2022 Climate Academy: Digitalization and Energy Transition

Topic: Weather variability and socio-economic factors effect on electricity demand in 47 African cities.

or 10 minutes to brainstorm innovative ways to manage energy systems in Africa in the face of climate change and weather variability

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13:00 - 14:30 CEST
Webinar driven by the participants - Energy Transition Cohort (A4)

Contextualization : The reason why we shoose this Topic

- By 2030, 54% of Africa's energy supply is expected to come from renewables, according to the latest analysis of the ECOWAS energy hub model.

- Other objectives of current energy measures and policies in the region
  - Reduce distribution losses of electrical energy, currently between 15 and 40%, to less than 10%.
  - Increase the capacity to meet ever-increasing peak demand, amounting to 21.3 GW in 2022 and possibly reaching 50.8 GW in 2033

- This requires better planning and thus a better understanding of demand behavior.

- It is crucial that utilities are able to forecast energy demand in real time in order to efficiently manage energy production and distribution.

Motivation and the key question that guided our research:

Motivation: Number of regions worldwide reported significant dependence of electricity demand on weather conditions, while there is gap in information in African countries

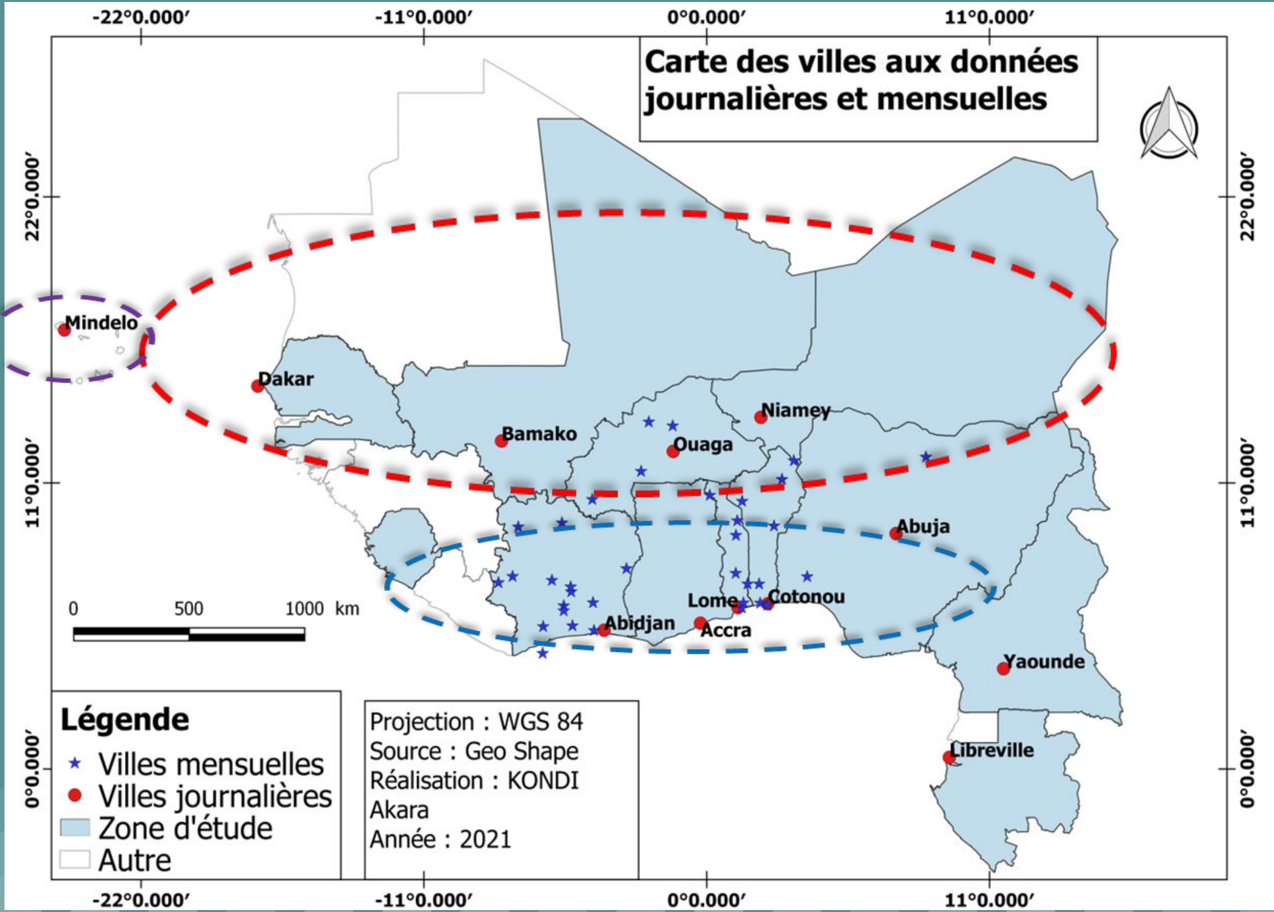
Question 1: In African cities, how sensitive is electricity demand to weather variability?

