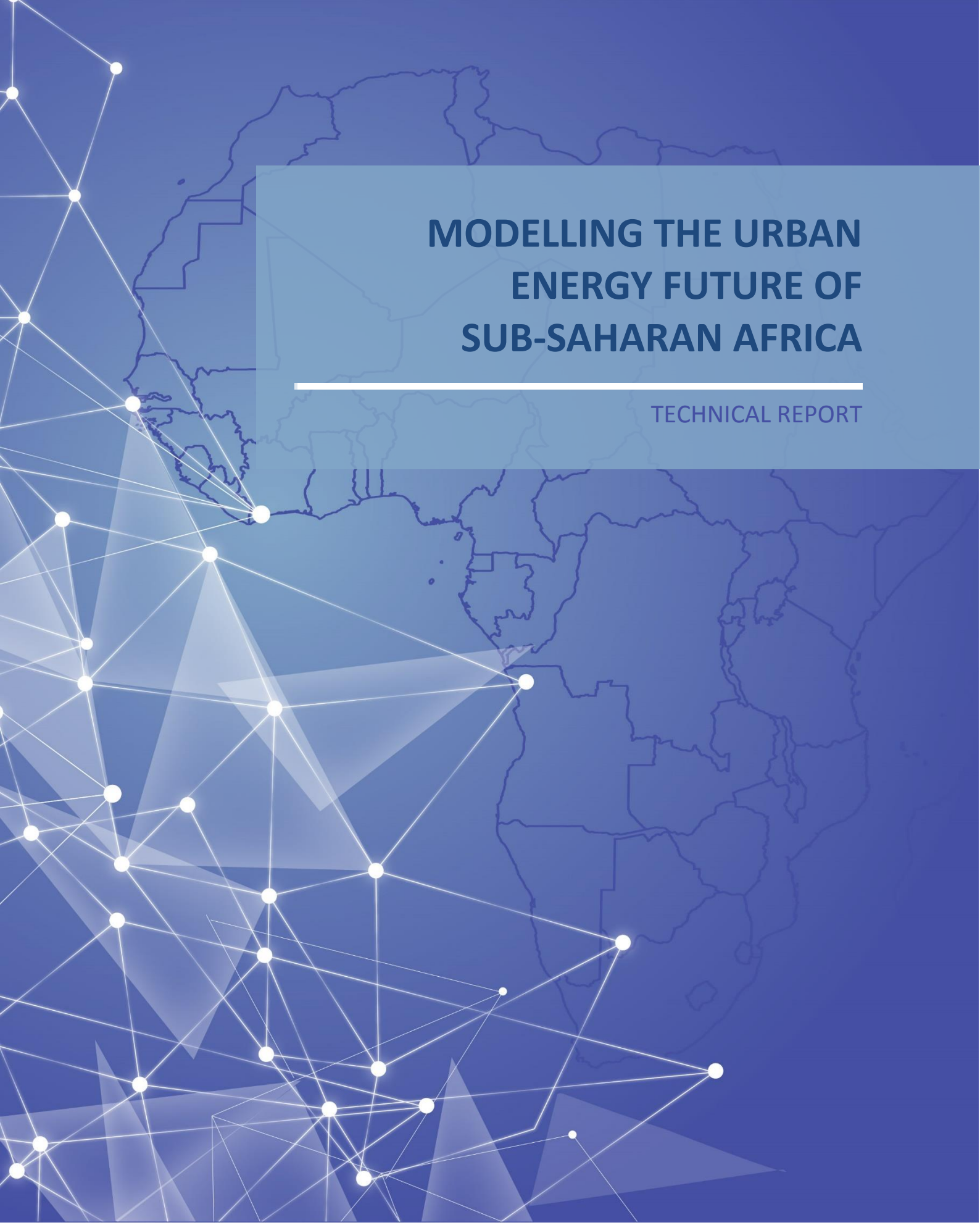

MODELLING THE URBAN ENERGY FUTURE OF SUB-SAHARAN AFRICA

TECHNICAL REPORT

SUSTAINABLE ENERGY AFRICA

SAMSET
Supporting Sub-Saharan Africa's Municipalities with Sustainable Energy Transitions

