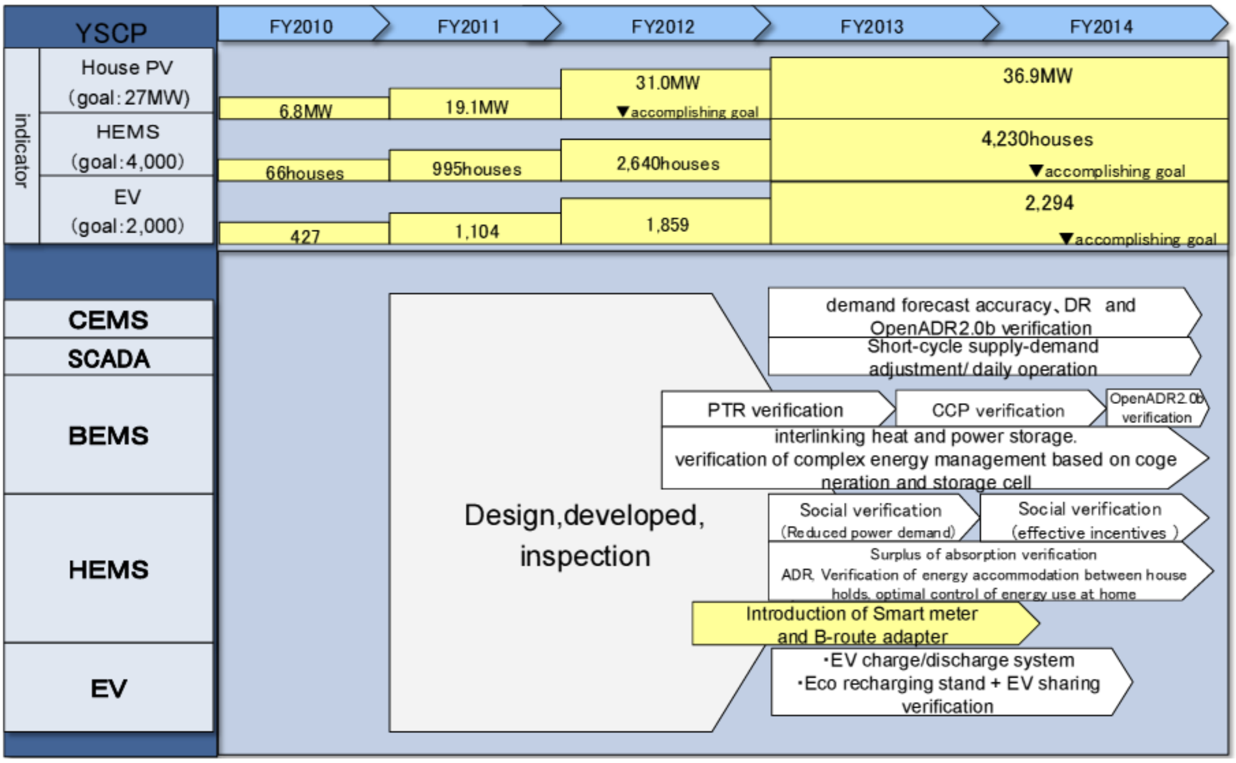


Figure 16. Project schedule. Copyright: Yokohama City Project, 2014–2015.

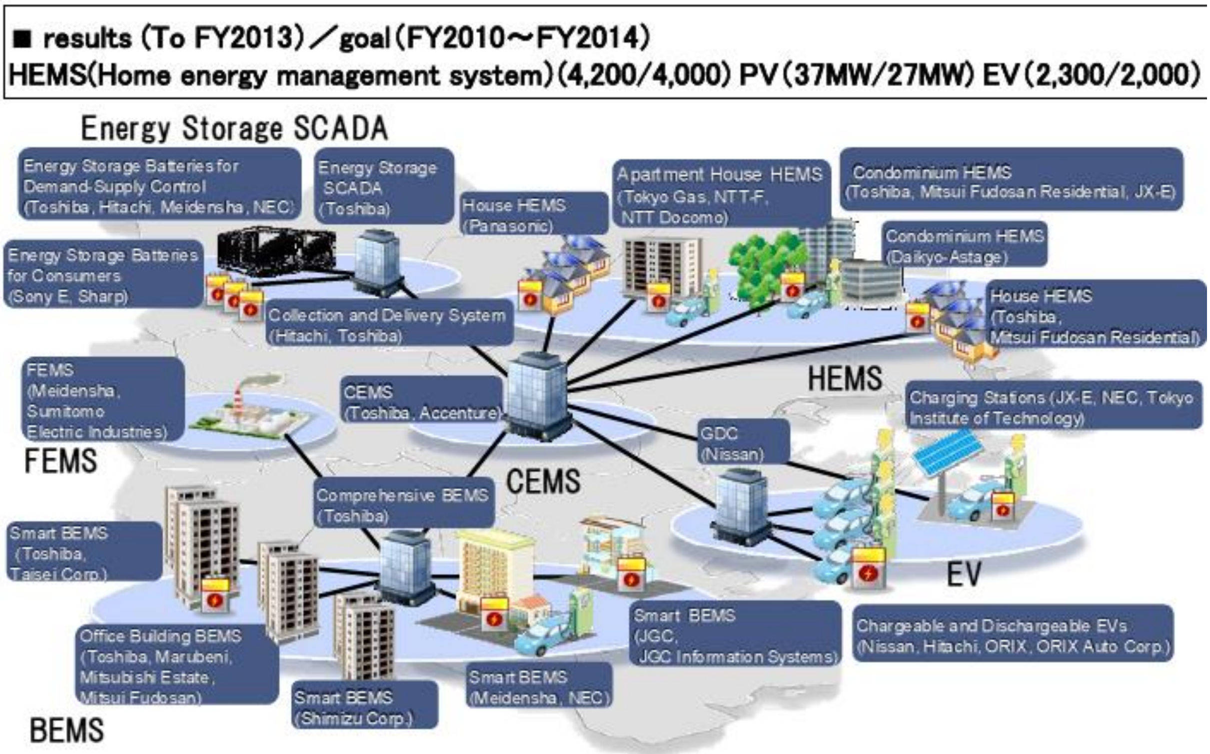


Figure 17. Energy storage in the Yokohama project. Copyright: Yokohama City Project, 2014–2015.

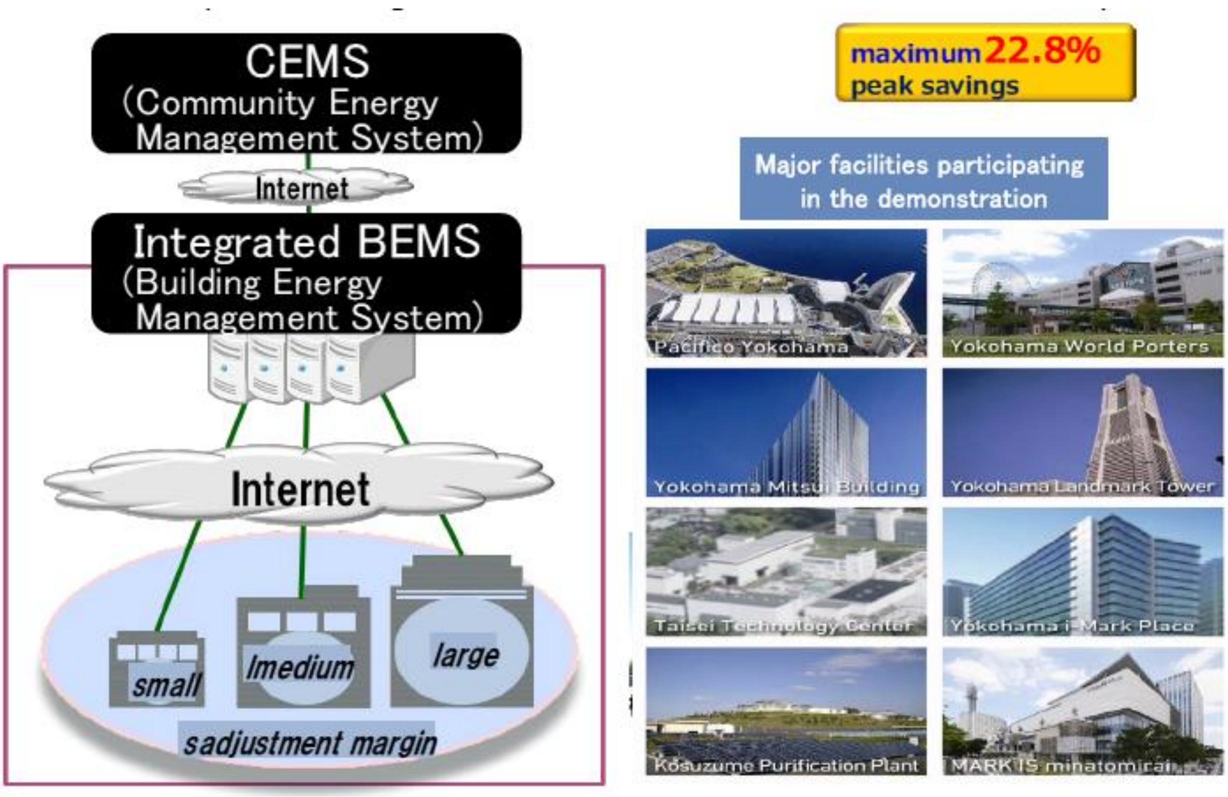


Figure 18. Energy management systems and participating facilities in the Yokohama project.
Copyright: Yokohama City Project, 2014–2015.