Question 2: - Which meteorological variables affect the most the demand and to what extent is the demand explained by weather variability?

Study Area

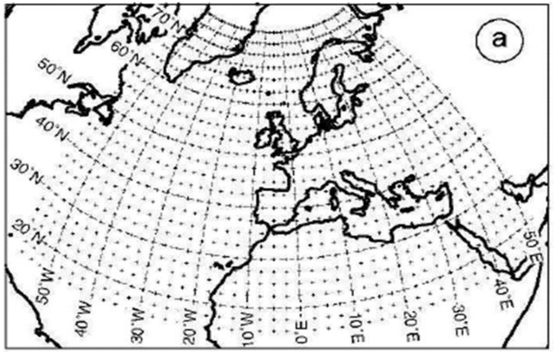
47 Cities (12 countries)

- 12 Capitales : Mindelo, Dakar, Bamako , Ouagadougou, Niamey, Abidjan ,Accra, Lomé Cotonou , Abuja, Yaoundé, Libreville
- 35 Secondary cities from Côte d'Ivoire, Togo et Burkina Faso.
- Three climatic contexts
  - Tropical humide
  - Sahelian
  - Oceanic



Energy Transition & Digitization in Africa : Need of availability and accessibility of data

- Electricity Consumption data (Conso: 1989 - 2019)



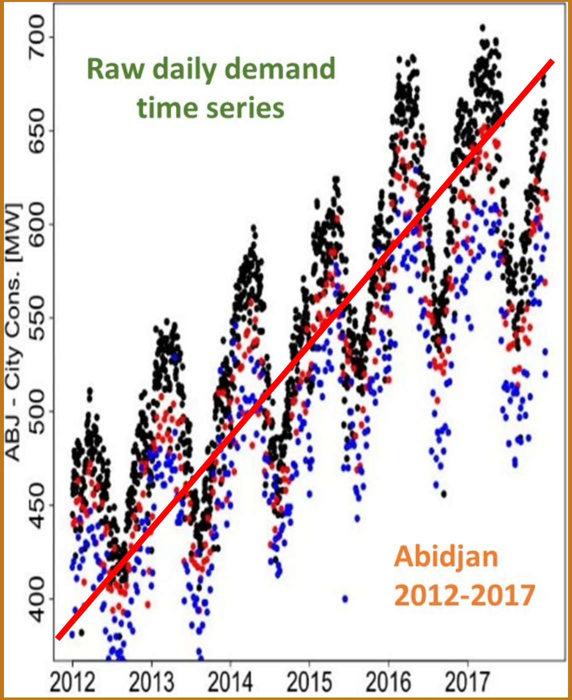
- Meteorological atmospheric reanalysis ERA5 (2000 - 2019) :
  - T & Td & Ws
  - RH (%) based on T/Td (°C) (Lawrence, 2005)

