Electricity sector subsidies and reforms in Ethiopia:
An Economy-wide Analysis

Amsalu Woldie Yalew

Ca' Foscari University of Venice (UNIVE)
Euro-Mediterranean Center on Climate Change (CMCC)

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Outline

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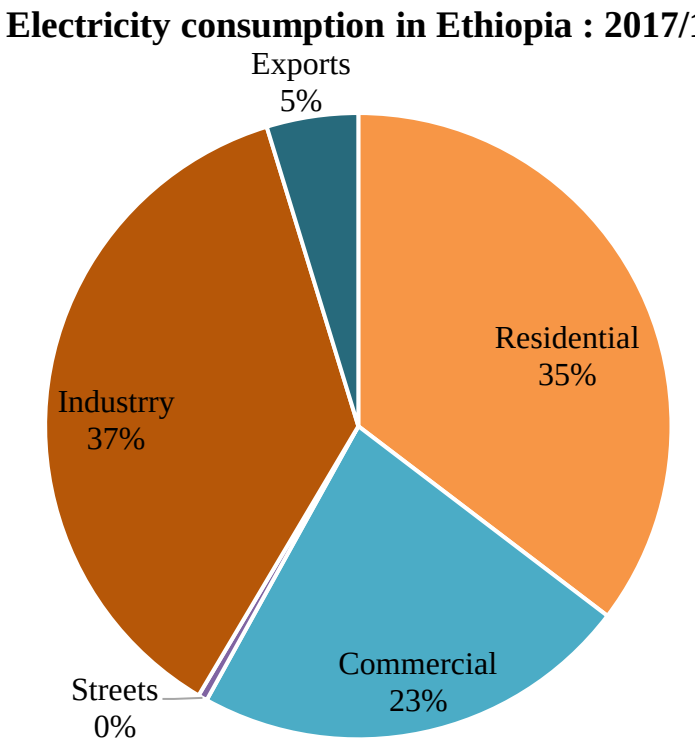
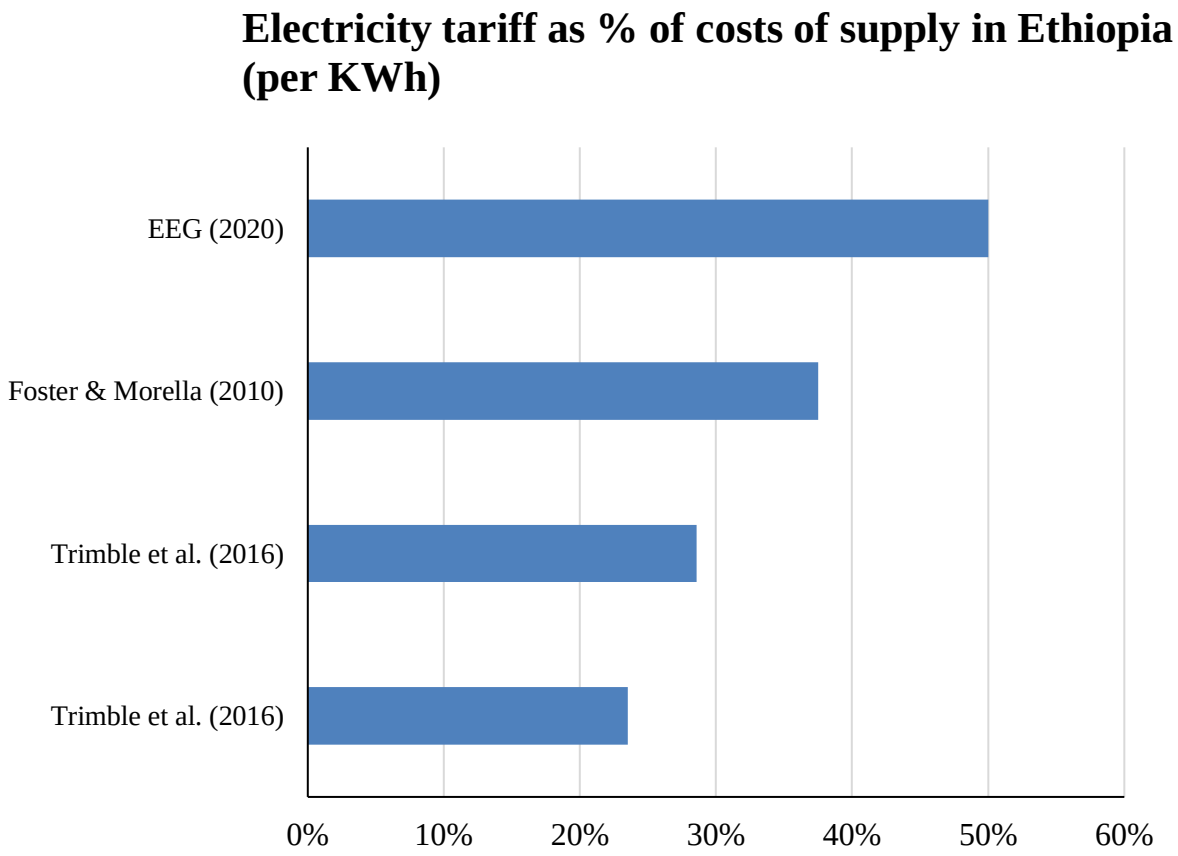
Introduction – Background

