

# ***Selected socio-economic and technical demand modelling data for Nandi County, Kenya.***

## **Authors**

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## **Keywords**

U4RIA, Demand Data, Demand Modelling, MAED, Nandi, Kenya, Energy Modelling, County Energy Planning, CEP

## **Abstract**

Modelling softwares can be used by policy makers to assess the impacts of different scenarios on energy systems to support planning and decision making. Demand forms an integral foundation of energy planning and insights into possible projections can aid in policy creation, yet access to data is often a barrier to utilising energy demand modelling to support such decision making. This data template provides proxy data that can be used to support a whole energy system demand model for Nandi County Kenya, providing a starting point for further data collection, model development and scenario analysis. All data is open sourced and collected via a literature review of international organisation databases, national and county documents and reports, journal articles, and existing modelling studies. The data can be easily updated with new and more accurate local data when it becomes available. The model and data can be utilised by in-county academics, planners, and policy makers to develop for future work and analysis.

## **Specifications Table**

<b>Subject</b>	<b>Energy Demand</b>
Specific subject area	Energy Demand Data
Type of data	Tables Graphs
How data were acquired	Literature Review (databases and reports from national and international organisations; journal articles)

Data format	Raw and analysed
Parameters for data collection	Data collected based on inputs required create an energy demand model for Nandi County.
Description of data collection	Data were collected from the websites, reports, and databases of national and international organisations, as well as from academic articles.
Data source location	Not Applicable
Data accessibility	With the article and in the supplementary files.

