Renewable Energy for Outlying Islands without Grid Connection

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SUMMARY

There are 262 outlying islands in Hong Kong [1]. Some larger islands such as Lantau, Cheung Chau and Lamma (Figure 1) are popularly inhabited, and with regular ferry and public utility services available. However, there are also some smaller inhabited islands which are difficult to access and without public utilities (e.g. freshwater supply, sewage treatment, waste treatment, grid electricity supply). Those “off-power-grid” small islands with few native residents have no choice but to rely on diesel generators as the only power source. Yet the electricity supply there is far from satisfactory – limited hour of supply, unstable supply, polluting exhausts and noise, expensive and troublesome fuel supply.

Some of these islands could have development potential to accommodate neighbour-sensitive social facilities like drug-addicts rehabilitation centres, to become tourist spots for cultural heritage, nature conservation or eco-sustainable education sites. However, new developments on these islands normally require extensive infrastructural work (e.g. laying submarine pipelines) which would be disturbing and not cost-effective. Heritage and nature conservation is also a key common concern in the course of any development on these islands.

The Hongkong Electric Co., Ltd. (HK Electric), one of the two electricity suppliers in Hong Kong and a subsidiary of Power Assets Holdings Ltd, is actively exploring opportunities to tap the full potential of renewable energy (RE) on these outlying islands. This paper discusses the potentials and possible approaches of deploying RE systems for provision of low-carbon electricity on isolated small islands with no grid connection, while striking a good balance between sustainable development and conservation. The paper also examines the potential benefits such as environmental, economic, social and educational benefits and heritage conservation that come along with the RE development.

KEYWORDS

Renewable energy, solar energy, photovoltaic, wind turbine, energy storage, microgrid, outlying island.
INTRODUCTION

HK Electric as a subsidiary of Power Assets Holdings Ltd., is one of the two electricity suppliers in Hong Kong. In support of the Government’s sustainable development policy and with corporate social responsibility and sustainable development rooted in its corporate culture, HK Electric has been embracing renewable energy (RE) developments over a decade. In 2006, HK Electric successfully commissioned Hong Kong’s first commercial-scale wind turbine, Lamma Winds (Figure 2), on Lamma Island. In 2010, HK Electric achieved another milestone by commissioning Hong Kong’s largest commercial-scale solar power system employing amorphous silicon thin film photovoltaic (TFPV) panels firstly in Hong Kong (Figure 3). At present, HK Electric is expanding the Lamma solar power system from 550kW to 1MW capacity, carrying out wind measurement for a proposed 100MW offshore wind farm, and exploring community RE.

RE DEVELOPMENT CONSTRAINTS IN HONG KONG

Located at the south-eastern tip of China, Hong Kong has a population of over 700 million on a land area of just 1104 km$^2$, which covers Hong Kong Island, Kowloon Peninsula, the New Territories and 262 outlying islands (Figure 1) [1].

Although Hong Kong is one of the world’s well-developed metropolises, about three-quarters of the land area is still suburban or countryside. Under the Country Parks Ordinance, about 40% of Hong Kong’s total land area is designated as Country Parks (24 parks) for nature conservation, countryside recreation and nature education and Special Areas (17 areas) for flora, fauna, geological, cultural or archaeological purposes [1][2]. There are also 4 Marine Parks, 1 Marine Reserve and a Hong Kong National Geopark covering a total marine area of 24.3 km$^2$ and land area of 50 km$^2$ respectively. For conservation purpose, no development will be allowed within the above areas without the consent of the Government’s Country and Marine Parks Authority [3].
Built-up and urban areas account for around 23% of total land area. Hong Kong is ranked by a world-wide building intelligence website the number one city in the world having the largest number of skyscrapers (at least 100m high) and high-rise buildings (at least 12 floors or 35m high) (1,216 skyscrapers and 7,686 high-rise buildings), followed by New York City (562 skyscrapers and 5,924 high-rise buildings). Given the topographical constraints of Hong Kong, the potential of RE development is rather limited due to a broad spectrum of land and marine constraints. Yet there are good potentials for deploying smaller-scale distributed or embedded RE systems at scattered localities and local communities in small inhabited outlying islands. HK Electric is actively exploring the opportunities for realisation of these RE potentials.