- The Ethiopian energy system is dominated by **biomass** fuels (> 85%) where **electricity** accounts barely **3%** of total energy [IEA, 2022]
- More than **50%** of Ethiopians have **no** access to electricity [World Bank, 2018]
- **Low per capita** electricity consumption, ≈ 100 KWh/year, compared to the sub-Saharan Africa [MoWIE, 2018]
- Electricity is dominated by **hydropower** sources and susceptible to climate change [MoWIE, 2018]
- The power sector is monopolized by **state-owned enterprises** (SOEs) [UNECA & RES4Africa, 2021]



Source: CSA (2018)

Introduction – Background



- **Low electricity** tariffs: US$ 0.04-06/KWh [EEG, 2020; Trimble et al., 2016]
- One of the **lowest** in the world and Africa [Teshome, 2022 ; Trimble et al., 2016; Foster & Morella, 2010]
- The tariffs are far **below** the supply costs [Tesfamichael et al., 2021]
- Could **not even cover generation costs** [Teshome, 2022; World Bank, 2019]

Introduction – Motivation

- Why are the electricity tariffs in Ethiopia low?
- Historically, power infrastructure has been developed through **central planning** and **public financing** [Tavoulareas, 2020; Trimble et al., 2016]
- This passes higher financial burden on the public sector

Indicator	Power sector (%)
Corporate bonds [NBE, 2021]	*75*
Public investment in major infrastructure [Nuru, 2019; MoWIE, 2013]	*31*
Outstanding external public debts [MoF, 2020]	*17*

Introduction – Motivation

REFORMS

- 2011: Climate-Resilient Green Economy (CRGE)
- 2015: Nationally Determined Contribution (NDC)
- 2018: Public-private partnership (PPP)
- **2018: Increase electricity tariffs**
- 2020: New investment law opening the sector to private sector
- 2020: Mini-grid directives

GOALS

- Significantly reduce GHG by 2030
- Achieve full electrification by 2025 (35% of households from off-grid)
- Increase power exports
- Diversify the sources of power
- **Increase private investment**
- **Recover costs of electricity supply**

Growing interest from independent power producers **(IPPs)** [UNECA & RES4Africa, 2021]

IPPs did **not start generation** [UNECA and RES4Africa, 2021]

"Electricity tariffs **must double** to sustain profits" in state-owned utilities [Teshome, 2022]

Are the regulated electricity tariff changes rendering what is expected?

Introduction – Research Question

- **What if** the government rather decides to gradually *remove* the implicit *subsidies* to the power sector?