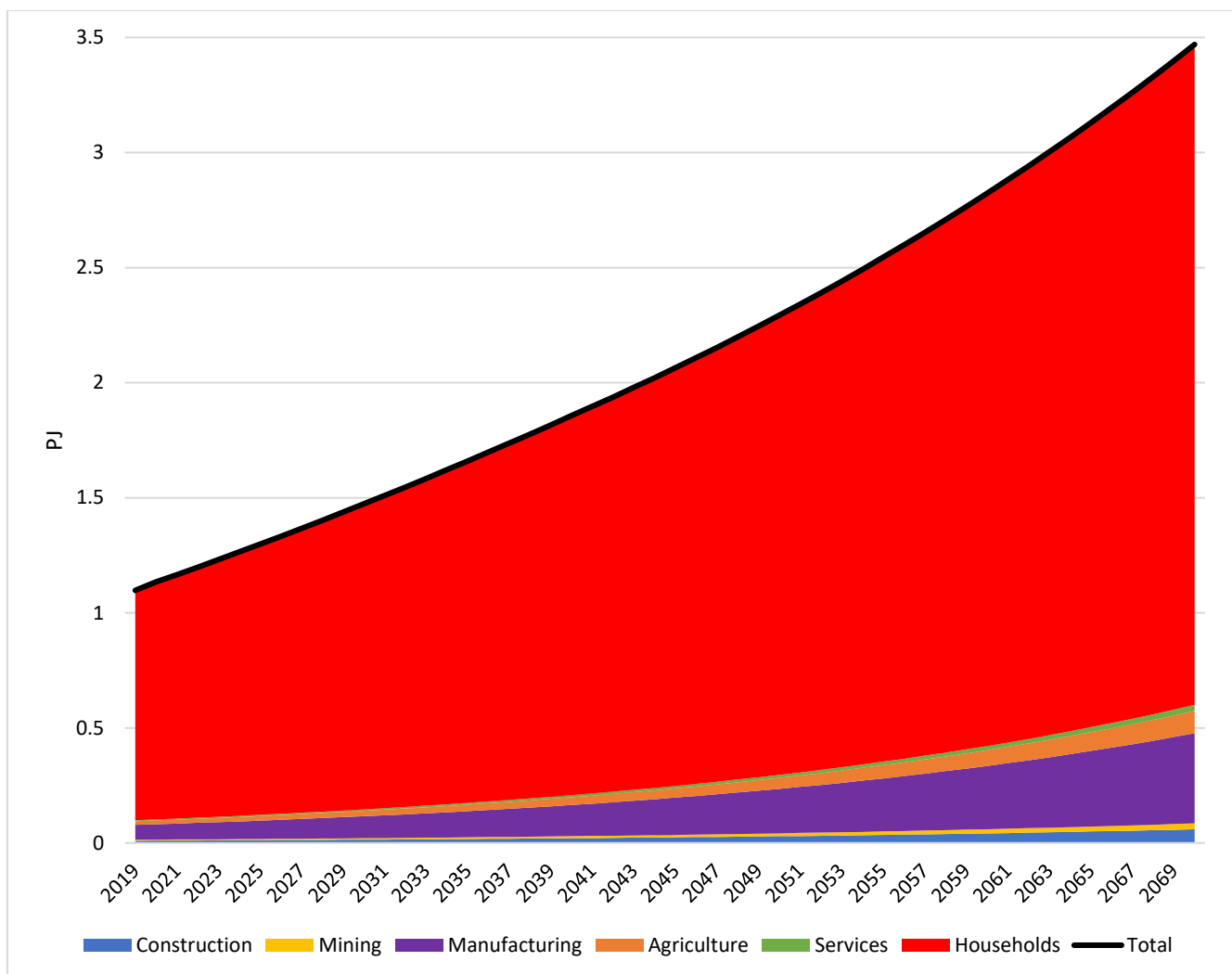
## Value of the data

The aim of the data is to be utilised for capacity building activities, providing a template of best available data in which further data collection and input, analysis and model development can be built upon. The data can be used to explore a wide range of energy system demand pathways. It can be utilised by in-country academics, planners, policy makers, analysts, and the broader scientific community as a zero-order basis for insights into energy demand under various trajectories. The supplementary file data template can be used as a data collection tool to substitute the disaggregated and national level data with more accurate and up to date in county data. The outputted demand projections produced from this data can also be used as a soft-linked input into energy optimisation models such as the open-sourced energy modelling system (OSeMOSYS) (1), allowing the creation of a modelling workflow.

## Data Description

The accumulated data within this paper can be applied to develop a county level energy demand model for Nandi County, Kenya. This data was used to develop an energy system model utilising the demand simulation tool MAED across a model period of 2018 to 2070. The year 2018 is taken as the base year, in which historic socio-economic and technical parameters were downscaled to acquire baseline 'template' energy intensity figures. This data models energy demand across the industry, services, and household sectors.

Figure 1 displays a baseline production of energy demand by sector for Nandi County across the period of 2018 to 2070. This shows an illustrative example of the possible outputs and insights from the application of the template data outlined within this paper. Utilising the template data outlined in this paper, the analyst can substitute with collected data to reproduce a baseline scenario alongside further analytical scenarios, such as high and low population and GDP growth, vary urbanisation levels, increased energy efficiency amongst integrating additional social aspects such as gender, social inclusion, and resilience considerations. Data is presented in PJ to allow for ease of data share and calibration between MAED and OSeMOSYS.



**Figure 1:** A possible baseline demand projection for Nandi County from 2019 to 2070 using template energy data.

The data set includes the socio-economic parameters of demography and GDP, disaggregated to a county resolution where available, alongside a base year energy balance disaggregation and subsequently derived energy intensities. The workflow for reconstructing the base year is as outlined in Kiley (2024) (2) and further training material on how to use MAED can be found in the [Open Learn](#) course ‘Energy Demand Projections with MAED’.

