WORLD OUTLOOK FOR GEOTHERMAL ELECTRICITY AND DIRECT USE 2016

Lúdvík S. Georgsson
Director UNU-GTP

ARGeo-C6 conference
Addis Ababa, November 2-4, 2016
1. Energy utilization in the World and future forecasts based on different scenarios from the World Energy Council, published last month at their Istanbul Congress (WEC, 2016)

At present, 1.1 billion people of the 7.4 billion people living on our planet (2015) have not access to electricity

UN predicts the world population to grow to about 10.2 billion by 2060

Key issue to improve standard of living is to make clean energy available to everybody at affordable prices

World energy consumption is expected to continue increasing

A large share of the increase is expected to come from renewables

A key question is – are we ready to pursue energy solutions needed to control climate change? – i.e. limit „the increase in global average temperatures to well below 2°C“ as agreed to at COP21 in 2015
HISTORIC CONTRIBUTION OF ENERGY SOURCES

- Coal
- Oil
- Nat. gas
- Hydro
- Nucl.
- Biom
## UTILIZATION OF PRIMARY ENERGY IN THE WORLD IN 2014

Total utilization 573 EJ (WEC, 2016)

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Primary Energy, EJ</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil fuel</td>
<td>465</td>
<td>81.1</td>
</tr>
<tr>
<td>Oil</td>
<td>180</td>
<td>31.4</td>
</tr>
<tr>
<td>Gas</td>
<td>121</td>
<td>21.1</td>
</tr>
<tr>
<td>Coal</td>
<td>164</td>
<td>28.6</td>
</tr>
<tr>
<td><strong>Renewables</strong></td>
<td><strong>81</strong></td>
<td><strong>14.1</strong></td>
</tr>
<tr>
<td>Biomass</td>
<td>59</td>
<td>10.3</td>
</tr>
<tr>
<td>Hydro</td>
<td>14</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>Other renewables</strong></td>
<td><strong>7.6</strong></td>
<td><strong>1.4</strong></td>
</tr>
<tr>
<td>Nuclear</td>
<td>28</td>
<td>4.8</td>
</tr>
</tbody>
</table>
Three quite different scenarios!!

**Modern Jazz** – complex and competitive market landscape driven by efficiency and innovation
Total utilization predicted to be **715 EJ** or **25%** increase
Share of renewables predicted to become about **29%**
Fossil fuels still fairly dominating with **63%**

**Unfinished Symphony** – focus on resilient, integrated, global low-carbon energy systems
Total utilization predicted to be **634 EJ** or **11%** increase
Share of renewables predicted to reach about **37%**
Fossil fuels still fairly strong – but utilization lowered to **50%**

**Hard Rock** – fractured world with diverse sets of economic, energy and sustainability outcomes
Total utilization predicted to be **767 EJ** or **34%** increase
Share of renewables predicted to reach about **21%**
Fossil fuels still very much dominating with almost **70%**

Positive is a prediction of considerably **improved energy efficiency**
## ELECTRICITY PRODUCTION VS. ENERGY SOURCES 2014-2060 (WEC, 2016)

<table>
<thead>
<tr>
<th>Source</th>
<th>2014 (TWh)</th>
<th>2014 (%)</th>
<th>2060 (TWh)</th>
<th>2060 (%)</th>
<th>2060 (TWh)</th>
<th>2060 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>9,697</td>
<td>41</td>
<td>3,299</td>
<td>7</td>
<td>1,068</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8,199</td>
<td>18</td>
</tr>
<tr>
<td>Gas</td>
<td>5,155</td>
<td>22</td>
<td>15,463</td>
<td>32</td>
<td>7,516</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11,781</td>
<td>26</td>
</tr>
<tr>
<td>Hydro</td>
<td>3,895</td>
<td>16</td>
<td>6,558</td>
<td>13.5</td>
<td>7,100</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6,573</td>
<td>15</td>
</tr>
<tr>
<td>Nuclear</td>
<td>2,535</td>
<td>11</td>
<td>4,908</td>
<td>10</td>
<td>7,617</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6,661</td>
<td>15</td>
</tr>
<tr>
<td>Oil</td>
<td>1,033</td>
<td>4</td>
<td>274</td>
<td>0.5</td>
<td>76</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>421</td>
<td>1</td>
</tr>
<tr>
<td>Oth. renewables</td>
<td>1500</td>
<td>6</td>
<td>17,987</td>
<td>37</td>
<td>20,888</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11,279</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>23,816</td>
<td></td>
<td>48,491</td>
<td></td>
<td>44,474</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>44,914</td>
<td></td>
</tr>
</tbody>
</table>
# Electricity Production from Renewables in 2014

