Electricity Economic Model of the African Continent

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09.09.2021

Introduction

- Five Power Pools in Africa
- Goal is to have a **greater cross-border trade** within the power pools
  - **More reliability** and
  - **More cost-effective** electricity production
- **Requirements** for functional **Power Pools**
  - Development of **cross-border interconnections**
  - A **common legal** and **regulatory framework**
  - Multi-country **organisational structures** that plan, **harmonise** and **develop** a **framework** for cross-border electricity trading

African Power Pools

Source: UNEP, „Atlas of Africa Energy Resources“, 2017

Overview African Power Pools

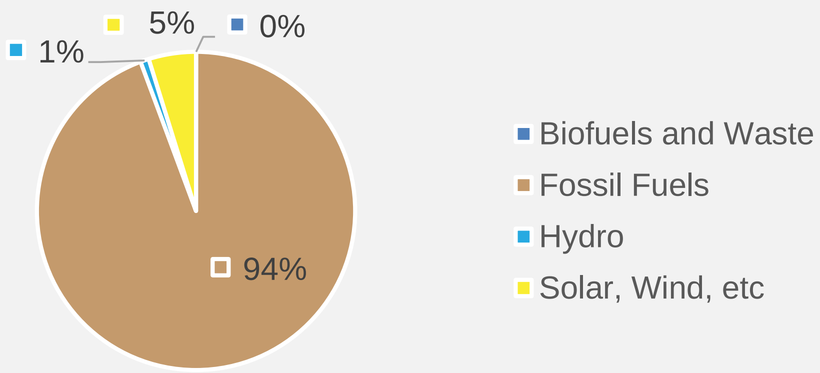
North African Power Pool

- Established in **1975**
- Also known as Electricity Committee of the Maghreb region (**COMELEC**)
- **NAPP** is the power pool with the **highest connectivity** and **best infrastructure** in Africa
- **Imports** and **exports** between the NAPP countries are **low**
- Existing **connections** to **Europe** via **Morocco-Spain** connection

Key Facts NAPP

Algeria, Libya, Mauritania, Morocco, Tunisia

Total Electricity Production [GWh]	**181,338**
Biofuels and Waste [GWh]	26
Fossil Fuels [GWh]	171,035
Nuclear [GWh]	0
Hydro [GWh]	1,564
Geothermal [GWh]	0
Solar, Wind etc. [GWh]	8,713
Final Consumption [GWh]	**130,990**
Net Import [GWh]	**6,414**



Source: African Energy Commission, „Africa Energy Database 2019“

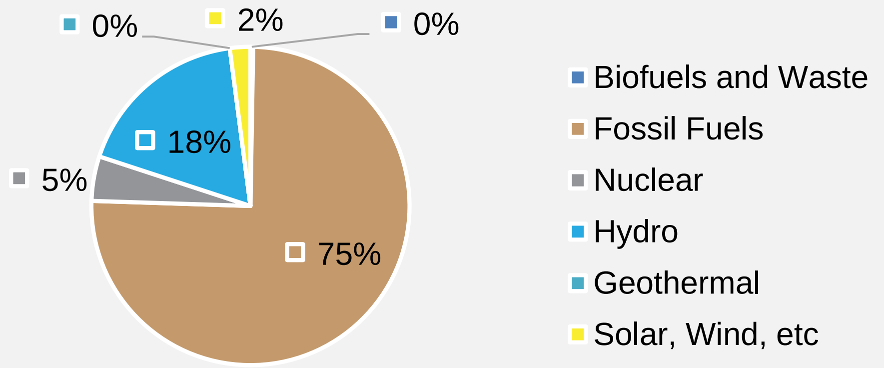
Southern African Power Pool

- Established in **1995**
- **South Africa major force** behind the SAPP
- The SAPP is Africa's **most advanced power pool** with
  - A **Day-Ahead-Market** for hourly energy contracts for the following day since 2009 and
  - an **Intra-Day-Market** for trades up to an hour before delivery since 2016
- **Lack** of **generation** and **interconnection capacity** prevents further development

Key Facts SAPP

Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland (Eswatini), Tanzania, Zambia, Zimbabwe