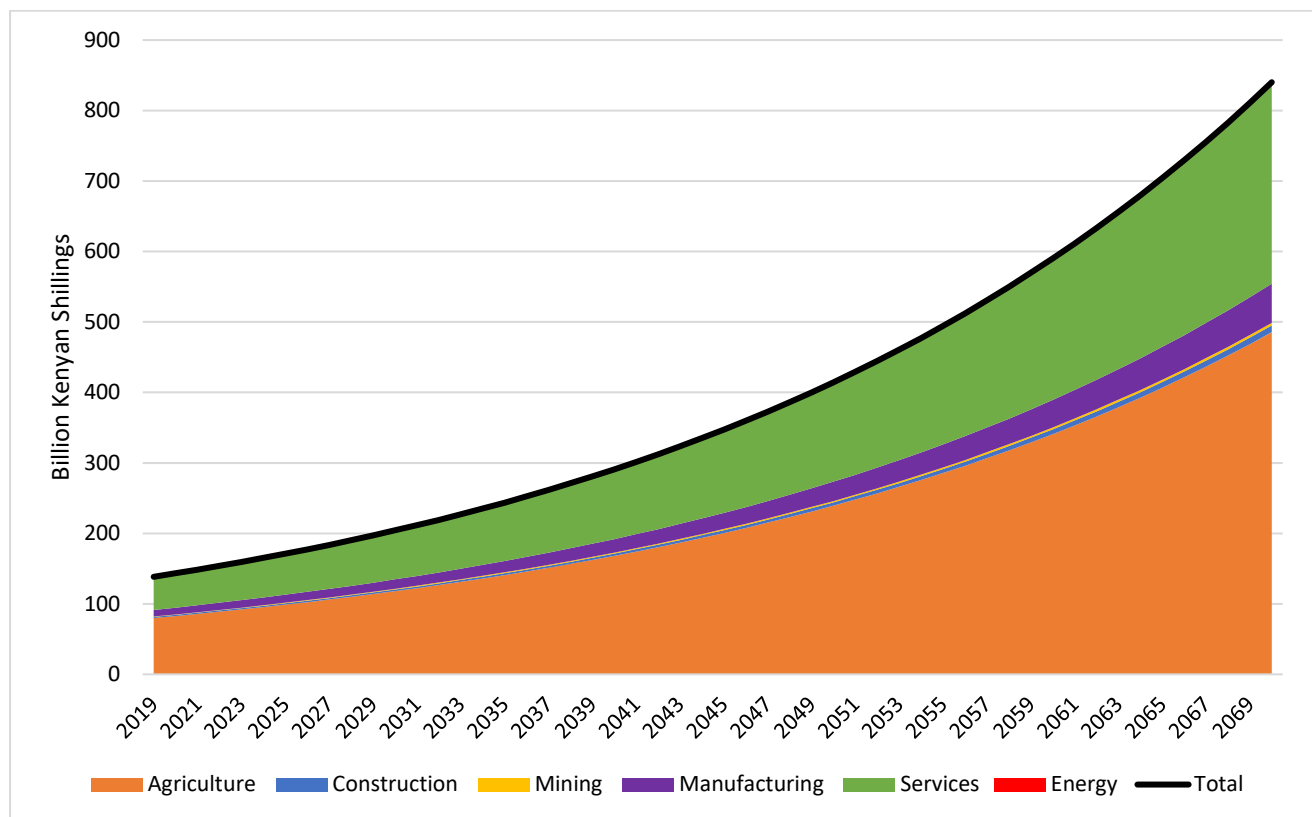
Below shows an overview of the tables and figures included within this template.

Item	Description of Content
<b>Figure 1</b>	An illustrative figure showing a possible baseline demand projection from 2019 to 2070.
<b>Table 1</b>	A Table showing the proxy demographic parameters for Nandi County from 2019 to 2070.
<b>Figure 2</b>	A figure showing projected population for Nandi County from 2019 to 2070.
<b>Table 2</b>	A Table showing the proxy GCP parameters for Nandi County from 2019 to 2070.
<b>Figure 3</b>	A figure showing projected GCP for Nandi County from 2019 to 2070.
<b>Table 3</b>	A Table showing the Kenyan national energy balance data in 2019.
<b>Table 4</b>	A Table showing the Kenyan national energy balance data in MAED format in 2019.
<b>Table 5</b>	A Table showing the proportional percentages of Nandi’s sectoral contribution to national GDP in 2019.





<b>Energy</b>	0.32	0.32	0.32	0.32	0.32	0.32	0.32
<b>Total</b>	100	100	100	100	100	100	100



**Figure 3:** Total GCP (Billion Kenyan Shillings) projection in Nandi County disaggregated by sector from 2019 to 2070.

## 2. Energy Balance Data

The collected and inputted base year energy balance data at the national level, and subsequently template disaggregated energy balance at a county level are presented in Table 3, 4 and 5.