(WEC, 2013**/2016*)

<table>
<thead>
<tr>
<th></th>
<th>Production/a*</th>
<th>Mjazz – 2060 Product./a*</th>
<th>USym – 2060 Product./a*</th>
<th>HRoc – 2060 Product./a*</th>
<th>Capacity factor**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TWh/a</td>
<td>%</td>
<td>TWh/a</td>
<td>%</td>
<td>TWh/a</td>
</tr>
<tr>
<td>Hydro</td>
<td>3,895</td>
<td>72.2</td>
<td>6,558</td>
<td>26.7</td>
<td>7,100</td>
</tr>
<tr>
<td>Biomass</td>
<td>493</td>
<td>9.1</td>
<td>2,574</td>
<td>10.5</td>
<td>2,508</td>
</tr>
<tr>
<td>Wind</td>
<td>717</td>
<td>13.3</td>
<td>8,818</td>
<td>36</td>
<td>9,326</td>
</tr>
<tr>
<td>Solar</td>
<td>198</td>
<td>3.7</td>
<td>5,718</td>
<td>23.3</td>
<td>7,943</td>
</tr>
<tr>
<td>Geothermal</td>
<td>77</td>
<td>1.4</td>
<td>638</td>
<td>2.6</td>
<td>1,111</td>
</tr>
<tr>
<td>Other</td>
<td>15</td>
<td>0.3</td>
<td>239</td>
<td>1.0</td>
<td>210</td>
</tr>
<tr>
<td>Total</td>
<td>5,395</td>
<td>100</td>
<td>24,515</td>
<td>100</td>
<td>28,223</td>
</tr>
</tbody>
</table>
TECHNICAL POTENTIAL OF RENEWABLE ENERGY SOURCES (EJ/YEAR)

EJ per year

- Hydro-power: 50
- Biomass: 276
- Solar energy: 1575
- Wind energy: 640
- Geothermal energy: 5000
ESTIMATED WORLD GEOTHERMAL ELECTRICAL POTENTIAL (Bertani, 2008)

2008 installed capacity (red), Present technology (blue), Enhanced technology (green)
TOTAL CUMULATIVE INSTALLED RENEWABLE CAPACITY 2013 & PREDICTED FOR 2030 (IRENA, 2014)
GEOTHERMAL ENERGY 2015
(Lund and Boyd, 2015, Bertani, 2015)

• A clean, renewable and environmentally benign energy source based on the heat in the earth
• Used in 82 countries of the world, known in over 90
• Electricity generation in 24 countries – installed capacity 12,635 MWe – utilization 73,549 GWh/a
• Direct use in 82 countries – installed capacity 70.3 GWt – utilization 587,786 TJ/year
• Geothermal used to be number four of the renewable energy sources in world electricity production after hydro, biomass and wind; but solar has now left it well behind
THE WORLD GEOTHERMAL ELECTRICITY STATUS
IN TOTAL 12.6 GW (Bertani, 2015)

2015 Geothermal Installed Capacity (MW)

North America: 3.45 GW
- USA: 3,450 MW
- Mexico: 1,017 MW
- Guatemala: 52 MW
- El Salvador: 204 MW
- Nicaragua: 159 MW
- Costa Rica: 207 MW

Latin America: 1.64 GW

Europe: 2.13 GW
- Germany: 27 MW
- Austria: 1 MW
- Iceland: 665 MW
- France: 16 MW
- Italy: 916 MW
- Portugal: 29 MW
- Turkey: 397 MW

Asia Pacific: 4.81 GW
- Japan: 519 MW
- China: 27 MW
- Indonesia: 1,340 MW
- Philippines: 1,870 MW
- Papua Nuova Guinea: 50 MW

Africa: 0.6 GW
- Kenya: 594 MW

North America: 3.45 GW
Europe: 2.13 GW
Asia Pacific: 4.81 GW
Latin America: 1.64 GW
Africa: 0.6 GW

<100 MW Installed
100-500 MW Installed
>500 MW Installed
<table>
<thead>
<tr>
<th>Country</th>
<th>MWe</th>
<th>GWh/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>3,450</td>
<td>16,600</td>
</tr>
<tr>
<td>Philippines</td>
<td>1,870</td>
<td>9,646</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1,340</td>
<td>9,600</td>
</tr>
<tr>
<td>Mexico</td>
<td>1,017</td>
<td>6,071</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1,005</td>
<td>7,000</td>
</tr>
<tr>
<td>Italy</td>
<td>916</td>
<td>5,660</td>
</tr>
<tr>
<td>Iceland</td>
<td>665</td>
<td>5,245</td>
</tr>
<tr>
<td>Kenya</td>
<td>594</td>
<td>2,848</td>
</tr>
<tr>
<td>Japan</td>
<td>519</td>
<td>2,687</td>
</tr>
<tr>
<td>Turkey</td>
<td>397</td>
<td>3,127</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>207</td>
<td>1,511</td>
</tr>
<tr>
<td>El Salvador</td>
<td>204</td>
<td>1,442</td>
</tr>
</tbody>
</table>
GEOTHERMAL ELECTRICITY - TOP 5 COUNTRIES IN GROWTH SINCE 2010 (Bertani, 2015)

