Integrated Renewable Energy Potential Assessment - IREPA -

Biomass for bioenergy potential assessment by a holistic and participatory approach

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University of Hohenheim
Why IREPA?

- Highest REP in rural areas of Africa, Latin America and Asia
  - Smallholder farmers manage 80% of natural resources

- Implementation challenging - e.g. project failure in SSA: 64%, in Thailand: 60%
  - Top-down approach with focus on techno-economic aspects

- Complex interaction: Technology | Society
  
  “Since I am poor, and that will not change even if many projects are launched, I want to be at least a rested poor”

  “Technology works. Users are the problem”

- Potential assessment and implementation requires holistic and participatory approach

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1. De Vries et al. 2007
2. IASSTD 2009
3. Barry et al. 2011
4. Green 2004
5. Garcia and Bartolome 2010
6. Stirling 2014
Methodology of the Integrated Renewable Energy Potential Assessment (IREPA)
### Biomass Potential Assessment

#### Brief overview of determining factors for the assessment of biomass potentials

<table>
<thead>
<tr>
<th>Potential category</th>
<th>Definition</th>
<th>Determining factors</th>
<th>Description of factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical</td>
<td>Bio-physical barriers</td>
<td>bio-physical</td>
<td>Climatic, geographical and geological conditions</td>
</tr>
<tr>
<td>Geographical</td>
<td>Suitable areas</td>
<td>bio-physical, technical, bio-physical</td>
<td>Incompatible land cover, Accessibility</td>
</tr>
<tr>
<td>Technical</td>
<td>Availability of suitable areas</td>
<td>technical, socio-economic, environmental, institutional, social</td>
<td>Infrastructure, Competition: land, resources and biomass uses, Policy support, Social acceptance</td>
</tr>
<tr>
<td>Economical</td>
<td>Investment costs</td>
<td>economic</td>
<td>Public and private investments/procurement</td>
</tr>
<tr>
<td></td>
<td>Energy production costs</td>
<td>institutional</td>
<td>Policy support</td>
</tr>
<tr>
<td>Implementation / Realizable</td>
<td>Complex interaction of social, institutional, environmental, technical, economic factors</td>
<td>Assessment on local to regional level</td>
<td></td>
</tr>
</tbody>
</table>

Based on: Amigun et al. 2011; Brohmann et al. 2006; De Vries et al. 2007; Dornburg et al. 2008; Gross et al. 2003; Hoogwijk 2004; IRENA-DBFZ 2013; Moriarty and Honnery 2012; Resch et al. 2008; Smeets et al. 2007; Thrän et al. 2010
Household and community assessment

- Bottom-up exploration of locally important factors for appropriate RET selection

⇒ Participatory Learning and Action (PLA) Research \(^7,\ 8\)

  - Open-ended, semi-structured HH interviews
  - Key-informant interviews
  - Visits of adjacent rural development projects
  - Transect walks
  - Participant observation (“do it yourself”)
  - Focus-group and workshop
  - Review of secondary sources

- Impact assessment and participatory decision making

⇒ Multi-Criteria Decision Analysis (MCDA) Methods \(^9\)

  - Analytical Hierarchy Process (AHP) \(^10\)
  - Simple Multi-Attribute Rating Technique (SMART) \(^11\)

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8. Chambers 1994
9. Velasquez and Hester 2013
10. Saaty 1990
11. Chen 2010
Case study research in South Africa and India

Mgwenyana

- Eastern Cape Province
- Small-scale, subsistence farming
- Main crops: Maize, few fruits and vegetables with very low yield level

Ghoragachha and Baikunthapur

- State of West Bengal
- Small-scale, subsistence and market-oriented farming
- Main crops: Rice, vegetables, fruits and flowers with very high yield level

Mgwenyana (own photo)

Baikunthapur (own photo)
## Case study: Renewable Resource Availability

### Power densities of renewable resources at Mgwenyana and Ghoragachha / Baikunthapur

<table>
<thead>
<tr>
<th>Source</th>
<th>Solar [W m(^{-2})]</th>
<th>Wind [W m(^{-2})]</th>
<th>Hydro [MW]</th>
<th>Geothermal [W m(^{-2})]</th>
<th>Biomass [W m(^{-2}) a(^{-1})]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mgwenyana</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ø power density</td>
<td>186</td>
<td>14</td>
<td>17</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>Source</td>
<td>Helio-Clim 3</td>
<td>WASA</td>
<td>DWEA</td>
<td>Banks and Schäffler 2006</td>
<td>NEO</td>
</tr>
<tr>
<td><strong>Ghorgachha and Baikunthapur</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ø power density</td>
<td>200</td>
<td>5</td>
<td>392</td>
<td>0.2</td>
<td>0.4</td>
</tr>
</tbody>
</table>
### Available biomass and biogas yields

