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The Namibian Energy Mix and Its Implications for Air Quality and Climate Variability

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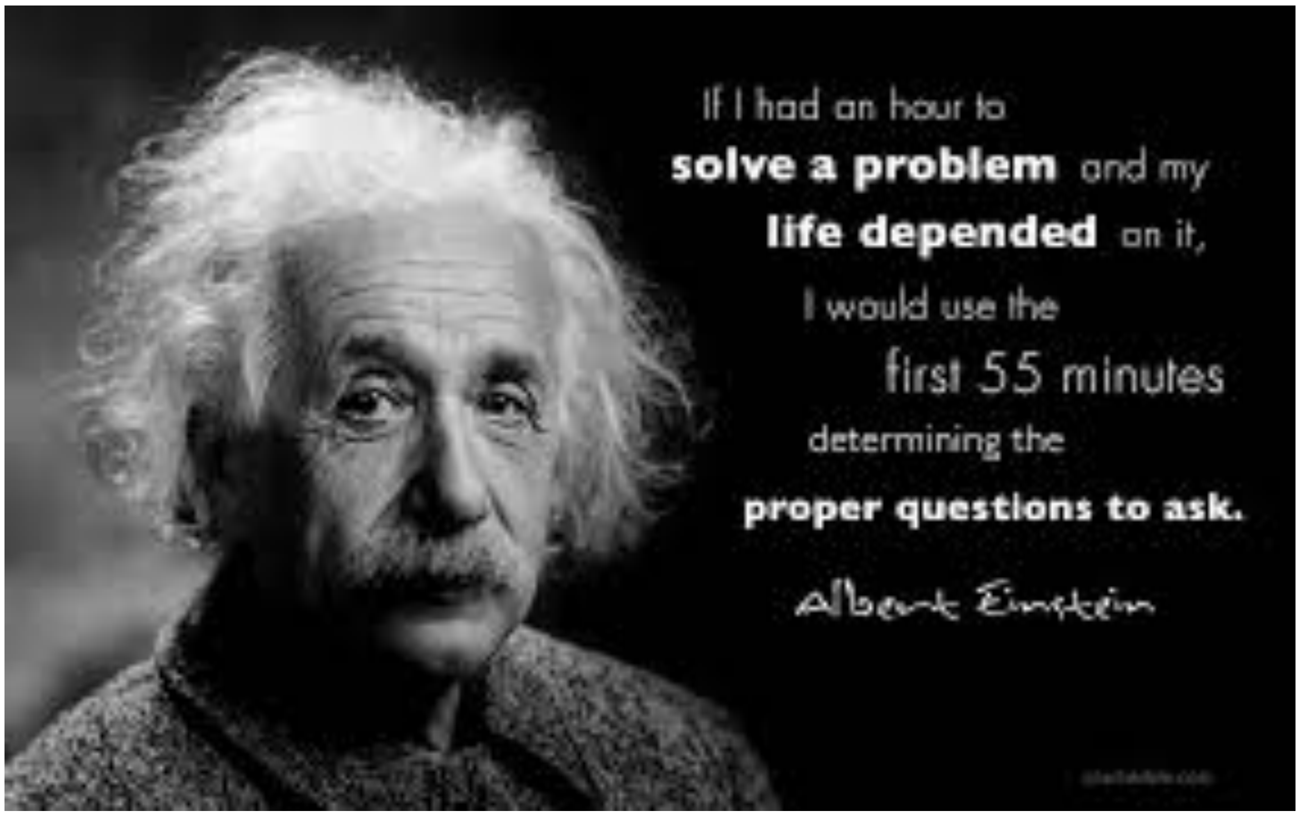
1. BACKGROUND & SIGNIFICANCE



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GHGs & Pollutant Emissions

- Greenhouse gas (GHG) and air pollutant emissions share the same sources—transport, industry, commercial and residential areas
- All these sources depend on production, distribution and utilization of energy
- Direct GHGs: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6)
- Indirect GHGs: non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), nitrogen oxide (NOx), and sulphur dioxide (SO2) (IPCC, 2006)

Link to Electrical Energy Demand & Production

- The world emits approximately 27 gigatonnes of CO_2e from multiple sources
- Electrical production emitting 10 gigatonnes, or approximately 37% of global emissions
- Electricity demand is expected to increase by 43% over the next 20 years (IAEA, 2009)
- Implication – Need for construction of new power generating facilities
- Opportunity - To construct new facilities in a way to limit GHG emissions (World Nuclear Association, 2011)

