Renewable energy deployment in Africa: opportunities, challenges & perspectives

Dr. Ir TCHOUATE HETEU Pépin
CEO & Director, DEECC Consulting, Belgique
Email: tchouateheteu@yahoo.fr
www.deeccconsulting.com

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Outline

1. Electricity access in Africa
2. The energy paradox of Africa
3. Renewable Energy opportunities and challenges in Africa
4. Conclusions
Africa hosts 17% of the world population but almost 50% of the population w/o access to modern energy live in Africa

<table>
<thead>
<tr>
<th></th>
<th>Population [10^6 inhabitants]</th>
<th>% world population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>1265</td>
<td>16.7%</td>
</tr>
<tr>
<td>America</td>
<td>1010</td>
<td>13.3%</td>
</tr>
<tr>
<td>Asia</td>
<td>4516</td>
<td>59.6%</td>
</tr>
<tr>
<td>Europe</td>
<td>742</td>
<td>9.8%</td>
</tr>
<tr>
<td>Oceania</td>
<td>41</td>
<td>0.5%</td>
</tr>
<tr>
<td><strong>World</strong></td>
<td><strong>7574</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Source: [http://www.worldometers.info/world-population/](http://www.worldometers.info/world-population/)

1-1 to 1.3 bn people in the world don’t have access to modern sources of energy, of which approx. 600 millions in Africa

**Cooking** : wood, charcoal, agricultural residues

**Lighting** : kerosene lamps, drycell batteries, candles, etc.
Electricity access is still very low in Sub-Saharan Africa less than 15% in rural areas

Dark-blue pie slice:
Percentage of the population that does not have access to electricity
Pies are scaled in % of each country’s 2012 population

Outlined pie: 100 percent of the population has access to electricity
Projections are pessimistic about Africa’s electricity consumption

<table>
<thead>
<tr>
<th>Country</th>
<th>Per capita power consumption [kWh/y]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senegal</td>
<td>210</td>
</tr>
<tr>
<td>Ghana</td>
<td>70</td>
</tr>
<tr>
<td>Nigeria</td>
<td>144</td>
</tr>
<tr>
<td>Cameroon</td>
<td>281</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>70</td>
</tr>
<tr>
<td>Kenya</td>
<td>168</td>
</tr>
<tr>
<td>Uganda</td>
<td>90</td>
</tr>
<tr>
<td>Rwanda</td>
<td>22</td>
</tr>
<tr>
<td>Tanzania</td>
<td>99</td>
</tr>
<tr>
<td>Zambia</td>
<td>703</td>
</tr>
<tr>
<td>Namibia</td>
<td>1564</td>
</tr>
<tr>
<td>South Africa</td>
<td>4229</td>
</tr>
</tbody>
</table>

Electricity consumption per capita
Few reasons for low power consumption…

- Low industrialization and industrial farming
- Low productive uses of energy
- Poor planning policy
- Low investment in the power sector
- Old distribution grids and high losses
- Unreliable electricity services: Load shedding in more than 25 SSA countries
- High cost of power generation due to emergency thermal plants
- Inappropriate grid expansion/densification tension considering low population density
- No steady enabling Environment for clean energy development
Africa’s Energy poverty is a paradox
Oil resources are abundant & Africa a NET LNG exporter

<table>
<thead>
<tr>
<th>Region</th>
<th>Oil Resources (Tn Barrels)</th>
<th>Share Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>2.6Tn Barrels</td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>0.23Tn Barrels</td>
<td>8.8%</td>
</tr>
<tr>
<td>Share Africa</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Renewable energy potential (1)

<table>
<thead>
<tr>
<th>Hydro</th>
<th>Solar PV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>280 GW, 10% world resources</strong></td>
<td><strong>Average sun irradiation 2000 à 2500 kWh/m²/y</strong></td>
</tr>
<tr>
<td><strong>Main rivers</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Congo</strong>: Grand Inga (44 GW), Gabon (&gt; 10 GW), Cameroun (&gt; 20 GW)</td>
<td><strong>100-300 kWhe/m²/y on 47% of SSA</strong></td>
</tr>
<tr>
<td><strong>Nil</strong>: Ethiopia (&gt; 30 GW)</td>
<td></td>
</tr>
<tr>
<td><strong>Zambezi</strong>: Angola (&gt;18 GW), Mozambique (&gt;12 GW)</td>
<td><strong>75 – 200 kWhe/m²/y elsewhere</strong></td>
</tr>
<tr>
<td><strong>Niger</strong>: Nigeria (&gt; 10 GW)</td>
<td></td>
</tr>
</tbody>
</table>

