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RESEARCH PROGRAM ON Water, Land and Ecosystems

Capacity Building for an Energy-Secure Future of Ethiopia-Final Workshop

September 30, 2:00pm - 4:00pm EAT (Ethiopia time)

IFPRI

Capacity Building for an Energy-Secure Future of Ethiopia--Objectives

- Development of a core group of energy modelers in Ethiopia that can take model alternative energy futures in Ethiopia—focus on a group to ensure longevity and on the collaboration across MOWIE, utilities and Ethiopian academics
- Capacity building of energy modeling group to independently develop, use and update a model of the Ethiopian energy sector
- Development of the Ethiopian TIMES model with core activities implemented by the Ethiopian energy modeling group
- Co-development of a series of alternative energy futures for Ethiopia and implementation with the Ethiopian TIMES modeling framework; joint final research paper

RESEARCH PROGRAM ON Water, Land and Ecosystems

Workshop Agenda

- Abiti Getaneh Gebremeskel, MOWIE: Recent energy developments in Ethiopia
- Alam Mondal, IFPRI, and Alebachew Azezew Belete, MOWIE: Modelling and Optimization of Future Energy Systems Using TIMES, the Case of Ethiopia
- Hua Xie, IFPRI: Diesel versus solar irrigation, what are the opportunities?
- Dawit Mekonnen, IFPRI: Productive uses of electricity access in Ethiopia: Insights from a recent study
- Closing panel on the future of sustainable and inclusive energy access for all in Ethiopia: H.E. Seleshi Bekele, Minister, MOWIE (invited); Abiti Getaneh Gebremeskel--MOWIE, Omer Bomba Mohammed--Veritas, Francis Elisha--Rocky Mountain Institute, Alam Mondal, IFPRI

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What do participants hope to learn from this event?

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Overview of Energy System Model (TIMES) Development for Ethiopia

Alam Hossain Mondal, PhD
Associate Professor
Daffodil International University
and
Non-Resident Fellow
International Food Policy Research Institute

Workshops and Capacity Development Activities Phase I (2017-2018)

1) Stakeholders workshop on Alternative Pathways to Improve Electricity Access in Ethiopia on November 28, 2017 &
2) Training workshop on Energy Model Options for Policy Planning on November 29, 2017

Different energy models such as RETScreen, HOMER for off-grid system and LEAP, MARKAL and TIMES for national scale energy systems analysis were presented

Workshops and Capacity Development Activities Phase I (2017-2018)

1) Stakeholder workshop on Alternative Pathways to Improve Electricity Access in Ethiopia on May 02, 2018
2) Organized Extensive training workshop on Energy System Model: TIMES on May 3-4, 2018

To select the best model for Ethiopian energy systems analysis, the energy stakeholders suggest to IFPRI to focus on the TIMES model with a first round of training activities in May, 2018

Workshops and Capacity Development Activities Phase II (2019-2020)

May 20, 2019:

a) Developed a core energy modelling team (total 20 participants) based on consultation with participants in the phase II capacity buiding activity

Capacity Building Training on TIMES Model

CAPITAL HOTEL

22 Mazoria, Haile G/Slassie Avenue, Addis Ababa, Ethiopia

May 22 and 23, 2019

The Core Energy Modelling Team

S.N	Full Name	Name of Organization/Institution	Department	Designation	Email	Phone
1	Alebachew Azezew	Ministry of Water, Irrigation and Energy (MoWIE)	Research and Development Directorate	Senior Energy Researcher	alexazeze@gmail.com genanawazeze@yahoo.com	0921393544 /0942126046
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18	Ferid Abdulselam	Ethiopian Electric utility (EEU)	Regional Manager		feridah2002@yahoo.com	0911933975
19	Kabtamu Ketsela	Ethiopian Electric utility (EEU)	Regional office	Power Engineer	kabtamu2007@gmail.com	0911362366
20	Abiyot Abrham	Ethiopian Electric utility (EEU)	Regional office	Power Engineer	abinazer@gmail.com	0911445673

License for the TIMES Model

b) Purchased full set of 10 TIMES (VEDA FE and BE) licenses including GAMS software license to use for academic and research purposes for energy system assessment and energy policy development in Ethiopia

Life-long license: 10 users/stakeholders can use the software

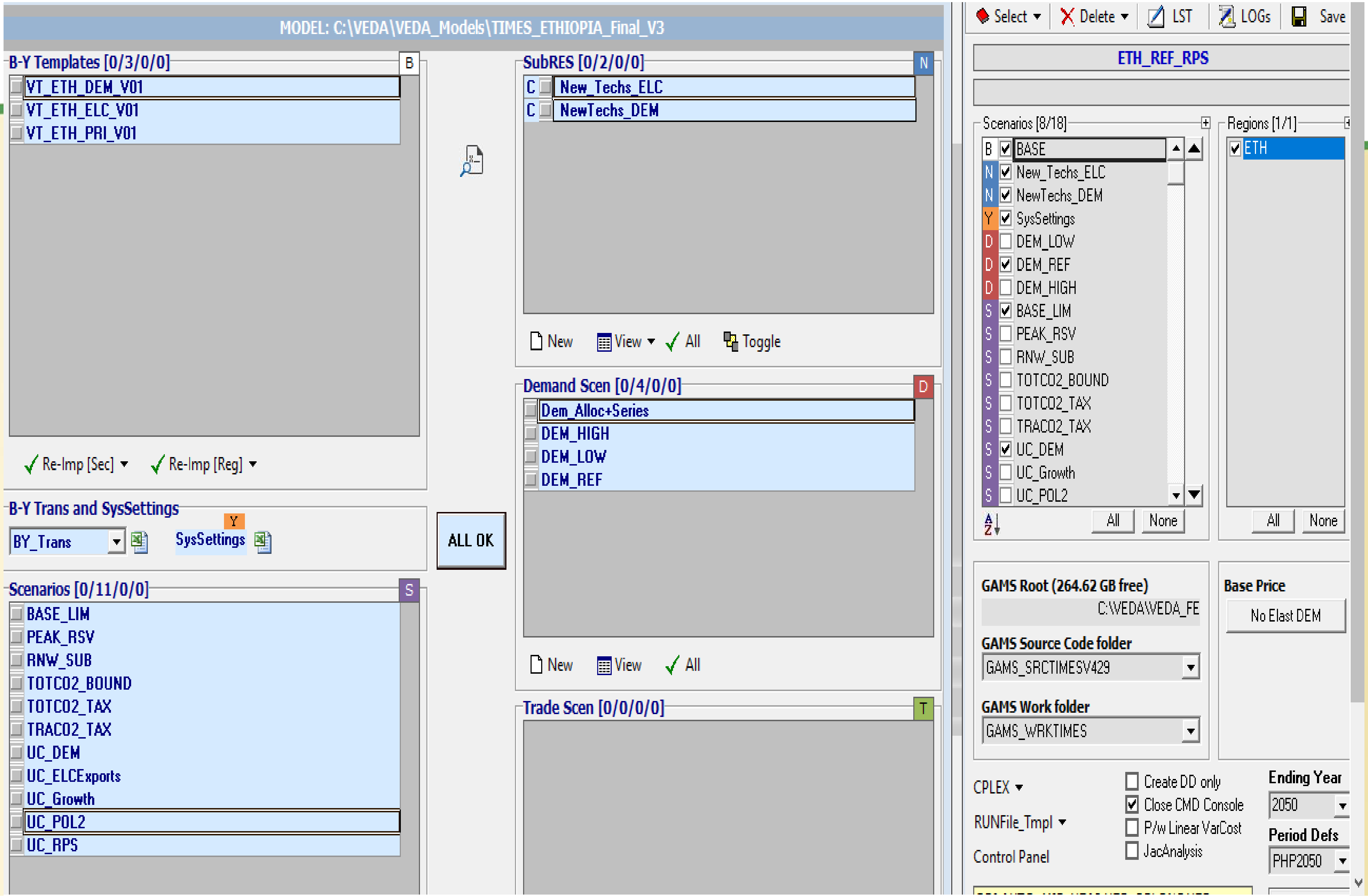
Workshops and Capacity Development Activities Phase II (2019-2020)

c) Organized capacity building training on Ethiopia's Energy Systems Model (TIMES) Development at Capital Hotel on October 21 – 22, 2019

d) Organized capacity building training on Ethiopia's Energy Systems Model (TIMES) Development at MoWIE on October 23 – 24, 2019

Intension was to provide desk-to-desk service (one-by-one service as well as Q&A) at MoWIE at the end of the capacity building training

Building Blocks of the Ethiopia TIMES model



Ethiopia-TIMES model

- Modeling framework developed for entire Ethiopian energy system
- Raw data for all sectors (residential, industry, commercial, agriculture, transport) included
- Selected existing and prospective technologies for all sectors included with raw data
- Alternative policy scenarios information added
- Key parameters for energy demand projection are added