Significance

- Stakeholders and/or beneficiaries: policy makers, regulators, environmental forums, and urban and rural communities of the developing world
- Basis for accurate energy fuel mix and climate change monitoring, reporting and planning for addressing a global problem at local level

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2. THE NAMIBIAN SITUATION

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Population Growth

YEAR	URBAN	RURAL	NAMIBIA
2015	1068625	1212091	2280716
2020	1295820	1208678	2504498
2025	1531917	1201421	2733338
2030	1770807	1189735	2960542
2035	2011793	1173212	3185005
2040	2256123	1145764	3401887

- Namibia Population Projections, 2011 – 2041
- Data Source: Namibia Statistics Agency (2014)

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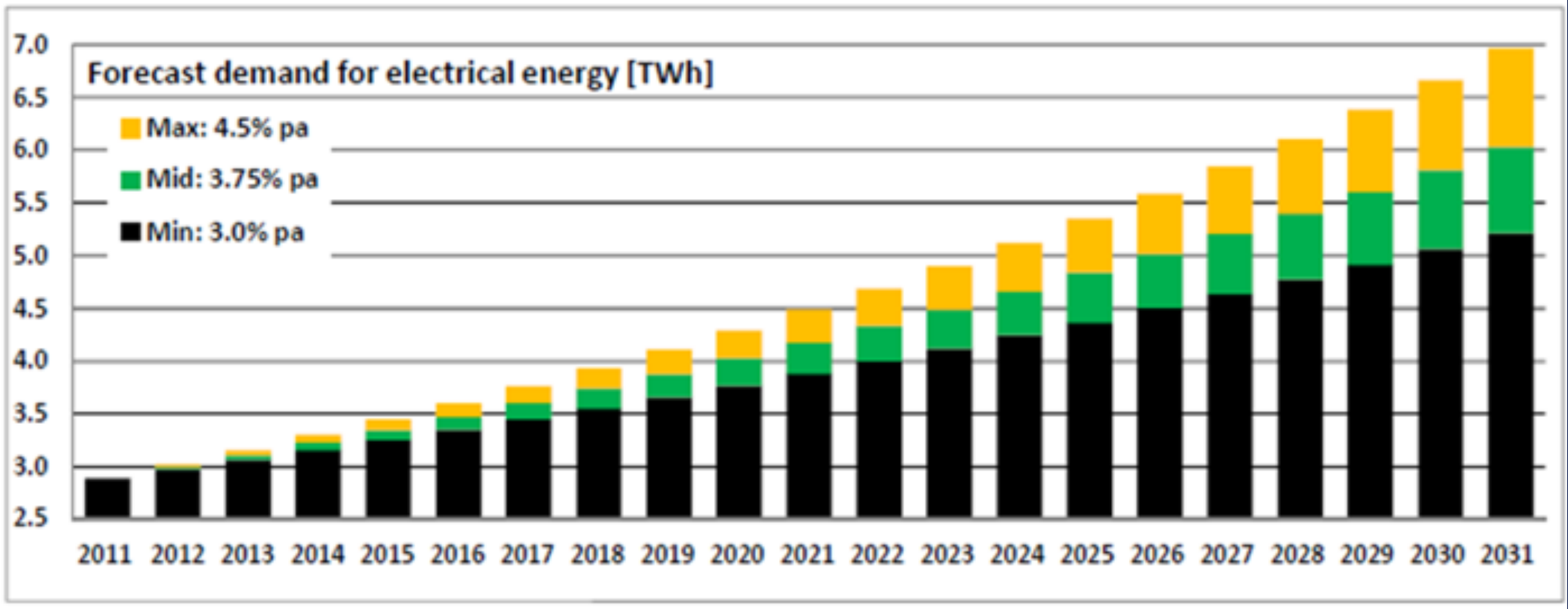
Electrical Energy Demand



(von Oertzen, 2012)

