Energy and Economic Growth
Applied Research Programme

Policy Brief: Energy solutions for irrigation in Ethiopia

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The policy brief presents a short summary of a study from the International Food Policy Research Institute (IFPRI) that used an integrated irrigation-energy planning framework to identify groundwater irrigation development potentials in Ethiopia under three energy solutions: grid-connected electricity, off-grid solar PV, and diesel.

Key messages and recommendations

- The relative cost-effectiveness of each energy solution compared to the other energy solutions differs by crop type and location.
- On-grid electricity is the most cost-effective energy solution in areas close to the electricity transmission network, while among the two off-grid energy solutions (solar PV and diesel), solar PV has advantage in the north and in eastern lowlands.
- There is potential to add about 1.1 million hectares of groundwater irrigated area in Ethiopia.
- For about 25 percent of this potential (0.26 million hectares), solar irrigation is the most cost efficient, while on-grid electricity is the most cost efficient for about 43 percent of the potential (0.46 million hectares). Diesel is the most cost efficient of the three energy options for about 32 percent of the potential (0.34 million hectares).
- An energy policy reform that removes subsidies on fossil fuels will help promote the use of irrigation systems powered by solar PV significantly.
- Government and other stakeholders need to promote adoption of irrigation technologies based on solar, electricity, and grid, with consideration on the type of energy most cost effective for the location and the crop to be irrigated.

The need for integrated irrigation-energy planning

Irrigation development is widely perceived as an important means to improve agricultural production in Ethiopia. The development of irrigated agriculture in Ethiopia is hampered by the prevalent energy poverty. Ethiopia launched the National Electrification Program (NEP) 2.0 in 2019, which calls for providing energy support for development of the irrigated agriculture in the country. However, in energy planning in Ethiopia, so far, not much attention has been paid to the productive use of energy in agriculture. An integrated irrigation-energy planning approach is needed to address the challenge because energy cost is a key determinant for economic feasibility of irrigation development, which is particularly important as Ethiopia's irrigation development potential is still uncertain.

Solar vs diesel vs electricity

We report the first integrated irrigation-energy planning analysis in Ethiopia at a national scale. The analysis has a planning horizon up to 2030. We focused on groundwater irrigation, which is where the energy demand in irrigated crop production concentrates. We first estimated the energy costs of groundwater irrigation, which include equipment and operating cost for a power unit, pump set, and borehole, under three energy solutions: grid-connected electricity, off-grid solar PV, and diesel, in irrigated production of maize, wheat, vegetables, and pulses. These crops are considered most suitable to be produced under irrigated conditions. The identified most cost-effective energy solutions are shown in Figures 1 to 4.

Figure 1: Maize

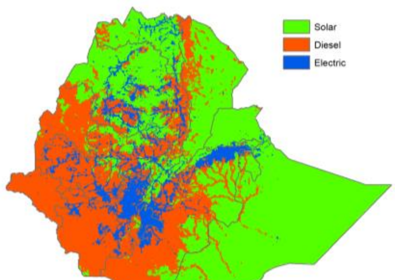


Figure 2: Wheat

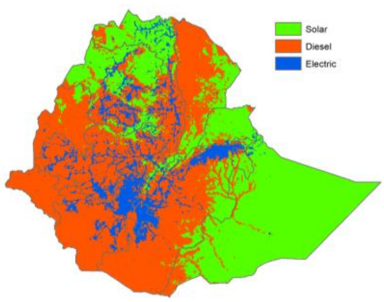


Figure 3: Vegetables

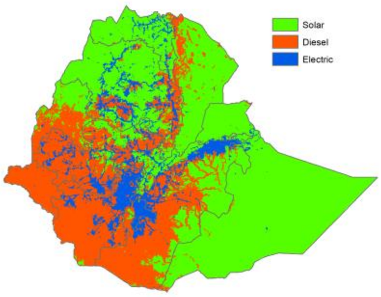
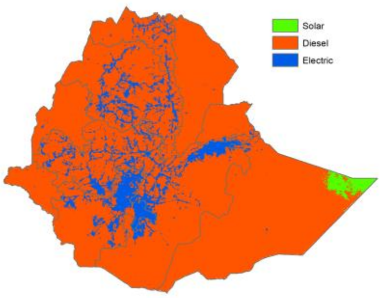