The project has also made Yokohama into an energy recycling city, i.e., a city with an increased energy supply that uses that energy in a manner that is efficient and waste-free. The testing is complete, and Yokohama can now move to full-scale implementation, becoming a demonstration project for other cities.

The Yokohama Smart Business Association will be a key coordinator for the transition from proven tests to actual implementation. Launched in April 2015, the Association is a centre for public–private partnerships. It is promoting the project and the benefits of “energy-recycling cities”:

- Promoting local energy production for local consumption
- Conducting feasibility studies and implementation plans for projects Introducing renewable energy
- Making highly efficient use of electricity, heat, and other forms of energy in certain areas
- Using BEMS to verify public facility demand response
- Verifying adjustment of supply and demand of electric power from power plant generation through demand response-driven reduction of electric power demand

This project has established new approaches to the operation of energy management systems. The aim is to conduct outreach, both inside and outside Japan, with the information gathered. This outreach promotes the benefits of energy management:

- Energy reduction and creation
- Higher resilience to disasters
- Economic stimulation
- Greater citizen recognition
- Power peak dispersion
- Demand response
- Reduced total power usage

JST's Activity towards the Realization of a Dynamic and Affluent Low-Carbon Society

Kenichi Furuhata, Director of the Center for Low Carbon Society Strategy, Japan Science and Technology Agency (JST)

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/8Furuhata_JST.pdf

The conceptual framework for a dynamic and affluent low-carbon society is shown in Figure 19. In the figure, Quantitative Economic & Social Scenarios, Quantitative Technology Scenarios, and Low

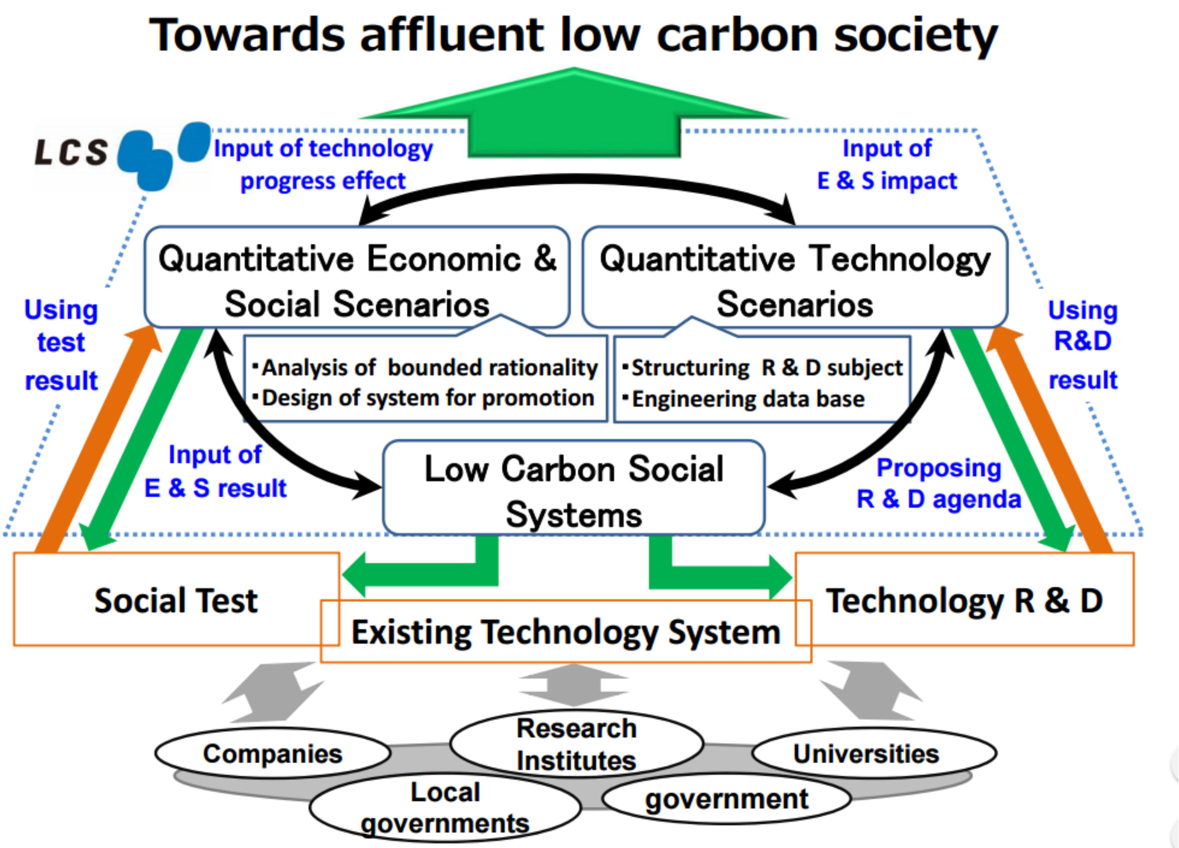


Figure 19. Framework for an affluent low-carbon society.

Carbon Social Systems are the three sides of a triangle that supports the low-carbon society. Each side has its own research and analyses. The results of these activities feed into the other two sides of the triangle, thereby strengthening the whole triangle. Realizing such a society is not a purely academic exercise; companies and national and local governments are stakeholders as well. Achieving a low-carbon society necessitates reducing CO_2 emissions in daily life. In FY 2013, total Japanese CO_2 emissions from energy were 1.2 billion metric tons (Gton). The contributions of different sectors are as follows: industry (42%), residential (20%), offices (16%), and transportation (22%). The share of emissions from daily life—a sum of residential, commercial and transport sectors—is 58%. Electric power contribution is 53%. Therefore, achieving zero-emission power generation will lead to 53% reduction.[15]

To reach an affluent low-carbon society by 2050, the focuses must include high energy efficiency, increased renewable energy usage, and resource recycling systems. Japan has a number of renewables options that can be implemented and integrated. Increased renewables sources can be combined with better wall insulation, better appliance efficiency, and LED lighting. Together, these strategies can reduce 75% of energy use from day-to-day activities by 2050. This scenario does not call for great sacrifice; people will be able to lead comfortable lives and enjoy good health.

