Renewable Energy Technologies Solutions
Grid Connected Systems

IRENA Workshop
Peter Konings – SEIAPI / APEG
Road map – policies – guidelines – frameworks – indicators ... How to navigate through all this to reach our goal?
Presentation outline

• Sustainable Energy Industry Association of the Pacific Islands (SEIAPI)
• Integrating Renewables into Diesel Grids
• Available Technologies
• Why Grid Connected RE
• Appropriate Technology – PV
• Questions to be answered
• Do we have the answers?
• A “Dutch” model – SOPRA
• Smart substations and Storage
• Case studies
• Concluding note
Sustainable Energy Association of the Pacific Islands (SEIAAPI)

- Launched in November 2010.
- The association aims to foster sustainable energy (renewable energy and energy efficiency) use in the Pacific Region.
- The association open to all countries & territories within the Pacific islands
- Access to information, technologies advancements and capacity building
- Develop and promote professional standards and guidelines
- Promote the development of a qualified and well trained workforce in the EE and RE industry throughout the Pacific islands and Territories
- 45 members and growing – Pacific Islands, Europe, S-America, Australia, NZ, US...
- LinkedIn discussion forum: more than 100 members
Integrating Renewables into Diesel Grids

• Why?
  – Reduce Diesel consumption
  – Reduce GHG emissions
  – Reduce community costs in long run
  – Cost effective

• How?
  – Site specific
  – Some tropical environments have issues
  – Cyclones/typhoons – Design of wind towers & blades
  – Cloud cover for solar
  – Availability of sufficient land for large scale PV
  – Distance to power station to simplify control
  – Distributed vs centralised
Integrating Renewables

- Need maximum flexibility to control diverse systems
- The role of storage – Short vs Long Term
  - Different technologies required
- Short term – frequency & stability control
  - Flywheel
  - Super-capacitor
- Long term – load shifting / shaping
  - Electrical Batteries
  - Hydrogen – Chemical batteries
  - Pumped Storage – Water / Air
Available RE Technologies

=> Most of us will think of
• Grid Connected PV
• Mini – Hydro
• Wind

But...
Other RE technologies are becoming more and more interesting and viable...

- Waste-to-Energy – example Hawaii
- Wave Energy – example Kosrae
- Portable Mini-hydro (containerized) – Pohnpei
- Bio-gas etc.
Why grid-connected RE

- Dependency on expensive fossil fuels
  - Electricity rates currently in many Pacific utilities above 45 USD cents/kWh
  - CO2 emission
- Cost per kWh of RE sources become cheaper
  - PV: 20-25 cts/kWh
  - Mini Hydro: 10-15 cts/kWh
  - Small Wind: 15-20 cts/kWh
  - Wave Energy: 10-15 cts/kWh
- Possibilities for IPP under a PPA structure
Economical comparison: diesel vs. hybrid systems (life cycle costs)

**Location**: Tanzania  
**Application**: Village power supply  
**System configuration PV/Diesel hybrid**: 30kVA hybrid inverter; 30kWp solar generator; 25kVA diesel generator 240kWh battery  
**System configuration diesel**: 25kVA diesel generator

**Location**: India  
**Application**: Village power supply  
**System configuration PV/wind Hybrid**: 100kVA hybrid inverter; 40kWp PV generator; 10kW wind generator; 276kWh battery  
**System configuration diesel**: 100kVA diesel generator
Oil prices

Weekly Non-OPEC Countries Spot Price FOB Weighted by Estimated Export Volume

Source: U.S. Energy Information Administration
PV panel prices

Source: Robert Margolis, NREL
Appropriate – whole pacific

- Grid Connected PV
  - Utility scale: 100 kWp – several MW (example New Caledonia 2 MW)
  - Mini-island Grids: 10 kWp – 100 kWp (example Yap-Ulithi: 28kWp – 100% PV)
  - Smaller grid connected: 1kWp - >50kWp (example Kosrae, Nauru, Niue etc)
  - Very small, systems: grid connected streetlights
Grid-connected PV streetlight
the question to be answered:

=> what are the problems of connecting to island grids.