Figure 4: Pulses

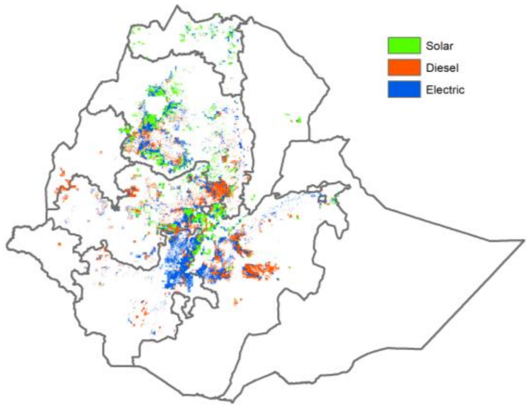


The groundwater irrigation potential under each energy solution is further estimated using a modelling approach to approximate the crop mix and determine the scale of expanded groundwater production by considering constraints of land suitability, quantity of renewable water resources, and market potential of irrigated crops. Figure 5 shows the dominant cost-efficient energy solutions to develop groundwater irrigation in different parts of the country. The model estimates the probability of successful adoption of each energy solution. The dominant energy solution at a location refers to the energy option with the highest success probability at that location.

Both on-grid and off-grid energy solutions will play an important role in the effort to develop groundwater-based irrigated agriculture in Ethiopia. It is estimated that the total groundwater irrigation development potential in Ethiopia is about 1.1 million hectares. This potential consists of 0.26 million hectares where solar irrigation is the most cost efficient, 0.34 million hectares where diesel irrigation is the most cost efficient, and 0.46 million hectares where on-grid electricity is the most cost-efficient energy solution for irrigation (Table 1).

The values of key cost and price parameters used in the analysis generating the above findings are listed in Table 2. The diesel fuel price and electricity tariff shown in column 2 of Table 2 are chosen to represent historical levels of the two input parameters between 2018 and 2021. Note that the diesel price is highly volatile; for example, the recent Russia-Ukraine war has created a sharp spike of prices of energies, including diesel. There was also a declining trend in solar PV cost in the past decade. Considering the difficulty in forecasting long-term diesel price and uncertainty of to what level the solar PV cost can decline to, we assume the constant diesel fuel price, electricity tariff, and installed cost of solar PV during a 25-year lifespan of an irrigation project.

Figure 5: Dominant cost-efficient energy solutions with diesel fuel price and electricity tariff between 2018 and 2021



Currently, the energy consumption in Ethiopia is heavily subsidized. Under an alternative scenario, we assume that the subsidies for diesel fuel and for production, transmission, and distribution of electricity will be removed. The estimates for dominant cost-efficient solutions and groundwater irrigation development potential by region under this “high” price scenario are shown in Figure 6 and Table 3. The “high” price scenario implies little change in the estimated total groundwater irrigation development potential and the application potential of on-grid electricity solution, but the reform will help promote the use solar PV powered irrigation system significantly.

Figure 6: Dominant cost-efficient energy solutions under “high” diesel fuel price and electricity tariff scenario