<table>
<thead>
<tr>
<th>Country</th>
<th>2015 MW</th>
<th>2015 GWh</th>
<th>New MW</th>
<th>New GWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenya</td>
<td>594</td>
<td>2,848</td>
<td>392</td>
<td>1.418</td>
</tr>
<tr>
<td>USA</td>
<td>3,450</td>
<td>16,600</td>
<td>352</td>
<td></td>
</tr>
<tr>
<td>Turkey</td>
<td>397</td>
<td>3,127</td>
<td>306</td>
<td>2.637</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1,005</td>
<td>7,000</td>
<td>243</td>
<td>2.945</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1,340</td>
<td>9,600</td>
<td>143</td>
<td></td>
</tr>
</tbody>
</table>
GEOTHERMAL ELECTRICITY
TOP-12 GEOTHERMAL FIELDS in 2015 (Bertani, 2015)

1st
The Geysers, 1°
California, USA
1585 MW

Salton Sea, 9°
California, USA
388 MW

2nd
Cerro Prieto, 2°
México
727 MW

Coso, 11°
California, USA
292 MW

3rd
Larderello, 4°
Italy
595 MW

Salak 10°
Indonesia
377 MW

Hengill – Hellisheidi & Nesjavellir, 7°
Iceland
423 MW

4th
Darajat 12°
Indonesia
260 MW

Olkaria, 5°
Kenya
592 MW

5th
Mak-Ban 6°
Philippines
458 MW

Tongonan 3°
Philippines
726 MW

Wairakei 8°
New Zealand
399 MW

16

LSG – Nov. 2, 2016
GEOTHERMAL ELECTRICITY
COUNTRY TRENDS 1995-2015 (Bertani, 2015)
GEOTHERMAL ELECTRICITY
FUTURE PERSPECTIVES (Bertani, 2015)

World Geothermal Electricity

MW


13 GW
15 GW
22 GW
GEOTHERMAL POWER ADDITION IN 2015
(WEC, 2016)

- About 315 MW installed – raising total capacity to 13.2 GW
- Main contributors: Turkey (half), US, Mexico and Kenya
- Biggest capacity under development is in Indonesia – 4000 MW, followed by countries such as US, Turkey, Kenya and Ethiopia – with short term planned additions of about 1000 MW each
- Kenya is now beyond 650 MWe – which means that it has reached - or even passed - Iceland as the seventh biggest producer of geothermal electricity in the world
# Geothermal Utilization 2015

## Direct Use – Top Twelve

*(Lund and Boyd, 2015)*

<table>
<thead>
<tr>
<th>Country</th>
<th>MWt</th>
<th>GWh/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>17,870</td>
<td>48,435</td>
</tr>
<tr>
<td>USA</td>
<td>17,416</td>
<td>21,075</td>
</tr>
<tr>
<td>Sweden</td>
<td>5,600</td>
<td>14,423</td>
</tr>
<tr>
<td>Turkey</td>
<td>2,886</td>
<td>12,536</td>
</tr>
<tr>
<td>Iceland</td>
<td>2,040</td>
<td>7,422</td>
</tr>
<tr>
<td>Japan</td>
<td>2,186</td>
<td>7,259</td>
</tr>
<tr>
<td>Germany</td>
<td>2,847</td>
<td>5,426</td>
</tr>
<tr>
<td>Finland</td>
<td>1,560</td>
<td>5,000</td>
</tr>
<tr>
<td>France</td>
<td>2,347</td>
<td>4,408</td>
</tr>
<tr>
<td>Canada</td>
<td>1,467</td>
<td>3,227</td>
</tr>
<tr>
<td>Hungary</td>
<td>906</td>
<td>2,852</td>
</tr>
<tr>
<td>Italy</td>
<td>1,014</td>
<td>2,412</td>
</tr>
</tbody>
</table>
• Geothermal energy use – 587,786 TJ/year:
  – 55.3% for ground-source heat pumps
  – 20.3% for bathing and swimming
  – 15.0% for space heating
  – 4.5% for greenhouse and open ground heating
  – 2.0% for aquaculture ponds and raceway heating
  – 1.8% for industrial process heating
  – 0.4% for snow-melting and cooling
  – 0.4% for agricultural drying
  – 0.3% for other uses (desalination, bottle washing, animal farming and spirulina cultivation, etc.)
GEOTHERMAL DIRECT-USE 1995-2015
(Lund and Boyd, 2015)