**POTENTIAL DEVELOPMENT ON SMALL OUTLYING ISLANDS**

Within the 262 outlying islands in Hong Kong, some are larger islands such as Lantau and Cheung Chau with sizeable population, regular ferry and public utility services. However, there are also some smaller inhabited islands which are difficult to access and without public utilities (e.g. freshwater supply, sewage treatment, waste treatment, grid electricity supply). Those “off-grid” small islands with few native residents have no choice but to rely on diesel generators as the only power source. Yet the electricity supply there is far from satisfactory – limited hour of supply, unstable supply, polluting exhausts and noise, expensive and troublesome fuel supply. Despite the aforementioned isolation of those small islands, some of them could have great potential to accommodate neighbour-sensitive social facilities in particular those so-called NIMBYs (Not In My Back Yard facilities) like drug-addicts rehabilitation centres and psycho recovering dormitories.

Even today, some small islands are still preserved with high ecological values (e.g. rare floral and faunal species) or rich cultural heritage resources (e.g. traditional fishing villages). They have good potentials of being developed or revitalized as tourist attractions for eco- and heritage tourism. With no power grid connection but relatively rich wind and solar resources, quite a number of these islands are potential candidate sites for developing wind and solar power facilities. These islands with small local communities are also the favourable pilot sites for trial of microgrid technologies in real-life.

**SUSTAINABLE LOW-CARBON VILLAGE CONCEPT**

Consolidating the above potentials of small islands, HK Electric is exploring a sustainable low-carbon village concept – developing RE systems that harness wind and solar resources on small islands for supplying low-carbon and reliable electricity to villages on the islands in combination of the state-of-the-art microgrid technologies. This will not only improve the environment on these islands but also facilitate the viability to establish community-sensitive social facilities, the revitalization of the heritage and development of nature conservation facilities. Such a marriage of technology, community, nature and heritage creates an all-win sustainable development showcase with the following key benefits.

**Table 1 – Envisaged Benefits of Sustainable Low-carbon Village Concept**

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Replacement of existing polluting and noisy diesel generators by RE systems to reduce carbon emission and noise pollution thus improving the environment on the island</td>
</tr>
<tr>
<td>Social</td>
<td>Outlying island with enhanced electricity supply provides a way out for site selection of neighbour-sensitive social facilities</td>
</tr>
<tr>
<td>Technological</td>
<td>Off-grid outlying island with small local community is an ideal place for pilot trial of microgrid and distributed RE facilities, and for the trial run of new RE technologies</td>
</tr>
<tr>
<td>Conservation</td>
<td>With stable electricity from RE-integrated microgrid, revitalization of the existing heritage and development of nature conservation/exhibition facilities become possible</td>
</tr>
<tr>
<td>Educational</td>
<td>Distributed RE facilities, microgrid, revitalized heritage and nature conservation facilities provide a broad spectrum sustainable development education opportunities</td>
</tr>
<tr>
<td>Economic</td>
<td>RE installations, revitalized heritage and nature conservation facilities are catalysts to stimulate eco- and heritage tourism</td>
</tr>
</tbody>
</table>
RE-integrated Microgrid – The Concept Enabling Key

The key element of the low-carbon village concept is a RE-integrated microgrid with a generalized symbolic configuration as shown in Figure 4 [6].

![Figure 4 - Generalized Symbolic Configuration of RE-integrated Microgrid](image)

RE facilities like photovoltaic panels and wind turbines will be installed at different locations (e.g. at the roof top of various structures/buildings, hilltops, etc.) to suit the actual site condition and to harness the largest possible RE resources. It would be a distributed RE generation arrangement. Considering the intermittent nature of RE, an optimally sized battery energy storage system will be integrated into the microgrid for balancing the load demand and supply in particular when the RE generation is not available due to weather conditions. Intelligent supervisory and control devices will be deployed to ensure the power delivered via the microgrid meets the system demand at all times taking into account the stability, quality and load levelling needs in a fully-automatic manner.

Indeed, the RE-integrated microgrid is the backbone of the whole low-carbon village concept and the RE generated power serves as the lifeblood that gives life to the realization of all the following elements.

**Testbed for RE Technologies**

The microgrid will be built on open technologies which enable easy grid connection of different RE systems. Such an open platform also facilitates the trial of different RE technologies (e.g. wave energy, concentrating photovoltaic modules, micro wind turbines, low-speed wind turbine, etc.) in a real-life situation on the low carbon island.