Priority was given to the electricity sector development plan and the team focused on selected priority policy scenarios and results that will presented by Alebachew (MoWIE)

Thank You

Contact:
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a.mondal-nsf@cgiar.org

Ministry of Water, Irrigation and Energy (MoWIE)
International Food Policy Research Institute (IFPRI)

Modelling and Optimization of Future Ethiopian Energy Systems Using TIMES

By Alebachew Azezew
Senior Energy Researcher

September 30, 2020

Outline

- Background
- Model Development and Scenarios
- Ethiopia -TIMES Electricity Model
- Scenario Development
- Reference Energy System
- Model Results

Background: Key Economic Figure of Ethiopia

Economic Indicators	Values
GDP (2018)	$83.84 billion USD
GDP per capita (2018 USD, PPP)	$220 USD
GDP Growth (2016, 2017, 2018)	+7.6%, +10.2%, +7.5%
Population (2018, million)	108
Access to electricity (2017)	45%
Urban	85%
Rural	29%
Power Consumption per Capita in KWh (2017)	77
CO_2 emissions (million metric tons, 2018)	14MT
Annual per capita energy consumption in KWh (2020)	1269
Transmission and Distribution infrastructure coverage (2019)	44%
Transmission and Distribution Loss (2020)	18%
Electricity Export million KWh (2015)	166

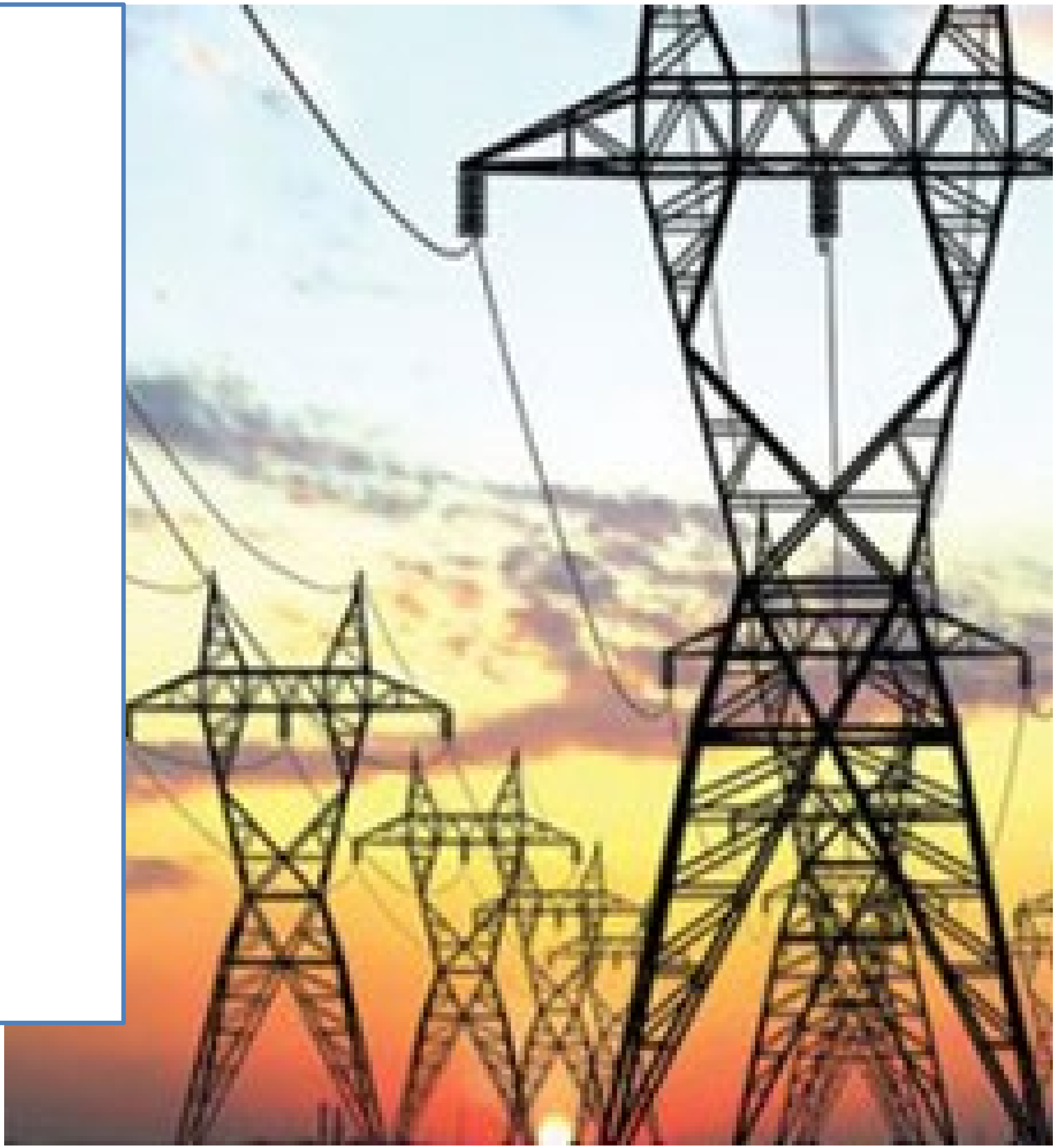
Background Cont'd
Energy Resources Potentials of Ethiopia

- Hydropower potential 45,000 MW
- • Small scale hydropower is estimated to be 7% of the total hydropower potential (3000MW).
- Geothermal potential ~ 10,000 MW
- Solar energy potential 5.5 kWh /sq. m/day – annual average daily irradiation
- Average wind speed > 7 meter/second at 50 m above ground level – 1,350 GW
- Wood – 1,120 million tones (annually exploitable)
- Agro-waste – 15 to 20 million tones (annually exploitable)
- Natural gas - 4 TCF (113 billion m^3)
- Coal > 300 million tones.
- Oil shale – 253 million tones

Background Cont'd
Overview of the energy sector

- Generation capacity in the grid(till 2020) – 4,482 MW
- Hydro – 3,810 MW ~ **(89%)**
- Wind – 324 MW ~ **(7.6%)**
- Geothermal – 7 MW ~ **(0.1%)**
- Diesel – 143 MW ~ **3-3%**,
- Electrified towns > 5,000, Customers more than 2 .5 million

Model development and scenarios



Ethiopia - TIMES Electricity Research Model

- Ethiopia-TIMES model is composed of four modules

(1) primary energy resources,

(2) process and conversion technologies,

(3) demand of electricity,

(4) GHG emissions.

- Ethiopia TIMES model is a single-region model
- covering the entire Ethiopia electricity system from resource supply to end use

Model description

- The objective of developing the Ethiopia Electricity TIMES model was to know the expected future energy demand, cost of energy production and new technologies and emission reduction over simulation time horizon (2014 – 2050).
- Ethiopia TIMES electric model has a time horizon of 36 years (2014 – 2050) in 9 unequal time periods

Model Assumptions(Overall Assumptions):

- The following assumptions have been taken into consideration in the model:

➢ The real discount rate is 10%

➢ The monetary units are in USD

➢ The timeframe of the model spans from 2014 to 2050, with yearly basis simulations

➢ In order to capture the key features of electricity demand load pattern, each year has been divided into THREE seasons and two day parts are considered

➢ Transmission and distribution losses are defined on a national level.

Over view of selected key conversion technologies

Technology Name	Year of introduction	Investment cost(MUSD/GW)	Fixed O & M cost(MUSD/GW/year	Fixed O & M cost(MUSD/PJ/year	Efficiency	Life Time
Pulverized coal Sub-Critic	**2020**	2012	40.24	1.15	0.39	35
Coal GCC	**2025**	2770	69.25	5.75	0.45	40
Diesel 01	**2016**	461	365	0.30	0.25	25
Diesel 02	**2020**	825	9	5	0.32	30
Biomass 01	**2020**	3081	67.78	1.12	0.42	35
Natural gas steam turbine	**2020**	800	35	3.0	0.55	35
Natural gas combined cycle	**2020**	917	13.20	1.00	0.34	25
Hydro Dam	**2020**	2079	62.37	0.96	1.0	50
Hydro run of river	**2020**	2000	60	0.96	1.0	25
Wind 01	**2020**	1800	45	0	1.0	25
Wind 02	**2030**	1800	60	0	1.0	25
Geothermal 01	**2020**	4007	100.18	0	1.0	30
Solar PV	**2020**	2000	25	0	1.0	25
Solar CSP	**2020**	3200	67.3	0.01	1.0	25

Scenarios Development

I. **A Base-case (reference scenario):** This scenario does not take any policy intervention and considers a continuation of existing energy economic dynamics of the country. It serves as a reference for comparing alternative policy options, their technology selection, investments, technology capacity, production, fuel consumption, energy requirement, electricity import and export, cost, and GHG emissions of the electricity consuming sectors.