TABLE OF CONTENTS

CONTACT DETAILS

SAMSET Project (Supporting Sub-Saharan African Municipalities with Sustainable Energy Transitions) www.samsetproject.site11.com, www.AfricanCityEnergy.org

Scientific lead: Sustainable Energy Africa (Non-Profit Company),

Westlake Business Park, Cape Town, +27 21 702-3622,

www.sustainable.org.za, www.cityenergy.org.za, mark@sustainable.org.za

November 2015

MODELLING THE URBAN ENERGY FUTURE OF SUB-SAHARAN AFRICA TECHNICAL REPORT INTRODUCTION

INTRODUCTION

This technical report accompanies the working paper, Modelling the Urban Energy Future of Sub-Saharan Africa (SEA, 2015). It outlines all of the data sources and assumptions used to create the Long Range Energy Alternatives Planning (LEAP) model that forms the basis of the report.

KEY ASSUMPTIONS

Urban population: Urban population for each sub-Saharan country (World Bank, 2013) were added to get a total urban population of 335,229,375 people.

Households: Demand is based on a per household basis. The number of urban households is calculated by taking the total urban population of 335,229,375 (World Bank, 2013) and dividing by 5 (assumed people per household average) to get 67,045,875 households.

GDP growth: A GDP growth of 5.1%, based on data from (IEA, 2014), was used to grow sectors in the model.

Population growth: Urban population growth was obtained for each country (CIA, 2015) and then averaged across the region to get a value of 3.6%.

RESIDENTIAL

Cooking

Proportions of urban households using electricity (12%), coal (1%) and wood (28%) were taken from StatCompiler (USAID, 2015).

Electric stoves: Assume 1 stove per HH that uses electricity for cooking and that they use 1200 kWh/HH/year (IEA, 2014).

Coal stoves: Coal consumption based on 10kg/HH/month (SEA, 2015). Only included data for RSA as this is the bulk.

Wood: Consumption based on surveys in Jinja Municipality, which estimated 1.056tons/HH/year.

Total fuel consumption in the residential sector for Charcoal, LPG and Kerosene taken from (United Nations, 2015).

For **Charcoal**, it was assumed that 82% (IEA, 2014) of total consumption of this fuel (22,391,950 tonnes) in the residential sector was used in urban households.

For **LPG** and **Kerosene**, it was assumed that 100% of total consumption of these fuels (1,306,968 kg and 2,573,817 litres, respectively) in the residential sector were used in urban households.

Lighting

Sub-Saharan Africa has an urban electrification rate of 54% (IEA, 2014). It is assumed that all of these households use electricity for lighting.

Assumption that, on average, there are three light bulbs per house and that they are on for 5 hours per day. It is also assumed that the split between incandescent (70W) and CFL (10W) lights is 50/50 (IEA, 2014).

The remainder of households are assumed to be using kerosene for lighting with an energy intensity of 13.4 litres/HH/year.

Appliances/other

Average proportion of households that use refrigeration and/or have TV's, taken from StatCompiler (USAID, 2015). It was assumed that all homes with a TV also had other small appliances (Mobile phone, fan, etc…). Assumed that all HH's with electric stoves have water heaters. Consumption data per HH for refrigeration, water heaters and "other" were estimated from (IEA, 2014).

COMMERCIAL

(IEA, 2014) fig 1.14, 70.4TWh of electricity for services sector (20% of 352 TWh demand in sub-Saharan Africa in 2012), assumed to all be urban commercial. Assumed all were 100% saturation and used energy intensities to disaggregate between end-uses. Assumed (From Cape Town (SEA, 2015)) Lighting (40%), HVAC (35.8%), Water heating (2.2%), Refrigeration (7%), Other (15%).

For other fuels (charcoal, LPG, wood, kerosene), average values from the Awutu Senya and Ga East models were used. These were converted into a per capita value and multiplied by population of urban SSA to get a total energy demand for each fuel type.