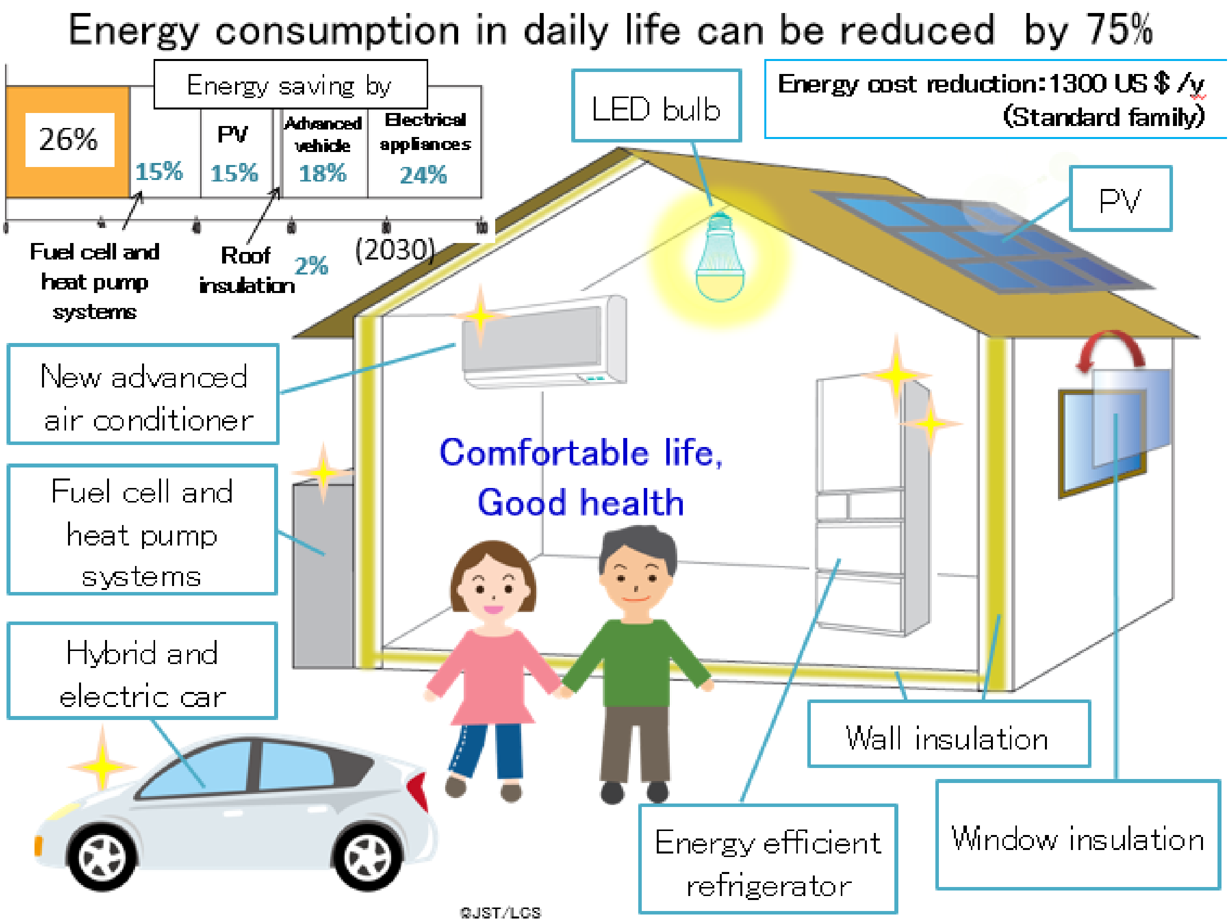


Figure 20. Ways to reduce energy consumption in daily life.

[15] The Energy Conservation Center, *Handbook of Energy & Economic Statistics in Japan*, The Institute of Energy Economics, Japan: 2015.

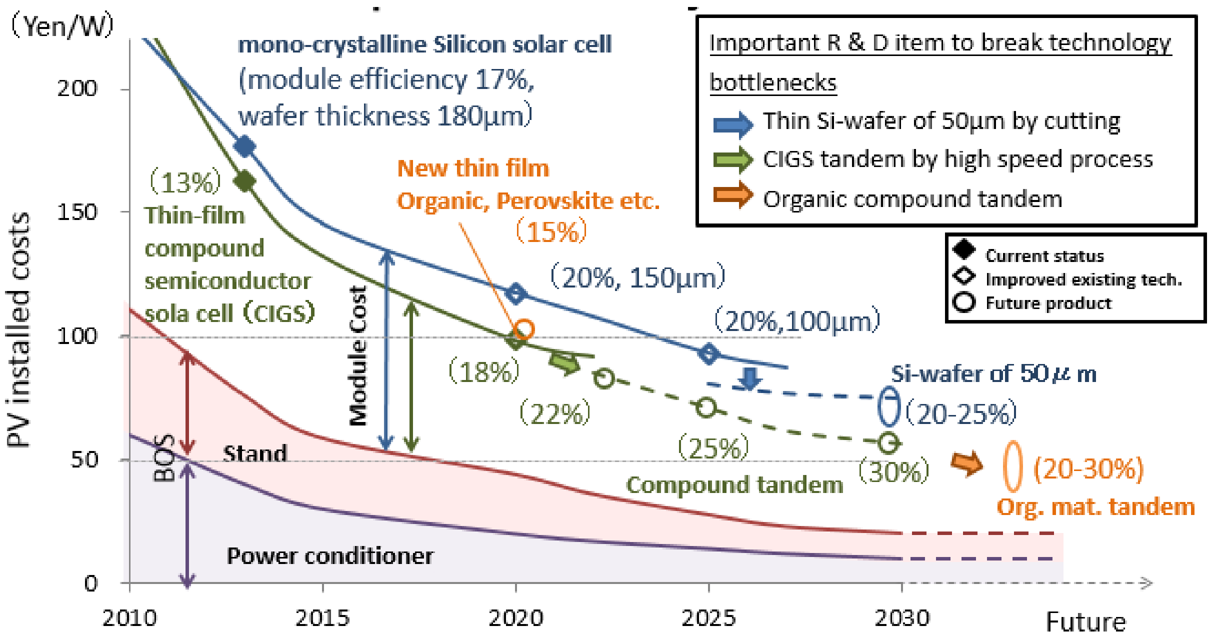
Regarding appliances, the Japanese Top Runner program was launched in 1990 and has moved the nation toward much higher efficiency. For example, the coefficient of performance (COP) of new air conditioning reached 5.9 in Japan, which is on average about twice as efficient as other countries. In 2013, the program affected over 70% of appliances in 26 categories.

Concerning transportation, the average fuel efficiency (km/gasoline-L) has risen since 1995 from 12 to 18 on average, but hybrids are far more efficient (30–40 km/gasoline-L). Hybrids now have a market share of 15%, which is expected to increase to 50% in coming years.

These efficiency improvements have had noticeable effects on TEPCO and other power grids. Final demand has decreased steadily since 2011.

Figure 21 shows prospective PV generation system costs based on different technology scenarios, providing an estimated cost of electricity generation systems with a high share of renewables in 2050.

Experiences in Tokyo can transfer to other global cities, especially to Asian cities.



		2013	2020	2030	Future PV
Annual product		1 GW/y	5 GW/y	5 GW/y	1 GW/y or larger
lifetime (years)		20	20	30	20 or longer
Installed sys. cost	Module cost	79 Yen/W	50 Yen/W	37 Yen/W	24 Yen/W
	BOS cost	84 Yen/W	47 Yen/W	20 Yen/W	20 Yen/W
	Total PV system cost	163 Yen/W	97 Yen/W	57 Yen/W	44 Yen/W
Cost of electricity		18 Yen/kWh	11 Yen/kWh	5 Yen/kWh	4 Yen/kWh

Resource：Center for Low Carbon Society Strategy (LCS)

Figure 21. Prospective PV system costs.

World Café Debate

The two Session 3 presentations were followed by a subgroup debate centred around three topics that are strongly intertwined:

- Technological solutions
- Similarities and differences between islands/remote areas and cities
- The role of the end user

Technological Solutions

The first step to meeting energy-based needs was to employ all available energy efficiency strategies: energy improvement in buildings, appliance labelling, advanced illumination (e.g., LEDs), etc. In other words, mine the "first fuel" (As presented in the IEA ETP)

When discussing islands, one of the most important technical topics is the shift from a central system to a distributed network, as more and more end users are implementing private renewables-based systems. This trend will have a considerable impact on the infrastructure, especially the rollout of smart grids.

Unlike on the mainland, islands usually have one central utility. Market competition with deregulation occurs only on very big islands or island clusters, such as Japan. Nonetheless, more and more options to produce energy are entering the market. The resulting ever-changing energy mix will increase the need for demand response and demand-side management to address the challenges of flexible production.

Storage has become an essential element of demand response/demand-side management. The storage market is divided into natural storage (pumped hydro etc.) and chemical solutions. The choice depends partly on local options; for example, pumped hydro is the obvious choice on the Faroe Islands but is not an option for the vast majority of the Pacific Islands. As batteries increase in lifetime and capacity and decrease in price, storage could become an affordable option for Islands. Of the available technologies, the use of thermal (ocean) energy seems the least developed and needs the most R&D. Sony's DC study shows that it is possible to have limited storage capacity if there is a good grid operating system in place.

Other technologies (solar PV, wind, biomass, biogas and hydropower, hydrogen) are more in need for adjustments to meet the sometimes harsh circumstances then the improvement of the option itself. Waste to heat seems to be less exploited, and the present nuclear options are not applicable to most island scenarios. Introducing electric cars to an island as part of the energy system presents one excellent solution to some challenges.

Similarities and Differences between Islands/Remote Areas and Cities

Like island, cities would benefit from implementation of the "first fuel", and energy efficiency techniques are comparable. Both cities and remote areas have options to attract investment by highlighting multiple benefits. In addition, demand-side management presents useful options in both urban and remote settings.

The main differences between islands/remote areas and cities, with some exceptions, are the population size, energy access, industry, and the buffering capacity of large networks. Because of the geographies, compact cities are usually not an option on islands, which affects technology and infrastructure options as well. Transport is also affected; individual transport options dominate in a island setting.

Looking not at physical differences but at market conditions, energy sector deregulation and industry participation are major differences. The feasibility of transposing results from islands to cities, or vice versa, depends on the technology at issue, among other factors.

The Role of the End User

End users comprise a heterogeneous group, so the energy industry tends to promote awareness rather than real involvement. However, it has become clear that, for projects aimed at change, the end user has to be involved at the earliest possible stage.

Consumers act differently from what “models” predict. Planners tend to look at consumers as “homo economicus,” i.e., they assume behavioural change based on least-cost options. In practice, people are willing to invest in renewable energy and even storage, even if there is not a valid profit model. Safety, independence, and security of supply turn out to be strong drivers for behaviour. Solar PV installations and participation in wind farms had a far stronger uptake than expected. When climate-related topics (CO_2, air quality, and climate readiness) are added to the mix, island coalitions of public and private parties arise that allow the drafting and implementation of sustainable roadmaps.