Total Electricity Production [GWh]	**336,289**
Biofuels and Waste [GWh]	910
Fossil Fuels [GWh]	253,023
Nuclear [GWh]	15,217
Hydro [GWh]	60,131
Geothermal [GWh]	1
Solar, Wind etc. [GWh]	7,007
Final Consumption [GWh]	**267,481**
Net Import [GWh]	**3,137**



Source: African Energy Commission, „Africa Energy Database 2019“

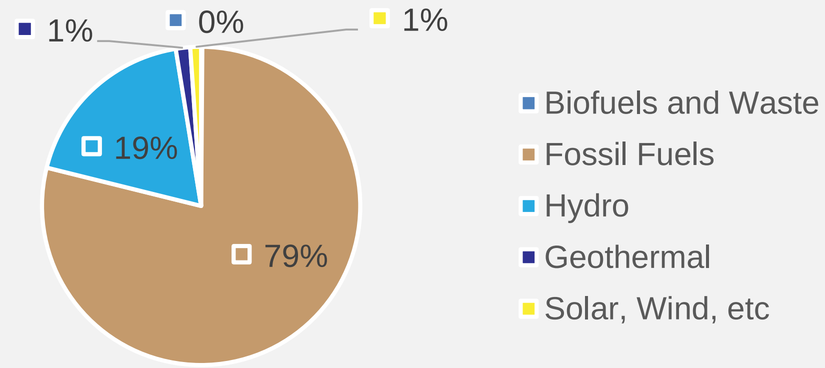
Eastern African Power Pool

- Established in **2005**
- **Eygpt[1] resigned** from the EAPP because of its **opposition** to the **Grand Ethiopian Renaissance Dam** (GERD)
- EAPP currently works with **bilateral agreements**
- Is planned to have a **centralised trading market** in place **until 2025**

Key Facts EAPP

Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Libya, Rwanda, Sudan, Tanzania, Uganda

Total Electricity Production [GWh]	**304,223**
Biofuels and Waste [GWh]	362
Fossil Fuels [GWh]	239,579
Nuclear [GWh]	0
Hydro [GWh]	56,514
Geothermal [GWh]	4,438
Solar, Wind etc. [GWh]	3,330
Final Consumption [GWh]	**247,389**
Net Import [GWh]	**-335**



[1] Egypt is still included here, because otherwise one of the biggest countries would not be included in any of the Power Pools

Source: African Energy Commission, „Africa Energy Database 2019“

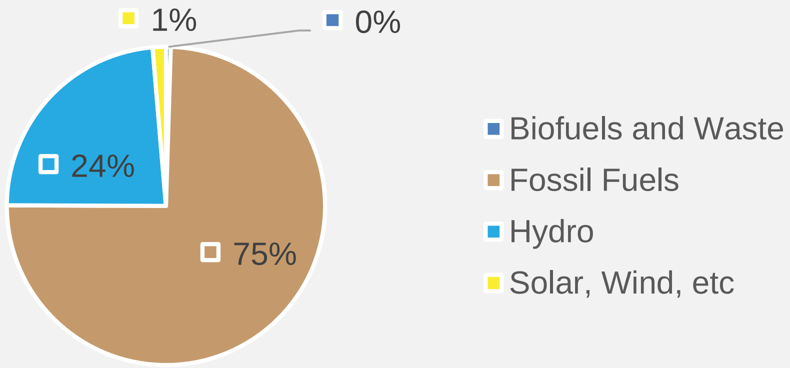
West African Power Pool

- Established in **2001**
- **Trading** is done via **bilateral agreements**
- **Weakly** developed **connections** between the member states of the WAPP are a big **obstacle** to **increase electricity trading**

Key Facts WAPP

Benin, Burkina Faso, Ivory Coast (Cote d'Ivoire), Gambia, Ghana, Guinea, Guinea Bissau, Libe-ria, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo

Total Electricity Production [GWh]	**76,028**
Biofuels and Waste [GWh]	368
Fossil Fuels [GWh]	56,702
Nuclear [GWh]	0
Hydro [GWh]	17,937
Geothermal [GWh]	0
Solar, Wind etc. [GWh]	1,021
Final Consumption [GWh]	**63,010**
Net Import [GWh]	**2,400**



Source: African Energy Commission, „Africa Energy Database 2019"

