Asia-Pacific
Economic Cooperation

# APEC WORKSHOP ON SMALL HYDRO AND RENEWABLE GRID INTEGRATION

# ROADMAP FOR DEVELOPMENT OF SMALL HYDROPOWER

**APEC Energy Working Group**

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# 1. Introduction

## 1.1. Background and rationale for roadmap development

Hydropower is a renewable energy where power is derived from the energy of water moving from higher to lower elevations. It is a proven, mature, predictable and typically price-competitive technology.

The installed capacity of hydropower by the end of 2010 contributed 13.5% of electricity supply of APEC Economies (APEC 21).

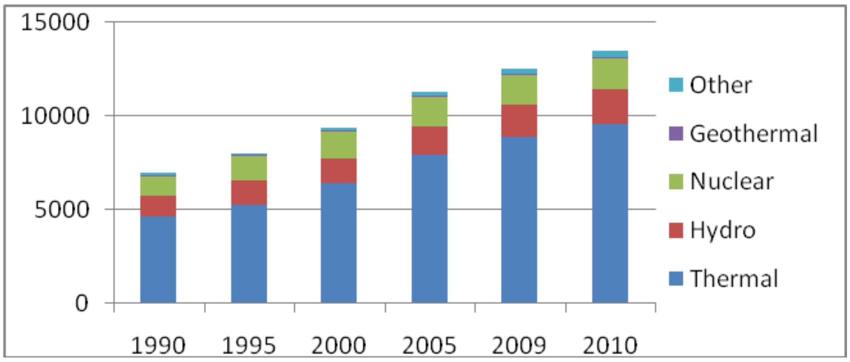


**Figure 1. ELECTRICITY POWER GENERATION BY TYPE - APEC 21**[1]

Situated at the crossroads of two major issues for development, water and energy, hydro reservoirs can often deliver services beyond electricity supply. The significant increase in hydropower capacity over the last 20 years[2] (from 1990 to 2010) is anticipated in many scenarios to continue in the near term (2020) and medium term (2030), with various environmental and social concerns representing perhaps the largest challenges to continued deployment if not carefully managed.

APEC 21 total installed hydropower capacity in 2010 was 502.3GW, producing annual generation of 1,820.5 TWh/year, and representing an average capacity factor of 44.5 %.

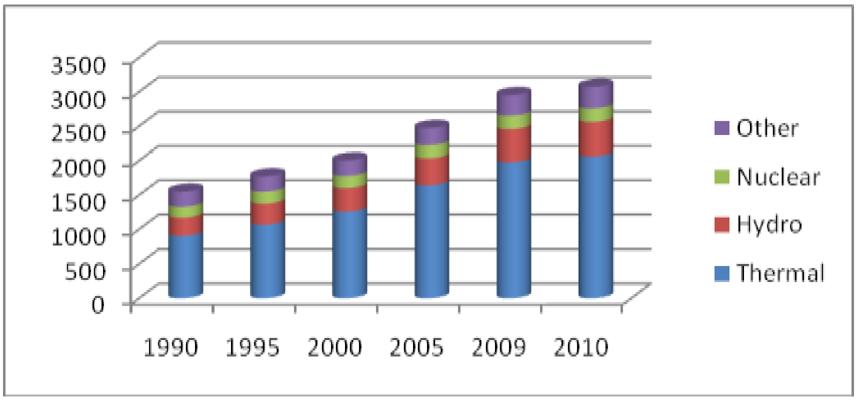


**Figure 2. POWER GENERATION CAPACITY BY TYPE - APEC 21**[3]

[1] Energy Working Group, October 2012, APEC, Energy Handbook, 2010
[2] From only 246.6GW in 1990 increased to 502.3GW in 2010
[3] Energy Working Group, October 2012, APEC, Energy Handbook, 2010

Regarding total feasible potential for small hydropower development, currently undeveloped capacity ranges from about 70% in APEC region (only for 12 APEC economies) , which indicates large opportunities for continued small hydropower development, with the largest growth potential in China, Mexico, Russia, US, Vietnam, etc. Additionally, possible renovation, modernization and upgrading of old power stations are often less costly than developing a new power plants because they have relatively smaller environment and social impacts, and require less time for implementation. Significant potential also exists to rework existing infrastructure that currently lacks generating units (e.g. existing barrages, weirs, dams, canal fall structures, water supply schemes) by adding new small hydropower facilities.

In the past, small hydropower has acted as a catalyst for economic and social development by providing both energy and water management services, and it can continue to do so in the future.

Small hydropower can serve both in centralized and small, isolated grids, and small-scale hydropower is an option for rural electrification.

Environmental and social issues will continue to affect small hydropower deployment opportunities. The local social and environmental impacts of hydropower projects vary depending on the project's type, size and local conditions and are often controversial. Some of the more prominent impacts include changes in flow regimes and water quality, barriers to fish migration, loss of biological diversity, and population displacement. Impoundments and reservoirs stand out as the source of the most severe concerns but can also provide multiple beneficial services beyond energy supply. While lifecycle assessments indicate very low carbon emissions, there is currently no consensus on the issue of land use change-related net emissions from reservoirs. Experience gained during past decades in combination with continually advancing sustainability guidelines and criteria, innovative planning based on stakeholder consultations and scientific know-how can support high sustainability performance in future projects. Trans-boundary water management, including the management of small hydropower projects, establishes an arena for international cooperation that may contribute to promoting sustainable economic growth and water security.

However, like other renewable, small hydropower plants (SHP) needs regulatory stability and fair market rules, especially concerning permit granting, technical rules and in the financial environment (tariffs). It is also important to recall that the licensing procedure for SHP is a time consuming and bureaucratic procedure as numerous permits are necessary to be issued. On top of that, most of the time in this process is dependent on poorly coordinated entities from different public authorities. Therefore, the future licensing should rely on simple, fair, solid and transparent criteria suitable with SHP scale promoting a faster and more predictable result in the outcome.

With this Roadmap, the SHP sector has made a first step to put down its current status, issues and barriers/problems and requirements on paper. It will help decision makers to assess the better situation to deployment of the potential of small hydropower.

## 1.2. Methodology and approaches for roadmap development

At present, it is difficult for policy makers to define the future of the small hydropower sector. Therefore, the objective of the SHP Road map development is to gather and consequently make available for Members of APEC, relevant energy, market and policy on SHP.

The roadmap for the development of SHP in APEC economies probably can not attempt to be a complete guide to SHP development, but will be directed at the following basic elements:

*i). Identify existing problems occurred in small hydro grid integration.*

*ii). Technical solutions available to address the identified problems.*

*iii). Non-technical issues impacting small hydro: legal framework, regulation, financial incentives, capacity building, etc.*

*iv). Identification of examples of successful small hydro/grid integration activities*

In the collection process of policy data, and the related information for roadmap development, three following approaches have been conducted:

*i). Organize workshops. The purpose of the workshop is to share information and experiences, lessons learned, as well as SHP development plans. The content of the workshop and the information are presented in Appendix 1.*

*ii). Design survey table, the questionnaire and send them to the APEC economies to gather data and information. Form of survey can be referred to in Appendix 2.*

*iii). Search information from the reports, studies that are available from the websites*

However, due to lack of SHP data of many APEC economies, this study cannot make fully comprehensive comments and analysis of SHP area and it does not reflect all situations.

## 2. Current status and development plan for SHP in APEC 21

### 2.1. General on threshold capacity of Small Hydropower Plants (SHP)

Classification according to size has led to concepts such as 'small hydro' and 'large hydro', based on installed capacity measured in MW as the defining criteria. Small hydropower plants (SHP) are more likely to be run-of-river facilities than are larger hydropower plants, but reservoir (storage) hydropower stations of all sizes will utilize the same basic components and technologies. Compared to large-scale hydropower, however, it typically takes less time and effort to construct and integrate small hydropower schemes into local environments (Egré and Milewski, 2002). For this reason, the deployment of SHPs is increasing in the APEC region, especially in remote areas of APEC developing economies where other energy sources are not viable or are not economically attractive.

**Table 2.1 Classification by installed capacity as defined by some APEC economies**

| No | Economies | Micro (kW) | Mini (kW) | Small (MW) |
|---|---|---|---|---|
| 1 | China | - | <500 | 0.5-50[4] |
| 2 | Canada | | | <50[5] |
| 3 | New Zealand | <=5 | <= 20 | <=20 |
| 4 | Philippines | <=10 | <=1000 | 1- 50[6] |
| 5 | Peru | - | - | <=20 |
| 6 | United States | | | <=30[7] |
| 7 | Vietnam | - | - | <=30 |

Nevertheless, until now there is no APEC wide consensus on definitions regarding size categories. Various economies or groups of economies defined 'small hydro' differently. Some examples are given in Table 2.1. From this it can be inferred that what presently is named 'small hydro' spans a very wide range of HPPs. However, it seems that the size of capacity by 30 MW considered as small hydro is more applied in the APEC region.

[4] Small hydropower in China refers to those hydropower stations whose installed capacity is not more than 50MW. There are four grades below the 50MW installed capacity: 0.5–5MW, 5–10MW,10–25MW, and 25–50MW (Zhou, et al., 2009).