Data for **informal commerce** derived from Awutu Senya and Ga East LEAP models (average between the two). Data were converted into a per capita value and used as such in the LEAP model.

	End-use\Energy carrier	**Energy Intensity**	**Unit**
Formal commerce	Lighting\Electricity	28160	Gigawatt-Hour
	HVAC\Electricity	25218	Gigawatt-Hour
	Water heating\Electricity	1534	Gigawatt-Hour
	Water heating\Charcoal	97507339	Kilogramme
	Water heating\LPG	28448973	Kilogramme
	Water heating\Wood	5800897	Kilogramme
	Water heating\Kerosene	22778	Liter
	Refrigeration\Electricity	4928	Gigawatt-Hour
	Other\Electricity	10560	Gigawatt-Hour
	Other\LPG	120	Metric Tonne
Informal commerce	HVAC\Electricity	0.267	Kilowatt-Hour
	Cooking\Electricity	0.065	Kilowatt-Hour
	Cooking\LPG	0.06	Kilogramme
	Cooking\Charcoal	0.215	Kilogramme
	Cooking\Wood	0.086	Kilogramme
	Cooking\Kerosene	0.0001	Liter
	Lighting\Electricity	1.147	Kilowatt-Hour
	Refrigeration\Electricity	0.793	Kilowatt-Hour
	Other\Electricity	1.916	Kilowatt-Hour
	Other\LPG	0.191	Kilogramme

INDUSTRY

Data for industry taken from (United Nations, 2015). Data were obtained for manufacturing, construction and other industries (excluding metal mining and oil & gas). It was assumed that all manufacturing and construction industries are urban. Total values for each fuel type were used, no disaggregation between types of industry was attempted.

Energy carrier	Energy Intensity	Unit
Electricity	178,528	Gigawatt-Hour
Natural Gas	294,871	Terajoule
Biomass	74,146,087	Cubic Meter
Coal	2,764,989	Metric Tonne
Fuel Oil	3,352,600	Metric Tonne
Charcoal	296,600	Metric Tonne
Kerosene	4,542,708	Metric Tonne
LPG	70,080	Metric Tonne
Bagasse	20,248,920	Metric Tonne

TRANSPORT

Total passenger km (544,737,109,959) and tonne km (217,356,007,339) were taken from two reports with data from 2008 (Gwilliam, et al., 2008) and (AICD, 2015). Urban passenger and tonne km calculated as 70% of total, using the assumption that approximately 70% of GDP is urban (assuming that all agriculture and mining (12 and 18% of GDP respectively) is rural). Percent share of various transport modes were taken from (Trikam & Stone, 2015) while energy intensity data were taken from (Trikam & Stone, 2015) and (DEA, 2013).

Freight transport mode	Percent share	Energy intensity (MJ/tonne km)
Large truck (diesel)	30	1.156
Medium truck (diesel)	32	4.560
Small truck (diesel)	20	9.272
Petrol truck	18	9.656

Passenger transport mode	Percent share	Energy intensity (MJ/passenger km)
Public	-	-
Minibus petrol	4.4	0.20
Minibus diesel	4.4	0.17
Scooter	82.9	0.02
Bus	7.9	0.22
Bus-Rapid-Transport	0.4	0.00088
Private	-	-
Car	48	0.12
Scooter	52	0.02

SCENARIOS

SUSTAINABLE ENERGY FOR ALL

The UN's Sustainable Energy for All (SE4All) initiative, a multi-stakeholder partnership uniting the public sector, private sector and civil society, is seen by many as the logical rallying point for action on a sustainable energy SDG. With its three interlinked targets—**ensuring universal access to modern energy services, doubling the global rate of improvement in energy efficiency, and doubling the share of renewable energy in the world's energy mix, all by 2030**—it provides a road map for a future in which ending energy poverty does not have to come at the expense of the planet.

UNIVERSAL ACCESS

This scenario only affects the residential sector, with a move to modern fuels by 2030.