- And what would be the economy-wide effects of such policy changes?
  - *On the electricity market – demand and supply*
  - *On rest of the economy – electricity as input and export item*
  - *The implications for the rest of power sector goals*
  - *On the climate change mitigation policies*

Related Literature

- **Quasi-Fiscal Deficits** (QFD) of state-owned public utilities
  - "The value of the *implicit subsidy* computed as the *difference* between the average *revenue* charged and collected at *regulated prices* and the revenue required to *fully cover the operating costs of production and capital depreciation*" [Trimble et al., 2016]
  - Also known as "**implicit subsidy**" or "**hidden cost**" [Trimble et al., 2016; Foster & Morella, 2010]

- QFD due to state-owned power utilities in Ethiopia
  - Absolute values: **US$ 402–636 million** [Trimble et al., 2016]
  - Relative to utility revenue: **132%** [Foster & Morella, 2010], **223-353%** [Trimble et al., 2016]
  - Relative to current GDP: **1.1-1.7%** [Trimble et al., 2016], **1.3%** [Foster & Morella, 2010]

Materials & Methods – Modelling Approach

- The study applied an economy-wide computable general equilibrium (CGE) model [JRC, 2021]
  - CGE models help to track both direct and indirect effects of a policy reform on different parts of the economy

- Some features of the model applied
  - Flexible nesting of production functions
  - Flexible nesting of household utility/demand systems
  - Designed and widely applied for African economies

Materials & Methods – Model Calibration

- The CGE model is calibrated to a modified and updated version (by author) of the 2015/16 Ethiopian SAM [Mengistu et al., 2019]

- Among others,
  - Introduced production subsidies (or negative taxes) for selected electricity activities
  - Disaggregated electricity generation by technology (and hydropower further by basin)
  - Included several energy fuels (inc. agricultural wastes)
  - Explicit accounting of electricity demand for irrigation/agriculture and railways/transport

Materials & Methods – Model Calibration

Electricity activities in the SAM (billion ETB, 2015/16)

Activities	Output	Share
Sugar Manufacturing, Bagasse	0.187464	0.015
Off-grid, Diesel	0.07988	0.006
Off-grid, Renewables	0.062701	0.005
Grid, Hydro, Abbay basin	1.080714	0.086
Grid, Hydro, Omo basin	3.456919	0.275
Grid, Hydro, Awash basin	0.15891	0.013
Grid, Hydro, Tekeze basin	0.419002	0.033
Grid, Hydro, Wabi-Shebele basin	0.213536	0.017
Grid, Hydro, Rest of Basins	0.014277	0.001
Grid, Renewable, Wind	0.453143	0.036
Grid, Renewable, Geothermal	0.009932	0.001
Grid, Renewable, Solar	0.018002	0.001
Grid, Renewable, Waste-to-Energy	0.034633	0.003
Grid, Non-Renewable, Diesel	0.160902	0.013
Grid, Transmission & Distribution	6.207432	0.494
TOTAL	12.55745	1

- Extract ***off-grid*** (diesel, renewables)
  - 1% [MoWIE, 2013]
- Grid ***Generation*** vs ***Transmission & Distribution (T&D)***
  - 50% [Chepeliev 2020; Pappis et al. 2021]
- Generation by ***technology*** (and by basin for hydro)
  - Installed capacities [Pappis et al. 2021; EAPP, 2014]
- The ***share of inputs*** per generation technology
  - LCOE - Levelized Costs of Electricity [GSE & JICA, 2015]

- **To model anticipated energy transition in the country**
- **To link with basin-specific modules and policies**

See also discussions in (Chepeliev, 2020; Willenbockel et al., 2017; Cai & Arora, 2015); Sue Wing, 2008; 2006).

Materials & Methods – Model Calibration

Electricity activities in the SAM (billion ETB, 2015/16)

	Off, DSL	Off, REN	HP, ABB	HP, OMB	HP, AWB	HP, TKB	HP, WSB	HP, ROB	RP, WND	RP, GEO	RP, SLR	RP, MSW	NP, DSL	T&D
	aogelecd	**aogelecr**	**ahpabb**	**ahpomb**	**ahpawb**	**ahptkb**	**ahpwsb**	**ahprob**	**arpwnd**	**arpgeo**	**arpslr**	**arpmsw**	**anpdsl**	**aeeu**
ccons														0.003
cwater												0.007		0.005
coilptrl	0.034		0.191	0.630	0.029	0.076	0.039	0.003	0.083	0.002	0.001	0.005	0.094	0.790
celect														0.050
cwoodp			0.003	0.010	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.012
crmnfg	0.005	0.013	0.282	0.887	0.041	0.108	0.055	0.004	0.116	0.003	0.003	0.007	0.032	1.050
crserv	0.009	0.013	0.439	1.400	0.064	0.170	0.086	0.006	0.183	0.004	0.001	0.003	0.002	1.761
ctrans														0.032
cheal														0.001
flbu	0.005	0.006												0.209
flbs	0.005	0.006	0.015	0.049	0.002	0.006	0.003	0.000	0.006	0.000	0.000	0.000	0.002	0.480
flbt	0.005	0.006	0.053	0.169	0.008	0.021	0.010	0.001	0.022	0.000	0.001	0.001	0.008	0.688
fkna	0.018	0.019	0.954	3.053	0.140	0.370	0.189	0.013	0.400	0.009	0.012	0.011	0.022	4.197
ptax			-0.857	-2.741	-0.126	-0.332	-0.169	-0.011	-0.359	-0.008				-3.069
total	0.080	0.063	1.081	3.457	0.159	0.419	0.214	0.014	0.453	0.010	0.018	0.035	0.161	6.207