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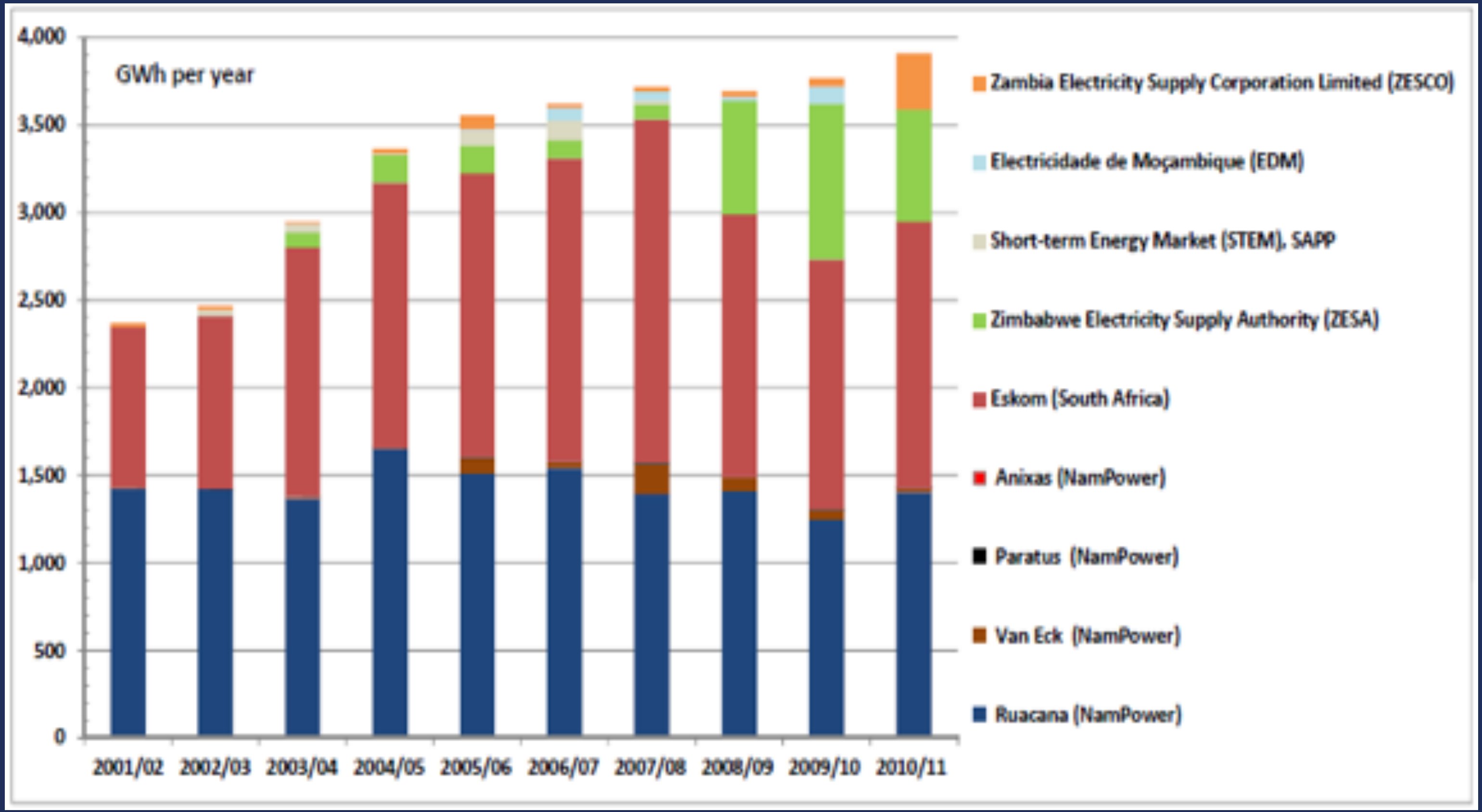
Electrical Energy - Demand Urban Areas

	Urban	Annual	Average	% HH using	% HH using
Arandis	*5170*	*2.6*	*4.2*	*95.7*	*96.1*
Aranos	3683		4.2	25.7	38.7
Eenhana	*5528*	*6.8*	*3.7*	*41.3*	*56*
Gobabis	19101	3.2	3.9	33.9	48.5
Grootfontein	*10415*	*-3.1*	*3.8*	*44.7*	*94.8*
HelaoNafidi	19375		3.8	36.6	47.3
Henties Bay	*4720*	*3.6*	*3.1*	*59.2*	*71.6*
Karasburg	4401	0.8	4.4	41.7	70.5
Karibib	*5132*	*3.2*	*3.7*	*55.9*	*60.5*
KatimaMulilo	28362	2.5	4.2	41.5	76.2
Keetmanshoop	*19447*	*2.1*	*4.2*	*58*	*86.6*
Khorixas	6796	1.4	4.1	42.2	78.7
Luderitz	*12537*	*-0.6*	*3*	*46.9*	*78.1*
Maltahohe	2379		4.3	45.1	56.7
Mariental	*12478*	*2.4*	*4.4*	*65.4*	*87*
Nkurenkuru	618		4.7	75.6	89.4
Okahandja	*22639*	*4.8*	*4.4*	*62*	*73.1*
Okahao	1833		2.9	66.1	77.3
Okakarara	*3927*	*1.8*	*3.7*	*39.7*	*48.2*
Omaruru	6300	2.8	3.6	38.3	53.3
Omuthiya	*3794*		*4.2*	*20.4*	*24.3*
NAMIBIA	*895691*	*3.9*	*3.8*	*59.7*	*71.1*