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Mgwenyana</th>
<th>Ghor. / Baiku.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[m³ d⁻¹ farm⁻¹]</td>
<td></td>
</tr>
<tr>
<td>Grass</td>
<td>0.31</td>
<td>n.a.</td>
</tr>
<tr>
<td>Organic wastes</td>
<td>0.0001</td>
<td>0.09</td>
</tr>
<tr>
<td>Animal manure</td>
<td>0.68</td>
<td>0.44</td>
</tr>
<tr>
<td>Human Excreta</td>
<td>0.09</td>
<td>0.13</td>
</tr>
<tr>
<td>Crop residues</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>- Rice straw</td>
<td>n.a.</td>
<td>4.13</td>
</tr>
<tr>
<td>- Vegetable (Rabi)</td>
<td>n.a.</td>
<td>2.53</td>
</tr>
<tr>
<td>- Vegetable (Zaid)</td>
<td>n.a.</td>
<td>0.59</td>
</tr>
</tbody>
</table>

**Total Biogas Yield:**

|              | 1.1 | 7.9 |

**Energy content [kWh]:**

|                | 6.8 | 49.4 |

**+ organic fertilizer**

Sustainable Livelihoods Framework (adapted from Scoones 1998)

Case study: Household and village assessment - India

Vulnerability Context
- Climate change: decline in rainfall frequency and intensity, higher temperature, occasional droughts -> agriculture heavily affected
- Unsustainable natural resource use
- Soil erosion, land degradation
- Land availability (all land in use)
- Decreasing groundwater levels
- Water highly contaminated (Arsenic)
- Air pollution
- No waste management system
- Increasing prices of food, feed, energy and agricultural inputs (affordability) -> food insecurity
- Traditional biofuels main energy source
- Agricultural extension influenced by agriculture (Mandis)
- Mid-size, medium-based, poor local economy
- Few people own land
- Weak health system
- Migration to towns and older generation goes for jobs in tertiary sector
- Cast-related hierarchies
- Low social status
- Bureaucracy burdens
- High level of corruption

Climate Change
- Land availability
- Access to clean water
- Input prices increase
- Dependency on government and private sector interests

Abundant natural resources
- Fertile, alluvial soils
- Abundant groundwater, channels (irrigation)
- > 2100 sunshine hours

Human Capital
- Good education (younger generation)
- High skills
- Mechanical and commercial skills
- Access to micro-irrigation system (62%) and energy (91%)

Social Capital
- Family networks, Agriculture, Extension and Self-sufficiency
- Agricultural extension services
- High productivity
- Micro-irrigation systems

Physical Capital
- Access to infrastructure and resources

Financial Capital
- Farm and non-farm occupations
- Various governmental supporting schemes (subsidies, loans, etc.)

Livelihood assets
- Education, skills and innovation proneness

Livelihood outcomes
- Food, water, and energy self-sufficiency
- Independence of fossil resources and prices
- Efficient and sustain. natural resource use
- Environmental conservation
- Climate change adaptation

Influence and access
- Adapted Livelihood strategies and possibilities of change

Governmen
- Centralized, unidirectional development
- Financial support (subsidies, loans, etc.)

Private sector
- Block development offices

Bank sector
- Farmers incentives
At all links ( ) middleman involved

Transforming structures and processes
## Overview of locally important technology selection factors

<table>
<thead>
<tr>
<th></th>
<th>Mgwenyana</th>
<th>Ghoragachha and Baikunthapur</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Socio-cultural factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food and nutrition security</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to clean water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender aspects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social cohesion and stability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social benefits and increased well-being</td>
<td></td>
<td>Ease of daily activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Education and development of new skills</td>
</tr>
<tr>
<td><strong>Environmental factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protection of soil, water, air and biodiversity</td>
<td>Environmental Conservation</td>
<td></td>
</tr>
<tr>
<td><strong>Techno-economic factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment costs</td>
<td></td>
<td>Investment costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced expenditures on energy sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land requirements</td>
</tr>
<tr>
<td>Operation and maintenance</td>
<td></td>
<td>Energy security and realibility</td>
</tr>
<tr>
<td>Creation of jobs, new products / markets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy security</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Institutional factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government support</td>
<td></td>
<td>(financial and O&amp;M)</td>
</tr>
<tr>
<td>(financial and O&amp;M)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Case study: Proposed RETs