Materials & Methods – Model Calibration

Energy commodities in the SAM (billion ETB, 2015/16)

	Agriculture	Industry	Transport	Services	Households	Exports	TOTAL	Share (%)
Electricity	0.066	4.206	0.452	3.272	3.896	0.665	12.56	**7.40%**
Petroleum	0.261	22.246	37.095	7.735	4.920		72.26	**42.56%**
Fuelwood				1.495	77.104		78.6	**46.29%**
Resdiues	*36.007*	*0.328*			2.427		2.427	**1.43%**
Dung	*2.5466*				3.725		3.725	**2.19%**
Biogas					0.07		0.070	**0.04%**
Biofuels			0.097		0.048		0.145	**0.09%**
TOTAL	0.327	26.452	37.644	12.502	92.189	0.665	169.779	**100%**
Share (%)	**0.19%**	**15.58%**	**22.17%**	**7.36%**	**54.30%**	**0.39%**	**100%**	

- Non-energy use of agricultural wastes is not considered in calculating the energy shares

- Allow imperfect substitution between energy commodities – CES
- Capture the *fuel stacking* behavior of the households
- Easy to link with sector-specific modules [e.g., SEEA-Energy, 2019]
- Capture the agriculture–energy nexus, e.g., agricultural wastes

Materials & Methods – Regulatory Reform

- **Baseline (BAU) scenario**
  - Runs for the period from 2016 to 2030
  - Driven by exogenous economic growth rates [IMF, 2022], and population growth rates [UN, 2022]
  - Economic growth rates (e.g., 3.84% in 2022) considers the impacts from recent crises such as the COVID-19, droughts, and armed conflicts [IMF, 2022]

- **Regulatory Reform (implicit subsidy removal) scenario**
  - Gradually reducing the "implicit" subsidies to the electricity production activities
  - The subsidies decline by 10% every three years, starting from 2019, until it declines by 50% in 2030
  - The policy reform scenario implemented here is an **indirect approach** (compared to the direct and actual steps taken by the government which to gradually increase electricity tariffs starting from 2019)
  - As such, it should be considered as a hypothetical scenario

- **Results**
  - Are reported as **percentage changes** relative to the baseline economy

Results – Macroeconomy

Effects on the macroeconomy (% change)

Year	Prv.Cons	Gov.Cons	Invest	Imports	Exports	GDP
2019	-0.03	0.26	0.01	-0.01	-0.03	0.00
2020	-0.03	0.26	0.00	-0.01	-0.03	0.00
2021	-0.03	0.27	0.00	-0.01	-0.03	0.01
2022	-0.07	0.54	0.01	-0.02	-0.07	0.01
2023	-0.06	0.54	0.01	-0.03	-0.07	0.01
2024	-0.07	0.55	0.01	-0.03	-0.07	0.01
2025	-0.10	0.83	0.01	-0.05	-0.12	0.02
2026	-0.10	0.85	0.01	-0.05	-0.13	0.02
2027	-0.10	0.86	0.01	-0.06	-0.14	0.02
2028	-0.14	1.16	0.02	-0.08	-0.20	0.03
2029	-0.14	1.18	0.02	-0.09	-0.21	0.03
2030	-0.18	1.50	0.02	-0.13	-0.29	0.03

- The impact on many of the macroeconomic variables are **negligible**
- **Slight** increase in **government spending** following a slight increase in government revenue (i.e., because of lesser spending for subsidies)
- Note that electricity is part of the **export** items and thus aggregate exports react to the policy change.