### 2.1. National Energy Balance

The base year (2019) national energy balance data was taken from the International Energy Agency (IEA) World Extended Energy Balances dataset 2021(10) (Table 3).

**Table 3:** Total energy consumption (TJ) per sector per fuel type in the 2019 base year (10).

	Bitumen	LPG	Motor Gas	Kerosene	Gas/Diesel Oil	Fuel Oil	Primary Solid Biofuels	Charcoal	Electricity
<b>Agriculture</b>		330.21	19.21		38.46	46.79			
<b>Manufacturing</b>	6331.32								57.61
<b>Industry (non-specified)</b>		543.87		73.38	2013.33	501.9			1645.03

<b>Residential</b>	602.1 5	658.42	37680.4 6	12363.64	1099.17
<b>Commercial</b>					489.26

The energy balance fuel consumption data was aggregated into fossil fuels (bitumen, LPG, motor gas, kerosene, gas and diesel oil, fuel oil), traditional fuels (biofuels and charcoal) and electricity to fit the MAED sectoral and fuel categorisations. Due to a lack of data, Industry (non-specified) energy consumption was split into construction and mining proportionate to the sector contribution to total national GDP as obtained from the KIPPRA Kenya Economic Report 2020 (8). It is therefore assumed that construction consumed 90% and mining 10% of the non-specified industrial consumption.

**Table 4:** Total national energy consumption (PJ) per sector per fuel type in the 2019 base year updated to follow the MAED structure (8,10).

	<b>Fossil Fuels</b>	<b>Traditional Fuels</b>	<b>Electricity</b>	<b>Total</b>
<b>Agriculture</b>	0.435			0.435
<b>Construction</b>	2.819		1.481	4.3
<b>Mining</b>	0.313		0.165	0.478
<b>Manufacturing</b>	6.331		0.058	6.389
<b>Household</b>	1.261	50.044	1.099	52.403
<b>Services</b>			0.489	0.489

## 2.2. Template Disaggregated County Energy Balance

Due to a lack of accessible energy balance data at a county resolution, the 2019 energy consumption data have been disaggregated from the national data. Energy consumption for the economic sectors (agriculture, mining, manufacturing, construction and services) has been disaggregated proportionally to Nandi's individual sectoral contribution to the total sectoral GDP. Data on economic contribution per sector per county to total sectoral GDP was acquired via the KNBS gross county product report 2021 (9). Household energy consumption has been disaggregated proportionally to the percentage of the total population residing in Kwale, and data acquired via the Commission of Review Allocations Kenya County fact sheets third edition (11). The proportional percentage for each individual sector is displayed in Table 5, and the subsequent template county resolution energy balance data (TJ) in Table 6.

**Table 5:** Total proportional percentages for each of Nandi's sectors based on contribution to national figures (9,11).

<i>County Sectoral % of total national GDP</i>					<i>County % of total national population</i>
<b>Agriculture</b>	<b>Construction</b>	<b>Mining</b>	<b>Manufacturing</b>	<b>Services</b>	<b>Household</b>
3.686	0.228	0.881	1.009	0.879	1.915

**Table 6:** Total county energy consumption (TJ) for Nandi per sector per fuel type in 2019.

<i>County Disaggregated Energy Balance (MAED sectors and fuels)</i>
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TJ	Fossil Fuels	Traditional Fuels	Electricity	Total
<b>Agriculture</b>	16.021			16.021
<b>Construction</b>	6.434		3.379	9.813
<b>Mining</b>	2.76		1.449	4.209
<b>Manufacturing</b>	63.931		0.582	64.513
<b>Household</b>	24.135	958.146	21.045	1003.325
<b>Services</b>			4.301	4.301

### 3. Sectoral Energy Intensity

An overview of the template energy intensities for all sectors are displayed in Table 7. The workflows to derive the energy intensities per sector by end use and fuel type are displayed in Tables 8-12.

Table 7: Energy Intensity inputs for the 2019 base year for the sectors per end use.