Both industry and households need incentives to become sustainable. Although economic incentives do not play as large a role as expected for most end users, these incentives do need to be partly financial on islands, as energy costs include fuel transport and low generation efficiency, resulting in extremely expensive electricity. These schemes do not have to be subsidies, per se. The price of energy threatens healthy economic development. Business models that can bridge the gap between concept and realization can make a difference. On many islands, many of the present energy (diesel) generators are outdated and in need of expensive maintenance, which can help to establish the business case.

Consultancy is needed to get processes started. Governmental organizations and universities can (and do) play a central role. Experts indicate developing a global city index and a global island index could be helpful tools to provide comparisons and guidance.

Session 4. Island States

Moderator: Birte Holst Jørgensen

Many small island states are highly dependent on imported fossil fuels to meet their energy needs. This supply chain has a number of impacts: high and often rising costs for electricity, vulnerability to oil price shocks, and supply interruptions. Therefore, many small island states are looking to more sustainable energy systems, in which improved energy efficiency and renewable energy play increasingly important roles. Unlike subnational territorial units, island states have jurisdiction to decide on proper actions and frameworks to transform their energy systems.

De-Risking System-Wide Investments through Energy Transition Planning: Lessons from Hawaii, U.S. Virgin Islands, Puerto Rico

Stephen Walls, Department of Energy, United States

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/09Walls_DOE.pdf

The island states of Hawaii, Puerto Rico, and the U.S. Virgin Islands all have wider jurisdiction than, for example, cities. The *Energy Transition Initiative: Islands* is an opportunity for insular areas to define and realize their own visions for clean economies. The mission is to accelerate commercial opportunities to transition island economies off imported fossil fuels by focusing on local resources. The initiative aims to eliminate island economies' dependence on imported fuels and to identify replicable solutions for other such economies around the world.

A "playbook" was developed to support the Islands. The Islands Playbook is an action-oriented guide to successfully initiating, planning, and completing a transition to an energy system that relies primarily on local resources, lessening a dependence on one or two imported fuels.[16] The guide highlights the process of organizing an energy transition and implementing projects. It is intended to serve as a readily available framework that any community can adapt to organize its own energy transition effort. Topics include identifying near-term actions that support long-term goals, tracking progress to maintain momentum, and improving execution. The guide also provides lessons learned from work to date on the U.S. Virgin Islands, Hawaii, Aruba, Barbados, and the Canary Islands.

The playbook focuses on people as well as projects. There is guidance for engaging stakeholders proactively and empowering the community—not just the government and utility—to create a vision. In addition, the guide discusses developing human capital and ensuring that efforts do not depend on one administration or one person.

The playbook contains downloadable worksheets and templates, providing community organizing tools, such as stakeholder and donor coordination matrices, and project management tools, such as a risk register and Strengths–Weaknesses–Opportunities–Threats (SWOT) matrix.

The combination of federal support and engagement of the island governance system had very good results in terms of increasing share of renewables and improving energy efficiency. Some of the

[16] The playbook can be downloaded: www.energy.gov/islandsplaybook.

cases, such as Hawaii's,[17] are well documented. Hawaii has a goal of 70% clean energy by 2030. The U.S. Virgin Islands has a goal of 60% fossil fuel reduction by 2025. So far, milestones have been met earlier than planned (see Figure 22).

The U.S. Department of Energy (DOE) supports the islands projects with planning tools such as the Islands Playbook, technical assistance, investment subsidies, and outreach materials. The island state provides the political commitment and strategic pathway, adoption of legislation and regulation, and support for demonstrations and other technology projects.

More information can be found on the DOE website,[18] which also provides snapshots of island energy scenarios.[19]

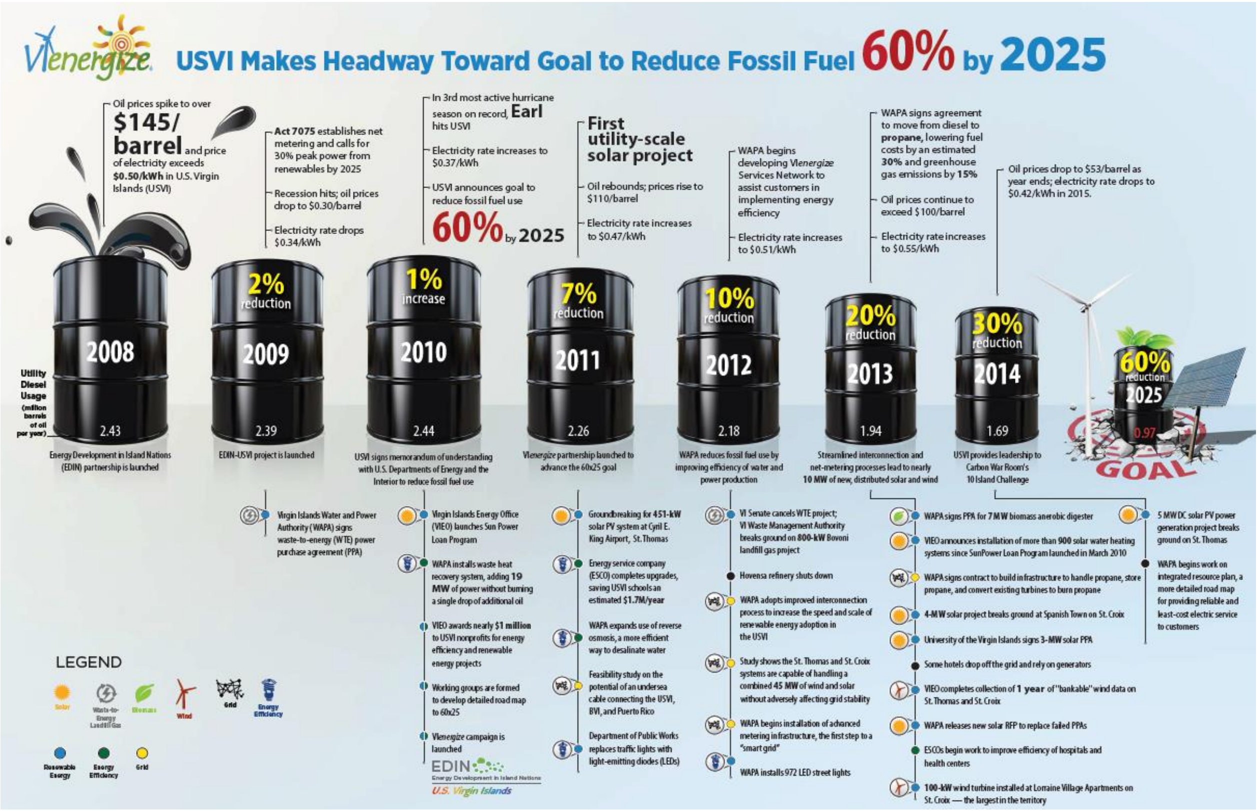


Figure 22. Virgin Islands project achievements.

[17] More information about the Hawaii effort can be found at http://www.hawaiicleanenergyinitiative.org.
[18] DOE, "Energy Transition Initiative" (webpage), accessed October 2015, http://energy.gov/eere/technology-to-market/energy-transition-initiative.
[19] DOE, "Island Energy Snapshots" (webpage), accessed October 2015, http://energy.gov/eere/about-us/island-energy-snapshots.

The Advanced Technology and Future Prospect of OTEC for Islands – Towards Stable Energy and Sustainable Development

Yasuyuki Ikegami, Professor, Institute of Ocean Energy, Saga University, **Japan**

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/10Ikegami_SagaU.pdf

Japan and several other countries (e.g., the European Union and the United States) are investigating ocean thermal energy conversion (OTEC). Many are members of the Implementing Agreement on Ocean Technology.[20]

Several completed projects implemented technologies with multiple functionalities to improve the economics of the installation. For example, the Island Kumejima OTEC project provided multiple benefits through the use of deep seawater, such as increased production of sea grapes and prawns, benefitting those industries.

OTEC provides multiple advantages:

- A clean and renewable energy source. OTEC uses only seawater as energy resource.
- Inexhaustible energy. In Japanese territory alone, 1014 kWh/year are available.
- Broad utility. The technology is applicable in 98 countries.
- Stable energy. Energy can be generated stably day and night thoughout the year.
- Zero emissions. OTEC has no CO_2 or other greenhouse gases, SOx, NOx, or wastes.

Despite its apparent benefits, ocean energy requires further research, development, and demonstration (RD&D) to increase reliability in harsh waters and reduce costs. Consequently, ocean energy was not included in national energy analyses and forecasts. Nonetheless, the growing number of patents in the field indicates progress.