Additionally Small hydro sites are abundant across SSA
## Renewable energy potential (2)

### Table 1: Technical potentials for power generation from renewables (numbers are subject to uncertainty, typically +/- 50%)

<table>
<thead>
<tr>
<th>Region</th>
<th>CSP</th>
<th>PV</th>
<th>Wind Total</th>
<th>Wind CF 30%-40%</th>
<th>Wind CF &gt; 40%</th>
<th>Hydro TWh</th>
<th>Biomass TWh</th>
<th>Geothermal TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Africa</td>
<td>299</td>
<td>616</td>
<td>120</td>
<td>16</td>
<td>6</td>
<td>1,057</td>
<td>1,572</td>
<td></td>
</tr>
<tr>
<td>Eastern Africa</td>
<td>1,758</td>
<td>2,195</td>
<td>1,443</td>
<td>309</td>
<td>166</td>
<td>578</td>
<td>642</td>
<td>88</td>
</tr>
<tr>
<td>Northern Africa</td>
<td>935</td>
<td>1,090</td>
<td>1,014</td>
<td>225</td>
<td>69</td>
<td>78</td>
<td>257</td>
<td></td>
</tr>
<tr>
<td>Southern Africa</td>
<td>1,500</td>
<td>1,628</td>
<td>852</td>
<td>100</td>
<td>17</td>
<td>26</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>Western Africa</td>
<td>227</td>
<td>1,038</td>
<td>394</td>
<td>17</td>
<td>1</td>
<td>105</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>Total Africa</td>
<td>4,719</td>
<td>6,567</td>
<td>3,823</td>
<td>667</td>
<td>259</td>
<td>1,844</td>
<td>2,631</td>
<td>88</td>
</tr>
</tbody>
</table>

Source: Herman, et al., 2011; IRENA, 2011a.

Estimated annual RE Potential: 20,600 TWh
Despite a quarter of the world’s population estimated to live in Africa by 2050, only 25% of the hydropower potential is expected to be tapped

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</thead>
<tbody>
<tr>
<td>Geothermal</td>
<td>15</td>
<td>1.123</td>
<td>7.5%</td>
<td>4.224</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Wind</td>
<td>3.862</td>
<td></td>
<td></td>
<td>7.85</td>
<td>101</td>
<td>304</td>
</tr>
<tr>
<td>Solar (PV&amp;CSP)</td>
<td>2972</td>
<td></td>
<td></td>
<td>3.65</td>
<td>69</td>
<td>230</td>
</tr>
<tr>
<td>Other Renewables</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hydro</td>
<td>32.43</td>
<td>122</td>
<td></td>
<td></td>
<td>101</td>
<td>402</td>
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</table>
Renewable Electricity generation in Africa has considerably increased over the past 10 years.

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</thead>
<tbody>
<tr>
<td>World</td>
<td>994.2</td>
<td>1062.6</td>
<td>1138</td>
<td>1228.8</td>
<td>1331.4</td>
<td>1449.5</td>
<td>1568.7</td>
<td>1693</td>
<td>1849.5</td>
<td>2011.3</td>
</tr>
<tr>
<td>Africa</td>
<td>22.94</td>
<td>23.41</td>
<td>25.05</td>
<td>26.97</td>
<td>27.34</td>
<td>28.49</td>
<td>30.53</td>
<td>32.35</td>
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</thead>
<tbody>
<tr>
<td>World</td>
<td>3530.6</td>
<td>3730.8</td>
<td>3845.5</td>
<td>4200</td>
<td>4440.8</td>
<td>4765.8</td>
<td>5057</td>
<td>5334.9</td>
<td>5537.2</td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>96.9</td>
<td>1028.6</td>
<td>1073</td>
<td>1134</td>
<td>1170</td>
<td>1186</td>
<td>1259</td>
<td>1358</td>
<td>1370</td>
<td></td>
</tr>
</tbody>
</table>