2019 Energy Intensity (MJ/KES)	Specific Electricity Use	Motive Power	Thermal Uses
<b>Agriculture</b>	0	0.000203349251	0
<b>Construction</b>	0.00246670793	0.00422741343	0.00020878725
<b>Mining</b>	0.002277268397	0.003902754319	0.000192752699
<b>Manufacturing</b>	0.000072485183	0	0.0039033878985
<b>Services</b>	0.000087577926	0	0

#### 3.2. Agriculture, Construction, Mining

Due to a lack of available county resolution data on energy consumption by end use per sector, data on the proportional split were obtained in line with the national OSeMOSYS demand workbook (11), for agriculture, and Kiley (2024) (2) for construction and mining. Similarly, template data on average fuel efficiencies, as per MAEDs fuel groupings, were obtained from the national demand workbook (11). The workflow used to obtain the base year energy intensities per sector by end use is outlined in Table 8.

**Table 8:** Tables demonstrating the workflow from (a) Final energy consumption per sector (b) Proportional splits for sectoral energy end uses (c) Un-weighted and weighted efficiency of fuel type by end use (d) Final useful energy consumption per sector by end use and fuel type (e) penetration of energy forms for the fuel categories derived from the useful energy demand (f) inputted template energy intensities per sector by end use and fuel type.

(a)

Final Consumption TJ	Fossil Fuels	Traditional Fuels	Electricity
<i>Agriculture</i>	16.021	0	0
<i>Construction</i>	6.434	0	3.379
<i>Mining</i>	2.76	0	1.449

(b)



Proportional Split %	Fossil Fuels	Traditional Fuels	Electricity
<b>Agriculture</b>			
<i>Specific Electricity Use</i>	0	0	0
<i>Motive Power</i>	100	0	0
<i>Thermal Uses</i>	0	0	0
<b>Construction</b>			
<i>Specific Electricity Use</i>	0	0	100
<i>Motive Power</i>	90	0	0
<i>Thermal Uses</i>	10	0	0
<b>Mining</b>			
<i>Specific Electricity Use</i>	0	0	100
<i>Motive Power</i>	90	0	0
<i>Thermal Uses</i>	10	0	0

(c)

Thermal efficiency of fuel types %	Fossil Fuels	Traditional Fuels	Electricity
<i>Un-Weighted</i>	40	25	90
<i>Weighted</i>	44.45	27.8	100

(d)

Final Useful Consumption TJ	Fossil Fuels	Traditional Fuels	Electricity	Total
<b>Agriculture</b>				
<i>Specific Electricity Use</i>	0	0	0	0
<i>Motive Power</i>	16.021	0	0	16.021
<i>Thermal Uses</i>	0	0	0	0
<b>Construction</b>				
<i>Specific Electricity Use</i>	0	0	3.379	3.379
<i>Motive Power</i>	5.791	0	0	5.791
<i>Thermal Uses</i>	0.286	0	0	0.286
<b>Mining</b>				
<i>Specific Electricity Use</i>	0	0	1.449	1.449
<i>Motive Power</i>	2.484	0	0	2.484
<i>Thermal Uses</i>	0.123	0	0	0.123

(e)

Thermal Penetration of Energy Forms %	Fossil Fuels	Traditional Fuels	Electricity
<b>Agriculture</b>			
<i>Thermal Uses</i>	0	0	0
<b>Construction</b>			
<i>Thermal Uses</i>	100	0	0
<b>Mining</b>			
<i>Thermal Uses</i>	100	0	0

(f)

Energy Intensity 2019 (MJ/KES)	MJ	Kenyan Shilling	Energy Intensity
<b>Agriculture</b>			
<i>Specific Electricity Use</i>			
<i>Motive Power</i>	16021340.22	78787308600	0.000203349251
<i>Thermal Uses</i>			
<b>Construction</b>			
<i>Specific Electricity Use</i>			
<i>Motive Power</i>	3379027.499	1369853100	0.00246670793
<i>Motive Power</i>	5790935.397	1369853100	0.00422741343
<i>Thermal Uses</i>	286007.8649	1369853100	0.00020878725
<b>Mining</b>			
<i>Specific Electricity Use</i>			
<i>Motive Power</i>	1449475.414	636497400	0.002277268397
<i>Motive Power</i>	2484092.977	636497400	0.003902754319
<i>Thermal Uses</i>	122686.592	636497400	0.000192752699

### 3.3. Manufacturing

Due to a lack of available county resolution data on energy consumption by end use per sector, data on the proportional split, and average fuel efficiencies, were obtained in line with the national OSeMOSYS demand workbook (11). The workflow used to obtain the base year final energy intensities by end use for services is outlined in Table 9.