[5] Natural resources Canada, 2009

[6] Presentation by the Philippines representative in the APEC hydro workshop , April 2013, Hanoi, Viet Nam

[7] http://www1.eere.energy.gov/water/hydro_plant_types.html

This broad spectrum in definitions of size categories for hydropower may be motivated in some cases by national licensing rules to determine which authority is responsible for the process or in other cases by the need to define eligibility for specific support schemes (e.g. US Renewable Portfolio Standards). It clearly illustrates that different economies have different legal definitions of size categories that match their local energy and resource management needs.

Regardless, there is no immediate, direct link between installed capacity as a classification criterion and general properties common to all HPPs above or below that MW limit. Hydropower comes in manifold project types and is a highly site-specific technology, where each project is a tailor-made outcome for a particular location within a given river basin to meet specific needs for energy and water management services. While run-of-river facilities may tend to be smaller in size, for example, large numbers of small-scale storage hydropower stations are also in operation worldwide. Similarly, while larger facilities will tend to have lower costs on a USD/kW basis due to economies of scale, that tendency will only hold on average. (Egré and Milewski, 2002).

For that reason, even the cumulative relative environmental and social impacts of large versus small hydropower development remain unclear, and context dependent.

## 2.2. Potential small hydro power

As a general definition in the hydropower area, SHP potential decreases from the gross theoretical to the technical potential and finally the feasible potential for development in each period. As mentioned in the previous paragraph, because of limited data and deferent definition on SHP among APEC economies, only feasible potential under the SHP development in several economies is considered in this report.

The estimation of feasible potential in terms of capacity is manifold distributed across the APEC members. China, Russia, US, Canada, Mexico, Philippines, Viet Nam, Chile and Indonesia are the economies with the largest capacity. To the contrast, Thailand and Korea are relatively low. Small hydropower has not been developed in Singapore and Brunei Darussalam.

Table 2.2 Feasible potential of capacity in several APEC economies[8] (MW)

| No. | Economies | Feasible potential | No. | Economies | Feasible potential (in capacity) |
|---|---|---|---|---|---|
| 1 | China | 128000 | 7 | The Philippines | 1854 |
| 2 | Russia* | <=100000 | 8 | Chile[9] | 1432 |
| 3 | US[10] | 10000 | 9 | Indonesia | 1066 |
| 4 | Canada[11] | 4000 | 10 | Malaysia | 490 |
| 5 | Viet Nam | 2925 -4200 | 11 | Korea | 283 |
| 6 | Mexico | 3250 | 12 | Thailand | 183 |

[8] Presentations by representatives of APEC economies in the APEC SHP Workshop, April, 2013, Ha Noi, Viet Nam
[9] Mini hydropower plants, a chance to develop NCRE in Chile, news, 7 January 2013
[10] Lea Kosnik, "*The potential for small scale hydropower development in the US*", Energy Policy, Elsevier 38 (2010) 5512-5519
*Estimation by the consultant based on the figure on potential of small hydropower in Russia is 1520 billion kWh
[11] Small hydro, International gateway, website: http://www.small-hydro.com/Past-Contributors-Pages/Canada.aspx

## 2.3. Current status of grid connected SHP and shared in power generation

Role of hydro in electricity generation sector of the APEC by 2010 was mentioned in the Annex 3. Below is some information from the selected economies.

**China:** The designed capacity has increased from 3,634kW in 1949 to 55,121,211kW in 2009. The actual realized capacity also increased from $523x10^4$kWh in 1949 to $15,672,470x10^4$kW in 2009. The rapid increase of small hydropower has supplied over 300 million rural people's demand on electricity and covering 99% of rural areas in 2009. Nonetheless, although the installed capacity of small hydropower in 2009 has been increased four times of the 1990, it constantly consisted of around 30% of the whole hydropower in the electricity industry (Table 2.3). Therefore, the large hydropower stations and dam construction are still the main components that sustain the growth of China's hydropower.

**Table 2.3 Development of small hydropower**

| Year | 1949 | 1978 | 1990 | 2000 | 2009 |
|---|---|---|---|---|---|
| Designed Capacity (kW) | 3,634 | 5,266,500 | 13,180,300 | 24,851,721 | 55,121,211 |

Source: China Water Statistical Yearbook 2010.

**Chile:** Today, Chile has abundant types of hydropower technologies including small hydropower plants, large hydroelectric reservoir power plants and run-of-river hydropower plants. As of 2007, approximately 38% of the electricity supply was derived from hydropower. Hydropower has supplied Chile with an abundance of energy throughout the past century; however, environmental controversy and climate change does not favour this renewable energy as a future primary energy supply for Chile.

Figure 12 categorizes that fossil fuels, coal, natural gas and diesel represent approximately 58% of the electricity generation, and hydropower delivers 38%. Even though hydroelectricity reservoirs are not emitting greenhouse gases, this electricity generation is not considered a renewable energy source because its capacity is not less than 20 MW in size. Thus in 2007, approximately 3% of the capacity for electricity generation was derived from biomass, wind and small hydro sources.

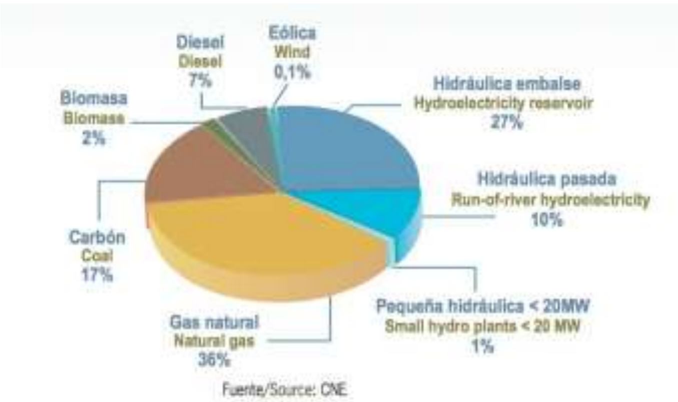


**Figure 3. Installed capacity by generation, 2007**

Hydropower accounts for nearly 38% of the electricity generation in Chile. The rivers that flow from the Andes Mountains have been dammed to create a reservoir for potential energy. The majority of the hydropower that is generated is connected to the SIC power grid.

**Indonesia:** Has a number of SHP installations and more are being planned. The micro-hydro projects developed by the Government of Indonesia (GOI) and the GTZ are standardized hydro and electricity schemes with nominal capacities of 10-100 kW. Plans to continue the projects will focus on implementing standardized technologies for off-grid decentralized village hydro schemes with nominal capacities less than 100 kW and replacing diesel by installing on-grid schemes with nominal capacities greater than 25kW.

**Korea**

The type of small hydropower in Korea is mainly to use small rivers because there is a regional characteristic of many mountains and valleys. Considering the size of capacity less than 30 MW is small hydro, about 1,500MW of developable potential small hydropower is remained in Korea [Lee, 2005][12]. However, only 228 MW of capacity could be feasibly developed which correspondents to 15% of potentials (KEMCO 2007).

Current capacity of small hydro power is estimated about 80 MW, accounting for 35% of total developable capacity.

**New Zealand**

Hydroelectricity has been the backbone of New Zealand's electricity supply system for decades, and hydroelectric dams are a well-known feature of the New Zealand landscape. New Zealand generates more than 50% of its electricity from hydro generation, much of it through large hydro plants such as Benmore, Manapouri, and Clyde.

Most new hydro developments being proposed in New Zealand are relatively small scale. Small hydro scheme classifies not larger than 20 MW (megawatts) in capacity. This includes micro-hydro, which is usually less than 10kW and is used on domestic applications.

There is currently over 160MW collectively of small hydro schemes (of a size less than 20MW) already installed in New Zealand (enough to provide electricity for over 80,000 houses). The potential for additional small hydro generation capacity is substantial.

Small hydro schemes are a means of providing electricity to remote farms, homes and holiday retreats, or for selling electricity to other users or into the electricity market.

There are a number of competing interests and values associated with use of water in rivers and lakes and these need to be considered when assessing opportunities for further development of hydro schemes of any size. But because small hydro energy schemes often do not require dams or significant storage they usually result in significantly less impact on the environment than large hydro schemes. Many small hydro schemes already exist on rivers and streams around New Zealand, and there are many more opportunities to use water-driven generation to provide electricity to remote farms and homes.

The New Zealand government has support policies to remove barriers to, and encourage the uptake of, all renewable energy technologies. This includes providing independent and impartial information, and in some situations supporting projects through the Resource Management Act consenting process. See more at http://www.eeca.govt.nz/efficient-and-renewable-energy/renewable-energy/hydro-energy

**Philippines: C**urrently, the Philippines have 68 micro-hydro systems, generating an aggregate capacity of 233 kW and benefiting some 6,000 households. The Philippines has 51 existing mini-hydropower facilities with a total installed capacity of 82.07 MW. These mini-hydro

[12] Lee,K.B. (2005) Status and Prospect of hydro power development technology, Proc. Seminar of small hydro power technology study group, 29-40

plants contribute around 200 GWh or 0.34 million barrels of fuel oil equivalent (BFOE) every year. The total installed capacity of mini-hydro will increase to 89.07MW as a 7-MW plant in near completion. In 2011, aggregate mini-hydropower capacity together with small hydropower reached 380 MW.

**Thailand:** The Department of Alternative Energy Development and Efficiency (DEDE), formerly known as the Department of Energy Development and Promotion (DEDP), and the Provincial Electricity Authority (PEA) are some of the institutions involved with mini and micro-hydro. The DEDP installed 23 mini hydropower plants with capacities ranging from 200 kW to 6 MW for a total of 128MW. Aside from mini hydro, the DEDP has also built many village-level micro-hydropower plants. Meanwhile, the PEA operates three small hydropower generation stations with a total capacity of 3.8MW. It plans to implement five more small hydropower generation stations to increase the total capacity of its small hydro to 18MW.