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<thead>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>793.4</td>
<td>849.1</td>
<td>890.1</td>
<td>1111.7</td>
<td>1321.7</td>
<td>1568.4</td>
<td>1866.5</td>
<td>2195.7</td>
<td>2771</td>
<td>4031</td>
</tr>
<tr>
<td>Africa</td>
<td>197.4</td>
<td>210.1</td>
<td>221.4</td>
<td>259.5</td>
<td>344.3</td>
<td>406</td>
<td>456.6</td>
<td>510.4</td>
<td>649.1</td>
<td>887.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>offgrid Hydro</td>
<td>120.89</td>
<td>120.94</td>
<td>121.36</td>
<td>127.87</td>
<td>128.11</td>
<td>133.95</td>
<td>135.81</td>
<td>138.37</td>
<td>157.77</td>
<td>157.85</td>
</tr>
<tr>
<td>offgrid PV</td>
<td>68.66</td>
<td>81.31</td>
<td>91.94</td>
<td>122.75</td>
<td>187.32</td>
<td>237.55</td>
<td>281.71</td>
<td>317.96</td>
<td>435.46</td>
<td>672.47</td>
</tr>
<tr>
<td>Other offgrid RE</td>
<td>7.84</td>
<td>7.84</td>
<td>8.15</td>
<td>8.84</td>
<td>28.85</td>
<td>34.47</td>
<td>39.09</td>
<td>54.05</td>
<td>55.92</td>
<td>54.05</td>
</tr>
</tbody>
</table>
Way forward?
Africa final electricity demand to triple by 2030

Figure 7: Southern Africa: Final Electricity Demand by Country

Figure 12: East Africa: Final Electricity Demand by Country


Figure 2: West Africa: Final Electricity Demand by Country

Figure 16: Central Africa: Final Electricity Demand by Country
Projections are pessimistic about Africa’s energy consumption.
Primary energy consumption per source and prospect

<table>
<thead>
<tr>
<th></th>
<th>Consumption (Mtoe)</th>
<th>Shares (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2015</td>
<td>2035</td>
</tr>
<tr>
<td>Primary energy</td>
<td>13147</td>
<td>17157</td>
</tr>
<tr>
<td>By fuel:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil</td>
<td>4257</td>
<td>4892</td>
</tr>
<tr>
<td>Gas</td>
<td>3135</td>
<td>4319</td>
</tr>
<tr>
<td>Coal</td>
<td>3840</td>
<td>4032</td>
</tr>
<tr>
<td>Nuclear</td>
<td>583</td>
<td>927</td>
</tr>
<tr>
<td>Hydro</td>
<td>893</td>
<td>1272</td>
</tr>
<tr>
<td>Renewables*</td>
<td>439</td>
<td>1715</td>
</tr>
</tbody>
</table>
Access to electricity is an essential component of accelerating human development

- Agriculture: water pumping for irrigation and livestock, added value food processing and conservation
- Education and health services enhancement
- Employment creation
- Improved social life and business development
Sustainable Improvement of electricity access in Sub-Saharan Africa requires a significant scale-up of electricity infrastructure.

Electricity demand in Africa is projected to triple by 2030, offering huge potential for renewable energy deployment.

Access: 12-20m households to be connected annually (2017-2030)

Transmission & Distribution:
Grid expansion/intensification/densification still considered as main solution but offgrid electrification will play a key role in reaching the most dispersed rural population.

Generation: 250 – 302 GW renewable capacity to be added

Investment in Renewable electricity is limited by low tariffs and consumption in Africa

<table>
<thead>
<tr>
<th>Country</th>
<th>Per capita power consumption [kWh/y]</th>
<th>%Renewable energy production</th>
<th>%Renewable energy consumption</th>
<th>LV domestic tariff [$/kWh]</th>
<th>LV commercial tariff [$/kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senegal</td>
<td>210</td>
<td>10.42%</td>
<td>43.60%</td>
<td>0.18 - 0.2</td>
<td>0.26</td>
</tr>
<tr>
<td>Ghana</td>
<td>70</td>
<td>99.90%</td>
<td>92.70%</td>
<td>0.08 - 0.22</td>
<td>0.22 - 0.37</td>
</tr>
<tr>
<td>Nigeria</td>
<td>144</td>
<td>17.60%</td>
<td>87.30%</td>
<td>0.07 - 0.086</td>
<td>0.12 - 0.14</td>
</tr>
<tr>
<td>Cameroon</td>
<td>281</td>
<td>74.30%</td>
<td>77.40%</td>
<td>0.09 - 0.18</td>
<td>0.14 - 0.18</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>70</td>
<td>99.90%</td>
<td>92.72%</td>
<td>0.012 - 0.031</td>
<td>0.027 - 0.034</td>
</tr>
<tr>
<td>Kenya</td>
<td>168</td>
<td>75.00%</td>
<td>78.50%</td>
<td>0.025 - 0.205</td>
<td>0.07 - 0.13</td>
</tr>
<tr>
<td>Uganda</td>
<td>90</td>
<td>78.60%</td>
<td>89.22%</td>
<td>0.17 - 0.19</td>
<td>0.10 - 0.16</td>
</tr>
<tr>
<td>Rwanda</td>
<td>22</td>
<td>39.00%</td>
<td>88.40%</td>
<td>0.10 - 0.23</td>
<td>0.23</td>
</tr>
<tr>
<td>Tanzania</td>
<td>99</td>
<td>42.30%</td>
<td>86.70%</td>
<td>0.045 - 0.156</td>
<td>0.09 - 0.175</td>
</tr>
</tbody>
</table>
Off-grid mini-grids are the optimal solution for energy access in dispersed rural areas