Cooking

Electricity from 12% to 45%
LPG from 26% to 50%
Coal from 1% to 0%
Wood from 28% to 1%
Charcoal from 82% to 4%
Kerosene from 8% to 0%

Lighting

Lantern from 46% to 0%
Incandescent from 27% to 50%
CFL from 27% to 50%

Appliances

No change, all already modern fuels (electricity).

ENERGY EFFICIENCY

Residential

Cooking

Same as Universal Access scenario.

Lighting

Lantern from 46% to 0%
Incandescent from 27% to 10%
CFL from 27% to 90%

Appliances

Refrigeration energy intensity down by 20%
Water heating energy intensity down by 30%
Other energy intensity down by 10%

Commercial

I used the same savings for all sub-sectors. Percentage reduction in energy intensity from City Mitigation LEAP modelling. Only did efficiency in electrical uses.

Lighting energy intensity down by 40%
HVAC energy intensity down by 25%
Water heating energy intensity down by 30%
Refrigeration energy intensity down by 5%
Other energy intensity down by 5%

Industry

Percentage reduction in energy intensity from City Mitigation LEAP modelling, average for all electricity interventions was 15%. Electricity energy intensity down by 15%

Transport

Reduced all energy intensities of private transport by 10% by 2040.

Proportion of public passenger transport increased from 77% to 80% by 2040. This is essentially modelling a change in urban form to allow the retention of such a high proportion of public transport

RENEWABLE ENERGY

The sustainable energy for all targets call for “a doubling the share of renewable energy in the world’s energy mix”. To do this in LEAP, the total final energy demand needs to be calculated and then the supply mix needs to be configured to supply this demand. This was done outside of LEAP and then copied back in for the global warming calculations. The tables below show the proportions of each electricity supply technology as well as the functions used for the exogenous supply in the LEAP model.

Business as usual

Table 1: Proportion of each electricity supply technology in the supply mix for the Business as Usual scenario

	2012	2015	2020	2025	2030	2040
Landfill Gas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pumped Storage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Solar PV large-scale	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Solar Th Elec with st	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Wind	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Nuclear	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Coal	42.0%	42.0%	42.0%	42.0%	42.0%	42.0%
CCGT	12.6%	12.6%	12.6%	12.6%	12.6%	12.6%
OCGT	22.0%	22.0%	22.0%	22.0%	22.0%	22.0%
Backup	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Hydro	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Geothermal	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Existing Nuclear	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table 2: Exogenous supply functions used in the LEAP model for the Business as Usual Scenario

Technology	Function
Landfill Gas	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0)
Pumped Storage	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0)
Solar PV large-scale	interp(2012,179,2015,206,2020,261,2025,331,2030,420,2040,678)
Solar Th Elec with st	interp(2012,79,2015,92,2020,116,2025,147,2030,187,2040,301)
Wind	interp(2012,598,2015,690,2020,874,2025,1108,2030,1406,2040,2268)
Nuclear	interp(2012,829,2015,956,2020,1211,2025,1536,2030,1949,2040,3144)
Coal	interp(2012,17010,2015,19601,2020,24838,2025,31497,2030,39967,2040,64475)
CCGT	interp(2012,4843,2015,5581,2020,7072,2025,8968,2030,11379,2040,18357)
OCGT	interp(2012,8211,2015,9461,2020,11989,2025,15203,2030,19292,2040,31122)
Backup	interp(2012,187,2015,215,2020,272,2025,346,2030,438,2040,707)
Hydro	interp(2012,12622,2015,14544,2020,18430,2025,23370,2030,29656,2040,47840)
Geothermal	interp(2012,99,2015,99,2020,99,2025,99,2030,99,2040,99)
Existing Nuclear	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0)

Renewable Energy

Table 3: Proportion of each electricity supply technology in the supply mix for the Renewable Energy scenario