**United States**

Hydropower is the largest source of renewable energy in US, for examples, Federal surveys have identified several hundred potential small hydropower projects under 5 megawatts (MW) in Colorado with a capacity of more than 1,400 MW; although development of this resource has not increased significantly in decades. However, in recent years, the Commission has experienced increased interest from entities seeking to develop small, low-impact hydropower projects. In 2007 The Federal Energy Regulatory Commission (FERC) issued 15 permits for small hydro, a number that soared to 50 permits in 2009. With that rapid growth comes the need to build upon these efforts and offer greater support for low-impact projects. Greater intergovernmental cooperation, improvements to the exemption process and more R&D funding can help spur development of small hydro. Meanwhile, the vast majority of already permitted non-federal projects — 89 percent — are small, at 30MW capacity or less.

The National Hydropower Association stands ready to work with FERC, other agencies, and stakeholders to implement an even more effective process for small hydro projects.

Recently President Obama on August 9, 2013 signed into law two bills aimed at boosting development of small U.S. hydropower projects. The bills, H.R. 267, the Hydropower Regulatory Efficiency Act, and H.R. 678, the Bureau of Reclamation Small Conduit Hydropower Development and Rural Jobs Act, are expected to help unlock some of the estimated 60,000 megawatts of untapped U.S. hydropower capacity.

H.R. 267 promotes the development of small hydropower and conduit projects and aims to shorten regulatory timeframes of certain other low-impact hydropower projects, such as projects that add power generation to the nation's existing non-powered dams and closed-loop pumped storage projects.

H.R. 678 authorizes small hydropower development at existing canals, pipelines, aqueducts, and other manmade waterways owned by the U.S. Bureau of Reclamation. Such development could provide enough power for 30,000 U.S. homes. See the National Hydropower Association press release .

**Vietnam:** Hydropower in Vietnam falls into four main classifications:

- Pico-hydropower systems, owned by individual households in rural areas, with capacity between 200W and less than 1000W and typically sufficient only for a few electric lights.
- Off-grid hydropower systems that serve isolated mini-grids, with typical size 1kW to less than 1MW.

- Grid-connected small hydropower systems in the range of 1-30MW
- Large hydropower with capacity greater than 30MW

In 2007, MoIT defined that small hydropower is that with capacity not exceeding 30MW. ERAV is also likely to adopt 30MW as the threshold for mandatory participation in the competitive power generation market, and the avoided cost tariff and standardized PPA which were issued later in 2008 applied to all qualified renewable energy projects with capacity not exceeding 30MW. This threshold is therefore also adopted in the many plans.

Estimates of the small hydropower resource endowment are subject to high uncertainty. There is no question that many provinces of Vietnam are richly endowed with small rivers in hilly and mountainous areas potentially suitable for development of small hydropower. But without reference to project costs, estimates of "physical potential" are not useful.

The most comprehensive assessment of small hydropower is the Small Hydropower Development Master Plan in which the aggregate capacity of 2,925 MW is estimated to generate 13.3 TWh, for an overall average load factor of 0.52.

As of 2005, over 500 small hydropower stations (SHP) with total installed capacity of about 100 MW have been constructed and put into operation. However, of the total 507 stations with capacity less than 10MW, about one third is not working.

In addition, micro hydropower units and stations with capacity of 0.2-5kW have been extensively developed in mountainous remote areas which cannot be reached by the national power grids: it is estimated about 110,000-150,000 units of this type, mainly pico hydropower units with capacity < 500W, and their total installed capacity of 30-60 MW

**Box 1.1: Development of SHP in Vietnam**

There are 5 main phases of SHP development:

***1960 –1975, and 1981-1985*** saw extensive construction of SHPs in remote areas to serve mini-grids. Most were built with funds from the state budget for construction of civil works, with equipment imported from China and Eastern Europe.

***1985 - 1990*** saw a diversification of the forms of investment: in addition to central state budget-funded projects, many were built by military units, cooperatives and local communities, many with provincial assistance.

***1990 to 1995*** SHP development slowed down due to lack of investment capital for construction of new stations and lack of equipment, spare parts for replacement and repairing. At the same time, the national power grid began to expand rapidly into rural areas. The use of pico hydro units expanded greatly during this era.

***1995 – 2002***: SHP development slowed down further, and as the grid expanded into remote areas previously served by SHPs, these were abandoned. Some 200 stations with capacity of 5-50kW stopped operation, many of them are multipurpose facilities (power and irrigation)

***2002 to present***: Significant expansion of larger grid-connected SHP in the size range of 1-30MW.

In 2007, MoIT conducted a survey of grid-connected SHPs which revealed 319 projects at various stages of development. In the table below, MoU (memorandum of understanding) signifies projects for which EVN has agreed to take power in principle. For these projects, information is available only for the location, the name of the developer, and installed capacity. How many of the projects reported as being "under construction" which have commenced substantive works (rather than simply taken ground-breaking or no work at all) is not known: it would be a reasonable inference that the 21 projects for which no tariff agreement has been reached would unlikely have progressed very far.

**Table 3. The project pipeline**

| | Number of projects | Total Installed capacity | Average project size |
|---|---|---|---|
| | | MW | MW |
| MoU | 178 | 2,175 | 12.2 |
| Under construction, no tariff information | 21 | 260 | 12.4 |
| Under construction, tariff known | 67 | 630 | 9.4 |
| Under construction, signed PPA | 11 | 101 | 9.2 |
| In operation | 42 | 278 | 6.6 |
| Total | 319 | 3,443 | 10.8 |

That this aggregate capacity is larger than the 2,925 MW of the SHP Master plan should not surprise: it has been observed in many countries that once private developers begin to actively identify sites, the project pipeline exceeds previous estimates (though it is far from clear how many of the projects in the 2007 Survey are either economically or financially feasible). The total installed capacity in these identified projects (3,443 MW) may be compared to the targets in the final version of the $6^{th}$ National Power Development Master plan, which calls for 1,243 MW of RESPP capacity by 2010, and 2,498MW by 2020.

## 3. Identify existing problems occurred in small hydro grid integration

The workshop identified a number of problems in developing SHP in APEC economies. While the specific nature of challenges tended to vary from economy to economy but there are several common barriers identified as follows:

- At present, there are differences between APEC economies in terms of institutional framework, regulations, and policies for SHP development. Some economies have set policies and ROADMAP for SHP, meanwhile others don't have strong enough legal regulations for support and development of SHP.

- In electricity generation, there is lack of policy framework and lack of standard power purchase agreements for electricity production from SHP projects.

- Construction costs of SHP power projects are still high compared to traditional projects especially for the small projects located far from national power grids. The access to preferential financial resources is limited, not encouraging enterprises to make investments in SHP projects which have low profitability and high risk. Production costs of electricity generated from SHP power projects is generally higher than that from conventional power generations. Therefore, apart from development policies, the SHP funds are also needed.

- Lack of common APEC database (official data) on current status of SHP in terms of potential, existing and future development plans, share of SHP in total electricity production in base year (2010) and in target year (anticipated 2020 or 2030).

- At present, there are different definitions on capacity size of SHP project among APEC member economies. Therefore, the support policies are also different.

- There is no regulation on quality and technical standards of SHP equipment in some APEC economies. This problem also effects on quality, lifetime of the projects, interests of users and also impacts on possibility of expansion and development of technology markets in APEC.

- The SHP technology markets are not available in APEC.

- The information/ experience exchange in SHP area in the APEC is still limited. Therefore, it requires active promotion.

- For the grid connection, there is concern about the power flow management due to unstable power flow (depending on seasons, off peak of load curve) and difficulty in access to the grid.

- Grid congestion is also another problem in some areas where SHPs are concentrated and capacity of transmission and distribution network is not enough to transfer all power of SHP to national grid.

Some major issues hampering the commercialization of SHP in APEC include high investment cost, low quality of voltage compared to technical code, lack of government policies, socio-economic and environmental concerns.

The high initial capital cost of SHP schemes acts as a major impediment to SHP development in APEC where funding problems are most acute. The issue of distance between the hydro energy resource and the load centres, as in the case of Thailand and the Philippines, poses difficulties for SHP development. Project costing varies with the site, the size and the type of application. The specific investment cost per kW of SHP projects also varies greatly from economy to economy, ranging from US $1000/kW to US $6,000/kW. Further, the cost of pre-investment work site survey and feasibility study is higher for SHP in percentage of the ultimate investment than large hydro. Usually, the cost of pre-investment work for SHP could be higher than the acceptable 10-15% of total investment, even if they are supported by government or foreign aid.

Attention has been paid to the training and technology transfer in some APEC economies during the last decades, which enables them to master a great portion of work in SHP development. Although several countries have set up their own capabilities in SHP development, including pre-investment studies, engineering design, construction and operation. Some other countries need to rely to a great extent on technical support from abroad. This fact, added to the costs of importing foreign expertise, materials and equipment, even if subsidized, has greatly impeded the faster development and more widespread introduction of SHP projects.

As these SHP are commonly produced for consumptive (i.e., residential) use, financial resources for the necessary O&M are frequently insufficient to warrant sustained operation. It is common that some existing SHP plants would be dismissed and replaced by the grid once the grid is extended to the area (e.g., Vietnam). Also, the economic feasibility of many SHP projects is not clear especially if and when compared with large-scale hydro and thermal power generation.