A unique and extensive database on West Africa

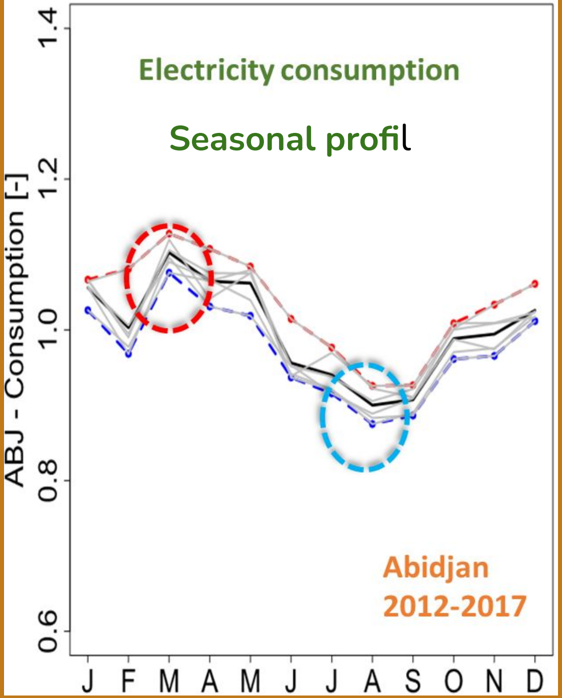
Countries	Mindelo	Dakar	Bamako	Ouaga	Niamey	Abidjan	Accra	Lomé	Cotonou	Abuja	Yaoundé	Libreville
Sources	Waite et al ., 2017	Waite et al ., 2017	EDM-SA	SONABEL	NIGELEC	CIE	Waite et al ., 2017	CEET	SBEE	Waite et al ., 2017	ENEO	SEEG

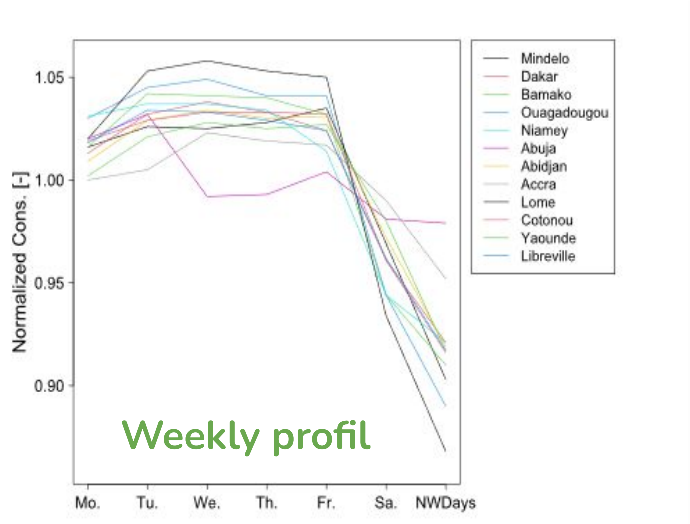
Energy Transition & Digitization in Africa : Need to understand

Factors affecting demand daily fluctuations



● = Jour ouvrable
● = Samedi
● = Dimanche & Jour férié





Electricity demand as a result of Weather & Activities related to

1. Economics,
2. Administration,
3. and Industry

Energy Transition & Digitization in Africa : Need of Electricity demand model

- Model used: daily mixed model (**MC0**) **: Adding and multiplying**
  Approach similar to Scapin et al.,2016 & Waite et al.. 2017

$$MC_0 = C(t) = \underbrace{f(t)}_{\text{Trend}} * \{C_0 + \beta_0.\underbrace{IT(t)}_{\text{CDD in °C}} + \beta_1 \underbrace{IRH(t)}_{\text{Humidity index in \%}} + \beta_2 \underbrace{Ws(t)}_{\text{Wind speed in m.s-1}} + \sum_{i=1}^{7} \gamma_i.\underbrace{IJ_i(t)}_{\text{Type of days}} + \underbrace{\varepsilon(t)}_{\text{Error}}\}$$

- Difference: There is a multiplicative trend, not an additive trend (the trend applies to all factors, not just C0)
- Parameters estimated for the model
  - Parameter of trend Model
  - Threshold temperature(Tseuil)
  - Baseline consumption : C0
  - Weather sensitivities: β_0 " in Watt/°C/hbt", β_1 " in Watt/%/hbt", β_2 "in Watt/m.s−1/hbt"
  - Day factors : _1 , _2 , _3....... _7 en Watt/"hbt" : surplus ou réduction de Conso pour jour t si i= 1 lundi, i= 2 mardi, ...ou i= 7 dimanche / jour férié respectivement