	2012	2015	2020	2025	2030	2040
Landfill Gas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pumped Storage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Solar PV large-scale	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%
Solar Th Elec with st	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%
Wind	0.5%	0.6%	0.7%	0.8%	1.0%	1.1%
Nuclear	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Coal	42.0%	41.9%	41.7%	41.4%	41.1%	41.0%
CCGT	12.6%	12.6%	12.6%	12.6%	12.6%	12.3%
OCGT	22.0%	22.0%	22.0%	22.0%	22.0%	22.0%
Backup	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Hydro	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Geothermal	0.2%	0.2%	0.3%	0.3%	0.4%	0.5%
Existing Nuclear	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table 4: Exogenous supply functions used in the LEAP model for the Renewable Energy Scenario

Technology	Function
Landfill Gas	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0)
Pumped Storage	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0)
Solar PV large-scale	interp(2012,179,2015,206,2020,261,2025,663,2030,841,2040,2034)
Solar Th Elec with st	interp(2012,79,2015,92,2020,116,2025,294,2030,373,2040,903)
Wind	interp(2012,598,2015,827,2020,1223,2025,1773,2030,2812,2040,4990)
Nuclear	interp(2012,829,2015,956,2020,1211,2025,1536,2030,1949,2040,3144)
Coal	interp(2012,17010,2015,19554,2020,24661,2025,31047,2030,39111,2040,62940)
CCGT	interp(2012,4843,2015,5581,2020,7072,2025,8968,2030,11379,2040,17920)
OCGT	interp(2012,8211,2015,9461,2020,11989,2025,15203,2030,19292,2040,31122)
Backup	interp(2012,187,2015,215,2020,272,2025,346,2030,438,2040,707)
Hydro	interp(2012,12622,2015,14544,2020,18430,2025,23370,2030,29656,2040,47840)
Geothermal	interp(2012,99,2015,99,2020,124,2025,149,2030,198,2040,248)
Existing Nuclear	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0)

Sustainable Energy for All

Table 5: Proportion of each electricity supply technology in the supply mix for the Sustainable Energy for All scenario

	2012	2015	2020	2025	2030	2040
Landfill Gas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pumped Storage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Solar PV large-scale	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%
Solar Th Elec with st	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%
Wind	0.5%	0.6%	0.7%	0.8%	1.0%	1.1%
Nuclear	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Coal	42.0%	41.9%	41.7%	41.4%	41.1%	41.0%
CCGT	12.6%	12.6%	12.6%	12.6%	12.6%	12.3%
OCGT	22.0%	22.0%	22.0%	22.0%	22.0%	22.0%
Backup	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Hydro	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Geothermal	0.2%	0.2%	0.3%	0.3%	0.4%	0.5%
Existing Nuclear	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table 6: Exogenous supply functions used in the LEAP model for the Sustainable Energy for All scenario

Technology	Function
Landfill Gas	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0)
Pumped Storage	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0)
Solar PV large-scale	interp(2012,179,2015,202,2020,247,2025,604,2030,734,2040,1613)
Solar Th Elec with st	interp(2012,79,2015,90,2020,110,2025,268,2030,326,2040,716)
Wind	interp(2012,598,2015,812,2020,1159,2025,1616,2030,2457,2040,3956)
Nuclear	interp(2012,829,2015,937,2020,1147,2025,1399,2030,1702,2040,2492)
Coal	interp(2012,17010,2015,19179,2020,23356,2025,28293,2030,34166,2040,49901)
CCGT	interp(2012,4843,2015,5474,2020,6698,2025,8172,2030,9941,2040,14208)
OCGT	interp(2012,8211,2015,9280,2020,11355,2025,13855,2030,16853,2040,24674)
Backup	interp(2012,187,2015,211,2020,258,2025,315,2030,383,2040,561)
Hydro	interp(2012,12622,2015,14265,2020,17455,2025,21298,2030,25906,2040,37929)
Geothermal	interp(2012,99,2015,99,2020,124,2025,149,2030,198,2040,248)
Existing Nuclear	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0)

RESULTS

ENERGY DEMAND

Below are tables of final energy demand (million tonnes of oil equivalent) for the Business as Usual and Sustainable Energy for All scenarios.