The socio-economic merits of electricity and of local resource exploitation are well established, but their quantification is still in infancy. In consequence, they do not usually enter into the evaluation of economic merits and projects, which could bring considerable advantages to the local population, and are in danger of being discarded by conventional economic analysis.

Almost SHP developments are located in mountainous areas, commonly on land belonging to cultural minorities. In such cases the right of way to a project site, or the actual acquisition of ancestral lands maybe problematic. Further more, there could be objections to water diversion if there are larger water users down stream for irrigation or drinking water supply.

In addition, there could be some environmental concerns although the environment al impact of run-of -river type developments is usually quite limited.

Focusing on the specific areas, the features of technical and non-technical issues of SHP in several APEC economies can be explained in following sub- paragraphs

### 3.1. Institutional frameworks, regulations, and policies

In the New Zealand, Institutional barriers can be thought of in two ways:

1. Arrangements for the production, distribution, sale and purchase of electricity are based on a large scale central generation model. Institutional arrangements, rules and regulations, installation and electrical requirements favour centralised generation over DG

2. Individual DG installations (including micro and embedded) are small by definition and therefore vulnerable to having the costs of getting established or the cost of participating in

markets overwhelming the value it  can capture where some of those costs are high fixed costs or set in relation to much larger schemes.

In addition to that it can be difficult to connecting into a network (as a result of institutional and cost barriers); energy supply has historically been much cheaper relative to other costs than it is now and promotion of alternate energy sources is weak; environmental concerns have created an impetus for renewable generation of all sizes but not the financial incentives; there is a disproportionate cost of gaining planning consents for small schemes; standards, codes of practice and supplier accreditation schemes are inconsistent and potentially onerous; and developers may struggle with the tax implications of developing small scale hydro

The other economies, e.g. Russia, a big issue is the absence of adequate support measures. Russia Hydro Company, which is a single largest operator of Russia's hydro power plants and selected renewable plants, drafted a Programme of small hydro energy development at small and medium size rivers for 2012-2020, but it has not been approved yet. Various support measures were provided for by the Electricity Law, but it has not been enacted through local legal acts. A significant barrier is the administrative procedures (construction permits, land lease, connection to grid etc.).

Most of the small hydropower potential is in Russian Siberia and the Far East. But there are environmental constraints as to the small hydro plant development, in particular, at the mouths of small rivers.

### 3.2. Technique and technology

In the case of Indonesia, Stakeholder involvement is often neglected during project selection, planning, and implementation. Active stakeholder participation is especially important for community-based systems, where the stakeholders will be managing and paying for a project upon completion. If stakeholder involvement is neglected, the project acceptance and sense of ownership by the stakeholders is often low, resulting in short project lifetime.

The quality of project selection and evaluation studies is in many cases insufficient. Pre-investment financial evaluations are often poor quality or are lacking altogether. Many businessmen and other potential developers are not familiar with the advantages and importance of preparing good business plans, as well as cash flow and cost benefit analyses.

Technical problems, resulting from poor design and construction quality (civil, mechanical, and electrical), are common with many small-scale hydropower schemes, and mostly have the same effects as described in the previous paragraph.

Local equipment design and manufacturing capability is limited, and is mostly concentrated on Java. There are no mechanisms in place (e.g. product liability, quality assurance, technical control institution) that warrant the quality of small-scale hydropower development.

Plant operation and maintenance are often haphazard, with little preventative maintenance. The results are frequent and often long-lasting power outages, which in the case of isolated plants require the customers to possess redundant equipment for lighting, cooking, etc. This hampers the trust in the technology in general, as well as the willingness to pay for the electricity supplied by such schemes.

Project development organizations often have a poor financial record keeping and revenue collection. The consequence is in many cases the inability to recover investment and production cost, leading to poor project performance and hindering replication.

Project owners often lack in managerial and organizational capacities required to sustainable operation of mini or micro hydropower schemes.

For Viet Nam:

Connection planning issues: In some cases, the investment boundary of network connection to power system was not clear, and it depends on the planning process.

Power flow management: Sometimes (in wet season or off-peak hours), the power flow turns back to China in the Northern provinces (Lao Cai, Yen Bai, Ha Giang,..)

Grid congestion: Capacities of transmission and distribution networks are not enough to transfer all the power of small HPPs in some areas to the national power system (the North and Highland).

Voltage quality normally does not meet the requirements specified in Technical code.

Communication and information (SCADA/EMS/DMS) do not meet the requirements or can not operate.

The operation cooperation was not good, there still exist contradiction.

### 3.3. Barriers related to economic and financing mechanisms

Financing for small-scale hydropower development is unavailable or difficult to locate. Prior to the financial crisis, banks were not lending for hydro or other renewable energy projects, because they were not familiar with the technology, and because the returns did not appear to be as high as for other investments. Currently, international banks are usually not willing or able to lend for any type of project.

Private energy suppliers face higher interest rates than government entities, and will prefer conventional energy options with lower capital costs, shorter payback periods and lower up-front investment cost.

There is a lack of micro-credits for the rural population to purchase electric appliances other than for lighting and thus to invest in productive activities based on electricity end-use.

For some economies, there is lack of the benefit sharing mechanism between stakeholders to invest connection network. In Viet Nam, the avoided cost tariff does not reflect all the cost of project (example: investment cost to of network connection, etc.) and may not have interest rate high enough to attract investors.

### 3.4. Barriers related to awareness, information and database

Many institutions and decision-makers are not aware of the possibilities for small-scale hydropower development. The result is often that conventional energy options are preferred, where the potential for hydropower would be promising.

Regional government involvement in development decisions is becoming increasingly important as increased local autonomy is implemented. Up to date, however, there is little understanding of the electric business at that level.

There is no center or network existing that collects and disseminates information on all aspects of small-scale hydropower development. The lack of broadly available information on past experience with SHP development for example in the form of lessons learnt and best practices often results in the repetition of the same mistakes and shortfalls in the efforts to implement projects.

Basic data needed for project evaluation (maps, surveys, hydrology, and geology) is often missing or difficult to obtain, especially for more remote regions in APEC developing economies.

A frequently updated and easily accessible inventory with potential small-scale hydropower sites is currently still inexistent. Potential project developers, therefore, often have to take a lengthy way through many institutions to identify hydropower investment opportunities. At the same time, attractive sites may remain undeveloped, because they are not known to potential project developers.

The public awareness on the implications of global warming in that every country is responsible to reduce its $CO_2$ emissions and the rapid depletion of the country's fossil fuel resources, as well as the importance of the development of renewable energy resources on the other hand is still greatly lacking.

## 4. Sharing and exchanging information and experiences

Environmental and social issues will continue to affect hydropower deployment opportunities. The local social and environmental impacts of hydropower projects vary depending on the project's type, size and local conditions and are often controversial. Some of the more prominent impacts include changes in flow regimes and water quality, barriers to fish migration, loss of biological diversity, and population displacement. Impoundments and reservoirs stand out as the source of the most severe concerns but can also provide multiple beneficial services beyond energy supply. While lifecycle assessments indicate very low carbon emissions, there is currently no consensus on the issue of land use change-related net emissions from reservoirs. Experience gained during past decades in combination with continually advancing sustainability guidelines and criteria, innovative planning based on stakeholder consultations and scientific knowhow can support high sustainability performance in future projects. Transboundary water management, including the management of hydropower projects, establishing an arena for international cooperation that may contribute to promoting sustainable economic growth and water security.

Hydropower offers significant potential for carbon emissions reductions. Baseline projections of the global supply of hydropower rise from 12.8 EJ in 2009 to 13 EJ in 2020, 15 EJ in 2030 and 18 EJ in 2050 in the median case. Steady growth in the supply of hydropower is therefore projected to occur even in the absence of greenhouse gas (GHG) mitigation policies, though demand growth is anticipated to be even higher, resulting in a shrinking percentage share of hydropower in global electricity supply. Evidence suggests that relatively high levels of deployment over the next 20 years are feasible, and hydropower should remain an attractive renewable energy source within the context of global GHG mitigation scenarios. That hydropower can provide energy and water management services and also help to manage variable renewable energy supply may further support its continued deployment, but environmental and social impacts will need to be carefully managed.

Renovation, modernization and upgrading (RM&U) of old power stations is often less costly than developing a new power plant, often has relatively smaller environment and social impacts, and requires less time for implementation. Capacity additions through RM&U of old power stations can therefore be attractive. Selective replacement or repair of identified hydro powerhouse components like turbine runners, generator windings, excitation systems, governors, control panels or trash cleaning devices can reduce costs and save time. It can also lead to increased efficiency, peak power and energy availability of the plant (Prabhakar and Pathariya, 2007). RM&U may allow for restoring or improving environmental conditions in already-regulated areas. Several national programmes for RM&U are available. For example, the Research Council of Norway recently initiated a program with the aim to increase power production in existing hydropower plants and at the same time improve environmental conditions.

The US Department of Energy has been using a similar approach to new technology development since 1994 when it started the Advanced Hydropower Turbine Systems Program that emphasized simultaneous improvements in energy and environmental performance (Odeh, 1999; Cada, 2001; Sale et al., 2006a). Normally the life of hydroelectric power plants is 40 to 80 years. Electromechanical equipment may need to be upgraded or replaced after 30 to 40 years, however, while civil structures like dams, tunnels etc. usually function longer before they requires renovation. The lifespan of properly maintained hydropower plants can exceed 100 years.