Role of temperature, humidity and wind speed on electricity demand

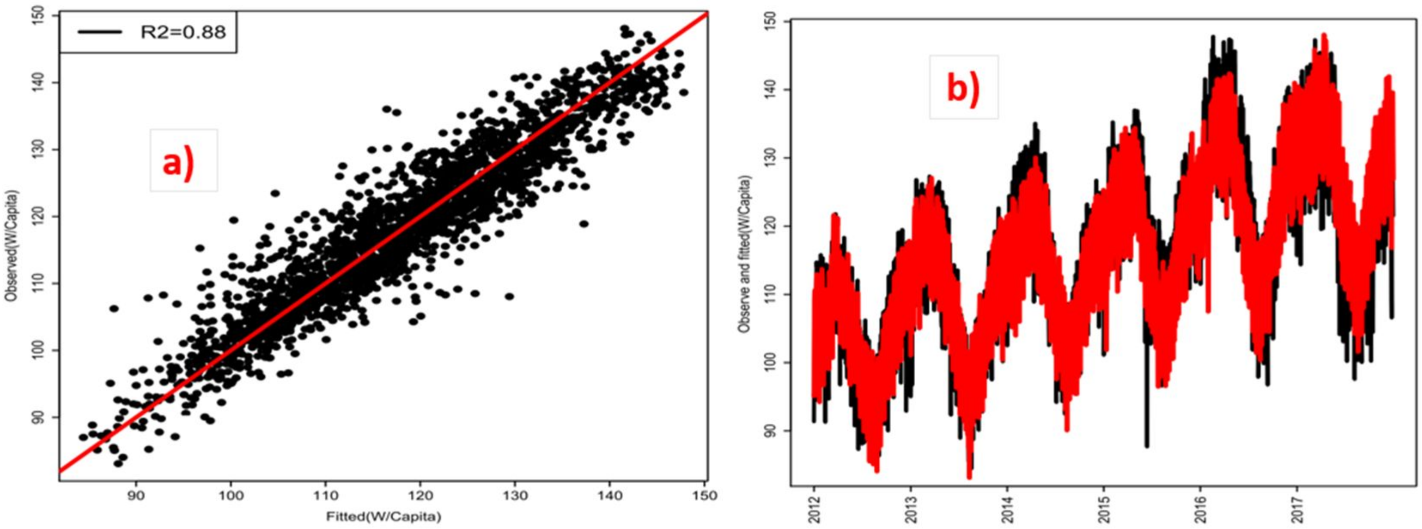
Table of Prediction Performance (NSE) for different sets of predictors with :
IT = temperature : RH = relative humidity and Ws = wind speed
NSE = 1 Model Perfect; NSE = 0 model less performing than Model = Average Consumption

NSE (%) Types of Model	Abidjan	Bamako	Dakar	Ouaga	Libreville	Lome	Niamey	Yaoundé	Mindelo	Cotonou
MC_0 (IT)	85.9	81.2	74.4	86.1	81.5	84.1	86.2	67.9	57.2	48.6
MC_0 (IT+RH)	87.6	85.5	81.8	86.8	81.6	84.3	88.2	70.8	58.2	50.1
MC_0 (IT+ Ws)	86.5	83.2	76.4	86.5	81.5	84.2	86.3	67.9	57.2	49.9
MC_0 (IT+ RH + Ws)	88	85.7	82.2	87	81.6	84.3	88.2	70.9	58.2	50.8

- Most important predictors: IT and HR
- Best performing model = MC0 (IT+ HR + Ws) : NSE of Majority cities > 80%.

Role of temperature, humidity and wind speed on electricity demand

Good predictive capacity of the daily model



a) Scatter plot of predicted vs. observed per capita consumption & b) Interannual evolution of predicted (red) and observed (black) per capita consumption in Abidjan (2012-2017)

Things to keep in mind : Interests for utilities & experts & decision making

- Weather explains a large part of the variability in consumption over the year
  - Share of consumption due to the weather effect (CDD+IRH+WS) > 50 % /An & = 50% Max Conso/Day
  - In particular: share of consumption due to temperature = 20% / An & +26 % Max Conso/Day
- We can propose a powerful prediction model Explaining more than 70% of the variance (NSE > 0.7)
  - Importance of both meteorological + socioeconomic to electricity demand variability:
- Weather sensitivity of consumption :
  - very important for temperature,
  - not negligible for humidity in some cities; less important for wind
- Gaps to fill in terms of availability and accessibility : Energy data & climate data and information

Things to keep in mind Interests for utilities & experts & decision making

Need to :

- to develop for Africa a real-time consumption forecasting system tool (local, national and regional scales)in order to optimize the operation and short-term management of the electric systems.

- Exploration of the effects of heat wave episodes or combined extreme temperature and humidity events on the average electricity demand of African cities.

- Estimation from predictive models of how climate change will affect average electricity demand in African megacities.

Thank you for your attention