<table>
<thead>
<tr>
<th>Year</th>
<th>TJ/yr</th>
<th>MWt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>587,786</td>
<td>70,329</td>
</tr>
<tr>
<td>2000</td>
<td>423,830</td>
<td>48,493</td>
</tr>
<tr>
<td>2005</td>
<td>273,372</td>
<td>28,269</td>
</tr>
<tr>
<td>2010</td>
<td>190,699</td>
<td>15,145</td>
</tr>
<tr>
<td>2015</td>
<td>112,441</td>
<td>8,664</td>
</tr>
</tbody>
</table>
WORLDWIDE DIRECT-USE (TJ/YR)
(Lund and Boyd, 2015)

Utilization, TJ/yr

1 - Geothermal Heat Pumps
2 - Space Heating
3 - Greenhouse Heating
4 - Aquaculture Pond Heating
5 - Agricultural Drying
6 - Industrial Uses
7 - Bathing and Swimming
8 - Cooling / Snow Melting
9 - Others

[Diagram showing the utilization of geothermal energy for various purposes with data from 1995 to 2015]
SIGNIFICANT CONTRIBUTIONS IN DIRECT-USE HIGHLIGHTS (Lund and Boyd, 2015)

- **Iceland**: 90% of buildings space heated
- **Japan**: 2000 onsen, 5000 public baths, and 1500 hotels serving 15 million guest/year
- **Sweden**: 20% of buildings heated with GHP
- **Switzerland**: 90,000 GHPs installed (~3 units/km²)
- **Tunisia**: 244 ha of greenhouses heated
- **Turkey**: 90,000 apartments heated (30% of total)
- **USA**: 1.4 million GHP units (7% annual growth)
• Acute energy need – abundance of indigenous geothermal energy assoc. with East African Rift System
• Kenya Vision 2030 aims at putting 5000 MW on-line in year 2030.
• Ethiopia has also started drilling and is looking at serious developm.
• Rwanda has been drilling but without success so far.
• Djibouti and Tanzania preparing for drill.
OLKARIA - KENYA

Production started in 1981
Reached 202 in 2010

Two new 140 MWe plants
and ~ 50 MWe of well-head
generators commissioned by
KenGen in 2014, and 26 MWe
by OrPower in Olkaria –
taking capacity to 594 MWe.

- Now in 2016 beyond the
650 MWe mark
OSERIAN GREENHOUSE FARM, KENYA

Produces cutflowers for European markets

Started geothermal heating plus CO$_2$ addition in 2003 to improve quality

Today biggest geothermal greenhouse farm in world with 50 ha heated w. geothermal
Replace cooling towers to cool irrigation water from deep wells in the oasis from 75°C down to 30°C. Geothermal is a biproduct of the irrigation. First UNDP experimental greenhouse in 1985. Steady expansion to 244 hectares in 2014 and still growing. Main products tomatoes and melons for export to Europe. Many jobs created for local men and women.
Utilization of indigenous renewable energy resources as a replacement for fossil fuels is a must in a world where ever increasing emission of greenhouse gasses and global warming is becoming one of the greatest threats to mankind.

According to the new UN Sustainable Development Goals (advanced draft), we must: “Ensure access to affordable, reliable, sustainable and modern energy for all”

WEC energy forecast predict that demand for electricity will double to 2060, but this will be met with cleaner sources.

Solar and wind are expected to grow at unprecedented rates.

Fossil fuel is though still expected to be the main energy provider, even though serious reductions will be seen if scenarios based on international cooperation and regulations will lead the way – putting emphasis on renewable energies.
LOOKING TO THE FUTURE II

- With emphasis on energy scenarios based on renewable energy sources, World Energy Council (2016) predicts that geothermal energy may grow up to 14 times to 2060, and reach a 2.5% share of the total generation
- With the expected energy revolution, GDP in Sub-Saharan Africa is expected to grow at a rate of up to 6-7% on an annual basis in the coming decades
- It is unlikely that we will be able to reach the goals set by COP21, but we still have to strive as possible for this
- Capacity building, transfer of technology and increased emphasis on policy making are key issues in the sustainable development of geothermal resources
- The UNU-GTP will continue to support geothermal as best it can


Thanks for the attention