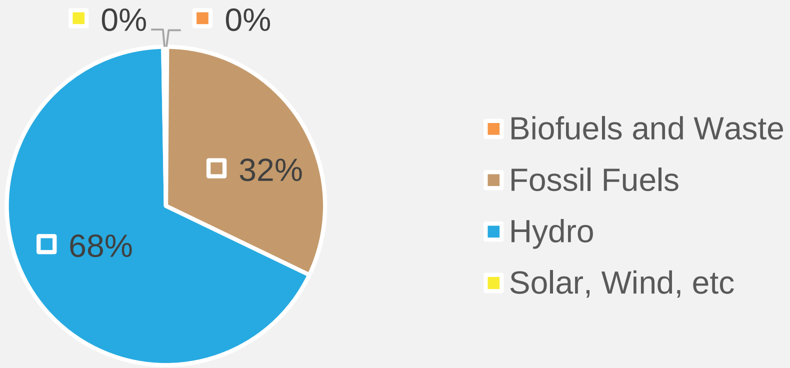
Central African Power Pool

- Established in **2005**
- **Smallest power pool** in Africa
- **Least developed** and only **basic infrastructure**
- Regional **trading** is very **low**
- In contrast to the other power pools it has a **large share** of **hydro power**
- Expected that **electricity demand** will **increase significantly** in the coming decades

Key Facts CAPP

Angola, Burundi, Cameroon, Central African Republic, Chad, Republic of Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, São Tomé & Principe

Total Electricity Production [GWh]	**38,434**
Biofuels and Waste [GWh]	44
Fossil Fuels [GWh]	12,310
Nuclear [GWh]	0
Hydro [GWh]	25,972
Geothermal [GWh]	0
Solar, Wind etc. [GWh]	108
Final Consumption [GWh]	**26,287**
Net Import [GWh]	**267**



Source: African Energy Commission, „Africa Energy Database 2019“

Building an Electricity Economic Model

of the African Continent

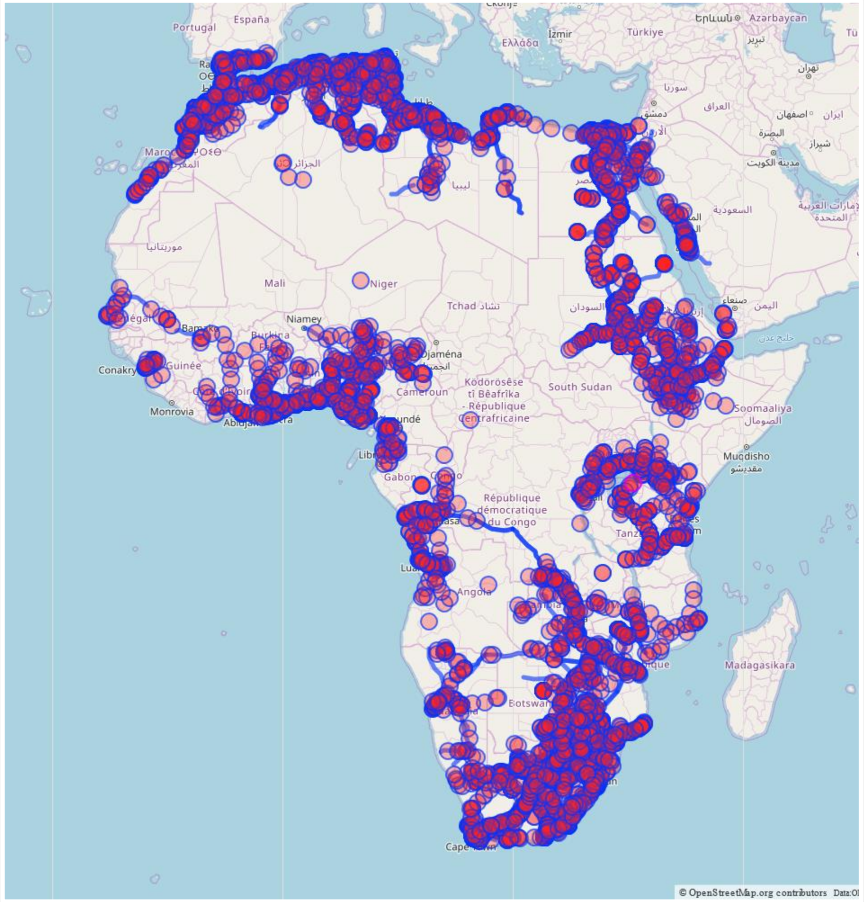
Path towards an Electricity Economic Model