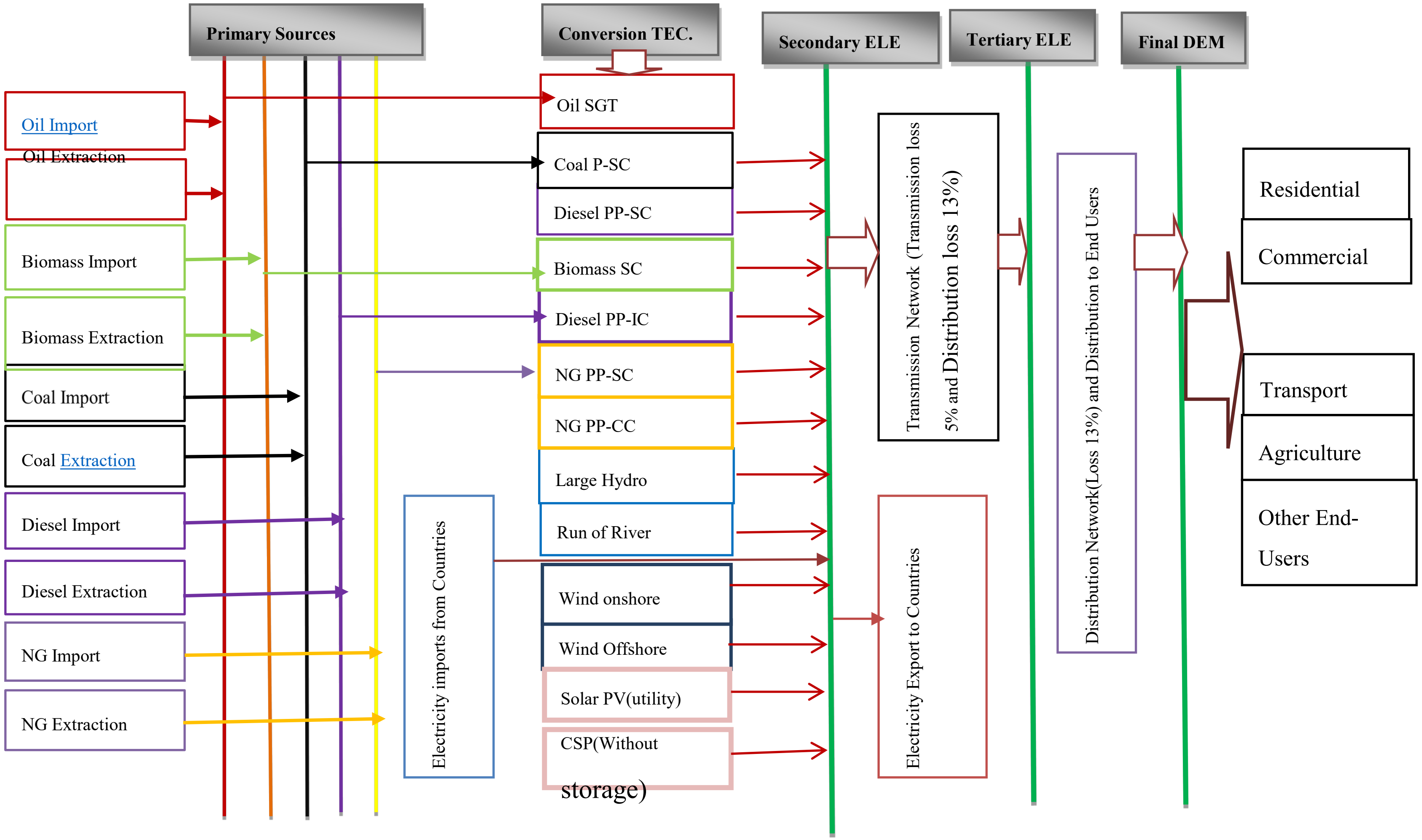
II. **High Demand Scenario:** This scenario take HIGH GDP policy intervention and considers a continuation of existing energy economic dynamics of the country and the study assumes annual average GDP growth rate of 12% in 2015 in this scenario consideration and also for the remaining 2015 – 2030 and 11% for remaining modelling years(2030-2050).

Scenario Developments

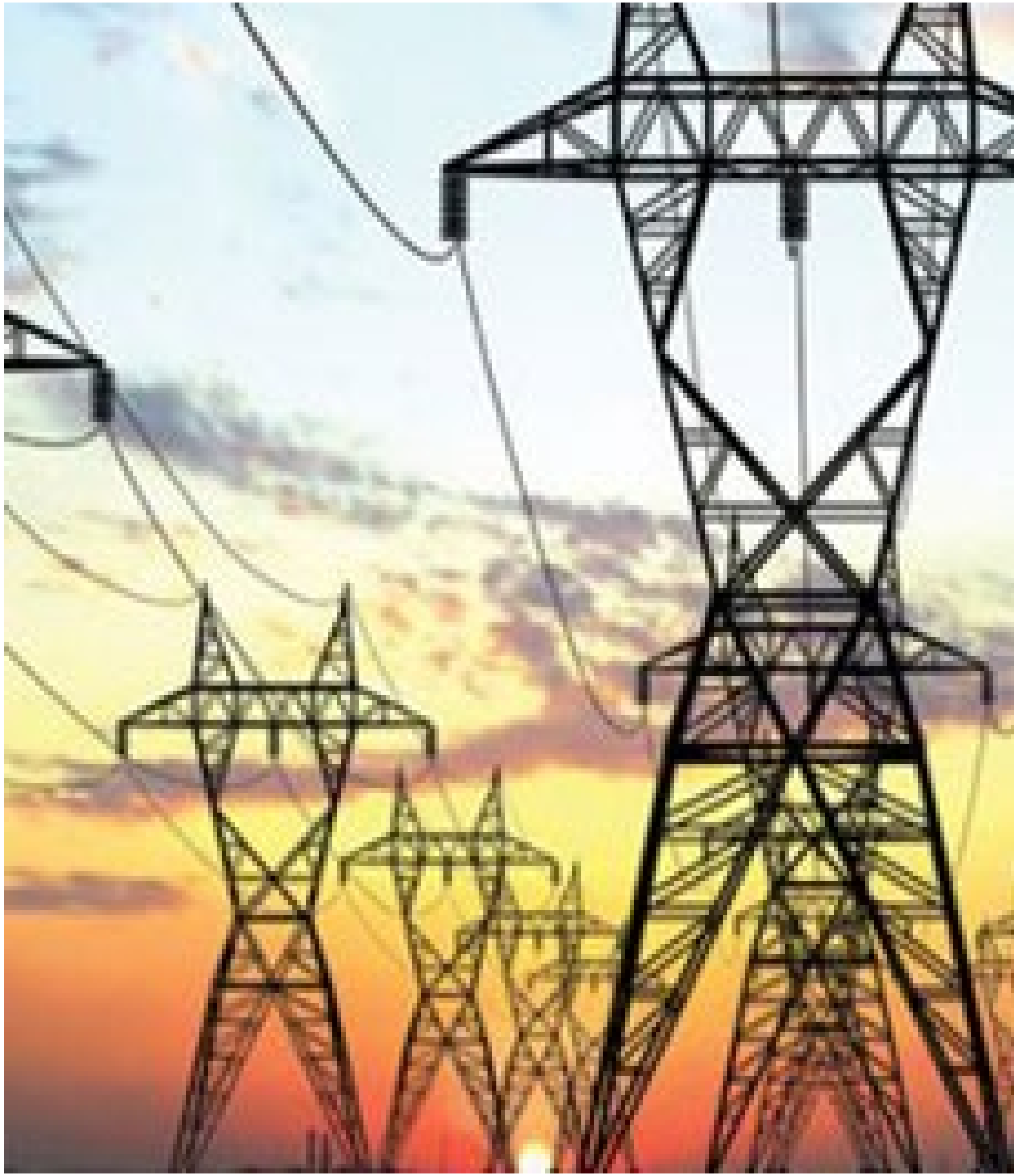
III. **Renewable-target scenario (REN.TARG 2025 &40):** This is the "what if" scenario, in which a certain share of renewable based power generation is targeted to meet the country's high electricity demand. It evaluates the impacts of a targeted renewable-based power (except hydro) generation in the future. The scenario targets a minimum of 20% of total power production by 2025 and 25% by 2040 as coming from solar, wind, and geothermal sources.