The possible influence on the great ocean currents[21] ,if OTEC were deployed widely, was not discussed.

[20] See ES: Ocean Energy Systems, An IEA Technology Initiative, "Ocean Energy: Saves, Tidal & Currents, Salinity, Thermal," accessed October 2015, http://www.ocean-energy-systems.org/.
[21] Ocean review: http://worldoceanreview.com/en/wor-1/climate-system/great-ocean-currents/

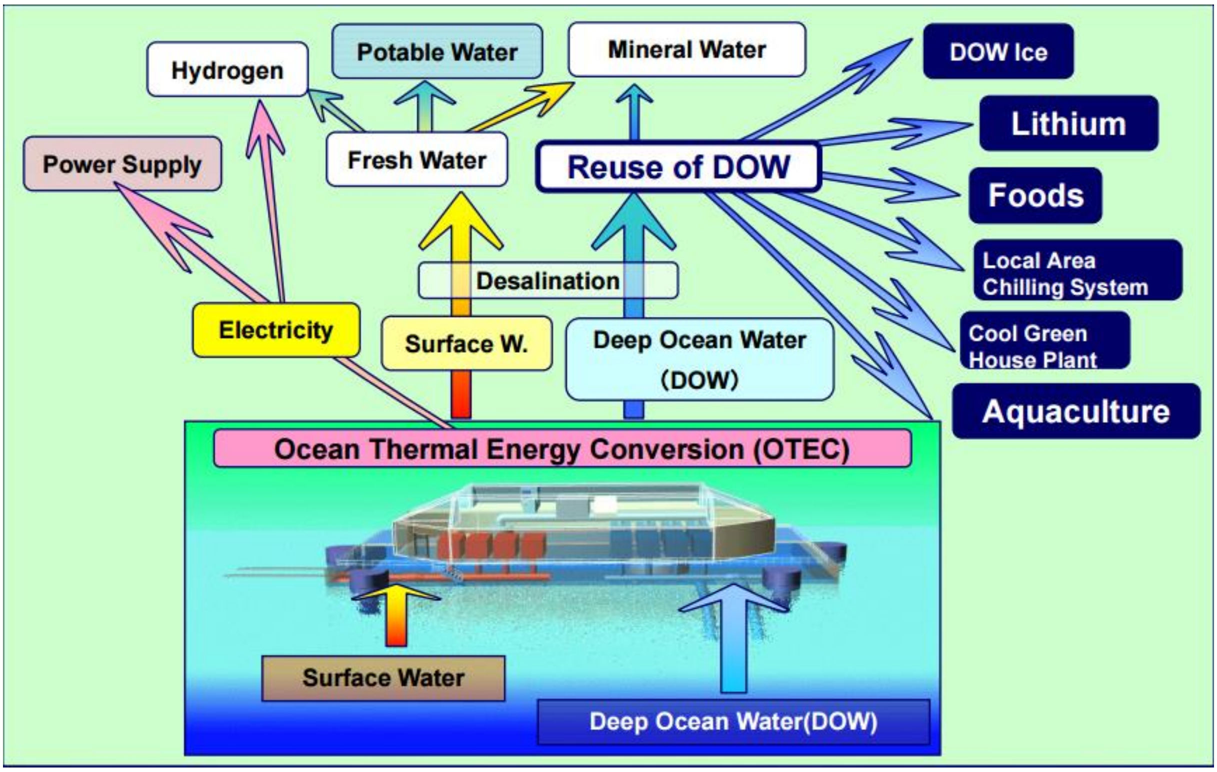


Figure 23. Byproducts of a hybrid OTEC plant for an island.

Appliance Labelling and Standards in the Pacific Islands

Timothy Clifford Farrell, Copenhagen Centre on Energy Efficiency, Senior Advisor, **UNEP DTU Partnership**, Denmark

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/11Farrell_DTU.pdf

Appliance standard and labelling programs commenced in the 1970s and now cover 80 countries and more than 50 products. The programs have reduced national and sectoral energy consumption by anywhere from 10% to 25%, and benefits outweigh costs by 3:1. Energy efficiency standards and labelling programs[22] have been very successful in fostering innovation, expanding existing markets, opening up new market opportunities, and increasing employment (800,000 direct jobs created in the European Union and 340,000 jobs in the United States).

When combined with active empowerment of local communities, standards and labelling of just a few products (refrigeration, lighting, and air conditioning) has effectively decreased energy consumption for several island communities.

The Global Energy Efficiency Accelerator Platform contributes to the empowerment. The platform was formally launched at the United Nations Climate Summit 2014 and is facilitated by public–private partnerships, international organizations, and major actors in the energy arena. The Accelerator

[22] Also see the IEA 4E website (www.iea-4e.org)

Platform aims to support specific sector-based energy efficiency accelerators and to target action at various levels: regional, national, city, and company.

Expanding standards and labelling to the Pacific Island countries and territories (PICTs) would provide a range of benefits.[23] Increased energy efficiency would reduce emissions and lower energy demand, which in turn would reduce the need for diesel imports, lead to financial savings, lower energy bills for consumers, and avoid costs associated with infrastructure to meet demand. Figure 24 shows the savings that energy efficiency measures could provide. Living conditions would improve with access to better quality products, and PICTs would not have to accept inefficient products banned from sale elsewhere.

The potential benefits led to the establishment of the Pacific Appliance Labelling and Standards (PALS) program, which is administered by the Secretariat of the Pacific Community Economic Development Division in partnership with the Australian Government Department of Industry and Science.

The PALS program assists PICTs with developing and implementing legislation on performance standards and energy rating labels of electrical appliances. The support includes multiple functions:

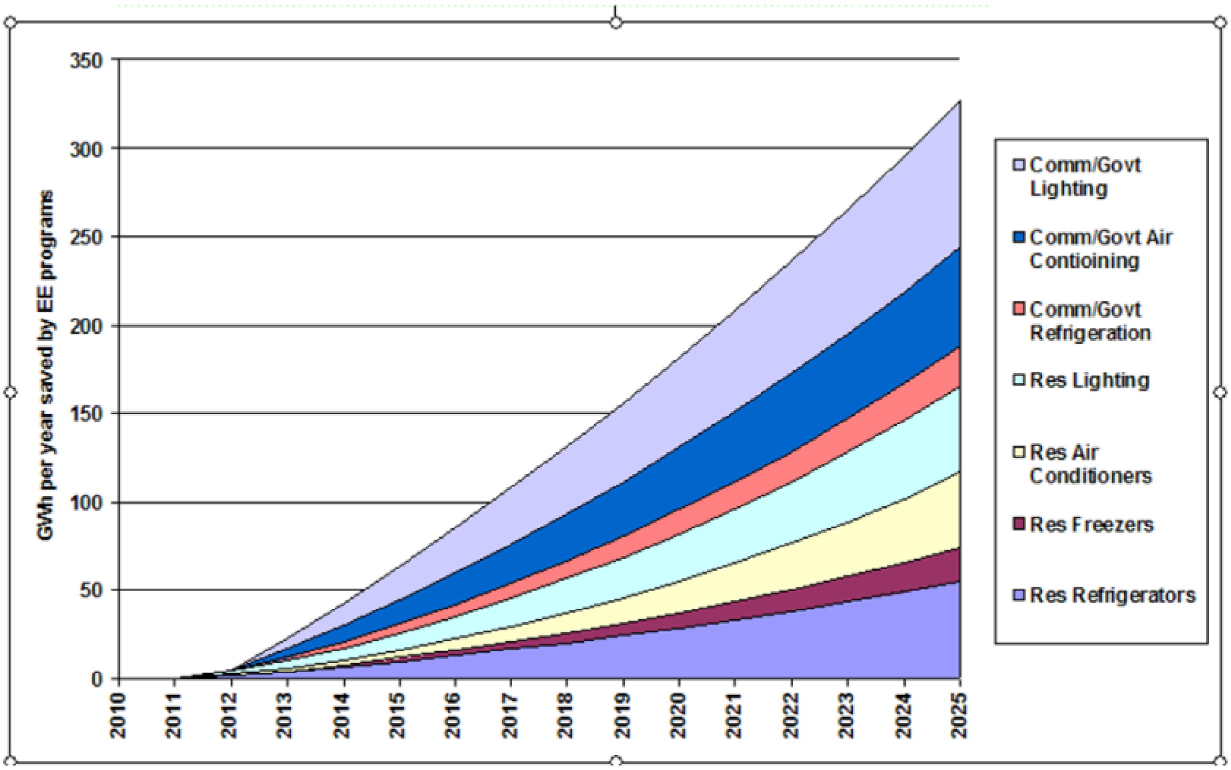


Figure 24. Projected electricity savings from energy efficiency measures, by end use.

building capacity in the region, engaging legal expertise, and developing legislation/regulation. Once legislation is established, the Program helps with implementation by raising public awareness and

[23] Secretariat of the Pacific Community, *The Cost and Benefits of Introducing standards and labels for electrical appliances in Pacific Island countries*, 2012, ISBN: 978-982-00-0518-1.

providing training for retailers, importers, and government officials. PALS also supports monitoring and evaluation efforts to ensure compliance and assess results.