- Information required to build an electricity economic model of Africa
  - **Electricity grid data**
  - **Power plant data**
  - Electricity consumption
  - Economic and other country specific data

- Problems
  - Compared to Europe **information** is **hard to find** and **scarce**
  - **Language barrier** is a problem

Methodology – Grid Data

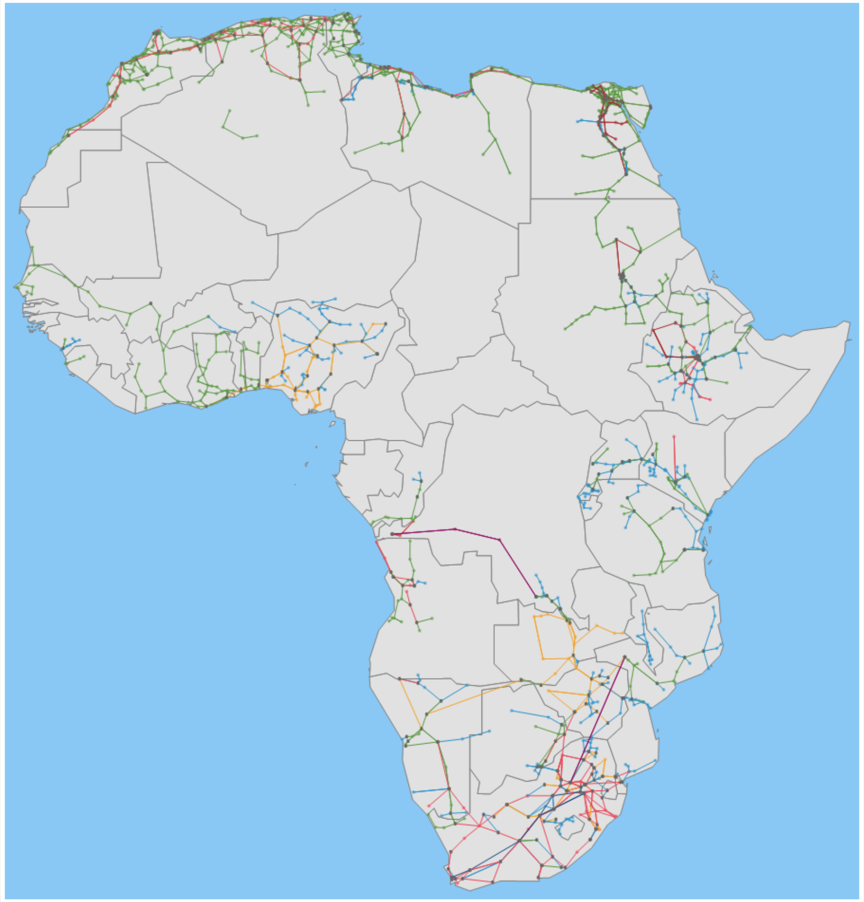
OpenStreetMap



Source: OpenStreetMap, “Power line data retrieved from https://overpass-turbo.eu/.”