**Heritage & Nature Conservation**

Hong Kong has a diverse habitat supporting numerous native plant species and a varied wildlife (e.g. over 2,100 species of native vascular plants, 490 species of birds and more than 230 species of butterflies)[7]. Hong Kong also has rich geological resources and a variety of cultural relics. It is not uncommon to have valuable natural landscapes, heritage and species on some small islands [8]. With the availability of stable power supply from the RE-integrated microgrid, revitalization and conversion of the abandoned heritage structures into heritage exhibition centre and/or nature conservation centre, ecological study bases become possible. This will certainly help to raise the public awareness of the heritage and nature conservation importance.
Contribution to Harmonization of the Community

The breathtaking natural environment, scarcely-populated local communities on small islands provide an ideal relaxed environment for rehabilitation of drug addicts and alcoholics. However, not until fundamental infrastructures are in place, the set up of rehabilitation facilities on any isolated islands is difficult, if not impossible. With the stable electricity supply from the RE-integrated microgrid in place, provision of other utility services on these islands becomes feasible. Without competing for the scarce space resources in congested urban areas and distancing from stressful city life, neighbour-sensitive social facilities could be planned with higher flexibility and operated more effectively in their rehabilitation/recovering services. This in turn contributes to better community harmonization.

Eco- and Heritage Tourism

Leveraging on the improved electricity supply and other infrastructural improvements, and bundling the existing tourist attractions (e.g. special landscapes, heritage buildings) with the new RE facilities and conservation facilities, small islands will be transformed as attractive spots for eco- and heritage tourism. Non-profit green/conservation organizations will be encouraged to arrange guided education tours covering RE technologies, natural landscape, and heritage conservation in line with their ethos. The boost in tourism will generate economic benefits not only to the local community on the islands but also to the whole Hong Kong community in creation of more tourism-related jobs.

KEY CHALLENGES AND POSSIBLE WAYS OUT

Stakeholders’ Acceptance

Hong Kong community is in general supportive of RE (over 60% of domestic households and about 90% of non-domestic electricity consumers support the introduction of RE into Hong Kong as revealed in Government’s surveys conducted in 2003 [9] and 2004 [10] respectively). However, there are also concerns whether RE installations (e.g. wind turbines) might damage natural landscape or endanger wildlife like migratory birds [11]. While it is a global trend to develop more and more RE to reap their environmental benefits for combating climate change, stakeholders’ concerns and indirect environmental impacts of RE should not be taken lightly.

Considering Hong Kong’s scenario, it is suggested that each potential RE project shall be carefully accessed by a stringent Environmental Impact Assessment process as stipulated under relevant ordinances. Besides, stakeholder engagement groups (with members from relevant government bodies, local communities, district councils, green groups, academics and other relevant community sectors) could also be set up to provide inputs from their perspectives throughout the project lifecycle. Such stakeholder engagement groups enable the collaboration and participation of stakeholders and create a sense of ownership of the RE projects for stakeholders. Further, to appeal for a wider acceptance of the RE projects, provisions including bird watch hides, conservation study facilities, RE exhibition facilities, heritage trails, etc. can be added as the project ingredients.

Engineering, Construction and Operation

Apart from the above “soft” issues, RE projects also face with “hard” technical challenges. For RE projects on small off-grid islands, key challenges arose during engineering, construction and operation stages, and the corresponding possible solutions are listed below (Table 2).
Table 2 – Challenges and Solutions of RE Projects on Small Islands

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Descriptions</th>
<th>Solutions</th>
</tr>
</thead>
</table>
| 1. Supply reliability            | To maintain balance of power supply and demand at all time so as to achieve a high supply reliability of an isolated system dominated by weather-dependent RE generation | a) Size RE systems with safety margin, actual load demand profile and on-site meteorological conditions taken into consideration  
 b) Deploy optimally sized battery storage system to help balance the supply-demand condition  
 c) Adopt fault-tolerant design for the microgrid  
 d) Utilize intelligent remote supervisory and monitoring devices to provide pre-failure abnormal alarms that enable preventive maintenance and timely attendance  
 e) Retain the existing diesel generators as backup power supply  
 f) Adopt standard design for system components and keep stock of strategic spare parts on the island to reduce the downtime for maintenance and repair  
 g) Educate and invite local residents to notify promptly the power utility for any system abnormality found |
| 2. Construction                  | No proper access and remote location for materials transportation             | a) Select RE equipment that can be dissembled into smaller components for easy transportation  
 b) Select sites in close proximity of the existing roads or trails (if any) to ease construction access |
| 3. Security, operation & maintenance | Remote site and unmanned operation                                           | a) Install fencing with remote surveillance CCTV and intruder detection system  
 b) Same as above solutions 1.c, d, f and g |