Results – Sectoral Production

Effects on domestic production by sectors (% change)

Year	Crops	Livestock	Other.Prim	Food.Bev	Text.Wood	Rest.Man	Utilities	Const	Prv.Service	Pub.Service
2019	-0.01	-0.01	0.00	-0.02	-0.04	-0.03	-0.49	0.00	-0.02	0.22
2020	-0.01	-0.01	0.00	-0.02	-0.04	-0.03	-0.53	0.00	-0.02	0.22
2021	-0.01	-0.01	0.00	-0.02	-0.04	-0.03	-0.57	0.00	-0.02	0.22
2022	-0.02	-0.02	0.01	-0.03	-0.08	-0.05	-1.25	0.00	-0.05	0.45
2023	-0.02	-0.02	0.01	-0.03	-0.08	-0.05	-1.34	0.00	-0.05	0.45
2024	-0.02	-0.02	0.01	-0.03	-0.08	-0.05	-1.44	0.00	-0.05	0.46
2025	-0.03	-0.03	0.02	-0.05	-0.12	-0.09	-2.41	0.01	-0.08	0.69
2026	-0.03	-0.03	0.03	-0.05	-0.12	-0.09	-2.60	0.01	-0.08	0.70
2027	-0.03	-0.03	0.03	-0.05	-0.12	-0.09	-2.80	0.00	-0.09	0.71
2028	-0.04	-0.04	0.05	-0.06	-0.17	-0.13	-4.18	0.01	-0.12	0.96
2029	-0.04	-0.03	0.05	-0.06	-0.18	-0.13	-4.48	0.01	-0.12	0.98
2030	-0.04	-0.04	0.07	-0.08	-0.24	-0.17	-6.20	0.01	-0.16	1.24

- Effects on the output in most aggregate sectors is **negligible.**
- **Slight** increase in **government spending** on public services following its increased revenue to spend
- Notable decline is observed only in the **utilities** which include the **electricity** sector.

Results – Electricity Supply Mix

Effects on the supply mix (% change)

	Bagasse	Off-grid		Hydro						Wind	Geo	Solar	Waste	Diesel	T&D
Year	asug	aogelecd	aogelecr	ahpabb	ahpomb	ahpawb	ahptkb	ahpwsb	ahprob	arpwnd	arpgeo	arpslr	arpmsw	anpdsl	aeeu
2019	0.00	0.02	0.00	-0.70	-0.71	-0.71	-0.71	-0.71	-0.71	-0.69	-0.69	0.07	0.40	0.98	-1.43
2020	0.00	0.02	0.00	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.77	-0.77	0.07	0.46	1.03	-1.45
2021	0.00	0.02	0.00	-0.90	-0.91	-0.91	-0.91	-0.91	-0.91	-0.87	-0.87	0.08	0.52	1.08	-1.47
2022	-0.01	0.04	0.01	-2.17	-2.19	-2.19	-2.19	-2.19	-2.19	-2.05	-2.05	0.17	1.20	2.34	-3.00
2023	-0.01	0.04	0.01	-2.45	-2.47	-2.47	-2.47	-2.47	-2.47	-2.27	-2.27	0.19	1.33	2.43	-3.03
2024	0.00	0.05	0.01	-2.75	-2.76	-2.76	-2.76	-2.76	-2.76	-2.50	-2.50	0.20	1.46	2.50	-3.07
2025	-0.01	0.08	0.03	-4.93	-4.94	-4.94	-4.94	-4.94	-4.94	-4.41	-4.41	0.34	2.53	4.12	-4.65
2026	-0.01	0.09	0.03	-5.48	-5.49	-5.49	-5.49	-5.49	-5.49	-4.82	-4.82	0.36	2.74	4.23	-4.70
2027	-0.01	0.09	0.04	-6.07	-6.07	-6.07	-6.07	-6.07	-6.07	-5.26	-5.26	0.38	2.94	4.33	-4.75
2028	-0.01	0.14	0.06	-9.47	-9.44	-9.44	-9.44	-9.44	-9.44	-8.09	-8.09	0.58	4.47	6.36	-6.36
2029	-0.01	0.15	0.07	-10.33	-10.29	-10.29	-10.29	-10.29	-10.29	-8.71	-8.71	0.61	4.71	6.46	-6.42
2030	-0.01	0.22	0.10	-14.73	-14.66	-14.66	-14.66	-14.66	-14.66	-12.37	-12.37	0.87	6.68	8.94	-8.02

