Quantifying Climate Change Impacts on Hydropower Availability and the Electricity Supply Mix in Mindanao, Philippines

Jason Veysey, Emily Ghosh, Vishal Mehta
Stockholm Environment Institute
IEW, 20 June 2018
A Hydropower-Dependent System

- Mindanao derives a greater % of its electricity from hydro than any other region of Philippines

Recent El Niño activity has demonstrated vulnerability to dry conditions

Source: DOE

Source: mindanaomaps.com
Mindanao Water-Energy Nexus Study

Systematically analyze potential impacts of climate change on hydropower and implications for Mindanao’s electricity system

- Availability of water for hydropower under climate change
- Hydropower’s role in future electricity mix
- Comparison to official hydro goals
- Sensitivities to costs of competing technologies and climate policy
Study Team

and other regional stakeholders

B-LEADERS staff
Analytic Approach

- Joint modeling and scenario analysis of energy and water systems in Mindanao

- Climate scenarios
  - Baseline
  - Medium-low: RCP4.5 (AR5)
  - Medium-high: A1B (AR3/4), RCP6.0 (AR5)
  - High: RCP8.5 (AR5)

- Energy system scenarios
  - Baseline
  - National RE Program (NREP)
  - Limited hydro
  - Differential solar and wind costs
  - Carbon pricing
Key Model Characteristics

**Energy**
- All energy supply and demand in Mindanao
- Engineering and econometric simulations of energy demand
- Least-cost optimization of electricity supply
- 2050 time horizon

**Water**
- Physical simulation of hydrology, rainfall run-off, and hydropower availability in Ranao-Agus (RA) River Basin
- All hydro treated as run-of-river
- Water uses other than for hydropower not explicitly represented (working assumption: max. 50% of streamflow available for hydro)
- 2080 time horizon
A Range of Climate Projections

Changes from Historical Reference Period

Annual Average Temperature

- A1B 2006-2035
- A1B 2036-2065
- RCP4.5 2041-2060
- RCP4.5 2061-2080
- RCP6.0 2041-2060
- RCP6.0 2061-2080
- RCP8.5 2041-2060
- RCP8.5 2061-2080

Annual Precipitation

- A1B 2006-2035
- A1B 2036-2065
- RCP4.5 2041-2060
- RCP4.5 2061-2080
- RCP6.0 2041-2060
- RCP6.0 2061-2080
- RCP8.5 2041-2060
- RCP8.5 2061-2080

Sources: PAGASA, WORLDCLIM
Modeling Process

• Climate scenarios simulated in water model, and availability of water for hydropower in RA basin calculated
• Results extrapolated to rest of Mindanao to provide estimates of region-wide hydropower availability
• Availability estimates introduced in energy model as a constraint in least-cost simulation of future electricity production
• Energy system scenarios evaluated in combination with availability estimates
Availability of Water for Hydro in RA Basin

• Strikingly similar across climate scenarios

Capacity-weighted Average Annual Availability of Hydropower in RA Basin

- Baseline
- A1B
- RCP4.5
- RCP6.0
- RCP8.5

2016 2020 2024 2028 2032 2036 2040 2044 2048
Regional Hydropower Production

• Also quite similar across climate scenarios

Percentage of Baseline Hydropower Production

<table>
<thead>
<tr>
<th>Year</th>
<th>Baseline</th>
<th>A1B</th>
<th>RCP4.5</th>
<th>RCP6.0</th>
<th>RCP8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>98%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>96%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2028</td>
<td>94%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2032</td>
<td>92%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2036</td>
<td>90%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2040</td>
<td>88%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2044</td>
<td>86%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2048</td>
<td>84%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Shares of Regional Electricity Generation

• **Hydro’s share declines in medium-term but rebounds in long run**

  Shares of Electricity Generation

  - Close to 3 GW of new small hydro capacity added in 2040s in each scenario
  - By 2050, hydropower accounts for about 27% of generation in all scenarios
  - Total hydropower output rises nearly fivefold between 2016 and 2050
Complementarities with Solar and Wind

- **Seasonal fluctuations in hydropower output balance seasonal variability of both solar and wind**

**Average Monthly Utilization**
Complementarities with Solar and Wind

- Seasonal fluctuations in hydropower output balance seasonal variability of both solar and wind.
Comparison with NREP

- NREP targets prescribe a faster expansion of hydro capacity than cost-minimizing solutions in climate scenarios.

- However, by 2050, deployed hydro capacity in all scenarios exceeds NREP target.
Insights from Limited Hydro Scenario

• Hydropower has important cost, energy independence, and air pollution benefits

• E.g., limited hydro scenario (assuming baseline climate) compared to baseline scenario, 2016-2050

- Energy system costs: ~$400M 2010 USD
- Energy imports: 400 PJ
- Cumulative GHG emissions: ~40 MtCO₂e
Managing Technology and Policy Risks

- High wind and solar cost scenarios (baseline climate)
  - Small hydro helps backfill for wind and solar – cumulative small hydro production increases 1-47% 2016-2050

- Results suggest small hydro could play a role in hedging against possibility that wind and solar do not evolve as projected

- Hedging value of small hydro could be significantly enhanced by climate policy
  - Carbon pricing + high wind and solar cost scenario – cumulative small hydro production nearly triples 2016-2050
• Findings from 2016-2050 modeling appear robust when longer-range climate change is considered.

• As simulated in water model, availability of water for hydropower in 2060s and 2070s varies about ± 1% from availability in 2040s and 2050s.

• Main driver: precipitation.
Key Conclusions

• Over a range of climate scenarios, **we did not find a significant impact from climate change on availability of water for hydropower or hydro output in Mindanao**
  • These conclusions hold through at least mid-century and probably beyond

• **Hydro is an important part of least-cost electricity supply mix for Mindanao in every scenario evaluated**
  • Plays a similar role across climate scenarios, providing more than a quarter of regional electricity in long term and offering cost, technical, climate, and other benefits

• **In each climate scenario considered, cost-efficient deployment trajectory for hydropower lags Mindanao hydro targets in NREP until after 2030**
  • Gap in baseline scenario is close or equal to that in other climate scenarios, suggesting that implications of NREP’s hydro program do not depend significantly on climate change
Key Conclusions

• Hydropower could complement solar and wind electricity in Mindanao in multiple ways
  • Helping to offset solar/wind variability, lower grid integration costs, and hedge against associated economic and policy risks

• Small hydropower is a critical part of study’s projections
  • Technical potential for small hydro is significantly higher than for large hydro
  • New small hydro production is key to maintaining hydropower’s role in electricity mix in long run
  • Least-cost solution in all scenarios analyzed includes substantial investments in small hydro
  • Expanding small hydro may also yield benefits such as improved energy resilience, economic development, and reduced environmental degradation