<table>
<thead>
<tr>
<th>Electricity Delivered</th>
<th>N/A</th>
<th>DC</th>
<th>AC</th>
<th>AC</th>
<th>AC</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upfront Payment ($)</td>
<td>12</td>
<td>35</td>
<td>Varies</td>
<td>10 - 20</td>
<td>150 - 350</td>
<td>120 - 250</td>
</tr>
<tr>
<td>Ongoing Costs</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Installation Time</td>
<td>N/A</td>
<td>Short Install Time</td>
<td>Almost plug-and-play</td>
<td>Quickly Deployable</td>
<td>Multi-year Project Timelines</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>✗</td>
<td>Poor quality lighting</td>
<td>Limited Product Life</td>
<td>Requires regular maintenance</td>
<td>Battery Storage</td>
<td>Intermittent Power Cuts</td>
</tr>
<tr>
<td>Full Energy Ladder? (Appliances / Productive Loads)</td>
<td>✗</td>
<td>Only Low-Power DC Devices</td>
<td>Yes, but expensive</td>
<td>Grid-equivalent power</td>
<td>Full Electrification</td>
<td></td>
</tr>
<tr>
<td>Main Grid Integration</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

* 1-year lease-to-own with 2-year warranty. PowerGen assumed a 3 year life for the SHS
Mini-grids build the energy system of the future from the grid edge in...

**Developed Country Grid**

Existing infrastructure and entrenched incumbents make transition to the future grid more challenging.

**Less-Developed Country Grid**

Lack of incumbent infrastructure provides an opportunity to build the power system architecture of the future from near scratch.
Why will minigrids play an important role in electricity access in Africa?

- Tap into Africa’s enormous Renewable Energy resources
- Faster deployment and more reliable than grid expansion
- Highlight real cost of electricity
- Drive new electrification policies and partnerships
- Stimulate electricity demand and PUE in rural areas
- Drive economic development
- Prepare the ground for future grid expansion
Valuable policy and regulations changes are needed

<table>
<thead>
<tr>
<th>Business &amp; Ownership Models</th>
<th>Public, Private, Public-private franchisee, PPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific regulations</td>
<td>Clear demarcation of offgrid areas, Site allocation – top-down vs bottom-up, Clear Licensing conditions &amp; process, Tariff setting and approval, What happens when the main grid arrives?</td>
</tr>
<tr>
<td>Support mechanisms</td>
<td>Independent of technology, rural electrification is not economically viable. Transparency in subsidy types and allocation. Keep the parity between off and ongrid customers</td>
</tr>
</tbody>
</table>
Conclusions (1)

Africa’s energy situation is paradoxal with many inequalities:

• The per capita energy consumption in Africa is a quarter of the average world PCEC

• 75% of Africa’s energy is consumed in Northern and Southern Africa, where 25% of the population live.

• Less than 10% in rural areas resp. around 40% of urban people have access to electricity

• African countries are net exporter of energy resources
Conclusions (2)

Sustainable development of Africa’s energy sector is possible:

Technology options:
• Renewable energy potential (10000 - 20000 TWh/y)
• Rational use of fossil energy resources
• Valorisation of flare gas (41-58 GW, 356-511 TWh/y)

Requirements:
• Rural Electrification Master Plan to include offgrid strategy
• Off-grid Policy towards an enabling environment for strategic offgrid development
• Capacity building of stakeholders
• New financing and business models that take into account private sector involvement and support local SME contribution
Grand-Inga requires about $50bn

50 million shares @ $1000
5 million shares @ $10,000
1 million shares @ $50,000
500,000 shares @ $100,000
+
+
other combinations