### Proposed renewable energy technologies

<table>
<thead>
<tr>
<th>Mgwenyana</th>
<th>Ghoragachha and Baikunthapur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini solar-PV light system (10 Wp)</td>
<td>Solar-PV system (500Wp - 1000Wp - 1500Wp)</td>
</tr>
<tr>
<td>Solar Geyser</td>
<td></td>
</tr>
<tr>
<td>Solar Water Heater</td>
<td></td>
</tr>
<tr>
<td>Household biodigester</td>
<td>Household biodigster</td>
</tr>
<tr>
<td>Rocket-stove + forest management</td>
<td></td>
</tr>
<tr>
<td>Integrated Food and Energy System</td>
<td>Integrated Food and Energy System</td>
</tr>
</tbody>
</table>

- **Mgwenyana**
  - Mini solar-PV light system (10 Wp)
  - Solar Geyser
  - Solar Water Heater
  - Household biodigester
  - Rocket-stove + forest management
  - Integrated Food and Energy System

- **Ghoragachha and Baikunthapur**
  - Solar-PV system (500Wp - 1000Wp - 1500Wp)
  - Household biodigester
  - Integrated Food and Energy System

**Solar-PV System**
- [www.kirtisolar.com](http://www.kirtisolar.com)

**Deenabandhu biodigester**
- [http://agridr.in](http://agridr.in)
### Selection factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Eigenvector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Access to clean water</td>
<td>0.2234</td>
</tr>
<tr>
<td>2. Protection of soil, water, air and biodiversity</td>
<td>0.1961</td>
</tr>
<tr>
<td>3. Food and nutrition security</td>
<td>0.1782</td>
</tr>
<tr>
<td>4. Gender aspects</td>
<td>0.0991</td>
</tr>
<tr>
<td>5. Social cohesion and stability</td>
<td>0.0746</td>
</tr>
<tr>
<td>6. Social benefits and increased well-being</td>
<td>0.0652</td>
</tr>
<tr>
<td>7. Operation and maintenance (local resources)</td>
<td>0.0603</td>
</tr>
<tr>
<td>8. Investment costs</td>
<td>0.0366</td>
</tr>
<tr>
<td>9. Creation of &quot;green jobs&quot;, new products/markets</td>
<td>0.0349</td>
</tr>
<tr>
<td>10. Energy security / reliability</td>
<td>0.0315</td>
</tr>
</tbody>
</table>

### RE systems

<table>
<thead>
<tr>
<th>RE Systems</th>
<th>Eigenvector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Integrated Food and Energy System</td>
<td>0.2115</td>
</tr>
<tr>
<td>2. Rocket stove</td>
<td>0.1167</td>
</tr>
<tr>
<td>3. Solar water heater coil</td>
<td>0.1154</td>
</tr>
<tr>
<td>4. Biodigester</td>
<td>0.1098</td>
</tr>
<tr>
<td>5. Solar geyser</td>
<td>0.0966</td>
</tr>
<tr>
<td>6. Photovoltaic light system</td>
<td>0.0775</td>
</tr>
</tbody>
</table>

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12. Saaty 1990
### Case study: RET selection – India

#### Result of the Analytical Hierarchy Process

**Step 1:**

<table>
<thead>
<tr>
<th>Selection factors</th>
<th>Ø Eigenvector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ease of daily activities</td>
<td>0.1669</td>
</tr>
<tr>
<td>2. Government support</td>
<td>0.1591</td>
</tr>
<tr>
<td>3. Land requirement</td>
<td>0.1504</td>
</tr>
<tr>
<td>4. Environmental Conservation</td>
<td>0.1358</td>
</tr>
<tr>
<td>5. Investment costs</td>
<td>0.1250</td>
</tr>
<tr>
<td>6. Reduced energy expenditures</td>
<td>0.1107</td>
</tr>
<tr>
<td>7. Energy security</td>
<td>0.0958</td>
</tr>
<tr>
<td>8. Skill development</td>
<td>0.0563</td>
</tr>
</tbody>
</table>

**Selection factors for farmers (n = 7):**

1. Government support
2. Investment costs
3. Land requirement
4. Reduced energy expenditures
5. Energy security
6. Ease of daily activities
7. Environmental Conservation
8. Skill development

**Selection factors for key informants (n = 3):**

1. Government support
2. Investment costs
3. Land requirement
4. Reduced energy expenditures
5. Energy security
6. Ease of daily activities
7. Environmental Conservation
8. Skill development