- These include small utility size,
- slow response diesel engines,
- undersized feeders giving voltage fluctuations,
- utilities that do not understand the technology and worry about the systems being installed on their grid,
- mismatch between solar system peak output and grid load curve for non A/C loaded grids - evening peaks
- Also, problems with equipment meeting the environmental requirements of the islands.
Example of load profile: village electrification

- Electricity demand
- Energy demand met by battery / other RES / genset
- Energy from PV generator
Do we have the answers?

- Small size utilities – investment and O&M of Renewables can be a challenge.
  - Grant monies available as well as RE loans
  - O&M can be outsourced
- Generators/Grid – upgrading the diesel generators, feeders etc part of the investment
  - Capacity Building
  - Need for Technical (Pacific) Guidelines
  - Important is proper assessment
A “Dutch Model”
Sustainable Off-grid Powerstation for Rural Applications (SOPRA)

1. Long distance = high costs => mini grid is the solution

2. Expensive diesel fuel

3. High PV and/or wind intensity

4. reducing costs of PV panels
Interesting parallelism:

- Telecom: not wired => mobile phone/internet
- Rural Electrification: “not wired” => minigrids

SOPRA Sustainable Off-grid Powerstation for Rural Applications
Yesterday
Centralized Power

Tomorrow
Clean, local power

Transmission network

Distribution network

House
Factory
Commercial building
Local CHP plant
Wind power plant
Solar PV power plant
Storage
House with domestic CHP
Multiple levels of integration – interoperability

- Distributed Generation
- Renewable Generation
- Storage
- Demand Response
Example of a typical Off-grid Hybrid system:

- **Local and remote service and control**
  - Windows XPE based

- **AC coupled PV / Wind**:
  - Using standard third party Grid tied PV inverters
  - Requirement: Frequency Shift Power Control (FSPC)

- **Internet based remote service**:
  - Error diagnostics
  - Statistics (PV, Gensets, tanks, MHI’s, Battery, etc)
  - Fuel-level check
  - Remote control and parameter change
  - Remote software and firmware upload

**Note:** not all components are EXENDIS supplied
SOPRA and Power Quality

⇒ Smart Grid Functions:
  ⇒ USP; in case of generator failure the Solar Hybrid Inverter can take over power seamlessly (even during charging)
  ⇒ Reactive power; to stabilize voltage of long distance grids due to grid inductance and capacity loads
  ⇒ Flicker and Dip compensation (to support the generator)
  ⇒ Inter phase load balancing
  ⇒ Harmonic compensation by harmonic damping
  ⇒ Etc.
Smart Substation

Objective:

- Enabling high penetration of renewable energy in a distribution grid.
  - Distributed generation:  
    - PV  
    - Wind  
    - Wave  
  - Power Quality improvement  
    - Active power  
    - Reactive power  
  - Fault Ride Through  
  - Automatic islanding (USP-mode)
Smart Substation with Energy Storage

www.smartsubstation.eu

Lab tests: May – December 2009
Field operation: started February 2010
SOPRA Consortium

More information: Evert Raaijen
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Storage

- Peak load shaving: discharge during the high power demand,
- charge during the low power demand.
- Store and transfer electricity = a smarter grid
- Improved transmission line and equipment lifetime
Energy Storage Station Benefits

Li-Fe battery technology

- Can stabilize power grids, balance electricity loads, and solve electricity storage requirement
- Ideal storage station for wind, solar and other new energy sources.
- Idea storage stations with advantages in cost and operational life and broad application areas to replace traditional pumped storage, compressed air energy storage, and other existing storage technologies.
- Can be customized to different scale of storage requirements.