Multiple benefits have been realized across nations, including remote islands, isolated areas, and densely populated areas such as cities. Several factors are key to this success, including regional commitments by PICT leaders who prioritize energy efficiency and implemented a standards and labelling program. Successful participants took part in a collaborative institutional framework established by PALS, which also provided a report that highlights the benefits of implementing a standards and labelling program in the Pacific. Other success factors include:

- Healthy competition among countries and a front runner (Fiji)
- Face-to-face workshops and study tours (Australia and Fiji), which build collaboration and information-sharing
- Early engagement and outreach to commercial stakeholders (importers and retailers)
- Training activities to help stakeholders (customs officers, government officials, suppliers, retailers, shop floor staff, and the general public) understand the legislation/regulation and its requirements

PALS provides many lessons learned for similar programs. Seeking joint commitments of senior officials and ministers is critical, and government support is more easily gained with quantifiable

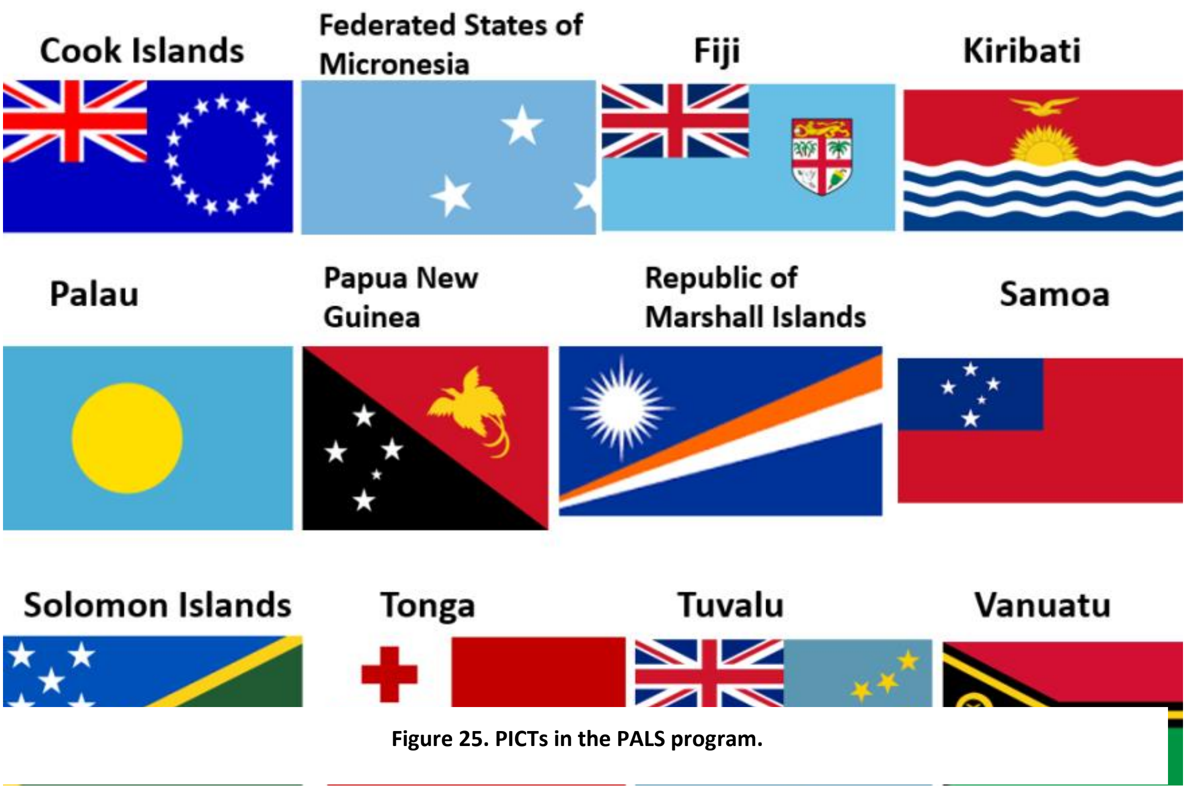


Figure 25. PICTs in the PALS program.

benefits. Legislation takes time and is complex; sovereign countries cannot be pushed, and it is important to establish the responsibilities of various players, including drafting legislation. PICTs have capacity issues, and staff are often overwhelmed with multiple projects. Sometimes adopting an existing label is an acceptable solution; for example, the South Pacific adopted the Australia/New Zealand labels. Once legislation is enacted, progress must be incentivized. Countries will progress at various rates. Finally, the program established a regional centre (Secretariat of the Pacific Community) and PALS national coordinators, which proved a successful delivery mechanism for support and capacity building.

Renewable Energy Developments in the Faroe Islands

Bjarti Thomsen, Faroese Earth and Energy Directorate, Ministry of Industry, the Faroe Islands

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/12Thomsen_Jarofeingi.pdf

The Faroe Islands are shifting from a fossil fuel-based energy system to a more sustainable system. The transition plan includes a higher share of renewables, energy savings, and storage to supplement the existing hydropower plants. Faroe currently uses pumped hydro for energy storage. The island state has been actively involved in several RD&D projects, including a steam concrete storage technology project with a university.

Faroe faces several challenges. Conditions could be harsh on the islands, so technology must be robust. Also, the island is so remote as to negate certain technology solutions; for example, wind turbines are limited in size, as there are no cranes to put large turbines in place. Nonetheless, Faroe has established ambitious targets (see Figure 26). Current government policy focuses on using electrical heat pumps and advanced insulation techniques to replace oil-fired boilers and on implementing wind power. The environment provides excellent wind penetration, and production rises and falls roughly in parallel with demand for heating. Intermittency issues can be addressed through demand response and storage technologies, whether thermal or pumped hydro. Faroe is also aiming to incorporate other sustainable technologies, such as smart grid and electric vehicles (see Figure 27).

Energy for Faroe fisheries is fully oil-based. A shift to renewable energy would require major RD&D breakthroughs in ship engines, followed by a very long timeline to make the fleet green.

The Faroe Islands were another example where energy was stored by using natural recources by pumping water.

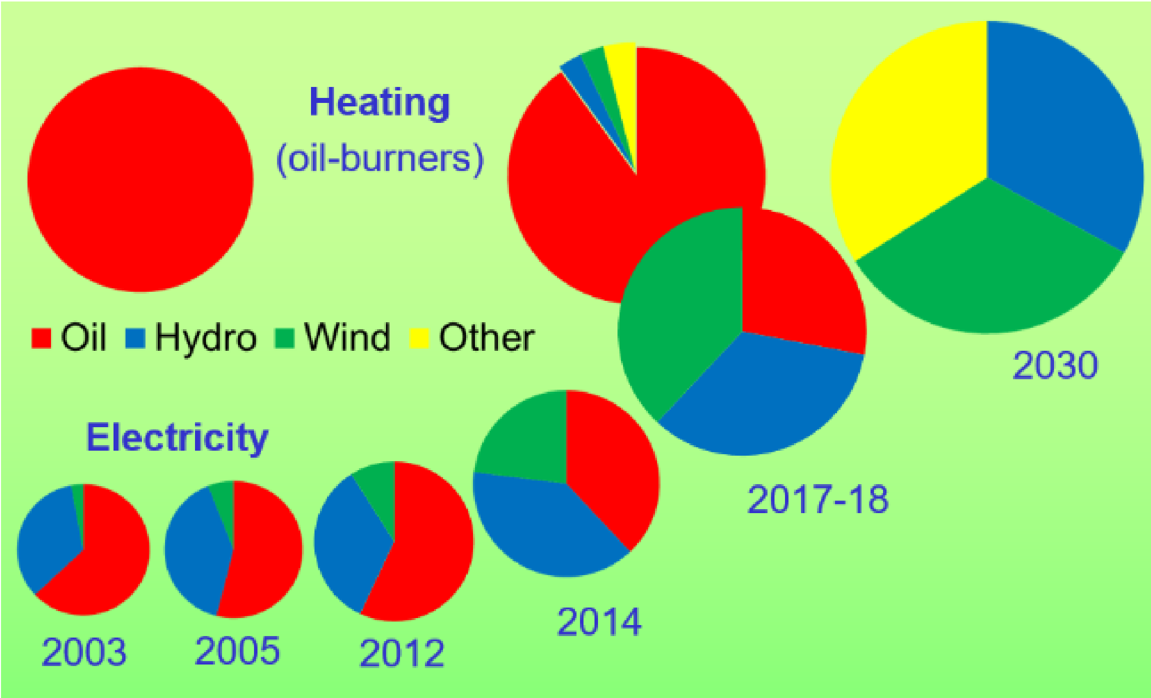


Figure 26. Faroe targets for energy sources for heating.

