Prospecting of renewable energy technologies for the Emirate of Abu Dhabi

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A collaborative research project with Masdar Institute of Science and Technology and Columbia University School of International and Public Affairs and Abu Dhabi Quality and Conformity Council, ADQCC.
Trend 1 – Renewable stall out the carbon pollution
Trend 2 – As solar prices (wind) drop, affordability rises
Trend 3 – Tesla’s gigafactory poised to unleashed battery revolution
Trend 4 – 100% renewable energy goes mainstream
Trend 5 – Carbon pricing is becoming the new normal
Trend 6 – Wind spreads like wildfire
Trend 7 – Developing world plugging in to renewable power
Trend 8 – Climate diplomacy rising – superpowers move from finger pointing to handshaking
Trend 9 – Global clean energy economy surging – more than $800 billion
Motivation

• The Emirate of Abu Dhabi has committed that by 2020, renewable energy sources will account for at least 7% of the Emirate’s total power generation capacity (WAM, 2009).
The UAE’s total GHG emissions grew an average 5% per year from 1992 to 2013.

Electricity demand is steadily increasing as a result of the continued growth in business, industry and population, placing huge pressures on the infrastructure involved in energy generation and distribution.
THE GREENWAVE PROJECT IS AIMED AT SUPPORTING THE GOVERNMENT RENEWABLE ENERGY STRATEGY

Wednesday, March 30, 2016

**Peak demand & Capacity Forecast (MW) 2012 - 2020**

- **Emir. of AD + Export**
- **Capacity required**

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Technology research and feasibility studies of renewable energy and energy efficiency technologies applicable to Abu Dhabi

Policy research and strategy development for achieving 7% target of installed capacity from renewables by 2020 and beyond.
Future projects green power capacity will be 341 MW i.e. 1.42% of the future installed capacity. It will remain 1,345 MW to install. Therefore the target is set at 1.4 GW.
The figure shows the ten years average wind speed (mps) in the United Arab Emirates at 120 meter high (RECREMA, 2015).
To Consider

- Both Abu Dhabi and Dubai has focus on Solar Energy
- Abu Dhabi has built a 100MW CSP
- Dubai bid a 100MW PV plant, with a world record cost of 5.98 USDcent/kWh
Additional data

- Waste to energy – Incineration, gasification, anaerobic digestion – only 20% of the target.
- Algae to Energy – 25% of Exclusive Economic Zone
- Tide power, Current power, Wave power – not efficient enough
- Fuel cell - technology not matured enough
Comparison of reduction of GHG,

<table>
<thead>
<tr>
<th>Conventional systems</th>
<th>Renewable systems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
<td><strong>g-CO₂/kWh</strong></td>
</tr>
<tr>
<td>Coal fired</td>
<td>975.3</td>
</tr>
<tr>
<td>Oil fired</td>
<td>742.1</td>
</tr>
<tr>
<td>Gas fired</td>
<td>607.6</td>
</tr>
<tr>
<td>Nuclear</td>
<td>24.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>System</strong></th>
<th><strong>Reduction of GHG</strong> (g-CO₂eq/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>483.9 – 597.9</td>
</tr>
<tr>
<td>Solar PV</td>
<td>357.6 – 554.2</td>
</tr>
<tr>
<td>Solar Thermal</td>
<td>405.6 – 594.0</td>
</tr>
<tr>
<td>Biomass</td>
<td>429.6 – 572.6</td>
</tr>
</tbody>
</table>
## Renewable technology characteristics in Abu Dhabi

<table>
<thead>
<tr>
<th>Technology</th>
<th>Load factor (%)</th>
<th>Invest ($/Wp)</th>
<th>O&amp;M ($/kWp/yr)</th>
<th>Production (kWh/kWp/yr)</th>
<th>LCOE (USD/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind – offshore</td>
<td>20 – 40</td>
<td>1.4 – 2.9</td>
<td>30 – 58</td>
<td>1753 – 3506</td>
<td>0.030 – 0.123</td>
</tr>
<tr>
<td>Wind – onshore</td>
<td>20 – 40</td>
<td>0.95 – 1.25</td>
<td>30 – 58</td>
<td>1753 – 3506</td>
<td>0.024 – 0.276</td>
</tr>
<tr>
<td>Solar PV</td>
<td>20 – 25</td>
<td>1.5 – 1.7</td>
<td>25 – 30</td>
<td>1753 – 2192</td>
<td>0.044 – 0.051</td>
</tr>
<tr>
<td>Solar Thermal</td>
<td>25 – 30</td>
<td>4.2 – 8.5</td>
<td>100 – 150</td>
<td>2192 – 2630</td>
<td>0.264 – 0.330</td>
</tr>
<tr>
<td>Solar Thermal (15 hours storage)</td>
<td>25 - 70</td>
<td>9.0 – 10.5</td>
<td>100 – 150</td>
<td>2192 – 6136</td>
<td>0.136 – 0.192</td>
</tr>
<tr>
<td>Biomass</td>
<td>40 – 90</td>
<td>4.1 – 8.2</td>
<td>105 – 356</td>
<td>3506 – 7889</td>
<td>0.100 – 0.350</td>
</tr>
</tbody>
</table>
EROI – Net-energy overview of energy technologies and sources