IV. **Electricity export (Export2020) scenario, beginning in 2020:** This scenario assesses the impact of exporting electricity the neighboring countries. Based on the Ethiopian electricity development plan, this scenario considers from 2019/2020 onwards an upper bound of electricity exports at 20 percent of total national electricity demand in 2030, and at 25 percent in 2050; this is designed to help determine the impact of exports on future power sector development.

Reference Energy System of Ethiopia



Model
Results



Reference Scenario: Technology installed capacity, power generation …..

Technology capacity(GW)	2016	2020	2025	2030	2035	2040	2045	2050
Bioenergy		**0.14**	0.14	**0.14**	**0.14**	**0.14**	**-**	**-**
Diesel	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Geothermal	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Hydro	4.06	4.77	4.77	5.98	7.77	10.28	13.94	18.96
Solar	-	-		-	-	-	-	-
Wind	0.32	0.40	0.40	0.38	0.36	0.34	0.31	0.29
Total	4.48	5.40	5.40	6.59	8.36	10.85	14.35	19.4
Electric Generation by Plant Type (TWh)								
Geothermal		**0.04**	0.04	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**
Hydro	11.5	26.20	26.20	35.12	48.08	66.08	92.16	127.8
Solar	-	-		-	-	-	-	-
Wind	1.14	1.36	1.36	1.28	1.20	1.12	1.04	.97
Total	12.60	27.60	27.60	36.44	49.32	67.24	93.25	128.8

Demand of Electricity in REF_EXPORT(2020) and HIGH_DEMAND scenario

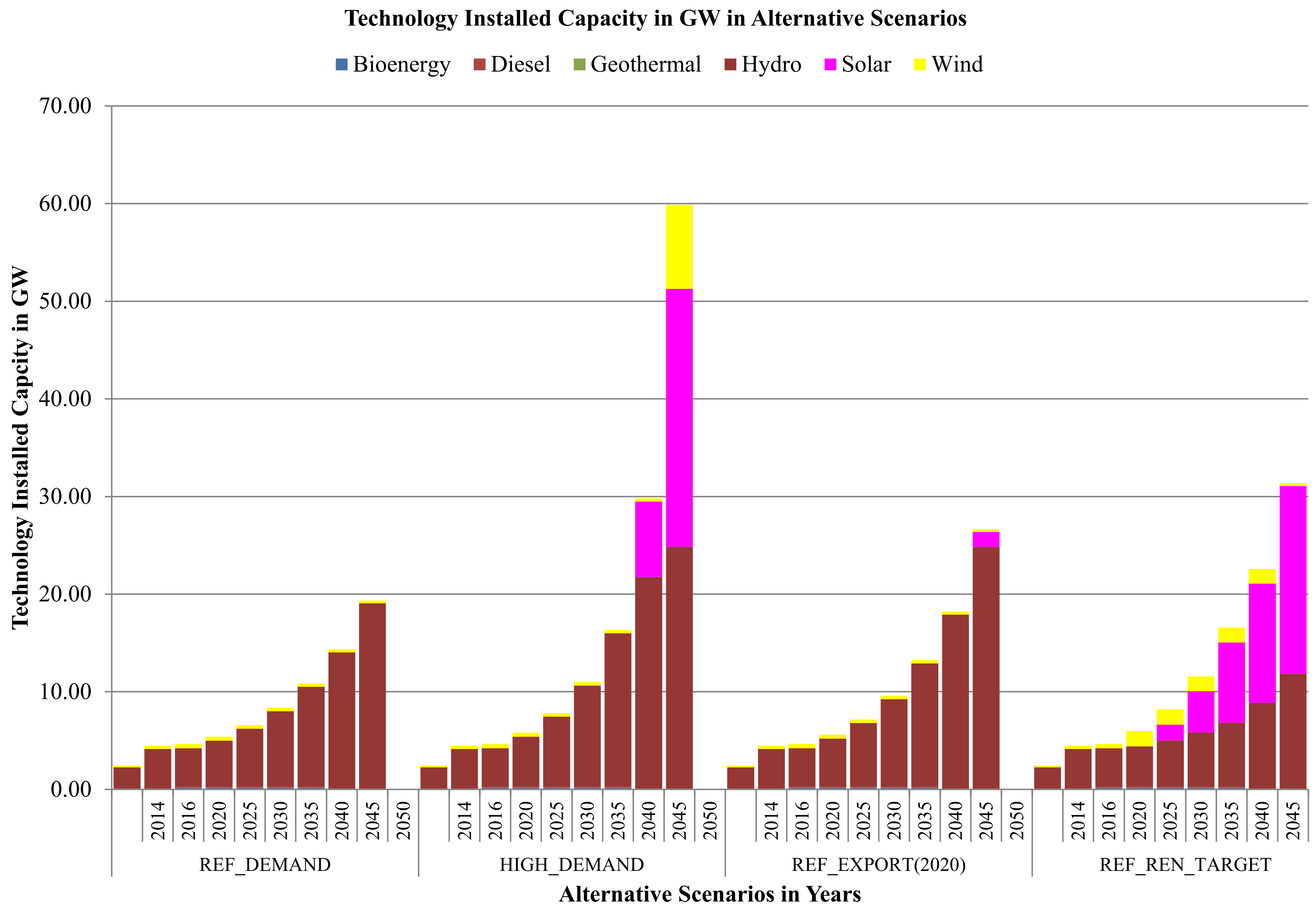
Demand of Electricity in the Reference Scenario in GWh

	Commodities	2016	2020	2025	2030	2035	2040	2045	2050
	ELC	12595.1	18057.3	27595.8	36439.3	49322.7	67243.3	93246.5	128770.5
	ELCD	10409.9	14924.4	22807.9	30117.1	40765.18	55576.6	77068.2	106428.9
	ELCE								
	ELCT	11965.3	17154.5	26215.9	34617.4	46856.5	63881.1	88584.1	122332.0
Demand of Electricity in the HIGH_DEMAND Scenario in GWh									
	ELC	12796.8	18975.3	30490.8	45054.3	67862.4	105727.7	166044.9	266224.5
	ELCD	10576.6	15683.1	25200.6	37237.3	56088.2	87383.9	137236.1	220034.6
	ELCE								
	ELCT	12157.0	18026.5	28966.2	42801.5	64469.2	100441.3	157742.7	252913.3

Discounted System cost for the Alternative Scenarios in 2014$M

HIGH_DEMAND	41352484.7		
REF_DEMAND	27084078.1		
REF_EXPORT(2020)	27087456.5		
REF.REN.TARG	27085251.2		

Results.. power generation technology and capacity



Power Generation Technology and Capacity…..

- The study results in the reference scenario in TIMES modelling show that:

- ➢ The country's total installed capacity for power generation is expected to grow from 6.59 GW in 2030 to 19.35 GW in 2050 of the modelling period .

- ➢ The contribution of large hydropower for power generation is the largest one, which is expected to grow from 5.98 GW in 2030 to 18.96 GW in 2050 which is an average annual growth rate of 33%