**Table 9:** Tables demonstrating the workflow from (a) Final energy consumption per sector (b) Proportional splits for sectoral energy end uses (c) Un-weighted and weighted efficiency of fuel type by end use (d) Final useful energy consumption per sector by end use and fuel type (e) penetration of energy forms for the fuel categories derived from the useful energy demand (f) inputted template energy intensities per sector by end use and fuel type.

(a)

Final Consumption TJ	Fossil Fuels	Traditional Fuels	Electricity
<i>Manufacturing</i>	63.93113683	0	0.581722736

(b)

Proportional Split %	Fossil Fuels	Traditional Fuels	Electricity
<i>Specific Electricity Use</i>	0	0	100
<i>Motive Power</i>	0	0	0
<i>Thermal Uses</i>	100	0	0
- <i>High Level</i>	10	0	0
- <i>Low Level</i>	90	0	0

(c)

Thermal Efficiency of fuel types %	Fossil Fuels	Traditional Fuels	Electricity
<i>High Level</i>	40		
<i>Low Level</i>	50		

(d)

Final Useful Consumption TJ	Fossil Fuels	Traditional Fuels	Electricity	Total
<i>Specific Electricity Use</i>	0	0	0.581722736	0.581722736
<i>Motive Power</i>	0	0	0	0
<i>Thermal Uses</i>	31.32625705	0	0	31.32625705
- <i>High Level</i>	2.557245473	0	0	2.557245473
- <i>Low Level</i>	28.76901157	0	0	28.76901157

(e)

Thermal Penetration of Energy Forms %	Fossil Fuels	Traditional Fuels	Electricity
<i>Share of Temperature level</i>			
<i>High Level</i>	8.163265306	0	0
<i>Low Level</i>	91.83673469	0	0
<i>Penetration of Energy Forms %</i>			
<i>High Level</i>	100	0	0
<i>Low Level</i>	100	0	0

(f)

Energy Intensity (MJ/KES)	MJ	Kenyan Shilling	Energy Intensity
<i>Specific Electricity Use</i>	581722.736	8025402000.00	0.000072485183
<i>Motive Power</i>			
<i>Thermal Uses</i>	31326257.05	8025402000.00	0.0039033878985

### 3.4. Services

Due to a lack of available county resolution data on energy consumption by end use per sector, data on the proportional split, and average fuel efficiencies, were obtained in line with the national OSeMOSYS demand workbook (11). Similarly, national data on the percentage of the labour force in the service sector was obtained from the KNBS 2019 population and housing census (12) due to no available data at a county resolution (Table 10).

**Table 10:** Basic services data & factors for the 2019 base year as required for MAED inputs.

Basic Services Data		2019
<i>Labour Force in Service Sector</i>	%	38.4

The workflow used to obtain the base year final energy intensities by end use for services is outlined in Table 11.

**Table 11:** Tables demonstrating the workflow from (a) Final energy consumption per sector (b) Proportional splits for sectoral energy end uses (c) inputted template energy intensities by end use and fuel type.

(a)

Final Consumption TJ	Fossil Fuels	Traditional Fuels	Electricity
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<i>Services</i>	0	0	4.300703037
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(b)

<b>Proportional Split %</b>	<b>Fossil Fuels</b>	<b>Traditional Fuels</b>	<b>Electricity</b>
<i>Specific Electricity Use</i>	0	0	100
<i>Air Conditioning</i>	0	0	0
<i>Space Heating</i>	0	0	0
<i>Thermal Use</i>	0	0	0
<i>Motive Power</i>	0	0	0

(c)

