
Getahun Demissie
Addis Abeba, Ethiopia
getahun.demissie.gemeda@gmail.com
Outline
• Why the need for geothermal energy development?
  – Electricity supply in Africa
• What has been, and is being done?
  – Synoptic case histories & prospects
• What contributions did Afar research make?
  – N.E. Africa, extrapolations
1. THE DARK CONTINENT

HAKUNA MATAA: No light
A number of things are wrong here:

- **Production:** About 1 Toe/yr per capita, 51% exported, 47% consumed
- **Consumption:** 60% biomass, 34% Fossil fuels, 6% renewables
- **Use in economic production:** 34%
- **Low energy use & poor structure**
The Paradox: Energy Poverty in the middle of plenty

Considering only the renewable energy sources, Africa’s potential, in TWh (from IRENA, 2010)

- Wind power: 5,000 – 7,000
- Solar Energy: 155,000 -170,000
- Geothermal energy: >125
- Hydropower: 1,844
- Bagasse: 3.0 - 13.6

❖ Of the non-intermittent sources, 9% of the hydro and 1% of the geothermal potentials have been developed by 2011
Electricity is a good energy form: Easy to produce, transport and use, but ........

<table>
<thead>
<tr>
<th>Sources</th>
<th>Capacity, GW</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-renewable</td>
<td>104.7</td>
<td>84.0</td>
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<tr>
<td>Coal</td>
<td>52.4</td>
<td>42.0</td>
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<tr>
<td>Natural Gas</td>
<td>34.9</td>
<td>28.0</td>
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<tr>
<td>Oil</td>
<td>15.0</td>
<td>12.0</td>
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<tr>
<td>Nuclear</td>
<td>2.5</td>
<td>2.0</td>
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<tr>
<td>Renewable</td>
<td>24.3</td>
<td>16.0</td>
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<tr>
<td>Hydro</td>
<td>21.2</td>
<td>14.0</td>
</tr>
<tr>
<td>Wind</td>
<td>1.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Biomass (bagasse)</td>
<td>1.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Totals</td>
<td>129.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

- Africa has small power generation capacity.
  - Only 20% Africans have electricity access (World average 86%)
  - Average African consumes 124KWh/yr (World average 2,784)

- Africa needs to increase capacity 33-fold to serve all Africans

- The present system is too dependent on fossil fuels.

- Africa needs to use its abundant renewable energy sources:
  - For additional generation capacity, and,
  - To replace thermal generation and expand
Regional differences exist

S. & N. Africa:
- 70% of Africa’s generation capacity:
  - Attributed to Coal in S. & natural gas in N.
- 1.617 & 739 KWh per capita in S & N
- Access to Electricity: >70%

SSA Less privileged: Access 20%, per capita consumption 107 KWh/yr.
- Oil & gas in Gulf of Guinea area help

Eastern Africa fares least: 15% access & 68 KWh/yr per capita consumption
- Each Eastern African could have a 60W light bulb to light for about 3 hours/day, but....
- There is no equity: the cities get 9/10th of the electricity
The reasons?

1. Low African purchasing power.
   - Economies grow 5%/yr. 7%/yr electricity demand growth promises more growth

2. High generation cost: Small power plants; Average hydro-plant size = 46MW
   - Develop large hydro, 2-6 GW: a 10-fold capacity increase halves the unit cost

3. Small markets can not accommodate large plant additions
   - Interconnect national power supply systems to create larger regional markets & power trading

4. Large electricity consuming industries are in the cities, other power supply is unprofitable;
   - Electricity is an essential social and economic infrastructure, do rural electrification schemes

So there are the regional power pools which are addressing these issues.
The EAPP Plan to 2020

- HV transmission lines connect Egypt, Sudan, Ethiopia-Kenya, Tanzania, Uganda, Rwanda, Burundi, Uganda, East DRC (Kivu)

- Generation capacity from renewables increases energy supply by 40%

- Thermal generation will be phased out, except from coal.