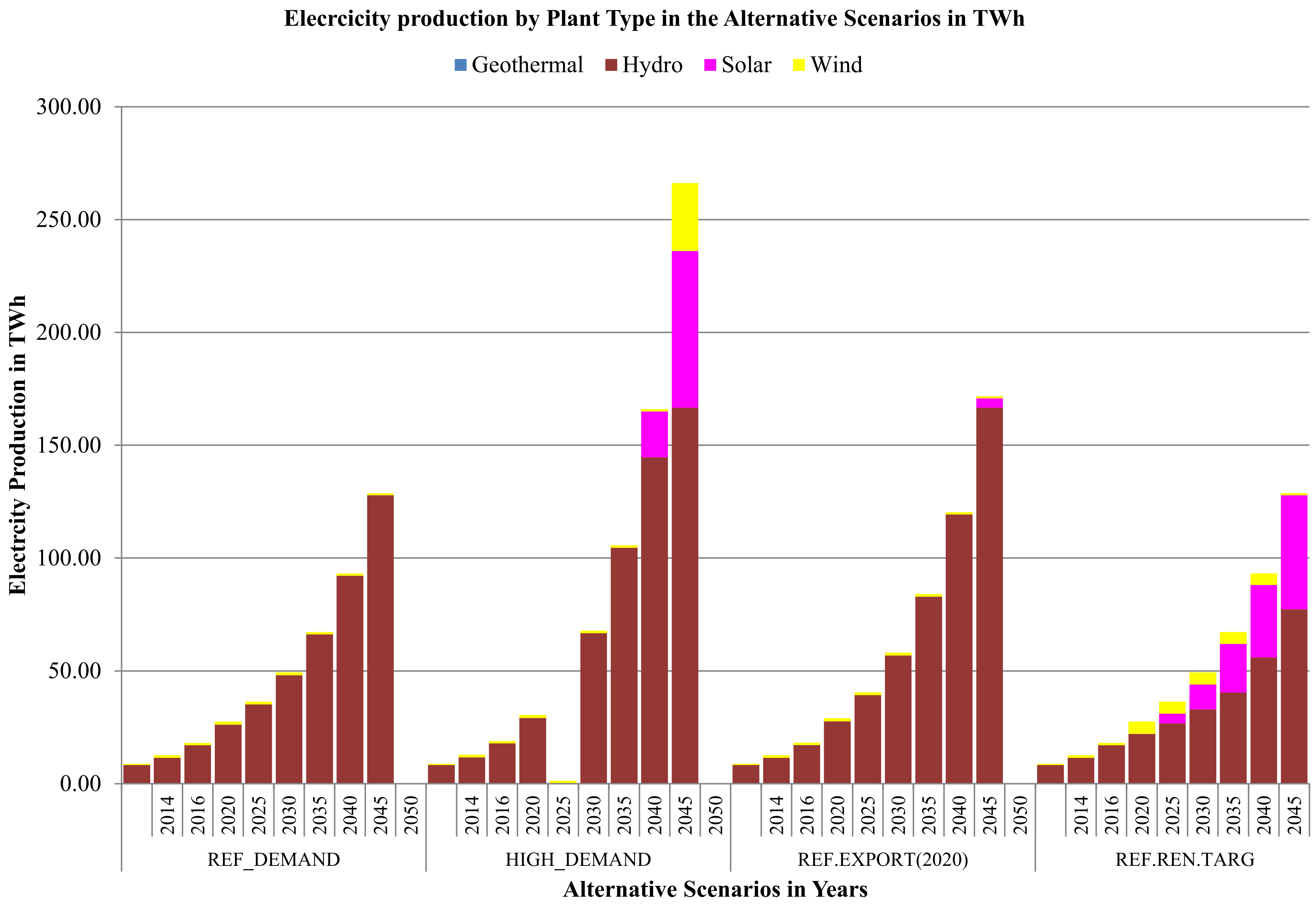
- ➢ The share of installed power capacity from wind sources will be start from 2025 but solar PV is not selected by the model until the end of the analysis period

- ➢ The Model Results also show that electricity production grows from 36.44 TWh in 2030 to 128.77 TWh in 2050 in the reference scenario

Power Generation Technology …Con’d

- In all alternative scenarios, power production from hydropower is still the dominant one and
- ➢ the export scenario and renewable targeted scenario, the power production from hydropower is 6.56 GW and 4.78 GW in 2030, respectively; and
- ➢ In 2050 their hydropower installed capacity are expected to be 24.74 GW and 11.75 GW respectively.
- ➢ In high demand scenario, power production is high compared to other scenarios and related to this 7.82 GW and 59.86 GW of total power are expected to be produced in 2030 and 2050, respectively.
- ➢ The model also selects the largest share of solar power generation capacity which is expected to be 19.22 GW in 2050 in the renewable targeted scenario.

Electricity Generation and Export



Electricity Generation…Cont’d

The study results in the reference scenario also indicate that:

- The share of electricity production from hydropower and wind technologies is expected to 35.12 TWh and 1.28 TWh in 2030, respectively;
- Similarly, their electricity production in 2050 will be 127.77 TWh and 0.97 TWh respectively.
- Hydropower still comprises the largest share of electricity production which is expected to grow from 35.1T Wh in 2030 to 127.77 TWh in 2050, which is annual average growth rate of 41% of total electricity production and 39% growth rate in 2050.
- Similarly, like power production, demand of electricity or total electricity production for all scenarios is increasing and related to this in high demand scenario in 2030 and 2050 ; 45.05TWh, 266.67 TWh of electricity are expected to be produced respectively.

Electricity Generation…Cont’d

- Specifically, electricity generation using solar PV-based technologies increases starting from 2030 to 2050 in the renewable targeted scenario, which is expecting to produce 11.05 TWh in 2035 and 50.50 TWh in 2050.
- In general, the modelling study results show that the main technologies contributing the electricity production in the power sector in 2050 in the renewable targeted scenario are large hydropower (77.26 TWh), Solar (50.50 TWh), and wind (0.97 TWh).
- Similarly, like power production, demand of electricity or total electricity production for all scenarios is increasing and related to this in high demand scenario in 2030 and 2050 ; 45.05 TWh, 266.67 TWh of electricity are expected to be produced respectively.
- wind and geothermal will be the second and the third in terms of their electricity production in the electricity export scenario with smallest share in 2050.

Gaps to close/Challenges

- Low Electricity Access: National Electric Access is 25% and must reach 100% by 2025; doing research on these areas is crucial by integrating different research institutes and universities
- Poor Grid Service Quality, Power interruptions are common and impair service reliability; doing research on these areas is crucial by integrating different research institutes and universities
- High Distribution and Transmission Losses; doing research on these areas is crucial by integrating different research institutes and universities

Gaps....

- Low Human Capacity: shortage of highly trained and skilled manpower in both technical and non-technical operations management.
- Limited Private Sector Engagement: Private sector engagement in generation, transmission, and distribution has been limited and in research areas
- **Weak Research Capacity/activities, no separated research energy institute center**

➢ Electrifying millions of households, remote communities and small-scale entrepreneurs remains challenge.

➢ Off-grid household systems and mini-grids along side the national grid are key to create energy access

Conclusion

- The study results in TIMES Ethiopia electricity modelling reflects that to satisfy the country's current power generation capacity, use of diversified supply of energy resources in addition to renewable sources needs to be diversified so as to the country to satisfy the country's high electricity demand
- The results also showed from the stated scenarios explained how the different parameters and constraints of the country like energy mixes from different sources, power generating technologies, energy production can be selected to address Ethiopia's energy demand growth, CRGE goal like CO_2 emissions, implementation of renewable technologies for power generation, for energy policy review and exploitation of indigenous energy resources at optimal level.

Conclusion Cont’d

- Lack of research in implementing modern energy is retarding economic growth, job creation, sustainable agriculture, health, education and constraint to 2030 Agenda for SD

➢ Ethiopia has huge energy resources potential; and investing with research application significantly in power generation, energy production is crucial


Thank You

Sustainability in the Water-Energy-Food Nexus

Diesel versus solar irrigation, what are the opportunities?

Hua Xie

Research Fellow, International Food Policy Research Institute, Washington D.C.

Capacity Building on Modeling the Ethiopian Energy System:
Final Workshop, September 30, 2020

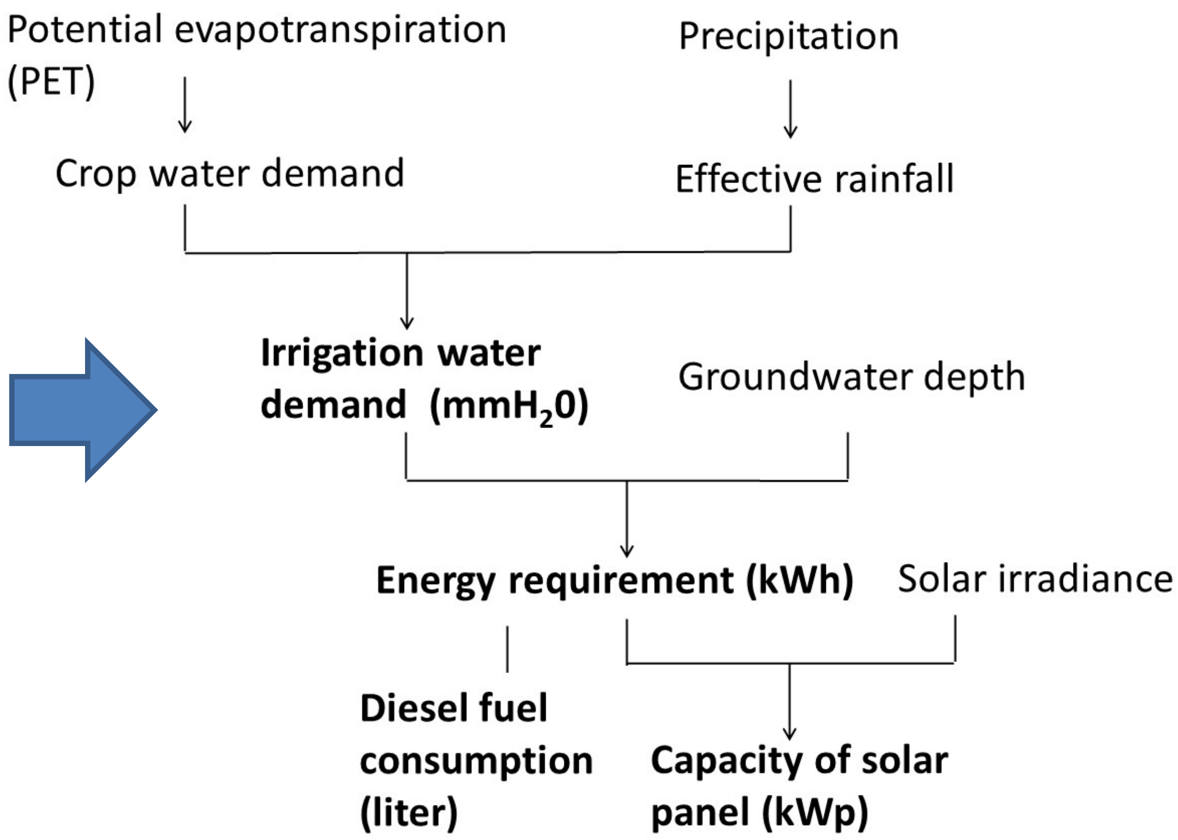
Motivation

- Productive energy use – a key to agricultural production growth and rural development
- Irrigation as main user of agricultural productive energy use
- Solar and diesel energy – two major off-grid solutions to meet demand of productive energy use in agriculture
- Solar energy – a more promising option to power irrigation development in Ethiopia?