<b>Energy Intensity 2019 (MJ/KES)</b>	<b>MJ</b>	<b>Kenyan Shilling</b>	<b>Energy Intensity</b>
<i>Specific Electricity Use</i>	4300703.037	49107158100.00	0.000087577926
<i>Motive Power</i>	0	0	0
<i>Thermal Uses</i>	0	0	0

#### 4. Household Energy Requirements

Data on county electrification rates alongside average annual increase in electrification from 2009 to 2019 were obtained from the commission of revenue allocations Kenya county fact sheets third edition (13). Electrification rates are assumed to increase annually in line with the average rates from the last decade. Due to a lack of urban and rural disaggregated data at a county resolution, the data is assumed to be the same. Table 13 displays the general household data inputted for Kwale County.

**Table 12:** Collected and inputted household electrification data for Kwale County.

<b>2019</b>	<b>Electrification %</b>	<b>Average annual increase electrification % (2009-2019)</b>
<i>Households</i>	30.7	2.43

An overview of the template specific energy requirements for all sectors are displayed in Table 14. The specific energy requirements for the household sector are assumed to increase 1% annually from 2019 to 2070.

**Table 13:** Specific energy requirement inputs for the 2019 base year for urban and rural households per end use

<b>2019</b>	<b>Specific Energy Requirements (MJ/dw/yr)</b>	<b>Specific Electricity Requirements (MJ/dw/yr)</b>	<b>Substitutable Fuels Energy Requirements (MJ/dw/yr)</b>
<i>Urban</i>			
<i>Cooking</i>	13637.10016	0	0
<i>Appliances</i>	0	412.1173131	0
<i>Lighting</i>	0	457.9081256	52.51464705
<i>Rural</i>			
<i>Cooking</i>	13637.10016	0	0

<i>Appliances</i>	0	412.1173131	0
<i>Lighting</i>	0	457.9081256	52.51464705

The workflows to derive the energy requirements for urban and rural households per end use by fuel type are displayed in Table 15.

**Table 14:** Tables demonstrating the workflow from (a) Final energy consumption per household type (b) Proportional splits for household energy end uses (c) Un-weighted and weighted cooking efficiency of fuel type (d) Final useful energy consumption for urban and rural households by end use and fuel type (e) Penetration of cooking energy forms derived from the useful energy demand (f) inputted template energy requirements by end use and fuel type.

(a)

<b>Final Consumption TJ</b>	<b>Fossil Fuels</b>	<b>Traditional Fuels</b>	<b>Electricity</b>
<i>Total Households</i>	24.13491104	958.1458399	21.0447418
<i>Urban (6.7%)</i>	1.617039039	64.19577127	1.4099977
<i>Rural (93.3%)</i>	22.517872	893.9500686	19.63474409

(b)

<b>Proportional Split %</b>	<b>Fossil Fuels</b>	<b>Traditional Fuels</b>	<b>Electricity</b>
<i>Urban</i>			
<i>Cooking</i>	95	100	5
<i>Lighting</i>	5		50
<i>Electrical Appliances</i>			45
<i>Rural</i>			
<i>Cooking</i>	95	100	5
<i>Lighting</i>	5		50
<i>Electrical Appliances</i>			45

(c)

<b>Efficiency of Cooking fuel types %</b>	<b>Fossil Fuels</b>	<b>Traditional Fuels</b>	<b>Electricity</b>
<i>Urban Cooking</i>			
<i>Un-Weighted</i>	45	25	80
<i>Weighted</i>	56.25	31.25	100
<i>Rural Cooking</i>			
<i>Un-Weighted</i>	45	25	80
<i>Weighted</i>	56.25	31.25	100

(d)

<b>Final Useful Consumption</b>	<b>Fossil Fuels</b>	<b>Traditional Fuels</b>	<b>Electricity</b>
<i>Urban</i>			
<i>Cooking</i>	0.864105237	20.06117852	0.070499885
<i>Lighting</i>	0.080851952	0	0.70499885

<i>Electrical Appliances</i>	0	0	0.634498965
<i>Rural</i>			
<i>Cooking</i>	12.03298785	279.3593965	0.981737205
<i>Lighting</i>	1.1258936	0	9.817372047
<i>Electrical Appliances</i>	0	0	8.835634843