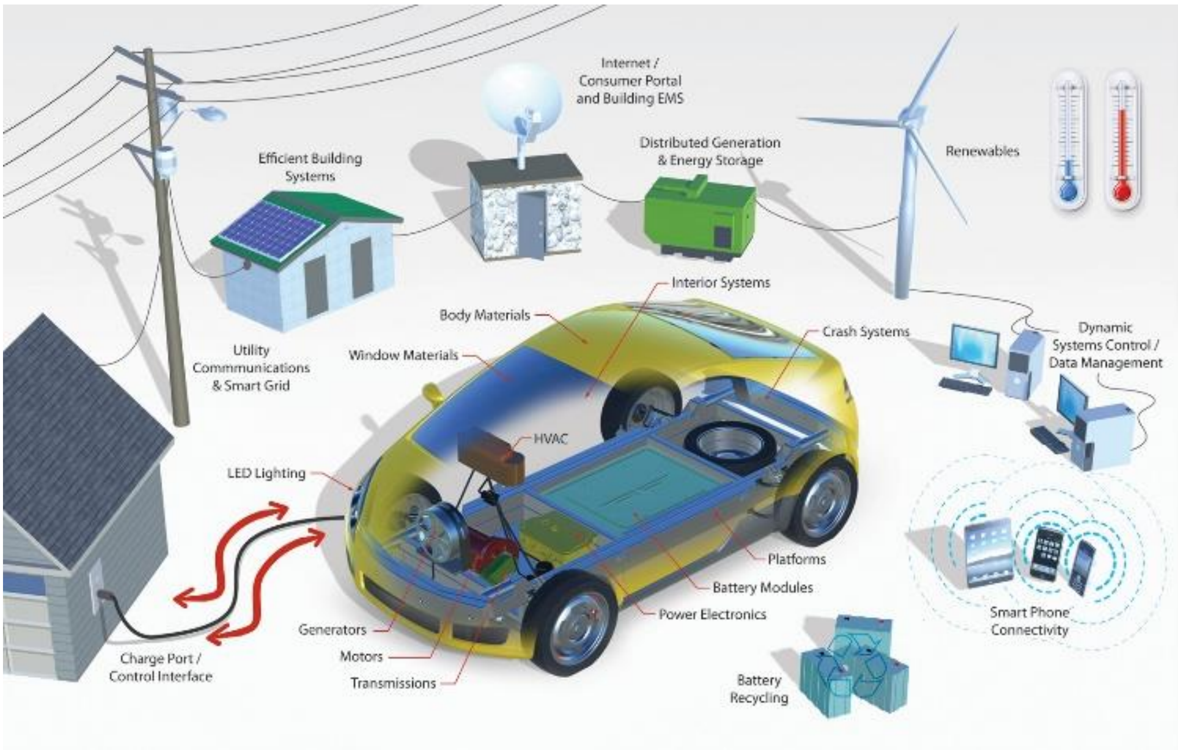


Figure 27. Smart grid, electric vehicles, and other technologies with potential in Faroe.

Synthesis and Conclusions

The following workshop summary is based on a final summary presentation, moderators' session summaries, and general observations.

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdoct/13.Kool6okt15summaryrevak2.pdf

The historic events at COP21 underline the importance of the workshop topic. Improving energy options for islands is a necessary step on the road to a global low-carbon society. This workshop helps raise awareness and promote collaboration among members of the IEA Technology Network, and the findings feed into IEA analyses and joint technological initiatives.

RD&D is necessary for robust and affordable technology options. Certain smart grid elements might improve cost efficiency and integration of intermittent generation in the future. There are a number of smart grid projects that can serve as examples for other areas. Japan has several ongoing demonstrations in which Japanese industry is highly involved, with METI as a strong supporter. There are international collaborations as well, such as the New Mexico Los Alamos microgrid and Hawaii Maui JUMPSmart projects. With the growing number of demonstrations, it is natural to ask whether we may be ready for full-scale deployment.

Much attention is being paid to storage, distributed generation, distribution, and electric transportation. Storage is critical for islands—more so than on the mainland. Storage knowledge is advanced enough to support adequate technology, although it might have to be adapted to extreme weather. There are limited examples of non-chemical storage (hydro, concrete, and compressed air). Islands are showcases for distributed generation and distribution, although each island has its own unique combination of technologies.

Japan provides an excellent example of challenges islands face. Fossil fuels have to be imported, which has an impact on the environment and the economy. In addition, islands are often particularly vulnerable to the effects of climate change (e.g., temperature rise and ocean tidal levels). Japan needs business models for the energy transition, particularly on the 7000 Islands.

Business models for islands are insufficient; islands mostly have limited markets and thus do not necessarily benefit from standard economic strategies (e.g., competition between service providers, cost reductions through unbundling). There are also limited options for demand response. When developing business models, it is best to identify solutions with multiple benefits.

Some challenges and solutions apply to both cities and islands/remote areas. Developing distribution networks in both city and island areas is difficult and expensive. Both compact cities and islands have space limitations that encourage rooftop generation.

There are as many differences as similarities. Islands usually lack interconnections, while large cities are typically surrounded by high-voltage transmission rings. In addition, cities and islands typically have different policy environments, and often have access to different financial schemes to fund projects. However, lessons learned from cities or islands can be adapted for use by each other, particularly in regard to incorporating renewables onto the grid at distribution voltages and pursuing energy efficiency[24].

There are core principles that apply to all types of areas. Successful transitions to sustainable systems require an integrated approach that includes both the supply side and demand side, and it is always important to have sound business plans.

In addition, engaged end users are critical to the success of any sustainable system—especially for end-use efficiency—and consumers should be involved from the start of a clean energy transition. Such inclusion necessitates understanding the effectiveness of incentives and the customer base, which is heterogeneous. Consumer actions and motivations are not always as expected; customers are not necessarily homo economicus.

There are many useful tools and techniques available for island clean energy system development. Modelling is useful in identifying the best energy solutions. A universally available strategy is energy efficiency—the "first fuel"—and appliances have good potential for improvement in this area. Standards and labelling systems have effectively decreased energy consumption for several island communities. The PALS program provides some helpful insights and lessons learned. Another very helpful tool is the U.S. DOE's Islands Playbook, a constructive guide to sustainability based on island project results. In addition, successful advanced energy system deployment on an island can provide insights and lessons learned. Faroe has provided a good example of careful sustainable development.

[24] (See, e.g., http://www.nrel.gov/docs/fy16osti/65368.pdf and http://www.utilitydive.com/news/how-the-heco-solarcity-partnership-is-turning-rooftop-solar-into-a-grid-ass/338838/)

Appendix A. Additional Material

The following material was also taken in consideration while writing this report:

- Bornholm Island: http://brightgreenisland.com/
- Pellworm Island: http://www.eon.com/en/sustainability/insight-into-our-value-chain/story-model-region-pellworm.html
- EGRD Workshop: Will a Smarter Grid Lead to Smarter End Users - or Vice Versa (2015)
- EGRD Workshop: The role of storage in energy system flexibility. (2014)

Session 2:

- The island of Miyakojima, Japan: http://ajw.asahi.com/article/sci_tech/environment/AJ201201220009
- The island of Kumejima, Japan – Ocean Thermal Energy Conversion (OTEC): http://www.otecnews.org/2012/07/otec-pilot-plant-to-be-built-in-okinawa-prefecture/
- The German island of Pellworm: https://www.eon.com/en/sustainability/insight-into-our-value-chain/story-model-region-pellworm.html
- The Korean Island of Jeju: http://www.ep.liu.se/ecp/057/vol10/022/ecp57vol10_022.pdf (IEA)
- The Danish island of Samsoe: http://www.scientificamerican.com/article/samso-attempts-100-percent-renewable-power/
- Tokelau – New Zealand: http://www.tokelau.org.nz/Tokelau+Government/Government+Departments/Power/Energy.html
- Okinawa – Hawaii clean energy cooperation: https://www.irena.org/documentdownloads/OkinawaMay2012/19_Satoshi%20Morozumi_NEDO.pdf and https://www.irena.org/documentdownloads/OkinawaMay2012/05_Richard%20Rochelleau.pdf
- Islands as lighthouses for the energy transition – Emanuele Taibi, IRENA

Session 3:

- http://c40-production-images.s3.amazonaws.com/other_uploads/images/176_CDP_Cities_2014_Yokohama_Final_%28reduced%29.original.pdf?1424835498

Session 4:

- Nukissiorfiit, the Energy Company of Greenland – http://northof56.com/energy/article/greenland-hydro-capacity-increases-with-new-plant
- Svalbard, Norway, newspaper article: http://barentsobserver.com/en/energy/2014/03/green-energy-future-svalbard-03-03
- PEEP2 Report: Promoting Energy Efficiency in the Pacific Faze 2 http://www.ee-pacific.net/index.php/component/docman/doc_download/65-peep2-final-report?Itemid=
- Pacific – Sione Foliaki, Assistant CEO, Ministry of Finance, Samoa (tbc)
- Small Island Developing States (SIDS) DOCK Support – http://www.esmap.org/sites/esmap.org/files/DocumentLibrary/SIDS%20DOCK_Apr%202015-v3.pdf and http://www.esmap.org/node/3044
- Iceland, Orkustofnun, a pioneer in renewable energy – http://os.is/gogn/os-onnur-rit/OS-2009-Meet-Iceland.pdf
- Indonesia Energy Policy – presentation - http://www.jst.go.jp/astf/document2/25pre.pdf]

- Financing in the Carribean: http://www.ifc.org/wps/wcm/connect/035d14804756f9909fcabf37b5ac3532/A2F_Product_Card_SEF_SEP2010_EN.pdf?MOD=AJPERES

Appendix B. Acronyms

Acronym	Name
AC	Alternating Current
ASEAN	Association of Southeast Asian Nations
BEMS	Building Energy Management Systems
C	Celsius
CAES	Compressed Air Energy Storage
CEMS	Community Energy Management Systems
CERT	(IEA) Committee on Energy Research and Technology
COP	Coefficient of Performance
COP(21)	Conference of the Parties
DC	Direct Current
DOE	U.S. Department of Energy
DTU	Technical University of Denmark
EGRD	Experts' Group on R&D Priority Setting and Evaluation
ETP	Energy Technology Perspectives
EV	Electric Vehicle
G20	Group of 20 (major economies)
Gton	Billion Metric Tonnes
HEMS	Home Energy Management Systems
HWPP	Hydro Wind Power Plant
IAE	Institute of Applied Energy (Japan)
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ISGAN	International Smart Grid Action Network
JST	Japan Science and Technology Agency
km	Kilometre(s)
kW	Kilowatt(s)
kWh	Kilowatt-Hour(s)
L	Litre(s)
LED	Light-Emitting Diode
LNG	Liquid Natural Gas
METI	Ministry of Economy, Trade and Industry
MW	Megawatt(s)
NEDO	New Energy and Industrial Technology Development Organization
OES	Open Energy System
OTEC	Ocean Thermal Energy Conversion

Acronym	Name
PALS	Pacific Appliance Labelling and Standards Program
PICTs	Pacific Island Countries And Territories
PV	Photovoltaic(s)
R&D	Research and Development
RD&D	Research, Development and Demonstration
RDDD&D	Research, Development, Demonstration, Deployment and Dissemination
RVO.nl	Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland)
SIDS	Small Island Developing States
SWOT	Strengths, Weaknesses, Opportunities and Threats
TWh	Terawatt-Hour(s)
UNEP	United Nations Environment Program
UNFCC	United Nations Framework Convention on Climate Change
V	Volt(s)

Appendix C. List of Participants

Name	Organization	Country
Makoto Akai	AIST	Japan
Timothy Farrel	DTU	Denmark
Kenichi Furuhata	JST	Japan
Yasuyuki Ikegami	Saga U.	Japan
Birte Jorgenson	DTU	Denmark
Etsushi Kato	IAE	Japan
Ruud Kempener	IRENA	Netherlands
Rob Kool	RVO.NL	Netherlands
Hiroshi Kujirai	IAE	Japan
Atsushi Kurosawa	IAE	Japan
Eric Masanet	IEA	USA
Koji Moriya	IAE	Japan
Satoshi Morozumi	NEDO	Japan
Yuki Murai	City of Yokohama	Japan
Kenji Murata	IAE	Japan
Gabriella Nemeth	CMNC	Spain (remote)
Junya Nishi	NEDO	Japan
Yuka Ogasawara	NEDO	Japan
Toshiro Okada	ANRE/METI	Japan
Susanne Supper	ENU	Austria

Kae Takase	JST	Japan
Bjarti Thomsen	Energy Directorate	Faroe Islands
Mario Tokoro	SONY CSL	Japan
Stephen Walls	DOE	USA
Shigenobu Watanabe	NEDO	Japan
Akira Yabe	NEDO	Japan
Annette Werth	SONY CSL	Italy

Appendix D. Agenda

Day 1: 5th October

Session 1: Welcome and introduction

The Session provides background and context for the Workshop. It reminds participants of the purposed, interactive nature of presentations, dialogue and social interactions, and the expected outcomes, and post-meeting activities and communications.

INTRODUCTION		
Moderator: Atsushi Kurosawa		
9:00	Welcome	*Atsushi Kurosawa, Director of Global Environmental Program, R&D Division, The Institute of Applied Energy (IAE)*
9:10	Introduction Meeting Objectives	*Rob Kool, Manager, Chair EGRD, NL Agency*
9:30	Key note A "New Era" of the IEA's Energy Technology Network and Implementation Agreements	*Toshiro Okada, Vice-Chair of CERT, Senior Energy Advisor, Agency for Natural Resource and Energy, Ministry of Economy, Trade and Industry, Government of Japan*
10.00	Clean Energy Systems for Islands: Insights from IEA Analyses.	*Eric Masanet, Head of IEA Energy Demand Technology Unit*
10.30	Break	

Session 2: Sustainable islands

A large number of small islands around the world have developed into great showcases for a range of promising solutions for the energy system of the future. The session will explore what has been the driving force behind these ambitious cases and assess the reliability and costs of technological solutions chosen. Not least, the question will be raised what are the lessons learned for the overall energy system, also in densely populated areas.

SUSTAINABLE ISLANDS		
Moderator: Atsushi Kurosawa		
11.00	Japanese Island Grid Experience	*Satoshi Morozumi, Smart Community Department Director General, New Energy and Industrial Technology Development Organization (NEDO)*
11.30	DC-based Open Energy System: A Bottom-up, Distributed Power System for Self-Sustaining Islands	*Mario Tokoro, Founder & Executive Advisor, Sony Computer Science Laboratories, Inc.*
12.00	Lunch	
13.00	Electricity storage for island transitions: A strategic niche?	*Ruud Kempener, Analyst, IRENA*
13.30	Integration of Hydro-Wind Power Generation on El Hierro Island	*Gabriella Németh, Energy Directorate. Electric Energy Department,Spain (video conference)*
14.00	Discussion	

Session 3: Sustainable cities

This session will explore similarities and differences in technology and other solutions for cities and islands as well as sparsely populated areas. Globally, cities are growing rapidly and municipal governments are being challenged to adapt to changing demands for energy, infrastructure and space. As providers of energy services to the majority of the world's population, cities are uniquely positioned to accelerate the transition to energy efficiency and renewable energy. The goal of expanding renewable energy uptake is intertwined with other objectives in increasing efficiency and enhancing livability.

The session will be organized as a world café with an inspirational speech and a true workshop with interventions and discussions of participations.

SUSTAINABLE CITIES		
Moderator: Rob Kool		
14.30	Yokohama Smart City Project : Large-scale Demonstration and Future Implementation	*Yuki Murai, Officer of Project Promotion Division, Climate Change Policy Headquarters, City of Yokohama*
15.00	JST's activity towards the realization of a dynamic and affluent low carbon society	*Kenichi Furuhata, Director, Center for Low Carbon Society Strategy, Japan Science and Technology Agency (LCS/JST)*
15.10	Group work	
16.10	Discussion	
16.40	Wrap up	

Day 2: 6th October

Session 4: Island states

Many small island states are highly dependent on import fossil fuels to meet their energy needs. This has a number of impacts: high and often rising costs for electricity, vulnerability to oil prices shocks and supply interruptions. Therefore many small island states are looking to more sustainable energy systems, where improved energy efficiency and renewable energy play an increasingly important role.

ISLAND STATES		
Moderator: Birte Holst Jørgensen		
9.30	De-risking System-wide Investments through Energy Transition Planning – cases of Puerto Rico, Hawaii and the US Virgin Islands	*Stephen Walls, Department of Energy, USA*
10.00	The Advanced Technology and Future Prospect of OTEC for Island -towards to Stable Energy and Sustainable Development-	*Yasuyuki Ikegami, Professor, Institute of Ocean Energy, Saga University*
10.30	Break	
11.00	Appliance Labelling And Standards in the Pacific Islands	*Timothy Clifford Farrell, Copenhagen Centre on Energy Efficiency, Senior advisor UNEP DTU Partnership*
11.30	Renewable energy developments in the Faroe Islands	*Bjarti Thomsen, Faroese Earth and Energy Directorate, Ministry of Industry, the Faroe Islands*
12.00	Discussion	
12.30	Lunch	

Session 5: Discussion and lessons to be learned

SYNTHESIS AND CONCLUSIONS		
Moderator: Rob Kool		
14.30	Discussion, key recommendations	
15.30	Workshop conclusions	
16.00	End of workshop	