Using modern control and regulatory equipment leads to increased reliability (Prabhakar and Pathariya, 2007). Upgrading hydropower plants calls for a systematic approach, as a number of hydraulic, mechanical, electrical and economic factors play a vital role in deciding the course of action. For techno-economic reasons, it can also be desirable to consider up-rating (i.e., increasing the size of the hydropower plant) along with RM&U/life extension. Hydropower generating equipment with improved performance can also be retrofitted, often to accommodate market demands for more flexible, peaking modes of operation. Most of the existing worldwide hydropower equipment in operation will need to be modernized to some degree by 2030 (SER, 2007). Refurbished or up-rated hydropower plants also result in incremental increases in hydropower generation due to more efficient turbines and generators.

**Rural electrification**

According to the International Energy Agency (IEA, 2010), 1.4 billion people have no access to electricity. Related to the presentations in the recent APEC Hydro Workshop in Ha Noi , small-scale hydropower (SHP) can sometimes be an economically viable supply source in these circumstances, as SHP can provide a decentralized electricity supply in those rural areas.

**Barriers for fish migration and navigation**

Dams may create obstacles for the movement of migratory fish species and for river navigation. They may reduce access to spawning grounds and rearing zones, leading to a decrease in migratory fish populations and fragmentation of non-migratory fish populations. However, natural waterfalls also constitute obstacles to upstream fish migration and river navigation. Dams that are built on such waterfalls therefore do not constitute an additional barrier to passage. Solutions for upstream fish migrations are now widely available: a variety of solutions have been tested for the last 30 years and have shown acceptable to high efficiency. Fish ladders can partly restore the upstream migration, but they must be carefully designed, and well suited to the site and species considered (Larinier and Marmulla, 2004).

**Optimization of operation**

Hydropower generation can be increased at a given plant by optimizing a number of different aspects of plant operations, including the settings of individual units, the coordination of multiple unit operations, and release patterns from multiple reservoirs. Based on the experience of federal agencies such as the Tennessee Valley Authority and on strategic planning workshops with the hydropower industry, it is clear that substantial operational improvements can be made in hydropower systems, given new investments in R&D and technology transfer (Sale et al., 2006b). In the future, improved hydrological forecasts combined with optimization models are likely to improve operation and water use, increasing the energy output from existing power plants significantly.

**Integration into water management systems**

Water, energy and climate change are inextricably linked. On the one hand, water availability is crucial for many energy technologies, including hydropower (see Section 9.3.4.4), and on the other hand, energy is needed to secure water supply for agriculture, industries and households, particularly in water-scarce areas in developing countries (Sinha et al., 2006; Mukherji, 2007; Kahrl and RolandHolst, 2008). This mutual dependence has lead to the understanding that the water-energy nexus must be addressed in a holistic way, especially regarding climate change and sustainable development (Davidson et al., 2003; UNESCO-RED, 2008; WBCSD, 2009). Providing energy and water for sustainable development will require improved regional and global water governance, and since hydroelectric facilities are often associated with the creation of water storage facilities, hydropower is at the crossroads of these issues and can play an important role in enhancing both energy and water security. Therefore, hydropower development is part of water management systems as much as energy management systems, both of which are increasingly becoming climate driven.

**Multipurpose use of reservoirs and regulated rivers**

Creating reservoirs is often the only way to adjust the uneven distribution of water in space and time that occurs in the unmanaged environment. Reservoirs add great benefit to hydropower projects, because of the possibility to store water (and energy) during periods of water surplus, and release the water during periods of deficit, making it possible to produce energy according to the demand profile. This is necessary because of large seasonal and year-to-year variability in the inflow. Such hydrological variability is found in most regions in the world, caused by climatic variability in rainfall and/or air temperature. Most reservoirs are built for supplying seasonal storage, but some also have capacity for multi-year regulation, where water from two or more wet years can be stored and released during a later sequence of dry years. The need for water storage also exists for many other types of water use, such as irrigation, water supply and navigation and for flood control. In addition to these primary objectives, reservoirs can provide a number of other uses like recreation and aquaculture. Reservoirs that are created to serve more than one purpose are known as multipurpose reservoirs. Harmonious and economically optimal operation of such multipurpose schemes may involve trade-offs between the various uses, including hydropower generation.

## 5. Technical and non-technical solutions to overcome barriers

- The input collected from the workshop, providing by APEC members and searching the website is divided into two categories: technical and non - technical measures.

- For the connected grid, to deliver commercially viable renewable energy electricity including small hydro power in sufficient quantities, the industry must overcome a number of key regulatory, technical planning, and commercial issues relating to connection and integration.

- Possible key solutions to overcome barriers that mentioned in the above paragraph are addressed by the most common technical and non - technical measures in the APEC member economies as follows:

The technical measures include technology and R&D.

### 5.1. Technology development and R&D

- Careful study of grid development plans before inventing in building the systems.

- There is a need to prepare adequate codes and connection guidelines that will help to improve the reliability of the network as well as the quality of supply to the system utility. This is especially pertinent for small hydro that fluctuates significantly throughout the course of a day and season. In addition to that, these should be reviewed and amended existing standards and grid codes by electricity regulatory agency of the government to allow for smooth integration of renewable energy in general and SHP in particular.

- Small hydropower development should be focused on the standardization and simplification of the facilities, technologies of efficiency improvement and system automation in order to form the commercial business.

- Enhance IT/automation infrastructure of SHPs i.e. SCADA, communication system to support the optimization of operation and communication between dispatch centers and SHPs.

- Develop technical requirements customized for embedded generators including SHPs to improve the quality of voltage, energy losses.

- Enhance contribution of grid small hydro power generation to the stable electricity supply provision by applying new technology.

- More research needs to be carried out on the combination of SHP with other RE power sources like solar, wind power as well as on possible application of SHP in future smart grid.

- Strengthen capacity building on small hydro enterprises to

  - Improve adjustability
  - Optimize operating mode
  - Adopt advanced technologies

- Intensify management, lay off redundant workers, and increase efficiency

- Non-technical measures include planning/institution/regulation; economics and finance, and sharing information.

### 5.2. Planning/institution/regulation

- Government should take leading role in guaranteeing long-term finance from installation and private institutions for RE including small hydro on fully commercial basis.

- Set up clear simple procedures for developers (for example “one stop procedures to support investment & implementation of grid renewable energy system”). Especially accountability among developers, power companies and local government needs to be clear with several issues such as SHP site, network expansion plan to accommodate small hydro and connection issues.

- Promotion of hydropower requires stable policy and regulations. Its stability is the important to attract investor on a sector that can be financially sustainable. Financial mechanisms for hydropower projects should account for multipurpose features related not only to generating green electricity but also other benefits regarding water resource management, socio-economic development at the location of hydropower plant.

- Establish regulations on safety management of hydropower dams, regulation on using surface water resource to ensure harmonizing water resource to irrigation and household use; develop efficient connection network to optimize construction cost, transmitting capacity and land occupation.

- Review SHP plans, eliminate projects are not efficient and feasible (technical, economic, social and environmental aspects).

- Developing hydro power cannot be successful and suitable if there is no involvement of local government and the consensus of local community. Therefore, it is important to enhance enforcing the process of SHP operation cooperation between HPPs/stakeholders. To do that benefit from the projects to local communes must set the first priority. Further, need for strong community to operate, maintenance, technical assistance and transfer to local people is still necessary for continuity of the projects.

- As the electricity consumption is normally low in the area of SHP, promotion of use of electricity for production is considered to improve the efficiency of SHP and local grid system, as the result, commercial business of SHP would be increased.

- SHP development should increase more intensive involvement of local community and private sector.

### 5.3. Economy and finance

- Hydropower is dependent on topography and rainfall. It results a wide range of scheme size and type. Further, the sites of SHP generally are far from load center. It must therefore be incentive and regulated in a relevant manner.

- Feed in tariff (FIT) is a good and common instrument that is used in many APEC economies but improvement of regulation of Feed-in Tariff for Renewable Energy especially on small hydro power generation should be developed more progressively to facilitate investors in hydro power generation business. At the same time, making a support finance mechanism for grid connection should be available.

- In some cases (at household/village level), Government needs to guarantee to bank if high risk of SHP projects and provide tax incentive for RE equipment

- Governments should make grants available for research and investment stage for generation of RE and hydropower. For example, the preparation and planning costs or in some cases even costs for feasibility study should be subsidized by the government. Also, the application of new technology like smart grid or concept of micro grid is necessary supported from government.

- Specific investment and pricing mechanism for development of SHP should be reviewed to achieve the attraction of investors (special policy for payment, credit period and interest rate); the benefit sharing mechanism for affected people by SHP should be considered.

- Environmental factors must be taken into consideration in pricing mechanism, protection of market price for SHP

### 5.4. Database collection, sharing information and cooperation

- Data collection and updated measurement data on RE: wind, solar, hydrology, RE maps and database should be supported and managed by the government. It's also necessary to have a kind of mechanism for sharing these data among research institutes, agencies.

- APEC is a region with high potential of hydropower. There is a lot of experts on the area of RE and room for the exchange of information on integrating RE into grid system. However, information and results of studies on SHP in each individual economy is likely not always available or updated. Therefore, the kind of information system exchange including organizing the workshop, training course on SHP, etc. should be more frequent and open in APEC.