Developed Conversion Tool

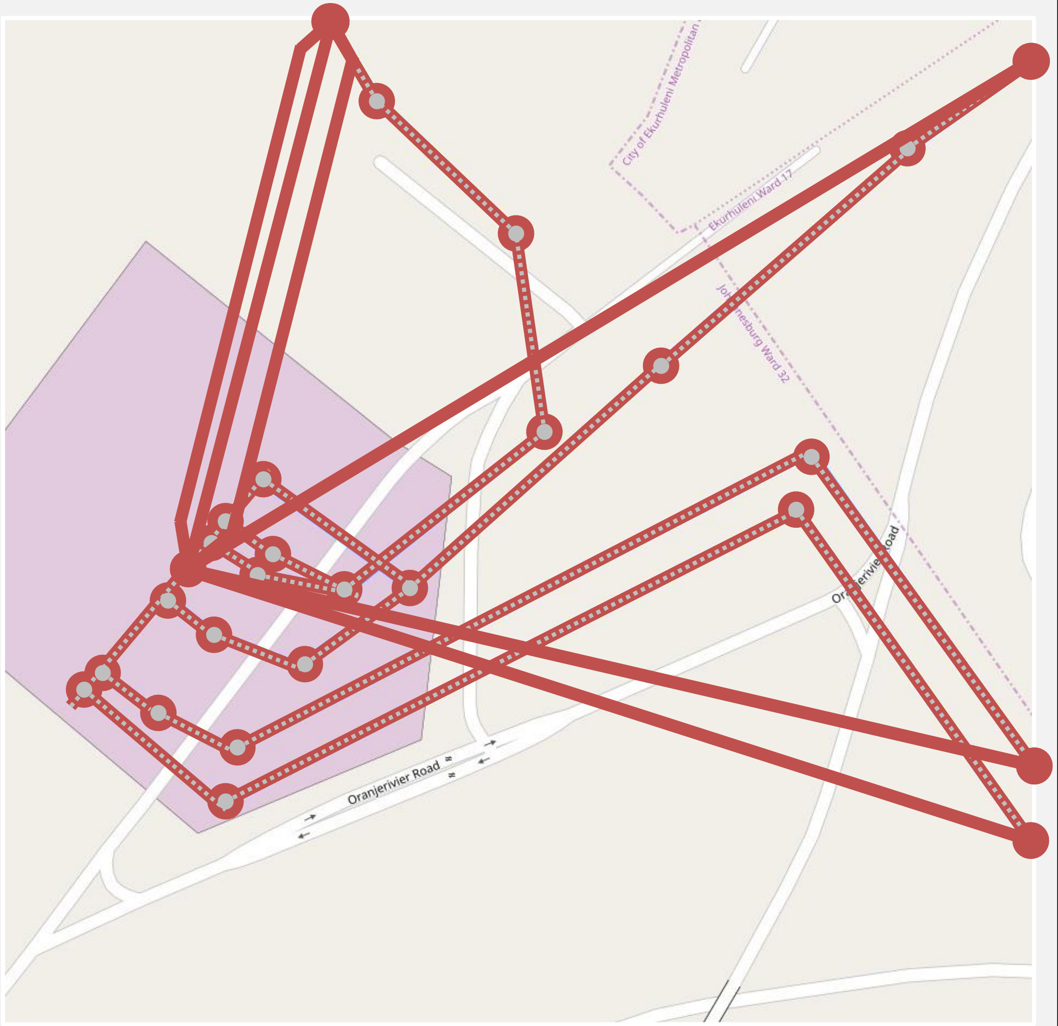
Result



Methodology – Grid Data

- **OpenStreetMap** data is **too detailed** to be used in our desired model
- **Line length** calculated using **actual path** of line before simplifications
- **Substation** with busbars have to be **converted** into **one node** per voltage level
- **Lines** simplified to be **straight connection** between **two nodes**

Conversion



Source: OpenStreetMap, “Power line data retrieved from https://overpass-turbo.eu/.”

Methodology – Grid Data

- **Available grid data** from **OpenStreetMap** converted to data format commonly used by various electricity models with **nodes** and **lines** stored in the **Excel file format**

Nodes

ID [-]	Country [-]	Voltage [kV]	Lat [°]	Long [°]
ZA00001	ZA	132	-33,836	25,522
ZA00002	ZA	132	-33,981	25,467
NA00003	NA	220	-24,655	18,033
NA00004	NA	132	-22,586	17,365
NA00005	NA	220	-22,586	17,365
NA00006	NA	400	-22,586	17,365
ZA00008	ZA	132	-34,000	24,783
ZM00009	ZM	330	-15,753	28,161
⋮	⋮	⋮	⋮	⋮

Lines

ID [-]	Country [-]	Node 1 [-]	Node 2 [-]	Voltage [kV]
LTGAO1764	AO	AO03077	AO01277	220
LTGDZ3436	DZ	DZ00934	DZ02105	220
LTGEG3854a	EG	EG00676	EG04730	500
LTGEG3854b	EG	EG00676	EG04730	500
LTGMA0838a	MA	MA00699	MA00709	220
LTGSD2473a	SD	SD00813	SD01024	220
LTGTZ4479	TZ	TZ01391	TZ01160	220
LTGZW1397	ZW	ZW01060	ZW01063	330
⋮	⋮	⋮	⋮	⋮