Conventional Power System
Huge fluctuations

Power System with Fe Battery System:
Storage energy, balance and stabilize the output.
Typical example of Solar Hybrid system (Sabah, Borneo, Malaysia)

- 500 houses, 2000 persons
- Main power station:
  - Grid inverter: 240 kVA
  - Solar power: 200 kWp
  - Battery: 600 kWh
  - 4 generators of each 200 kW
- Distribution: 10 kVac + 415 Vac
- Two sub power stations of each:
  - Grid inverter: 60 kVA
  - Solar inverter: 60 kVA
  - Battery: 360 kWh
Two Solar substations of 60 kW each
Looks like with local initiatives we are navigation towards energy security in our region... good that we had all the guidelines and policies in place...
Another example: Kosrae

<table>
<thead>
<tr>
<th>Country/state</th>
<th>System sizes</th>
<th>Total capacity</th>
<th>Installation date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kosrae</td>
<td>6 systems 1 – 16.4 kWp</td>
<td>53.5 kWp</td>
<td>September 2008</td>
</tr>
</tbody>
</table>

- Crystalline modules chosen for their proven track record
- One small system with Amorphous modules (1kW)
- Extended warranties purchased on all inverters
- Total of 6 systems: 5 are roof-mounted and 1 is on car park shading
- Data loggers installed on all systems
**Price per kWh**

current rate in Kosrae: **45 US¢/kWh**

<table>
<thead>
<tr>
<th>System</th>
<th>Cost of generation (incl. initial capital cost)</th>
<th>Cost of generation (excl. initial capital cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Systems:</td>
<td>45 US¢/kWh</td>
<td>3.4 US¢/kWh</td>
</tr>
<tr>
<td>Using Current price of PV</td>
<td><strong>18 US¢/kWh</strong></td>
<td></td>
</tr>
</tbody>
</table>

Yes indeed... installing Grid Connected PV is a financially attractive alternative!
Current Systems

- 52.5 kWp rooftop installations - public buildings and KUA car park
- 1 kWp installed on the recycling plant
- Installed in September 2008
- Average production 5,800 kWh/mo.

Specific yield: 1,340 kWh/kWp/yr
Generation till end 2010

- Legislature
  - kWh (Sol): 27,753
  - kWh (Grid): 37,000

- KUA
  - kWh (Sol): 11,100
  - kWh (Grid): 47,332

- State Capital
  - kWh (Sol): 36,000
  - kWh (Grid): 171,680

- Public Health
  - kWh (Sol): 145,741
  - kWh (Grid): 52,000

- Airport
  - kWh (Sol): 16,000
  - kWh (Grid): 89,820
Total (2009 – 2010) for the 5 buildings

76%

482,326 kWh (Grid)

24%

152,100 kWh (Sol)
<table>
<thead>
<tr>
<th>Area</th>
<th>kWh (Grid)</th>
<th>kWh (PV)</th>
<th>Total kWh</th>
<th>Total $$</th>
<th>Total w/o PV</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legislature</td>
<td>8,714</td>
<td>5,784</td>
<td>14,198</td>
<td>3,757</td>
<td>6,208</td>
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<tr>
<td>Hospital</td>
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<td>55,057</td>
<td>19,653</td>
<td>24,087</td>
<td>4,434</td>
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<td>30,009</td>
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<tr>
<td>KUA</td>
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<td>13,380</td>
<td>4,360</td>
<td>5,794</td>
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<td>Governor</td>
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<td>52,776</td>
<td>19,582</td>
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<td>3,527</td>
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<tr>
<td>Total</td>
<td>133,337</td>
<td>32,383</td>
<td>165,420</td>
<td>58,176</td>
<td>72,268</td>
<td>14,092</td>
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<th>All</th>
<th>kWh (Grid)</th>
<th>kWh (Sol)</th>
<th>Total kWh</th>
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<td>Total 2011 (1st &amp; 2nd Qtr)</td>
<td>80%</td>
<td>20%</td>
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<tr>
<td></td>
<td>kWh (Grid)</td>
<td>kWh (Sol)</td>
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Concluding note:

- PV grid connected solar systems is a viable option for the Pacific
- Other Renewable Technologies are currently available
- High penetration of renewable energy sources possible
- For PV problem is storage
- Storage options become within reach if an energy mix is possible
- SMART-grid options can be a wise investment
With your support and direction and ... with our passion and cooperative spirit ... We will be able to fulfill our common goals and mission!
Green Energy, Green Life

SEIAPI
Sustainable Energy
Thank you!

www.SEIAPI.org