Table 7: Final energy demand (million tonnes of oil equivalent) for Business as Usual Scenario

	2012	2015	2020	2025	2030	2040
Residential	32.0475	35.6347	42.5277	50.7541	60.5717	86.2715
Cooking	27.9007	31.0237	37.0248	44.1867	52.7339	75.1083
Lighting	1.0395	1.1559	1.3795	1.6464	1.9648	2.7985
Other	3.1073	3.4551	4.1234	4.9211	5.8730	8.3648
Commercial	6.4312	7.4662	9.5745	12.2781	15.7450	25.8923
Formal commerce	6.1550	7.1456	9.1633	11.7507	15.0688	24.7802
Lighting	2.4213	2.8110	3.6047	4.6226	5.9279	9.7483
HVAC	2.1684	2.5173	3.2281	4.1397	5.3086	8.7299
Water heating	0.2335	0.2710	0.3476	0.4457	0.5716	0.9400
Refrigeration	0.4237	0.4919	0.6308	0.8090	1.0374	1.7060
Other	0.9081	1.0543	1.3520	1.7337	2.2233	3.6562
Informal commerce	0.2762	0.3207	0.4112	0.5273	0.6762	1.1120
HVAC	0.0077	0.0089	0.0115	0.0147	0.0188	0.0310
Cooking	0.0850	0.0987	0.1266	0.1623	0.2081	0.3423
Lighting	0.0331	0.0384	0.0492	0.0631	0.0809	0.1331
Refrigeration	0.0229	0.0265	0.0340	0.0436	0.0560	0.0920
Other	0.1276	0.1481	0.1899	0.2436	0.3123	0.5136
Industrial	56.1417	65.1769	83.5810	107.1818	137.4468	226.0277
Transport	52.6255	61.0948	78.3461	100.4688	128.8382	211.8712
Freight	28.0260	32.5364	41.7237	53.5052	68.6135	112.8332
Passenger Transport	24.5995	28.5584	36.6225	46.9636	60.2247	99.0380
Public	17.8534	20.7266	26.5792	34.0844	43.7089	71.8781
Private	6.7461	7.8318	10.0432	12.8791	16.5158	27.1598
Total	**147.2459**	**169.3727**	**214.0293**	**270.6827**	**342.6017**	**550.0627**

Table 8: Final energy demand (million tonnes of oil equivalent) for Sustainable Energy for All

Branches	2012	2015	2020	2025	2030	2040
Residential	32.0475	33.0150	34.1904	34.5852	33.8535	27.0758
Cooking	27.9007	28.5301	29.0888	28.7962	27.3019	18.7622
Lighting	1.0395	1.0924	1.1773	1.2541	1.3167	1.3626
Other	3.1073	3.3925	3.9243	4.5349	5.2348	6.9510
Commercial	6.4312	6.9869	7.9351	8.8619	9.6792	10.3756
Formal commerce	6.1550	6.6686	7.5320	8.3514	9.0330	9.3403
Lighting	2.4213	2.6002	2.8838	3.1203	3.2604	2.9245
HVAC	2.1684	2.3488	2.6517	2.9384	3.1757	3.2737
Water heating	0.2335	0.2604	0.3111	0.3697	0.4367	0.5948
Refrigeration	0.4237	0.4643	0.5362	0.6118	0.6873	0.8103
Other	0.9081	0.9950	1.1492	1.3112	1.4730	1.7370
Informal commerce	0.2762	0.3183	0.4031	0.5104	0.6462	1.0353
HVAC	0.0077	0.0087	0.0106	0.0130	0.0158	0.0232
Cooking	0.0850	0.0987	0.1266	0.1623	0.2081	0.3423
Lighting	0.0331	0.0367	0.0436	0.0514	0.0601	0.0799
Refrigeration	0.0229	0.0264	0.0335	0.0426	0.0542	0.0874
Other	0.1276	0.1478	0.1888	0.2411	0.3080	0.5025
Industrial	56.1417	64.8905	82.6015	105.1408	133.8228	216.7574
Transport	52.6255	60.7665	77.2251	98.1357	124.7009	201.3143
Freight	28.0260	32.5364	41.7237	53.5052	68.6135	112.8332
Passenger Transport	24.5995	28.2302	35.5015	44.6305	56.0873	88.4810
Public	17.8534	20.5906	26.1088	33.0931	41.9291	67.2255
Private	6.7461	7.6396	9.3927	11.5374	14.1582	21.2555
Total	**147.2459**	**165.6589**	**201.9522**	**246.7236**	**302.0564**	**455.5230**