Methodology – Power Plant Data

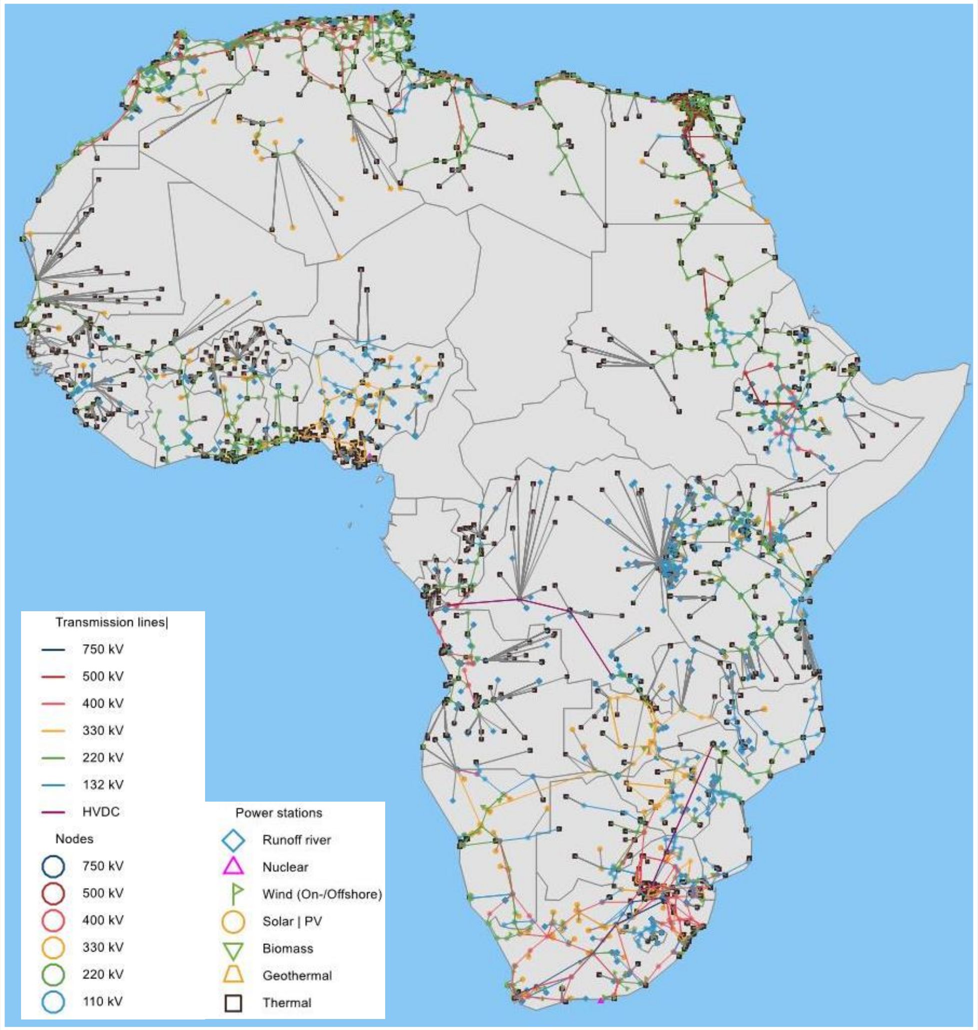
- Currently the **PLATTS database** is used (Options to use Open Source Data are considered)
- **Tool** to **convert** data into **format readable** by our considered **models**
- Challenges
  - **Location** only on **city level** available ➔ **Geocoding** process used to **transform** city into **GPS coordinates**
  - Which **nodes** do the power plants **feed into**? ➔ First approximation: **Feed into** nodes with **closest spatial distance** within country

Conclusion

- **Grid data** from OpenStreetMap **transformed** into files with
  - Nodes
  - Lines

- **Power plants** from PLATTS **converted** to be **readable** by **models**, **geocoded** and **feed-in nodes assigend**