The Net Energy Cliff

euan meams

europe.theoldrum.com

EROI

Energy output to energy input

Hydroelectric

Windmill

Nuclear

Tar sands

Most bio fuels

Energy for society

Energy used to procure energy
Sustainability assessment

![Bar chart showing EROI (kWh_output/kWh_input) for different technologies: Wind, Solar PV (multi-Si), Solar Thermal (PT), Solar Thermal (PT) + storage, Waste to Energy. The chart indicates that Solar Thermal (PT) has the highest EROI, followed by Wind, Solar PV (multi-Si), Solar Thermal (PT) + storage, and Waste to Energy.]
Figure 1: Economic-environmental comparison for Renewable Energy Technologies in Abu Dhabi.
EE-Coeff = \( \frac{\text{LCOE}}{\text{EROI}} \times 100 \)

**Figure 1:** Economic-environmental coefficient (EE-Coeff) for Renewable Energy Technologies in Abu Dhabi. A) EE-Coeff including Waste to Energy. B) Zoom-in into wind and solar technologies.
# Table 1: Energy mix proposed

<table>
<thead>
<tr>
<th>Target 7%</th>
<th>Share</th>
<th>Power</th>
<th>Investment cost</th>
<th>O&amp;M cost</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind – Offshore</td>
<td>10%</td>
<td>140 MW</td>
<td>196 to 406</td>
<td>4.2 to 8.1</td>
<td>245 to 491</td>
</tr>
<tr>
<td>Wind – Onshore</td>
<td>30%</td>
<td>420 MW</td>
<td>399 to 525</td>
<td>12.6 to 24.4</td>
<td>736 to 1473</td>
</tr>
<tr>
<td>PV</td>
<td>35%</td>
<td>490</td>
<td>735 to 833</td>
<td>12.2 to 14.7</td>
<td>859 to 1074</td>
</tr>
<tr>
<td>CSP with 15 hours storage</td>
<td>5%</td>
<td>70</td>
<td>665 to 735</td>
<td>7 to 10.5</td>
<td>153 to 430</td>
</tr>
<tr>
<td>Waste to Energy</td>
<td>20%</td>
<td>280</td>
<td>1160 to 2319</td>
<td>29.7 to 100.7</td>
<td>992 to 2231</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>1400</td>
<td>3155 to 4818</td>
<td>65.7 to 158.4</td>
<td>2986 to 5698</td>
</tr>
</tbody>
</table>
Proposed Policy Changes and Reforms

• Increase energy efficiency by at least 2-3% p.a. to reverse large increase in energy intensity of production (Energy/GDP) over the past 20 years – many new technologies have been developed at Masdar Institute.

• Develop a more conductive energy pricing framework where Renewable Energy operates on a level playing field compared to fossil fuel based generation.

• Gradually reduce fossil fuel/power/water and replace with incentives for renewable energy industry (production and R&D)

• Explore options of public and private financing; for example through bonds as a means of providing up-front financing for capital costs

• Greater national and regional collaboration on energy plants and strategies, for example a UAE and regional smart grid that allows greater amounts of renewable energy to be generated.

• Increasing investment to build capacity, knowledge and research and development on renewable energy could provide competitive advantage for the economy (i.e. solar panels that demonstrate high performance in hot, humid and dusty conditions)
Feed-in Tariffs Abu Dhabi Checklist

- Provide financial incentives (e.g. low interest loans)
- Mandate purchase of embedded generation to utility company
- Establish tariff scheme
- Establish periodic tariff adjustments
- Auction vs. incentive schemes
Competitive Bidding Abu Dhabi Criteria

- Sustainable design
- Water conservation
- Local supply chain
- Cost per kWh
Abu Dhabi Renewable Energy Portfolio

Additional benefits

• Renewable Energy is now economically attractive in Abu Dhabi and the UAE in general – hence more renewable energy in the mix will save money.

• Decreasing renewable energy costs are the main drivers, in particular solar PV module prices have fallen around 80% since 2008.

• 10% share of renewable energy in the total energy mix could generate annual savings of USD 1.9 billion by 2030 based on avoidance of fossil fuel consumption.

• Additional health and environmental benefits that range from USD 1bn to 3.7bn could be generated annually by 2030

• 25% share of renewables in power generation by 2030 could be cheaper to achieve than current targets

• Current initiatives in the UAE are promising indicators of policy progress in this direction
“We cherish our environment because it is an integral part of our country, our history and our heritage. On land and in the sea, our forefathers lived and survived in this environment. They were able to do so only because they recognized the need to conserve it, to take from it only what they needed to live, and to preserve it for succeeding generations.”

“With God’s will, we shall continue to work to protect our environment and our wildlife, as did our forefathers before us. It is a duty, and, if we fail, our children, rightly, will reproach us for squandering an essential part of their inheritance, and of our heritage.”