- Total grid electricity production declines from approximately 1% in 2019 to 8% in 2030
- Electricity supply mix changes – from subsidized (e.g., Hydro) to non-subsidized sources (e.g., Solar, Off-grid, Waste)
- Grid electricity supply price increases by approximately 1.4% in 2019 to 14.5% in 2030
- The shift to **decentralized** sources and increase in **prices positive** signal to the private investment in the power sector.

Results – Household Energy Mix

Rural Household Energy Mix (% change)

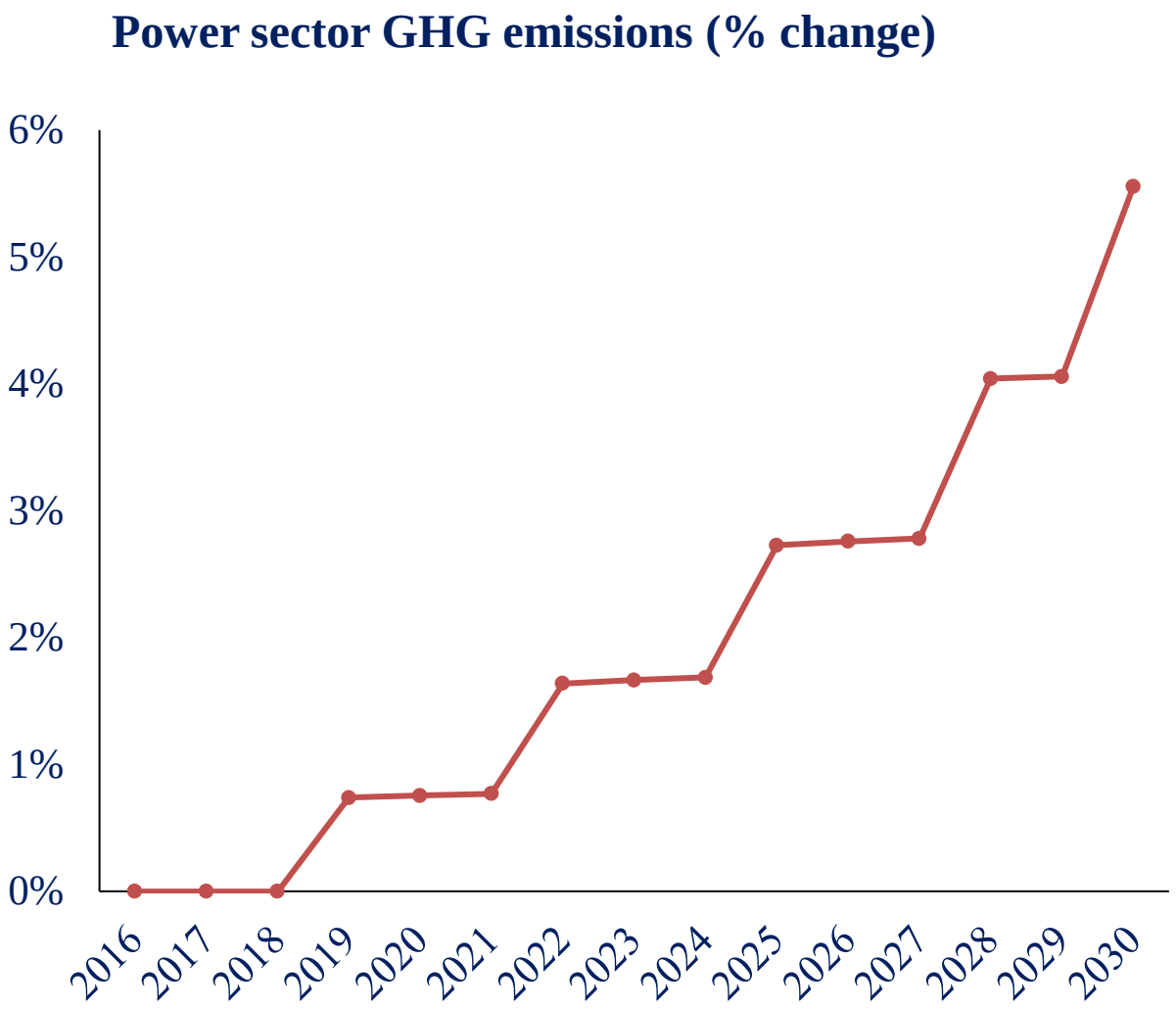
Year	Residues	Wood	Manure	Petroleum	Biogas	Ethanol	Electrcity, Off	Electriciy, Grid
2019	0.03	-0.01	-0.01	0.00	-0.01	0.01	-0.06	-2.88
2020	0.03	-0.01	-0.01	0.00	0.00	0.02	-0.06	-2.96
2021	0.03	-0.01	-0.01	0.00	0.00	0.02	-0.05	-3.05
2022	0.06	-0.02	-0.02	0.01	-0.01	0.03	-0.11	-6.44
2023	0.06	-0.02	-0.02	0.01	-0.01	0.04	-0.11	-6.67
2024	0.06	-0.02	-0.02	0.01	-0.01	0.04	-0.10	-6.92
2025	0.09	-0.02	-0.03	0.02	-0.01	0.06	-0.16	-11.11
2026	0.09	-0.02	-0.03	0.03	-0.01	0.06	-0.15	-11.58
2027	0.09	-0.02	-0.03	0.03	-0.01	0.07	-0.15	-12.07
2028	0.13	-0.01	-0.04	0.05	-0.01	0.09	-0.20	-17.25
2029	0.13	-0.01	-0.04	0.06	-0.01	0.09	-0.19	-17.95
2030	0.18	0.00	-0.05	0.08	-0.01	0.11	-0.23	-23.89