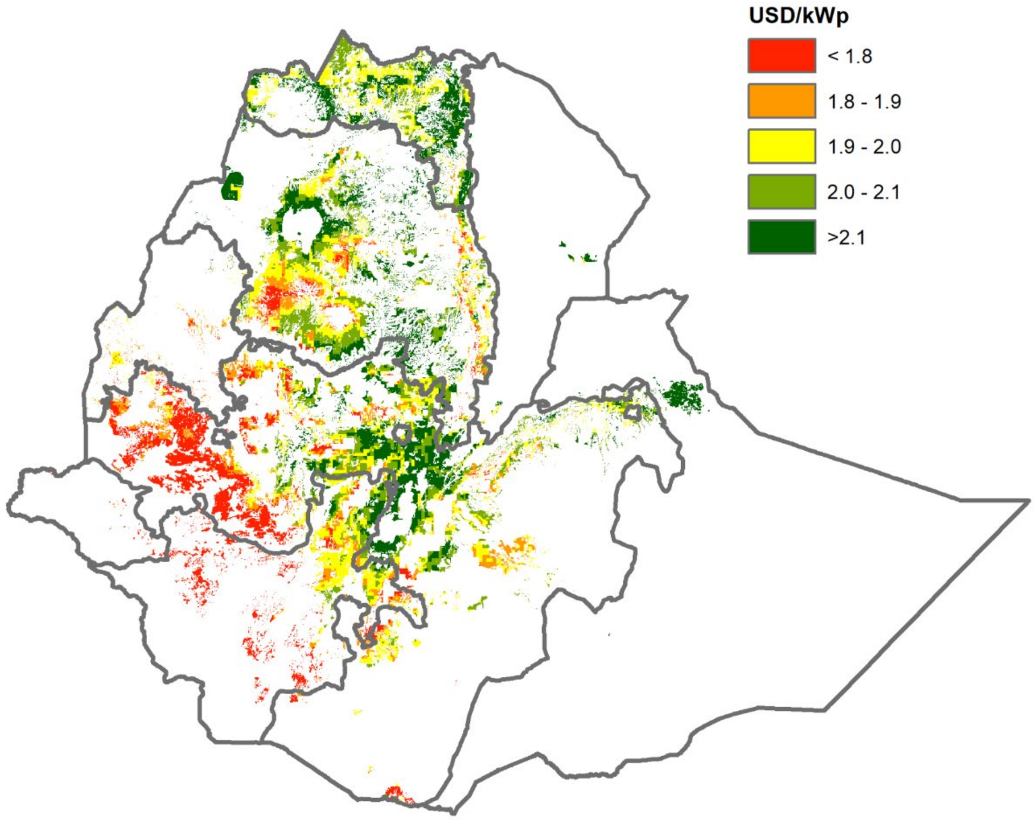
Methodology

Scenarios:

- Tomatoes
- Onions
- Chickpea
- Maize
- wheat



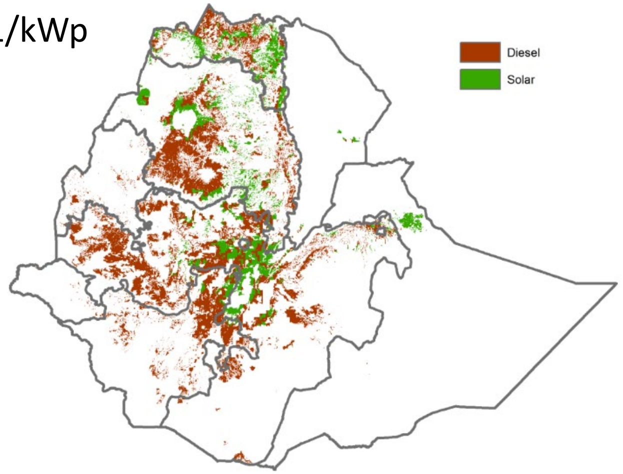
Breakeven installed cost of solar irrigation



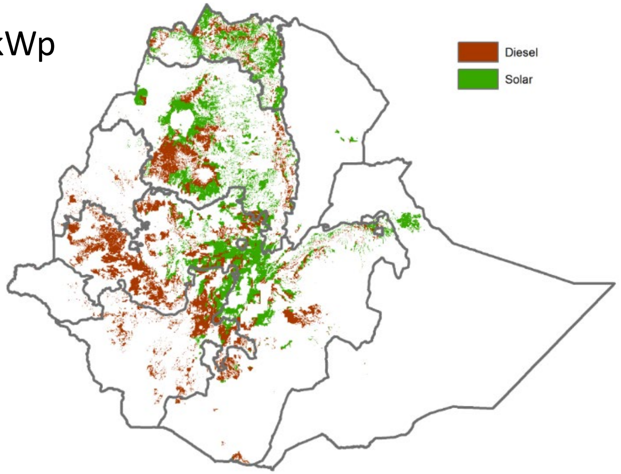
Maize

Solar energy development potential under different installed costs of solar power unit