## 6. Examples of successful small hydro/grid integration activities (case study of Nui Coc small hydro power plant, Viet Nam)

### 6.1. General introduction of Nui Coc Hydropower plant

Nui Coc small hydropower plant (Nui Coc HPP) is located at the downstream side of the dam of Nui Coc reservoir in Phuc Triu commune, Thai Nguyen city. With capacity of 1.5MW, it is designed by Hydropower Center of Irrigation Science Institute. Construction of Nui Coc HPP was started on 28 December 2007. Nui Coc HPP is invested by Nui Coc Hydropower Joint Stock Company which consists of 3 founding members namely Thai Nguyen Irrigation Joint Stock Company (40% share) VNCOLD (35% share) and other investors (25% share).

The Nui Coc HPP has 3 generator units with capacity of 630kW each. Generator voltage is 0.4kV. Each unit has one step-up transformer 2,500kVA – 0.4/22kV (manufactured by Hanoi Power Transformer Manufacturing Joint Stock Company). The total investment cost of this project is VND 32.5 billions. The components of the project include main penstock, branch penstock, downstream discharge canal, 22kV switchyard and auxiliary equipments. After two years of construction, installation and adjustment of equipments, Nui Coc HPP was officially synchronized into the national power grid and started commercial generation of maximum capacity of 1.89 MW at the end of August of 2009.

This is the first hydropower plant in Thai Nguyen province, which generates electricity for Thai Nguyen city and supplies water for irrigation. The annual electricity generated to the power grid is 7.97 million kWh.

At present, this power plant generates about 30,000 kWh per day (enough electricity for Tan Cuong tea production area).

In the present context with serious electricity shortage, one hydropower plant (even small) generating electricity to the national power grid without negative environmental impacts is an essential contribution to reducing difficulties of power sector and it is an electricity saving measure for the country as well.

### 6.2. Objectives of the project

- To generate electricity by using water from reservoir that supplies water for agricultural irrigation and domestic consumption.

- To contribute in reducing electricity shortage situation in the dry season in the Nui Coc HPP area.

### 6.3. Factors for success of Nui Coc hydropower project development:

In *Project investment preparation* the relevant issues were carefully considered such as check and assessment of available water resource of reservoir; request on adding function of electricity generation for Nui Coc reservoir; working with Electricity of Vietnam (EVN) on procedures of electricity sale and purchase (EVN is a electricity purchasing unit); selection of good consultant for project promulgation...

The procedures for project investment preparation are complicated but project owner dealt with them quickly and efficiently. Process of Nui Coc HPP investment preparation is strongly supported by authorities at national and provincial levels

*Mobilization of finance for construction of Nui Coc HPP* was carried out carefully. Selection of founding shareholders was based on the voluntary basic, capability and willingness of stakeholders. Then ***Nui Coc Hydropower Joint Stock Company*** was established..

*Experienced, qualified consultant for design of the project:* The Management Board of Nui Coc Hydropower Joint stock Company was aware of importance of investigation and design of the project. The project investigation and design were consulted with many experts, professors who are specialized in hydropower. Many workshops were held in order to identify the design option of the project with detailed items, optimal technical solutions and the lowest investment costs.

*Finance mobilization:* The Management Board paid high attention on mobilization of finance from stakeholders because they are employees in State owned enterprises, or retired so they don't have lot money. Therefore, mobilizing and expending finance must be carefully calculated for each investment period with taking into account of market price fluctuation (especially price of steel and equipment during project construction period). Getting loan from banks is also carefully considered even HPP benefits preferential interest rate.

*Selection of construction contractor and equipment supplier is an important issue* which can reduce construction cost (about 10 %). Contractors are selected based on competitive bidding (Bidders submit bids, then the company carried out negotiation with potential contractors separately in order to select one contractor with reasonable bid price and ensured quality).

*Construction process:* Management Board closely monitored construction work. The technical staffs with good experience in construction, equipment installation were assigned for supervising project construction works. With policy: strict management from beginning; never getting payments or gifts from contractor; accepting and making payment only for works which meet quality requirements and standards in design. Therefore, in construction process, there is no additional work due to wrong construction or reconstructed works. All construction items must be verified before acceptance and putting into operation.

*In order to ensure efficient and sustainable operation of the HPP project,* the Company selected and sent family members of stakeholders for training on HPP plant operation with the expectation that they are "the owners of the plant". Therefore, it can be said that workers of power plant are aware of protection and good operation of the HPP, complying technical procedures, norms. In order to enhance qualification for operators, the Company contracts one engineer responsible for management of operation (as chief of operators) who is always present at the power plant for guiding and steering operation work.

*The procedures for maintenance and operation of the hydropower plant* are strictly complied with. After 4 yeas of operation, the equipments are normally working without serious faults and accidents.

# ANNEX

## Annex 1: Main points of roundtable discussion

*Under APEC Workshop on Small Hydro and Renewable Grid Integration in Ha Noi, Viet Nam April 3-5, 2013*

In the roundtable discussion of the workshop, participants made suggestions on common issues across the economies, although each economy has distinct hydro resources and natural conditions, different type of social-economic system and technical system (for example, the grid system).

Looking at different aspects, a consensus view among participants suggested that the most important areas were:

1. Research projects

- Optimal combination of small hydro and wind/solar in the grid and harmonization of all kinds of distributed energies of the grid system
- Technology and policy solutions for these combination and harmonization
- Promoting a micro grid concept
- Cost effectiveness

2. Conducting feasibility studies and pilot projects
    - To keep people to know how to get effectiveness before expanding installation/building RE energy system
    - To demonstrate these studies and projects in specific community or particular local conditions
3. Building system information exchange based on regional cooperation.
    - APEC will lead joint study on the PV-hydro hybrid system.
    - Proposal projects for best practices for areas: Hybrid system; assessment of latest technology, for example, micro grid and RE technology; interconnection of the hydro into the grid system; and financing models for RE projects.
    - APEC will lead a project on clear definition on RE small scale, including small hydro power.
4. Standards for small hydro and other renewable energy system
   Workshop participants discussed a range of collaboration activities in the APEC region. In this regards, APEC could produce/propose some projects in this mentioned area.
5. Involvement of stakeholders, specifically local community in small hydro projects
    - Small hydro power plants normally can increase the life of local people. However, in several cases, it has negative impacts on environment in the area located plant. Therefore, their positive and negative influences to people living in around location of SHP should be addressed clearly so that local community can participate effectively in the involvement of the project and support to developers.
    - Increasing awareness and understanding to the community in the stage of study and implementation as well.
6. RE Integration grid code
   Participants considered APEC assist making some guidelines for setting up distribution code.

7. Flexibility of the power system issues
   It is also an important thing for RE small scale should be indicated such as: Demand side responds via the smart grid; energy storage facilities and dispatch able power plant.
8. Financing issue
   Another suggestion from participants addressed to the financing issue is establishing the framework for the effective cost sharing among stakeholders for RE development: Local government, developers, power companies (transmission/distribution power companies) and producers/operators.

Finally Mr. Ninh Hai on behalf of the project overseer delivered the closing remarks.

He mentioned that the workshop achieved fruitful results as all expected. The workshop provided a lot with vitally useful information experience and opinion on both policy making and practicing activities for diversification of energy resources to meet the energy demand and sustainable development in our current complex. Especially, the issue of small hydropower and renewable energy integration into the grid is increasingly to pay attention in APEC economies. It is a chance for Viet Nam to learnt experience in this area from experts of APEC.

## Annex 2: Template of questioners for data, information collection and the collected documents

### A. Template of questioners for data, information collection

**<u>Objective of data collection is</u>**: to develop a Roadmap of APEC Economies for Grid - Connected Small Hydropower Development (SHP)

To develop the Roadmap, the information and available data that relates to grid - connected small hydropower (e.g. development current, plans in the future, potential and development policies, etc.) from each Economy provided will be necessary for this study. The main collected information/data will held to make clear the four basic elements as following:

1) Identify existing problems that have been identified in small hydro grid integration

2) Technical solutions available to address the identified problems

3) Non-technical and institutional issues impacting small hydro: legal framework, regulation, financial incentives, capacity building, etc.

4) identification of examples of successful small hydro/grid integration activities

Based on above mentions, there are five Excel sheets that covers information/data will be expected to receive from each Economies. They are:

Sheet 1: Total small hydropower potential.