CONCLUDING REMARK

To better protect the environment and combat climate change, developing RE systems to supply low-carbon electricity is a global growing trend. Given Hong Kong’s topographical constraints, small outlying islands turn out to be potential sites for installing RE outside this densely populated metropolis for countryside sustainable development and accommodating neighbour-sensitive social facilities. In pursuit of excellence, HK Electric is developing a sustainable low-carbon village concept comprising elements like state-of-the art RE and microgrid technologies, social facilities, nature and heritage conservation, which is expected to bring environmental, social, technological, conservation, educational and economic benefits to the community and stakeholders. Despite the challenges ahead, it is considered worth pursuing the realization of this all-win sustainable concept for a better and harmonious environment of Hong Kong.

Link to Power Assets Sustainability Report 2010 - [http://powerassets.heh.net/pahweb/sr2010/home.htm](http://powerassets.heh.net/pahweb/sr2010/home.htm)

BIBLIOGRAPHY


**T.C. YEE** joined HK Electric after graduation and has worked on power project construction and energy investments outside HK. He is now the General Manager (Corporate Development) with main responsibility covering regulatory business and strategic sustainable developments. He is a Registered Professional Engineer of HK, Australia and the UK.
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HK Electric – a subsidiary of Power Assets Holdings Ltd.
Agenda

- Hong Kong – An Overview
- HK Electric – A Pioneer in HK’s RE Development
- Renewable Energy (RE) Development Constraints in Hong Kong
- Potentials of Outlying Islands
- Sustainable Low-carbon Village Concept
- Project Benefits
- Project Challenges
- Concluding Remarks
Over 7 million people
262 outlying islands

Total Land Area: 1,104 km²
- Hong Kong Island: 81 km²
- Kowloon Peninsula: 47 km²
- New Territories: 748 km²
- Outlying Islands: 228 km²
HK Electric – A Pioneer in HK’s RE Development

- Established in 1889, over 120 years of history
- A Subsidiary of Power Assets Holdings Ltd.
- Commissioned HK’s first commercial-scale wind turbine (800kW) in 2006
- Commissioned HK’s largest TFPV solar power system (550kW) in 2010
- Planning a 100MW off-shore wind farm in HK waters

HK’s first street lamps in Central were illuminated at 6:00pm on 1 Dec 1890.
RE Development Constraints in HK (1/2)

- About 40% of land area is designated as Country Parks and Special Areas
- 4 Marine Parks, 1 Marine Reserve and 1 National Geopark
- Remaining waters substantially designated for navigation channels, fairways, subsea pipeline routes, and anchorage zones

Source: Agriculture, Fisheries and Conservation Department, HKSAR Government
RE Development Constraints in HK (2/2)

- Built-up and urban areas account for 23% of land area

<table>
<thead>
<tr>
<th>Rank</th>
<th>City</th>
<th>High-rise Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hong Kong</td>
<td>7,686</td>
</tr>
<tr>
<td>2</td>
<td>New York City</td>
<td>5,924</td>
</tr>
<tr>
<td>3</td>
<td>São Paulo</td>
<td>5,667</td>
</tr>
<tr>
<td>4</td>
<td>Singapore</td>
<td>4,368</td>
</tr>
<tr>
<td>5</td>
<td>Moscow</td>
<td>3,275</td>
</tr>
<tr>
<td>6</td>
<td>Seoul</td>
<td>2,877</td>
</tr>
<tr>
<td>7</td>
<td>Tokyo</td>
<td>2,702</td>
</tr>
<tr>
<td>8</td>
<td>Rio de Janeiro</td>
<td>2,564</td>
</tr>
<tr>
<td>9</td>
<td>Istanbul</td>
<td>2,148</td>
</tr>
<tr>
<td>10</td>
<td>Toronto</td>
<td>1,868</td>
</tr>
</tbody>
</table>

Note: High-rise buildings are multi-storey buildings with height of 35m or above, or with 12 floors or more
Source: [www.emporis.com](http://www.emporis.com) (9/2011)