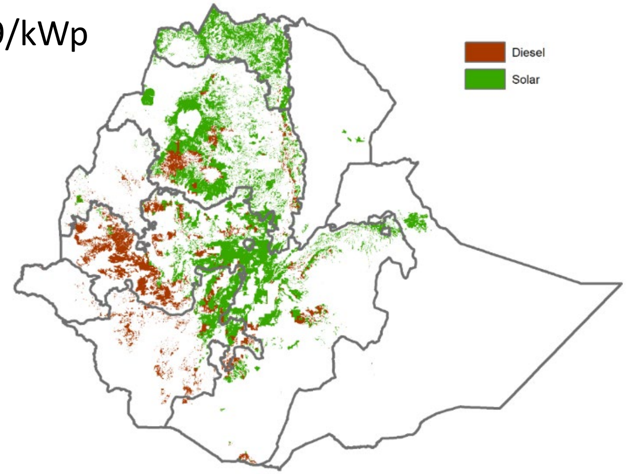
$2.1/kWp



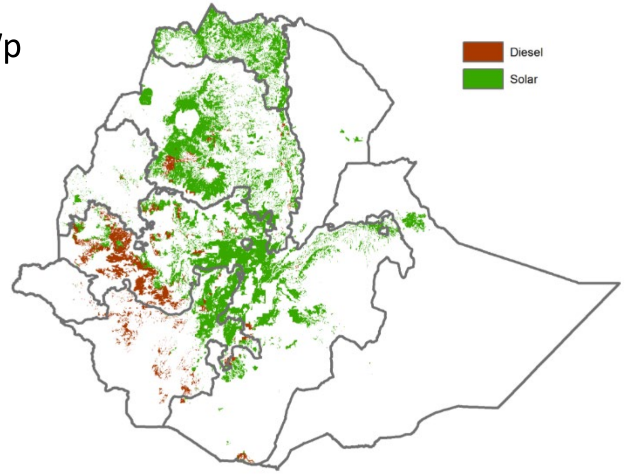
$2.0/kWp



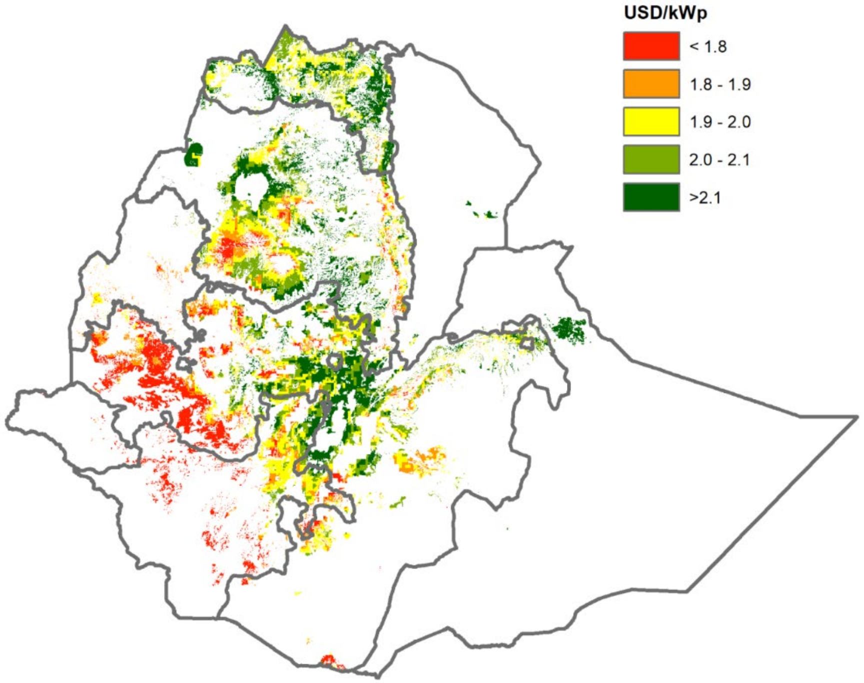
$1.9/kWp



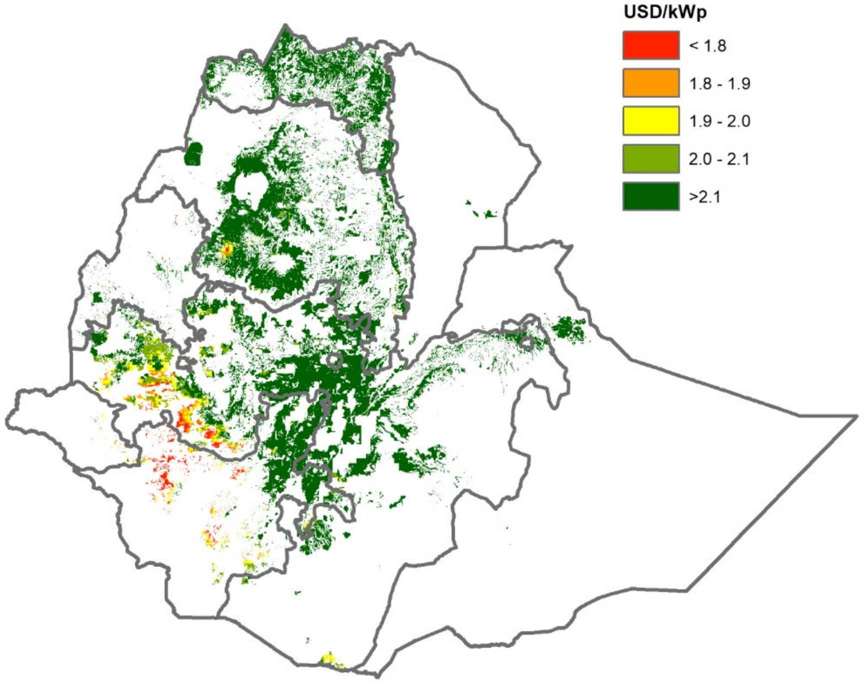
$1.8/kWp



Cost effectiveness of solar irrigation is sensitive to diesel fuel price



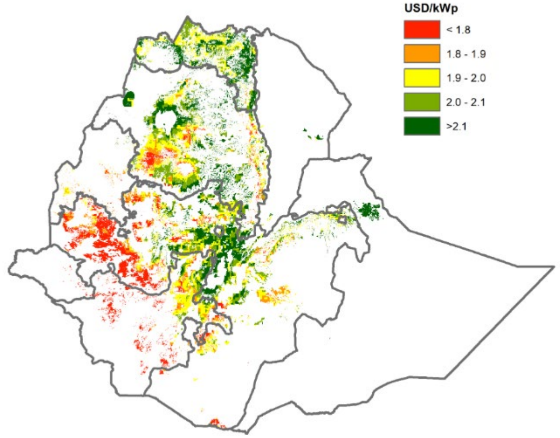
Maize (baseline diesel fuel price scenario)



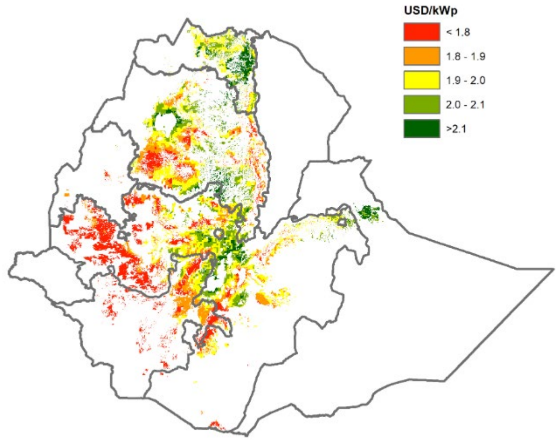
Maize (high diesel fuel price scenario)

Cost effectiveness of solar irrigation may vary with crop type

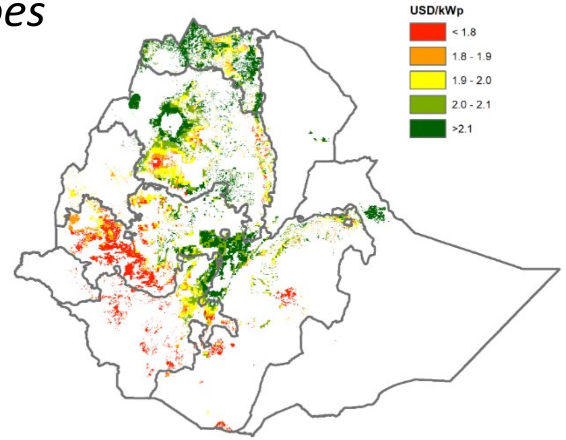
Maize



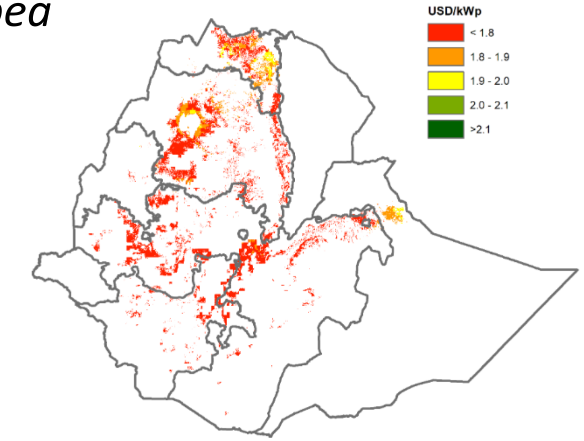
Wheat



Tomatoes



Chickpea



Conclusions

- Mapping product designed to inform energy technology selection for irrigation water pumping was developed
- Ethiopia possesses large potential to adopt solar irrigation
- Sensitivity of cost effectiveness of solar irrigation to installed cost of solar power unit, diesel fuel price and crop type highlights the risk in investment in solar irrigation

Acknowledgement

- *This project is part of the CGIAR Research Program on Water, Land and Ecosystems (WLE) and supported by CGIAR Fund Donors. The opinions expressed herein are those of the authors and do not necessarily reflect the views of WLE & CGIAR.*

Thank you !

Productive uses of electricity access in Ethiopia

Dawit Mekonnen

Environment and Production Technology Division
International Food Policy Research Institute (IFPRI)

Capacity Building on Modeling the Ethiopian Energy System: Final Workshop
30th September 2020

Key productive uses of energy in the agriculture space

- Farm/household level food vs fuel tradeoffs
- Energy as a requirement for agricultural intensification (irrigation, mechanization, fertilizer) - energy input for ag
- Electricity for value addition

Food Vs Fuel linkages - Mekonnen et. al, 2017

- Time spent collecting biomass energy sources reduce labor allocated to agriculture, but it depends on when the biomass energy sources are collected and who does the collecting.
- Rural households with and without electricity spend the same amount of time on collecting fuel wood, dung, and other biomass.
- Removal of dung and crop residues results in loss of soil fertility
- Lack of access to electricity (56% of the population) and to electric appliances made 81% of people remain reliant on fuelwood for cooking (FAO 2014)

Energy input for agricultural intensification

- Only ~ 6% of the total potential irrigated land was irrigated until recently.
- Ethiopian agricultural mechanization is about 0.1 kW/ha. India's level of mechanization was approximately 2 kW/ha in 2014, and China's was over 6 kW/ha.
- Most of the energy in Ethiopia's agriculture is the one embodied in chemical fertilizers, which has increased significantly in the last two decades.
- Investment in agriculture continues to be GoE's priority with greater emphasis on infrastructure, including water and irrigation schemes
- At least 13 ongoing large scale irrigation projects with a combined command area of more than 400,000Ha