Sheet 2: State of play of small hydro

Sheet 3: Support schemes for SHP

Sheet 4: Existing problems of SHP

Sheet 5: Examples of successful SHP

# Sheet 1: Total small hydropower potential

| Total Small Hydro Power (SHP) Potential in APEC | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Gross theoretical potential | | Technical feasible potential | | Economical feasible potential | | Available for development | |
| | SHP | SHP | SHP | SHP | SHP | SHP | SHP | SHP |
| Economies | (MW) | (MWh) | (MW) | (MWh) | (MW) | (MWh) | (MW) | (MWh) |
| Australia | | | | | | | | |
| Brunei | | | | | | | | |
| Canada | | | | | | | | |
| Chile | | | | | | | | |
| China | | | | | | | | |
| Hong Kong, China | | | | | | | | |
| Indonesia | | | | | | | | |
| Japan | | | | | | | | |
| Korea | | | | | | | | |
| Malaysia | | | | | | | | |
| Mexico | | | | | | | | |
| New Zealand | | | | | | | | |
| Papua New Guinea | | | | | | | | |
| Peru | | | | | | | | |
| Philippines | | | | | | | | |
| Russia | | | | | | | | |
| Singapore | | | | | | | | |
| Chinese Taipei | | | | | | | | |
| Thailand | | | | | | | | |
| United State | | | | | | | | |
| Vietnam | | | | | | | | |

# Sheet 2: State of play of small hydro

| State of Play of the Small Hydro Power (SHP) in APEC | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | | 2005 | | 2010 | | 2012 (current) | | 2020 | |
| | SHP | SHP | SHP | SHP | SHP | SHP | SHP | SHP | SHP | SHP |
| Economies | (MW) | (MWh) | (MW) | (MWh) | (MW) | (MWh) | (MW) | (MWh) | (MW) | (MWh) |
| Australia | | | | | | | | | | |
| Brunei | | | | | | | | | | |
| Canada | | | | | | | | | | |
| Chile | | | | | | | | | | |
| China | | | | | | | | | | |
| Hong Kong, China | | | | | | | | | | |
| Indonesia | | | | | | | | | | |
| Japan | | | | | | | | | | |
| Korea | | | | | | | | | | |
| Malaysia | | | | | | | | | | |
| Mexico | | | | | | | | | | |
| New Zealand | | | | | | | | | | |
| Papua New Guinea | | | | | | | | | | |
| Peru | | | | | | | | | | |
| Philippines | | | | | | | | | | |
| Russia | | | | | | | | | | |
| Singapore | | | | | | | | | | |
| Chinese Taipei | | | | | | | | | | |
| Thailand | | | | | | | | | | |
| United State | | | | | | | | | | |
| Vietnam | | | | | | | | | | |

## Sheet 3: Support schemes for SHP

| Support Machanisms for SHP in APEC | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Economies** | **FIT** | **FIP (premium)** | **Quota obiligation** | **Tendering** | **Avoided cost** | **Investment grants** | **Tax exemption/ deduction** | **Fiscal incentives** | **Others (specify)** |
| Australia | | | | | | | | | |
| Brunei | | | | | | | | | |
| Canada | | | | | | | | | |
| Chile | | | | | | | | | |
| China | | | | | | | | | |
| Hong Kong, China | | | | | | | | | |
| Indonesia | | | | | | | | | |
| Japan | | | | | | | | | |
| Korea | | | | | | | | | |
| Malaysia | | | | | | | | | |
| Mexico | | | | | | | | | |
| New Zealand | | | | | | | | | |
| Papua New Guinea | | | | | | | | | |
| Peru | | | | | | | | | |
| Philippines | | | | | | | | | |
| Russia | | | | | | | | | |
| Singapore | | | | | | | | | |
| Chinese Taipei | | | | | | | | | |
| Thailand | | | | | | | | | |
| United State | | | | | | | | | |
| Vietnam | | | | | | | | | |

## Sheet 4: Existing problems of SHP

| Existing problems of SHP in grid connection | | | | | |
|---|---|---|---|---|---|
| **Economies** | **Technology/technique** | **Policy/institution** | **Economic/finance** | **Planning/data** | **Others (e.g. Conflict)** |
| Australia | | | | | |
| Brunei | | | | | |
| Canada | | | | | |
| Chile | | | | | |
| China | | | | | |
| Hong Kong, China | | | | | |
| Indonesia | | | | | |
| Japan | | | | | |
| Korea | | | | | |
| Malaysia | | | | | |
| Mexico | | | | | |
| New Zealand | | | | | |
| Papua New Guinea | | | | | |
| Peru | | | | | |
| Philippines | | | | | |
| Russia | | | | | |
| Singapore | | | | | |
| Chinese Taipei | | | | | |
| Thailand | | | | | |
| United State | | | | | |
| Vietnam | | | | | |

## Sheet 5: Examples of successful SHP

| Example of successful of SHP in grid connection | | | | | |
|---|---|---|---|---|---|
| **Economies** | **Technology/technique** | **Policy/institution** | **Economic/finance** | **Planning/data** | **Others (e.g. Conflict)** |
| Australia | | | | | |
| Brunei | | | | | |
| Canada | | | | | |
| Chile | | | | | |
| China | | | | | |
| Hong Kong, China | | | | | |
| Indonesia | | | | | |
| Japan | | | | | |
| Korea | | | | | |
| Malaysia | | | | | |
| Mexico | | | | | |
| New Zealand | | | | | |
| Papua New Guinea | | | | | |
| Peru | | | | | |
| Philippines | | | | | |
| Russia | | | | | |
| Singapore | | | | | |
| Chinese Taipei | | | | | |
| Thailand | | | | | |
| United State | | | | | |
| Vietnam | | | | | |

## B. The collected documents

| Total Small Hydro Power (SHP) Potential in APEC | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Gross theoretical potential | | Technical feasible potential | | Economical feasible potential | | Available for development | |
| | SHP | SHP | SHP | SHP | SHP | SHP | SHP | SHP |
| Economies | (MW) | (MWh) | (MW) | (MWh) | (MW) | (MWh) | (MW) | (MWh) |
| Hong Kong, China | NA | NA | NA | NA | NA | NA | NA | NA |
| New Zealand | n/a | n/a | 1387 | 6078528 | 350 | 1533875 | 350 | 1533875 |
| Russia | 41,000 | 372,000,000 | | | 22,550 | 204,600,000 | | |
| Vietnam | NA | NA | >7,000 | 28,000000 | 5,000 | 16,000,000 | 3,000 | 12,000,000 |

| State of Play of the Small Hydro Power (SHP) in APEC | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | | 2005 | | 2010 | | 2012 (current) | | 2020 | |
| | SHP | SHP | SHP | SHP | SHP | SHP | SHP | SHP | SHP | SHP |
| Economies | (MW) | (MWh) | (MW) | (MWh) | (MW) | (MWh) | (MW) | (MWh) | (MW) | (MWh) |
| Hong Kong, China | | | | | | | 0.36 | 2900 | | |
| New Zealand | 118 | 475480 | 118 | 475480 | 123 | 494373 | 127 | 512780 | 473 | 2072923 |
| Russia | | | | | | | 250 | 1100 | | |
| Vietnam | | | | | 900 | 3,500,000 | 1,100 | 4,400,000 | | |

| Economies | Avoided cost | Tax exemption/deduction | Fiscal incentives | Others (specify) |
|---|---|---|---|---|
| Hong Kong, China | | Capital expenditure can be deducted over a 5-year period staring from the year of purchase. | Public and private funding schemes are available for promotion of renewable energy (including SHP). | |
| New Zealand | | | New Zealand has an Emissions Trading Scheme that will make renewable electricity favourable over fossil fuels.<br>To respond to cost barriers to installing distributed generation, the government ran a feasibility funding programme between 2008 and 2010 to "Kick-start" development of small-scale renewables. The aim was to facilitate projects that were close to being commercially viable and were being developed by a non-traditional electricity player. It also should to further identify the barriers to commercialising distributed generation and to test the DG market. 30 projects were funded ($447,000) and combined, they demonstrate potential niches for economic, or close-to-economic distributed generation projects in New Zealand. | New Zealand does not have feed-in tariffs or other financial subsidies for SHP or any other renewable electricity generation. New Zealand has a non-binding target for 90% renewable electricity generation by 2025 . To support this national guidance has been prepared in the form of a National Policy Statement for Renewable Electricity Generation, adopted in 2011, that confirms that the development of renewable energy resources in of national importance to New Zealand in tacking climate change issues and improving security of energy supply. |
| Russia(*) | | | | |
| Vietnam | Complied with Avoided Cost regulation: issued the avoided cost tariff for small renewable energy power plants and Standard PPA. All the PPAs will use the standard PPA (according to Decision No.18)<br>Generator will sign the contract with the Power Corporation according to the authorization of EVN.<br>Priority is carried out scheduling the Small HPP in wet season.<br>Every year, Electricity Regulatory Authority of Vietnam will issue the new generation charge structure for Renewable energy including small HPP in wet/dry season and peak/off-peak hour. | X | X | **Development and Planning:**<br>Provincial People's Committee develop small HPP planning in their provincial and submit to MOIT for approval<br>General Directorate of Energy develop the hydroelectric ladder planning and submit MOIT for approval<br>Orientation of connection voltage level in planning:<br>Less than 3MW: Connect to medium voltage at current local network<br>From 3MW to 10MW: Consider connect to medium bus bar of 110kV sub-station.<br>From 10MW to 30MW: connect directly to 110kV network or medium voltage.<br>**Technical regulation:**<br>Distribution Code stipulated:<br>Technical standards and requirements<br>Communication, operational and safety standards: Procedure of operation cooperation<br>Technical requirements of connection/integration of power plants (HPP)<br>Coordination in operation<br>Metering requirements,...etc<br>Technical procedures, connection procedure: Will be specified for each kind of renewable energy (Wind, small HPP,..)<br>**Scheduling and dispatching:** It depend on the ability of small HPP (reservoir, ability of daily, weekly,.. Regulation) and be consistent with the provisions in the SPPA, PCs will dispatch accordingly. |

***Note*** (*) Currently, there are no special support measures to small hydro development in Russia. The legal environment for small hydro is equal to that for large hydro power plants (same pricing policy, same market regulations, same investment policy and so on). It is expected that the Russian Government will soon enact the necessary legislation to support small hydro development through various incentives including FIT and other.