Urban Household Energy Mix (% change)

Year	Residues	Wood	Manure	Petroleum	Biogas	Ethanol	Electrcity, Off	Electriciy, Grid
2019	-	0.13	0.13	0.13	-	0.14	0.10	-1.61
2020	-	0.13	0.13	0.13	-	0.14	0.10	-1.65
2021	-	0.13	0.13	0.14	-	0.15	0.10	-1.71
2022	-	0.27	0.27	0.29	-	0.31	0.22	-3.64
2023	-	0.28	0.28	0.30	-	0.31	0.23	-3.78
2024	-	0.28	0.28	0.30	-	0.32	0.23	-3.93
2025	-	0.45	0.45	0.48	-	0.51	0.37	-6.39
2026	-	0.46	0.46	0.49	-	0.51	0.38	-6.67
2027	-	0.47	0.47	0.50	-	0.52	0.39	-6.98
2028	-	0.69	0.67	0.73	-	0.75	0.58	-10.12
2029	-	0.70	0.68	0.74	-	0.76	0.59	-10.56
2030	-	0.95	0.92	1.00	-	1.02	0.81	-14.30

- **Electricity consumption declines** in both rural and urban households
- The decline in demand is relatively visible in rural households
- Whereas the substitution of electricity by other fuels is relatively visible in urban households

Results – Emissions



- Changes in electricity supply mix (e.g., ↑ diesel power) and households' energy mix (e.g., ↓ electricity) is expected to have implications for the country's **climate change mitigation** targets.
- The preliminary results show that **almost no effect** on the total GHG emissions
- However, 1% to 6% increase in **emissions from the power sector**

Conclusions - Remarks

- In general, reducing “implicit” subsidies to state-owned power utilities results in increasing electricity price and declining demand
- But bears **negligible** macroeconomic effects which could be **due to small shares of the electricity** sector in the economy and energy systems
- The increases in the share of **decentralized** sources and **electricity prices** due to the subsidy reforms could considered as a positive sign to the **private investors** and complement **other power sector reform** goals
- The changes in power supply and demand mixes may however **undermine** the country’s ambitious climate policy
- An initial exercise linking the **economic model** results with a **GHG emission** module shows the effects on the total emissions are minuscule although it could increase **power sector emissions**.

Thank you

amsaluwoldie.yalew@unive.it
amsaluwoldie.yalew@cmcc.it

@amsalu_w

Università Ca'Foscari Venezia

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