(e)

<b>Penetration of Cooking Energy Forms</b>	<b>Fossil Fuels</b>	<b>Traditional Fuels</b>	<b>Electricity</b>
<i>Urban</i>			
<i>Cooking</i>	2.334543615	97.55831771	0.1071387
<i>Rural</i>			
<i>Cooking</i>	2.334543615	97.55831771	0.1071387

(f)

<b>Specific Energy Requirements 2019 (MJ/dw/yr)</b>	<b>MJh</b>	<b>Number of Dwellings</b>	<b>Specific Energy Requirement</b>
<i>Urban</i>			
<i>Cooking</i>	183923064731.31	13486.96295	13637.10016
<i>Lighting</i>			
- <b>Electricity</b>	6175789927	13486.96295	457.9081256
- <b>Substitutable Fuels</b>	708263099.3	13486.96295	52.51464705
<i>Electrical Appliances</i>			
- <b>Electricity</b>	5558210934	13486.96295	412.1173131
- <b>Substitutable Fuels</b>	0	0	0
<i>Rural</i>			
<i>Cooking</i>	2561197304392.70	187810.9916	13637.10016
<i>Lighting</i>			
- <b>Electricity</b>	86000179135	187810.9916	457.9081256
- <b>Substitutable Fuels</b>	9862827935	187810.9916	52.51464705
<i>Electrical Appliances</i>			
- <b>Electricity</b>	77400161222	187810.9916	412.1173131
- <b>Substitutable Fuels</b>	0	0	0

## 5. Experimental Design, Materials, and Methods

The data was collected via publically available sources, including the reports of national and international organisations, journal articles, and existing databases, complying with the U4RIA analytics and good governance goals of Ubuntu, Retrievability, Reusability, Repeatability, Reconstructability, Interoperability, and Auditability. The U4RIA goals aim to provide guidance on best practices within energy modelling (14). The datasets include raw data on gross county product (GCP), population alongside national energy consumption, energy efficiency and electrification rates where available. County energy consumption by sector (agriculture, construction, mining, manufacturing, services, and households) were processed based on assumptions. This disaggregation was constructed to align with the structure of the Model for the Analysis of Energy Demand (MAED) tool, however the data outline in this paper remains independent from the tool. The data in the County Demand Starter Data Kit were collected from the KNBS data portal (5), economic (7,9,15,16) and census (3,12,17–19) reports, the KIPPRA economic report (8), the International Energy Agency

(IEA) world energy balances (10), the commission on revenue allocation county fact sheets (13) and previous modelling literature (11). Due to missing data on county and sectoral disaggregated energy balances, assumptions were made by the authors to address this. The data were collected for use with the Model for the Analysis of Energy Demand (MAED) tool, which can project whole energy system demand based on historical data. Despite this, the data outlined through this document remains independent from the models and tools identified. The time-period is selected based on data availability, for the base year of 2019, and relevancy to long-term energy planning time scales in national Kenyan energy planning.

## Ethics Statement

Not Applicable.

## Credit Author Statement

**Neve Fields:** Conceptualisation, Methodology, Data Curation, Writing – Original draft preparation, validation, visualisation, Writing – reviewing and editing. **Ariane Millot:** Conceptualisation, Methodology, Data Curation. **Pietro Lubello:** Conceptualisation, Data Curation. **Martin Mutembei:** Investigation. **Anne Nganga:** Investigation. **Leonard Hofbauer:** Conceptualisation. **Ed Brown:** Supervision. **Mark Howells:** Supervision.

## Acknowledgements

As well as support in kind provided by the employers of the authors of this note, we also acknowledge core funding from the UKPACT and Climate Compatible Growth Program (#CCG) of the UK's Foreign Development and Commonwealth Office (FCDO). The views expressed in this paper do not necessarily reflect the UK government's official policies.

## Funding

This work was supported by the Climate Compatible Growth Programme (#CCG) and the UKPACT programme of the UK's Foreign Development and Commonwealth Office (FCDO). The views expressed in this paper do not necessarily reflect the UK government's official policies.

## Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

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