**Step 2:**

<table>
<thead>
<tr>
<th>RE systems</th>
<th>Ø Eigenvector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Solar-PV System</td>
<td>0.2934</td>
</tr>
<tr>
<td>2. Solar-Irrigation System</td>
<td>0.2925</td>
</tr>
<tr>
<td>3. Integrated food and energy system</td>
<td>0.2404</td>
</tr>
<tr>
<td>4. Biodigester</td>
<td>0.1954</td>
</tr>
</tbody>
</table>

**Selection factors for farmers (n = 7):**

1. Government support
2. Investment costs
3. Land requirement
4. Reduced energy expenditures
5. Energy security
6. Ease of daily activities
7. Environmental Conservation
8. Skill development

**Selection factors for key informants (n = 3):**

1. Government support
2. Investment costs
3. Land requirement
4. Reduced energy expenditures
5. Energy security
6. Ease of daily activities
7. Environmental Conservation
8. Skill development

**RE systems:**

1. Solar-PV System
2. Solar-Irrigation System
3. Integrated food and energy system
4. Biodigester

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4. Reduced energy expenditures
5. Energy security
6. Ease of daily activities
7. Environmental Conservation
8. Skill development

**RE systems:**

1. Solar-PV System
2. Solar-Irrigation System
3. Integrated food and energy system
4. Biodigester

13. Saaty 1990
Case study: Summary

South Africa:

• Initiative by traditional leaders: Utilization of assets and natural resources for self-sustainable community development

⇒ Selected RET:
  • Simple, cheap and made from locally available resources and materials
  • Show cases for educational purpose

India:

• Initiative by progressive farmers: Solutions for current issues related to farming: climate change, irrigation, soil fertility depletion, prices – input ↑ / output ↓ and lifestyle: modern energy, reliable technologies, independence, education

⇒ Selected RET:
  • Self-sustainable, reliable and clean energy
  • Adapted to individual needs
Implementation potential determined by complex interaction of social, institutional, environmental, technical and economic factors on local to regional level

- Bottom-up assessment of locally relevant factors
- Involvement of intended users in the selection
  - of suitable and available renewable resources – in particular for biomass
  - of locally appropriate renewable energy technologies
- IREPA provides a suitable approach to encourage the effective implementation of RET into smallholder farming systems in rural areas
“When you talk, you are only repeating what you already know; But when you listen, you may learn something new.”

Dalai Lama XIV
References

Amigun B., Musango J. K., Brent A.C. (2011)  
Community perspectives on the introduction of biodiesel production in the Eastern Cape Province of South Africa,  

The potential contribution of renewable energy in South Africa. RAPS Consulting, Rondebosch, South Africa.

Barry M-L., Steyn H., Brent A.C. (2011)  
Selection of renewable energy technologies for Africa: Eight case studies in Rwanda, Tanzania and Malawi.  


Greenhouse crop residues: Energy potential and models for the prediction of their higher heating value.  

CD4CDM - Capacity development for the clean development mechanism (2009)  

Chambers R. (1994)  
The Origins and Practice of Participatory Rural Appraisal. World Development (22), p. 953-969.

References


DWEA - Department of Water and Environmental Affairs South Africa (2012)

FNR - Fachagentur Nachwachsende Rohstoffe eV (2016)

García V.G. and Bartolomé M.M. (2010)
Rural electrification systems based on renewable energy: The social dimensions of an innovative technology. Technology in Society (32), p. 303-311.

References


Demystifying participatory research and its role in development. Department of Sociology and Social Anthropology, Occasional Paper No. 21, University of Stellenbosch.

Helio-Clim 3 database (2012)


IAASTD (International assessment of agricultural knowledge, science and technology for development) (2009)

IRENA-DBFZ (2013)
References

Jölli D. and Giljum S. (2005)
Unused biomass extraction in agriculture, forestry and fishery. Sustainable Europe Research Institute (SERI), Vienna, Austria.

Lfl - Bayerische Landesanstalt für Landwirtschaft (2007)
Methanproduktivität nachwachsender Rohstoffe in Biogasanlagen.

Moriarty P. and Honnery D. (2012)
What is the global potential for renewable energy? Renewable and Sustainable Energy Reviews (16), p. 244-252.


https://eosweb.larc.nasa.gov/sse/RETScreen/, accessed 22.01.2015.


NEO - NASA Earth Observations (2012)

References

Parua P.K. (2010)

Patil V.S. and Deshmukh H.V. (2015)


Saaty T.L. (1990)


Stirling, A. (2014)

References


Velasquez M. and Hester P.T. (2013)


RE-Symbols:
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Dalai Lama XIV
The University of Hohenheim