GLOBAL WARMING POTENTIAL

Below are tables of global warming potential (million metric tonnes of CO_2) for the Business as Usual and Sustainable Energy for All scenarios.

Table 9: Global warming potential (million metric tonnes of CO_2) for the Business as Usual scenario

	2012	2015	2020	2025	2030	2040
Residential	59.4318	66.0858	78.8731	94.1351	112.3470	160.0238
Cooking	36.6002	40.6973	48.5703	57.9664	69.1797	98.5334
Lighting	5.0046	5.5650	6.6421	7.9276	9.4615	13.4773
Other	17.8270	19.8235	23.6608	28.2410	33.7058	48.0131
Commercial	35.9383	41.7243	53.5120	68.6305	88.0149	144.7570
Formal commerce	34.8984	40.5169	51.9636	66.6447	85.4682	140.5687
Lighting	13.8915	16.1280	20.6845	26.5284	34.0212	55.9544
HVAC	12.4402	14.4431	18.5235	23.7568	30.4669	50.1086
Water heating	0.9259	1.0750	1.3786	1.7681	2.2674	3.7291
Refrigeration	2.4310	2.8224	3.6198	4.6425	5.9537	9.7920
Other	5.2097	6.0485	7.7573	9.9489	12.7590	20.9846
Informal commerce	1.0400	1.2074	1.5484	1.9858	2.5467	4.1883
HVAC	0.0442	0.0513	0.0657	0.0843	0.1081	0.1779
Cooking	0.1360	0.1578	0.2024	0.2596	0.3329	0.5474
Lighting	0.1897	0.2202	0.2824	0.3622	0.4645	0.7640
Refrigeration	0.1311	0.1523	0.1953	0.2504	0.3212	0.5282
Other	0.5390	0.6258	0.8026	1.0292	1.3199	2.1708
Industrial	146.3720	169.9340	217.9333	279.4918	358.4248	589.4670
Transport	160.7958	186.6736	239.3848	306.9800	393.6622	647.3675
Freight	85.6327	99.4141	127.4857	163.4840	209.6470	344.7592
Passenger Transport	75.1631	87.2595	111.8991	143.4961	184.0151	302.6082
Public	54.5506	63.3298	81.2122	104.1442	133.5515	219.6220
Private	20.6125	23.9298	30.6868	39.3519	50.4637	82.9863
Total	**402.5380**	**464.4177**	**589.7033**	**749.2374**	**952.4488**	**1,541.6153**

Table 10: Global warming potential (million metric tonnes of CO2) for the Sustainable Energy for All scenario