| Existing problems of SHP in grid connection | | | | | |
|---|---|---|---|---|---|
| **Economies** | **Technology /technique** | **Policy/institution** | **Economic/finance** | **Planning/data** | **Others (e.g. Conflict)** |
| Hong Kong, China | NIL | NIL | NIL | NIL | NIL |
| New Zealand | | Institutional barriers can be thought of in two ways.<br><br>1. Arrangements for the production, distribution, sale and purchase of electricity are based around a large scale central generation model. Institutional arrangements, rules and regulations, installation and electrical requirements favour centralised generation over DG<br><br>2. Individual DG installations (including micro and embedded) are small by definition and therefore vulnerable to having the costs of getting established or the cost of participating in markets overwhelming the value it an capture where some of those costs are high fixed costs or set in relation to much larger schemes<br><br>In addition: it can be difficult to connecting into a network as a result of institutional and cost barriers); energy supply has historically been much cheaper relative to other costs than it is now and promotion of alternate energy sources is weak; environmental concerns have created an impetus for renewable generation of all sizes but not the financial incentives; there is a the disproportionate cost of gaining planning consents for small schemes; standards, codes of practice and supplier accreditation schemes are inconsistent and potentially onerous; and developers may struggle with the tax implications of developing small scale hydro | Developers may be reluctant to sell direct to the wholesale (spot) market<br><br>There is no access to a liquid and transparent forward electricity market<br><br>Developers face the prospect of forward selling their electricity to competitors<br><br>Capital costs may be high relative to the price of network supplied electricity<br><br>Adopting new technology can be extra costly and risky<br><br>Few electricity retailers offer to buy back excess output from micro generation | Access to information is not readily available particularly on where to start with the steps required to establish embedded generation | Un-priced externalities including carbon and air pollution from thermal fuel generation<br><br>Distributors do not necessarily pass back benefits of higher security, investment deferral or avoided transmission charges |
| Russia | | A big issue is the absence of adequate support measures. RussHydro company which is a single largest operator of Russia's hydro power plants and selected renewable plants, drafted a Programme of small hydro energy development at small and medium size rivers for 2012-2020, but it has not been approved yet. Various support measures were provided for by the Electricity Law, but have not been enacted through local legal acts. A significant barrier is the administrative procedures (construction permits, land lease, connection to grid etc.). | | | Most of the small hydro potential is in Russian Siberia and the Far East. But there are environmental constraints as to the small hydro plant development, in particular, at the mouths of small rivers. |
| Vietnam | Connection planning issues: In some case the investment boundary of network connection to power system was not clear, and it depend on the planning process.<br>Power flow management: Sometime (wet season or off-peak of system), the power flow turn back to China in the Northern (Lao Cai, Yen Bai, | | | | Quality of EIA was not good<br>Change the natural flow on the river (downstream).<br>Deforestation.<br>Impact to ecosystem<br>Migration and resettlement.<br>Impact on the agriculture in dry |

| | | | | | |
|---|---|---|---|---|---|
| | Ha Giang province,..)<br>Grid congestion: Capacity of transmission and distribution network are not enough to transfer all the power of small HPP in some area to national power system (the Northern and Highland).<br>Quality of voltage normally does not meet the requirement in Technical code.<br>Communication and information (SCADA/EMS/DMS) do not meet the requirements or can not operate.<br>The operation cooperation was not good, still exist contradiction.<br>Lacking the benefit sharing mechanism between stakeholders to invest connection network.<br>The avoided cost tariff may not enough interested to attract investors<br>The avoided cost tariff do not reflect all the cost of project (example: cost to invest the network connection,..) | | | | season.<br>There is not the benefit sharing mechanism for affected people |

| Example of successful of SHP in grid connection | | | | | |
|---|---|---|---|---|---|
| **Economies** | **Technology/technique** | **Policy/institution** | **Economic/finance** | **Planning/data** | **Others (e.g. Conflict)** |
| Hong Kong, China | Asynchronous integration through DC inverters/ converters. Anti-islanding protection relay with power quality tests are provided | Connection Agreement with Utility is made | The electricity generated is to be used within the waterworks installation. Saving in operating cost resulted. | NA | NA |
| New Zealand | The 2 MW Talla Burn hydro scheme in Central Otago is connected to the local distribution network in a remote location. The station is generating 13 GWh of electricity a year, powering 1,000 homes in the district. Local retailer Pulse Energy buys the electricity which is supplied to the grid via a 21 km transmission line. The project was initiated and developed by two local families. As well as being locally owned and operated, the project gained strong community buy-in: the consenting phase took only a year. With an indefinite lifespan and secure supply, the families describe the project as an example of stewardship rather than ownership. | | | | |
| Russia | In 2006-2009, two small hydros with rated capacity 1.2MW and 0.5MW were mounted at a sewage collector in Ulyanovsk city. | | In 2008-2009, Fasnalskaya hydro power plant was built in North Osetia, with rated capacity of 6.4MW. The investment came entirely from a private investor. The plant is part of a planned cascade of small hydros at Urukh river. | In 2012, the Far Eastern Federal University developed a Concept of local energy systems for the Primorsky Territory where 6 mini hydros would be integrated into local energy management systems (microgrid-based). Gross technical potential of Primorsky Territory in terms of mini hydro was estimated at 150-180 MW. | |
| Vietnam | Contributed to balance the power supply – demand of national power system.<br>Ensure power supply at local province, increase electrification rate.<br>Contributed to development of social-economic.<br>Develop infrastructure system (transportation, water transport, etc).<br>Increase the employment opportunities in the local.<br>Reasonable cost.<br>Supplement the green energy for power system.<br>Contributed to prevent from flood.<br>Reduce greenhouse gas emissions | | | | |

## Annex 3: The Role of Hydro in Electricity Generation of APEC [13]

### General in Electricity Supply of APEC 21

Coal was by far the dominant source of primary energy for electricity generation in the APEC region in 2010. Under our BAU assumptions, it will continue to be so in 2035. Coal has the advantages of being widely available and relatively inexpensive in many APEC economies. Therefore, it will experience significant growth: 17Mtoe or 2002 terawatt-hours (TWh). Growth in China's output of electricity from coal accounts for most of this growth (161 Mtoe or 1872 TWh), while coal generation in the United States is projected to decline by 37 Mtoe or 426 TWh.

The absolute demand for natural gas generation will grow much more rapidly than coal (246 Mtoe or 2867 TWh). Gas has the advantages of also being widely available in many APEC economies and environmentally preferable to coal, since its greenhouse gas emissions are generally lower. New renewable energy (NRE) (which does not include hydro) will show the third-largest absolute growth of 150 Mtoe or 1740 TWh, spurred by declining costs and supportive government policies in many economies. Despite the re-examination of policies on nuclear energy in many APEC economies, nuclear generation is also projected to show a significant growth of 113 Mtoe or 1315 TWh. About two-thirds of this growth will be in China.

### Renewable Energy Supply

Renewable energy resources offer significant benefits for APEC economies. They are potentially secure, sustainable and low in greenhouse gas (GHG) emissions. The quantity of resource potentially available is enormous.

Technological advancements have made it possible for APEC economies to harness more renewable energy resources, especially in the power generation sector. Spurred by these technological advances, coupled with existing supportive government policies, the contribution of renewable energy to the APEC region's energy supply is projected to grow over the outlook period under business-as-usual (BAU) assumptions-at an average annual rate of 1.8%, increasing from 684 Mtoe in 2010 to 1050 Mtoe by 2035.

China and the United States are expected to be the major contributors, making up over 50% of the total APEC primary renewable energy supply by 2035. At the same time, all APEC economies are expected to have some from of renewable energy contribution by 2035.

### Renewable energy in the electricity generation sector

As APEC economies strive to minimize greenhouse gas emissions and pollution, more renewable energy power generation capacity is being developed to counter the harmful effects of fossil fuel combustion. Figure 15.3 shows the renewable energy share (including hydro and new renewable energy) in the power generation mix will increase over the outlook period from 17% in 2010 to 22% by 2035.

### The Role of Hydro in Electricity Generation

[13] Source: Asia Pacific Energy Research Centre, Feb. 2013, APEC Energy Demand and supply Outlook, 5th edition

Use of renewable energy resources is not new in the APEC region. New Zealand, Canada and Peru used hydropower-mostly large-scale hydro-to generate more than half of their total electricity needs in 2010. Large-scale hydropower is a mature technology with generally economic viability.

Further development options for large-scale hydro are limited in many APEC economies, as the best sites have already been developed. In addition, large-scale hydro has substantial social and environmental effects, such as dislocation of large numbers of people, loss of considerable amounts of productive land, and downstream impacts including diversion of water and trapping of silt. Hydro reservoirs may also emit methane, a potent greenhouse gas. However, the Intergovernmental Panel on Climate Change (IPCC) notes that for most hydro projects, lifecycle assessments have shown low overall net greenhouse gas emission (IPCC, 2007, p.274)

Total hydropower capacity in the APEC region is projected to increase from 532 GW in 2010 to 732 GW in 2035 under BAU assumptions. Accordingly, hydropower generation will increase at an annual average rate of 1.5% from 1840 TWh in 2010 to 2690 TWh in 2035. The share of hydro in the electricity generation mix will fluctuate between 12-15% over the outlook period. Since electricity production is growing faster than the primary energy supply coming from hydropower generation will increase from 2.1% in 2010 to 2.3% 2035.

More details in review of each APEC member economy, please refer the material “APEC Energy Demand and supply Outlook, 5$^{th}$ edition released by Asia Pacific Energy Research Centre (APERC), Feb. 2013.