<table>
<thead>
<tr>
<th>Rank</th>
<th>City</th>
<th>Skyscrapers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hong Kong</td>
<td>1,216</td>
</tr>
<tr>
<td>2</td>
<td>New York City</td>
<td>562</td>
</tr>
<tr>
<td>3</td>
<td>Tokyo</td>
<td>343</td>
</tr>
<tr>
<td>4</td>
<td>Chicago</td>
<td>282</td>
</tr>
<tr>
<td>5</td>
<td>Dubai</td>
<td>220</td>
</tr>
<tr>
<td>6</td>
<td>Shanghai</td>
<td>218</td>
</tr>
<tr>
<td>7</td>
<td>Toronto</td>
<td>146</td>
</tr>
<tr>
<td>8</td>
<td>Singapore</td>
<td>122</td>
</tr>
<tr>
<td>9</td>
<td>Bangkok</td>
<td>108</td>
</tr>
<tr>
<td>10</td>
<td>Guangzhou</td>
<td>104</td>
</tr>
</tbody>
</table>

Note: Skyscrapers are multi-storey buildings with height of 100m or above
Source: [www.emporis.com](http://www.emporis.com) (8/2011)
Outlying Islands are good for:
- RE Development
- Conservation
- Eco- & heritage Tourism
- Accommodation of neighbour-sensitive facilities
Case Review – Locating a NIMBY

- An NGO-run high school with a shabby “campus” has been providing mainstream curriculum and rehabiliting services for school-age drug abusers.
- An attempt to relocate the school to a long vacated well-conditioned school compound had faced strong oppositions from the nearby local residents.
- Small outlying islands could be a way out in addressing similar cases involving conflicting interests of different community sectors.
Sustainable Low-carbon Village Concept

- Develop RE systems on small islands for electricity generation to replace polluting and noisy diesel generators
- Deploy microgrid technologies to improve electricity supply
- With the improved electricity supply, revitalize heritage buildings and convert them into conservation and RE educational facilities
A RE-integrated Microgrid Showcase

- Photovoltaic System
- Wind Turbine
- Other RE Technologies

Intelligent Supervisory & Control Devices

- Backup Diesel Generators
- Battery Energy Storage
- Electricity Users

Microgrid
## Project Benefits

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>• Reduce carbon emission and noise pollution from diesel generators</td>
</tr>
<tr>
<td>Technological</td>
<td>• Pilot trial of microgrid and distributed RE technologies</td>
</tr>
<tr>
<td></td>
<td>• RE technologies Testbed</td>
</tr>
<tr>
<td>Social</td>
<td>• Small islands provide a way out for siting neighbour-sensitive social facilities</td>
</tr>
<tr>
<td>Conservation</td>
<td>• Improved electricity supply enables revitalization of the heritage and development of new conservation facilities</td>
</tr>
<tr>
<td>Educational</td>
<td>• RE facilities, microgrid, heritage and nature conservation facilities provide a broad spectrum sustainable development education opportunities</td>
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<tr>
<td>Economic</td>
<td>• RE, revitalized heritage and nature conservation facilities are catalysts to stimulate eco- and heritage tourism</td>
</tr>
</tbody>
</table>

Source: Commissioner for Heritage's Office, Development Bureau; and Tourism Commission, Commerce and Economic Development Bureau, HKSAR Government
Project Challenges – Stakeholders’ Acceptance

To gain stakeholder’s acceptance:

- Go through a stringent Environmental Impact Assessment process
- Establish stakeholders engagement groups to enable stakeholders’ participation throughout the project lifecycle
- Include social economy / community value-added provisions for stakeholders (e.g. bird watch hides, conservation study facilities, heritage trails, etc.) as project ingredients
**Project Challenges – Technical**

**Supply reliability**
To maintain balance of power supply and demand at all times for an isolated system dominated by weather-dependent RE generation

- Smaller equipment components
- Select sites with close to existing accesses

**Construction**
No proper access and remote location for materials transportation

- Optimal capacity sizing
- Batter energy storage
- Intelligent remote monitoring and control
- Local residents to help monitor the system
- Existing diesel generators as final backup

**Security, operation & maintenance**
Remote site and unmanned operation

- Fencing, CCTV, intruder detection
- Remote monitoring and surveillance
Concluding Remarks

- HK Electric is developing a sustainable low-carbon village concept applicable to small outlying islands
- Comprise state-of-the art RE and microgrid technologies, social facilities, nature and heritage conservation
- Expected to bring environmental, social, technological, conservation, educational and economic benefits to stakeholders
- Despite the challenges ahead, it is considered worth pursuing the realization of this all-win sustainable concept for a better and harmonious environment of Hong Kong
Thank You