	2012	2015	2020	2025	2030	2040
Residential	59.4318	63.9233	72.0716	80.9109	89.4706	105.4850
Cooking	36.6002	39.5042	44.6969	50.2790	55.8120	65.8224
Lighting	5.0046	5.2504	5.6715	6.0750	6.3475	6.5006
Other	17.8270	19.1687	21.7032	24.5568	27.3111	33.1620
Commercial	35.9383	38.3906	42.5368	46.3156	48.4788	46.6413
Formal commerce	34.8984	37.2088	41.0705	44.4959	46.2429	43.2900
Lighting	13.8915	14.6917	15.9487	16.8965	17.0098	13.9522
HVAC	12.4402	13.2711	14.6650	15.9118	16.5681	15.6182
Water heating	0.9259	1.0013	1.1362	1.2750	1.3949	1.5678
Refrigeration	2.4310	2.6232	2.9655	3.3128	3.5856	3.8659
Other	5.2097	5.6215	6.3552	7.0997	7.6844	8.2858
Informal commerce	1.0400	1.1818	1.4663	1.8198	2.2359	3.3513
HVAC	0.0442	0.0491	0.0588	0.0703	0.0825	0.1109
Cooking	0.1360	0.1577	0.2018	0.2584	0.3305	0.5401
Lighting	0.1897	0.2076	0.2411	0.2783	0.3137	0.3810
Refrigeration	0.1311	0.1491	0.1855	0.2308	0.2826	0.4171
Other	0.5390	0.6183	0.7790	0.9819	1.2267	1.9022
Industrial	146.3720	166.7617	207.7707	258.9522	319.9013	485.3488
Transport	160.7958	185.6707	235.9596	299.8514	381.0206	615.1109
Freight	85.6327	99.4141	127.4857	163.4840	209.6470	344.7592
Passenger Transport	75.1631	86.2566	108.4738	136.3674	171.3736	270.3517
Public	54.5506	62.9141	79.7747	101.1151	128.1134	205.4059
Private	20.6125	23.3425	28.6991	35.2524	43.2602	64.9458
Total	**402.5380**	**454.7463**	**558.3386**	**686.0301**	**838.8713**	**1,252.5860**

REFERENCES

AICD, 2015. *Africa Infrastructure Country Diagnostic (AICD) Database – Roads Indicators.* [Online]
Available at: http://www.infrastructureafrica.org/library/doc/1056/aicd-database-%E2%80%93-roads-indicators
[Accessed November 2015].

CIA, 2015. *Central Intelligence Agency - The World Factbook.* [Online]
Available at: https://www.cia.gov/library/publications/the-world-factbook/fields/2212.html
[Accessed 03 November 2015].

DEA, 2013. *Draft 2012 Integrated Energy Planning Report,* s.l.: Department of Energy.

GEA, 2012. *Toward a Sustainable Future,* Cambridge, UK: Cambridge University Press.

Gwilliam, K. et al., 2008. *The Burden of Maintenance: Roads in Sub-Saharan Africa,* Washington, DC: World Bank.

Hijioka, Y. et al., 2008. Global GHG emissions scenarios under GHG concentration stabilization targets. *Journal of Global Environmental Engineering,* pp. 97-108.

IEA, 2014. *Africa Energy Outlook,* s.l.: International Energy Agency.

Knöpfle, M., 2004. *A study of charcoal supply in Kampala,* s.l.: Ministry of Energy and Mineral Development (MEMD) & Energy Advisory Project (EAP).

SEA, 2015. *Modelling the Urban Energy Future of sub-Saharan Africa Technical Report,* s.l.: s.n.

SEA, 2015. *State of Energy in South African Cities,* Cape Town: Sustainable Energy Africa.

Trikam, A. & Stone, A., 2015. *Baseline Energy Demand Analysis for Kenya. Manuscript in preparation.,* Cape Town, South Africa: Energy Research Centre, UCT.

U. N., 2015. *UN Data - Record view.* [Online]
Available at: http://data.un.org
[Accessed November 2015].

USAID, 2015. *StatCompiler - ICF International, 2012.* [Online]
Available at: http://www.statcompiler.com
[Accessed November 2015].

W. B., 2013. *Urban Population Data Table.* [Online]
Available at: http://data.worldbank.org/indicator/SP.URB.TOTL/countries
[Accessed November 2015].

This document is an output from a project co-funded by UK aid from the UK Department for International Development (DFID), the Engineering & Physical Science Research Council (EPSRC) and the Department for Energy & Climate Change (DECC), for the benefit of developing countries. The views expressed are not necessarily those of DFID, EPSRC or DECC, or any institution partner of the project.

UKaid
from the British people

Research Councils UK
Energy
For a Low Carbon Future

DEPARTMENT OF
ENERGY
& CLIMATE CHANGE