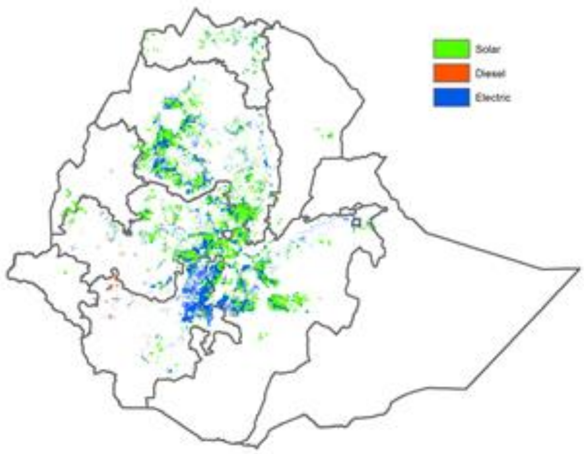


Table 1: ***Expected values of areas with groundwater irrigation development potential under three energy solutions (in hectares) with diesel fuel price and electricity tariff at historical level***

Region	Solar	Diesel	Electric	Total
Addis Ababa	13	0	39	52
Afar	1,121	118	35	1,274
Amhara	138,212	97,372	145,280	380,865
Benishangul Gumuz	2,780	6,642	1,645	11,067
Dire Dawa	0	0	0	0
Gambela	0	720	204	923
Hareri	0	3	581	585
Oromia	93,636	202,227	185,062	480,926
Somali	139	0	102	240
SNNPR	5,562	28,996	113,737	148,295
Tigray	19,587	34	9,889	29,510
Total	261,050	336,112	456,574	1,053,736

Table 2: ***Cost and price parameters used in the analysis***

	Historical (2018-2021)	High
Diesel fuel price (USD/liter)	**0.57**	**0.9**
Electricity tariff (USD/kWh)	**0.03**	**0.09**
Installed cost of solar PV (USD/W_p)	**1.2**	

Table 3: ***Expected values of areas with groundwater irrigation development potential under three energy solutions (in hectares) under "high" diesel fuel price and electricity tariff scenario***

Region	Solar	Diesel	Electric	Total
Addis Ababa	13	0	39	52
Afar	1,237	0	33	1,270
Amhara	235,215	662	144,591	380,468
Benishangul Gumuz	8,200	258	1,548	10,006
Dire Dawa	0	0	0	0
Gambela	530	189	204	923
Hareri	5	0	572	577
Oromia	291,225	2,874	184,928	479,027
Somali	134	0	102	235
SNNPR	28,997	5,710	113,548	148,255
Tigray	19,607	0	9,849	29,455
Total	585,163	9,692	455,414	1,050,269

Conclusions and policy implications

The study presented in this policy brief represents the first attempt to evaluate the groundwater irrigation potential and application potential of energy technologies to support the groundwater irrigation development in Ethiopia at a national scale. We included three energy solutions in the analysis – grid-connected electricity, off-grid solar PV, and diesel.

It is estimated in this study that in Ethiopia groundwater irrigated area can be added by about 1.1 million hectares by 2030. The analysis highlights the need to invest in both on-grid and off-grid energies to support the groundwater irrigation development. The cost-effectiveness of each energy solution is found to vary by crop and by location, but overall, on-grid electricity is the most cost-effective energy solution in areas close to the electricity transmission network. At the same time, there is considerable groundwater irrigation development potential that is located outside the service area of electricity grid where the groundwater irrigation development needs to rely on the use of off-grid energies. Compared to diesel energy, solar PV tends to have advantage in the north and in eastern lowlands, which could constitute the focal region for solar irrigation investment.

The analysis also reveals the challenges in making decision to provide cost-effective energy solution for expanding groundwater irrigation. The financial performance of energy technologies, especially the performance of groundwater irrigation systems powered by off-grid solar and diesel energies, critically depends on the energy pricing policy of the country. A reform that removes the subsidies on fossil fuels thus will help promote the use solar PV powered irrigation system significantly.

Finally, Ethiopia is a country rich in renewable energy resources. Apart from solar energy, other sources of renewable energy available in Ethiopia include wind, geothermal, and micro-hydrology. There is also keen interest in investing in mini-grids. The approach developed in this study can be extended to accommodate these energy solutions, and this constitutes a topic that invites future research.

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The views expressed in this Policy Brief do not necessarily reflect the UK government's official policies.