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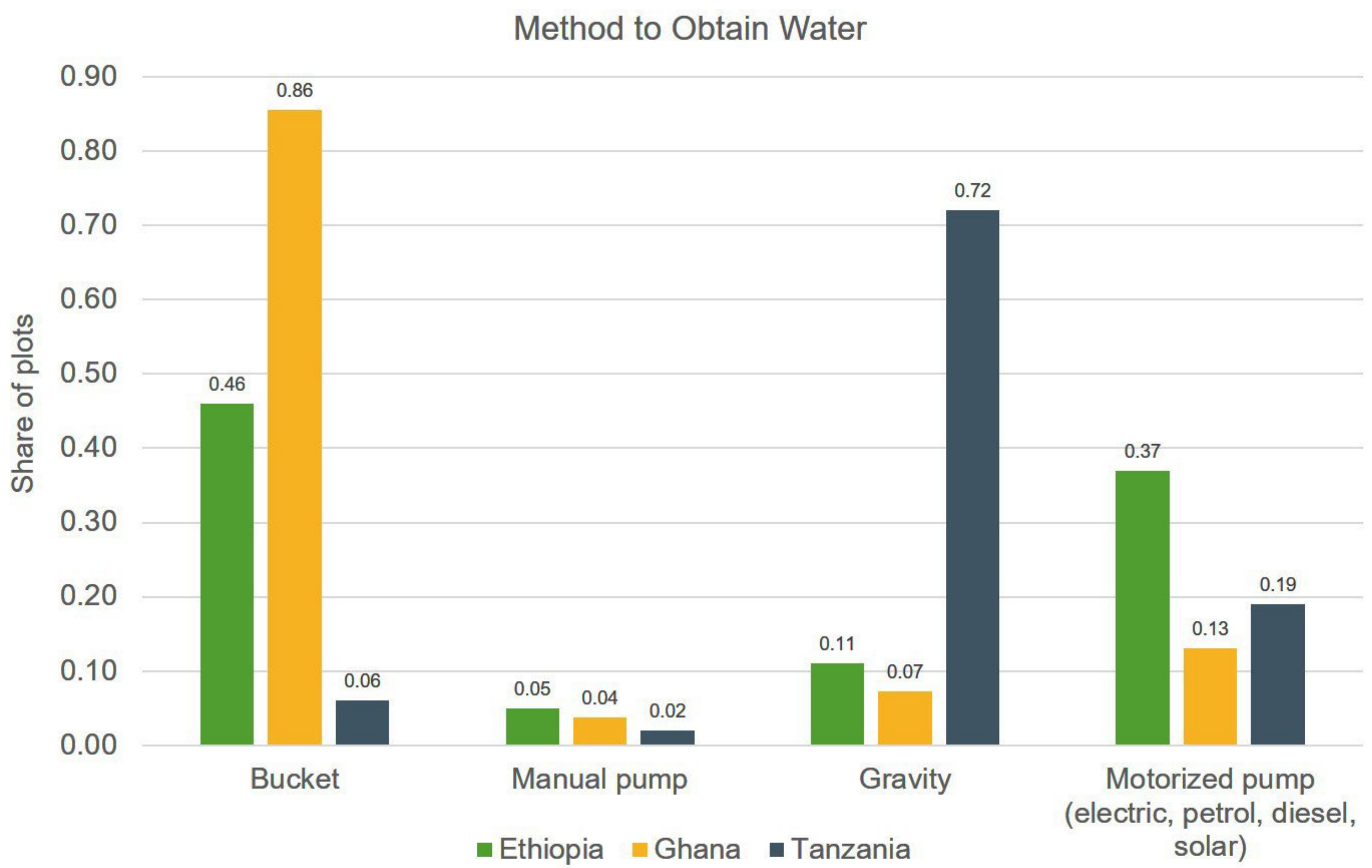
Agricultural intensification is hampered by lack of energy supply for irrigation



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Energy/Electricity for value addition

- Electrification has great potential to help rural small holders power increased agricultural productivity, unlock local processing activities, and create new businesses.
- Borgstein et. al (2020) examined six agricultural production and processing opportunities for rural areas in Ethiopia: horticulture irrigation, grain milling, injera baking, milk cooling, bread baking, and coffee washing.
- These areas have the potential to produce US$4 billion in annual value using electric appliances by 2025.
- Supplying the appliances is itself a US$380 million investment opportunity.
- These six areas can produce an additional US$22 million annual revenue stream for the utility by 2025, by selling more units of power with the same capital investment.

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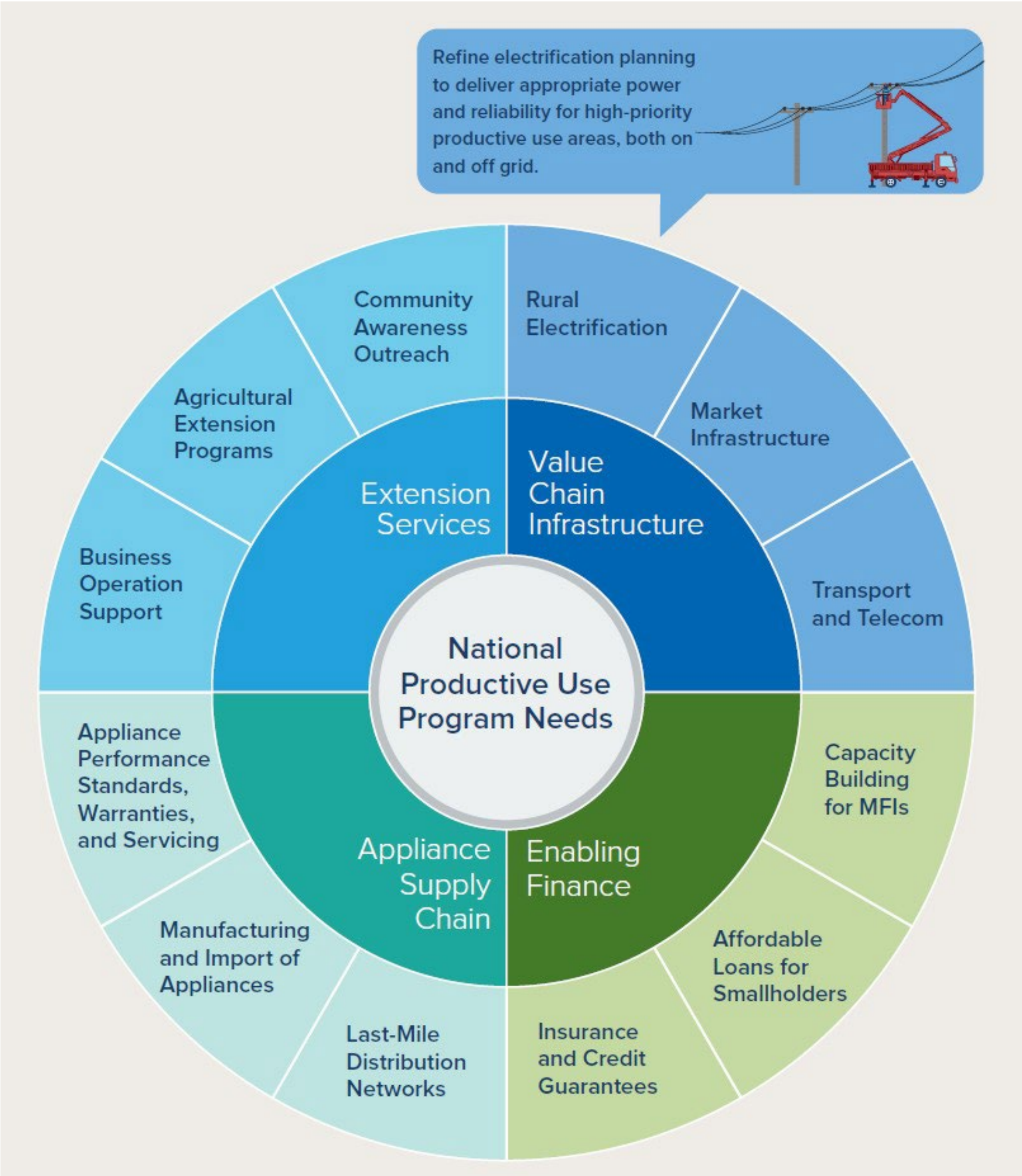
What needs to happen? Borgstein et. al (2020)



THANK YOU

Capacity Building for an Energy-Secure Future of Ethiopia-Final Workshop

September 30, 2:00pm - 4:00pm EAT (Ethiopia time)