- Unified electricity system will be regulated by a singly organization

- New Generation: 82.5% hydro, 13% geothermal, 4.5% wind

- Role of geothermal power is to support mainly hydro-based regional electricity system by base-load power supply.
2. GEOTHERMAL EXPLORATION AND DEVELOPMENT IN ETHIOPIA

1. MER

- 1969-71: 24 month reconnaissance covered 150,000 sq km ERS
- 1972: Inventory in the highlands
  - Over 600 hydrothermal features associated with about 20 heating systems located
- 1973-80: Detailed surveys by Geology, Geochemistry, geophysics at Langano, Corbetti, Abaya
- 1981-84: Exploration drilling of Alutu, 8 wells, 1,100-2.500m depth, $T_{\text{max}} = 320^\circ\text{C}$
  - 2 wells cold, 4 wells produced, one was lost
  - 1996-99 Pilot plant installed: 7.3MW
- 210-2110 Further geophysical surveys: MT
- Present: Financing acquired for production drilling and 50MW power plant
2. Tendaho

- **1978-80**: Detailed exploration of Tendaho graben
- **1993-95**: 3 deep & 1 shallow exploration wells drilled to depths of 2196 & 466 m

Deep wells: $T=278^\circ$C, but impermeable

- 200-400m depth in Quaternary sediments
- $245^\circ$C geo-fluid 1,000 kJ/kg, 100 tph, 27% dry

- **1997-98**: Drilled 2 wells to ~500m, same result
- Geophysical survey ongoing;

plan developing for drilling 3,000 m wells to find deep resource
3. **S. Afar-N. MER Surveys**

- No more drilling finance: US$ 3-4 million/well
- Semi-detailed surface exploration of 10 areas, to minimize pre-drilling surface exploration work.

- **Tulu Moye, Gedemsa, Dofen & Meteka** have good prospects for yielding >250°C geo-fluids.

- No more than one year of surface exploration is needed at each to ready them for drilling
- IPP now exploring Tulu Moye and Gedemsa, as well as Abaya and Corbetti.

- **THE FUTURE?**

- Regional geothermal programmes becoming active to support 7 EARS countries to explore and develop their geothermal resources: UNEP-ARGeo & AUC-RGP
3. HOW DID AFAR RESEARCH CONTRIBUTE TO GEOTHERMAL EXPLORATION?

- In the beginning there were only geologic or topographic maps, or only good aerial photographs.
- The rift floor was covered by the “Aden series” of Blanford from a century earlier. The Oligocene flood basalts were also thought to outcrop.

MER:

- First clue: P. Mohr’s perception of the “Wenji Fault Belt”, still used, even if since found to have been a bit enthusiastic.
- The interpreted high “reservoir temperatures” were from thermal springs associated with rhyolite centers in the fissure lava field of the WFB.
- Rift transverse structures favor positioning of silicic centers:
- Why all this rhyolite, crust anatexis or differentiation? What does it mean in terms of geothermal resource generation?
AFAR Rift

Enigmatic at first

• Allalobeda thermal springs & Magenta fumaroles occur in block faulted basalt terrain, but
  • what and where is the heat source?
• Dubti farm mud volcanoes lie on SE trajectory of Manda-Hararu range faults.
  • what and where is the heat source?

➢ CNR-CNRS research explained Afar tectonic and magmatic development in terms of Plate Tectonics

• Manda Hararu: youngest microplate boundary
• Tectonic setting and interpreted high “reservoir temperature” ranked Tendaho high as a prospect area
• Geophysics by German universities showed crustal attenuation and deep temperature structures
Key Lessons Learned

• Where late Pleistocene rhyolites and co-occurring fissure basalts are known to be differentiation products, the most common case:
  ○ Long lived shallow magma body heat sources should be expected

• Rift transverse faults are micro-plate boundaries.
  ○ Positioning of silicic centers is favored where they cross WFB in MER and rift margin fault in N. Afar rift

• Calderas focus heat flux and geo-fluid upwelling & are easy to explore

• Allalobeda and the Dubti mud volcanoes could occur due to shallow ground water table supported by Awash River
  ○ Other “axial zones” in N. & Central Afar can be predicted to have blind geothermal systems due to paucity of shallow ground water
In ERS, there are only a small variety of tectonic and magmatic associations. A few geothermal models can describe a large number of geothermal areas.

Young bimodal volcanic rock occurrences situated on micro[plate boundary structures are sure to be good geothermal targets.

Research generated knowledge of this association in Ethiopia.

Geothermal exploration could start at a higher level of knowledge and go further to “prove steam” than many
Thank you for your kind attention