Result



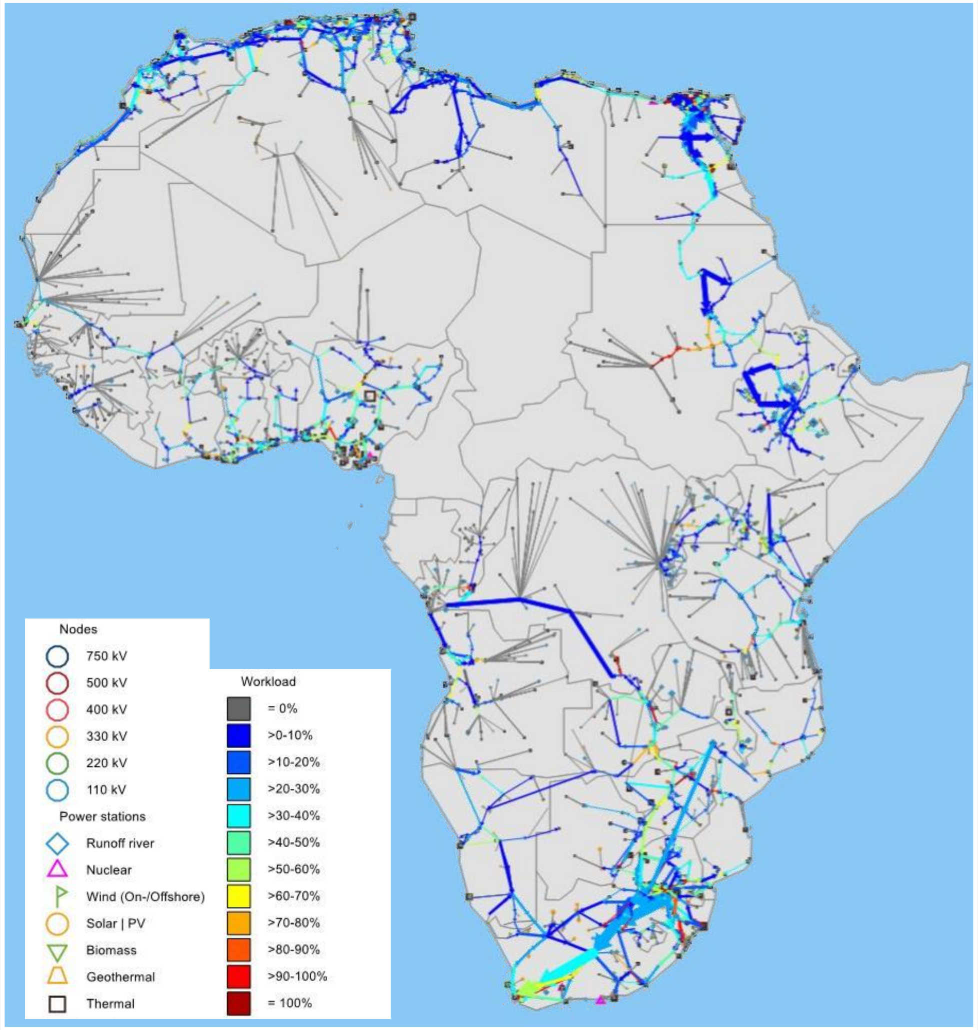
Conclusion

- **Grid data** from OpenStreetMap **transformed** into files with
  - Nodes and
  - Lines

- **Power plants** from PLATTS **converted** to be **readable** by **models**, **geocoded** and **feed-in nodes assigend**

- Proof-of-concept is working

Proof-of-Concept



Next Steps

- **Complete** the **economic** and other **country** specific **data**
- **Choose** the **model** to run simulations
  - ATLANTIS [1]
  - LEGO [2]
  - Both?
- **Calibrate** the model
- **Develope scenarios** for simulation
  - Business-as-Usual-Scenario
  - Existing-Plans-Scenarios
  - Renewable-Scenario

[1] H. Stigler, U. Bachhiesl, G. Nischler, and G. Feichtinger, "ATLANTIS: techno-economic model of the European electricity sector"
[2] S. Wogrin, D. Tejada-Arango, S. Delikaraoglou, and A. Botterud, "Assessing the impact of inertia and reactive power constraints in generation expansion planning"

Thank you for listening!

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