Data Source: National Statistics Agency (2011)

Electrical Energy Production & Consumption



(von Oertzen, 2012)

NB: Need for clear quantifiable electrical energy production mix

Van Eck, ZESA, ESKOM – Coal

Paratus, Anixas – Diesel Oil

Ruacana, EDM, ZESCO – Hydro

STEM – Not Specified

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Electrical Energy Production & Consumption

Year	Production	Export	Import	Supply	Gap	Consumption
2000	1,407	108	785	2,084	-89	1,318
2001	1,211	69	1,066	2,208	871	2,082
2002	1,429	54	942	2,317	44	1,473
2003	1,421	53	1,045	2,413	772	2,193
2004	1,380	23	1,519	2,876	1,392	2,772
2005	1,662	31	1,695	3,326	1,283	2,945
2006	1,612	36	1,867	3,443	1,551	3,136
2007	1,590	40	1,931	3,480	1,629	3,219
2008	1,595	47	2,126	3,673	1,797	3,392
2009	1,520	144	2,202	3,578	1,770	3,290
2010	1,347	294	2,462	3,515	2,007	3,354

NB: Unit - GWh

Data Source: Manuel (2013)

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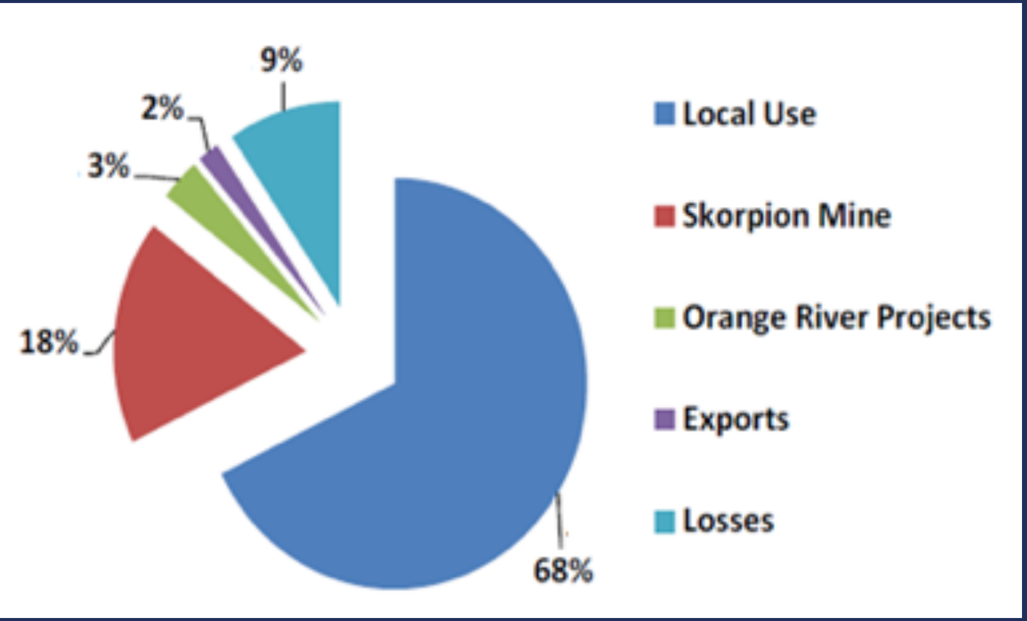
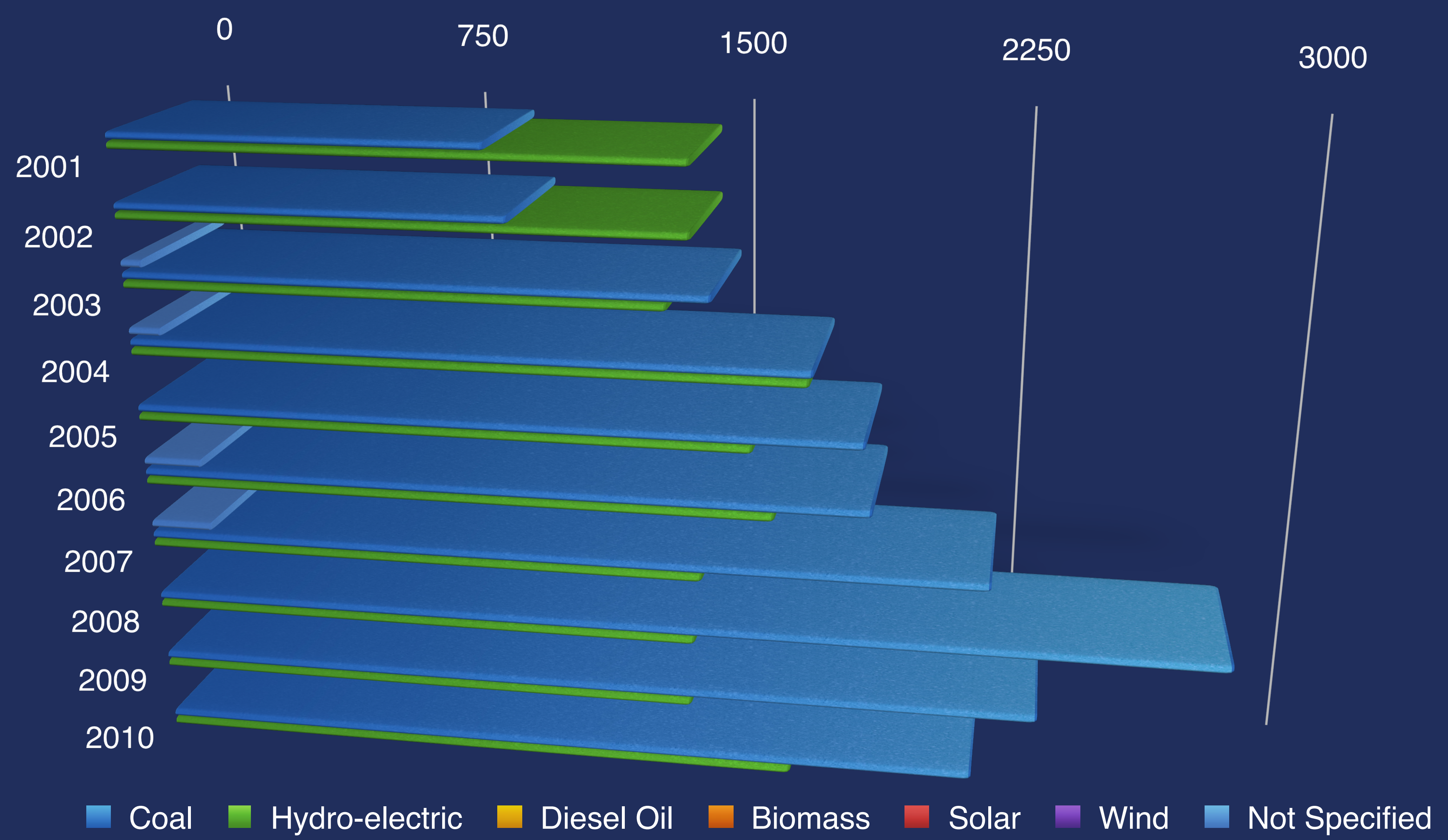
Electrical Energy Consumption



Adapted from von Oertzen (2012)

Electrical Energy Fuel Mix



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Renewable Energy Supply

Period	Total Renewables	Hydro Power	Wood Charcoal	Solar CSP+ PV	Wind Power
2000	*7,155*	*5,026*	*2,129*		
2001	*6,489*	*4,360*	*2,129*		
2002	*7,204*	*5,123*	*2,081*		
2003	*7,266*	*5,108*	*2,157*		
2004	*7,952*	*4,921*	*3,031*		
2005	*8,984*	*5,962*	*3,022*		
2006	*8,520*	*5,443*	*3,077*	*0.2*	
2007	*8,943*	*5,551*	*3,392*	*0.4*	
2008	*9,302*	*5,023*	*4,278*	*0.7*	
2009	*9,352*	*5,072*	*4,278*	*0.9*	*0.6*
2010	*8,952*	*4,489*	*4,461*	*1.4*	*0.6*
2011	*9,260*	*5,058*	*4,200*	*1.4*	*0.6*

- Total Renewable Energy Supplied from 2000 to 2011 (MWh)
- Data Source: Electricity Control Board of Namibia (2014)

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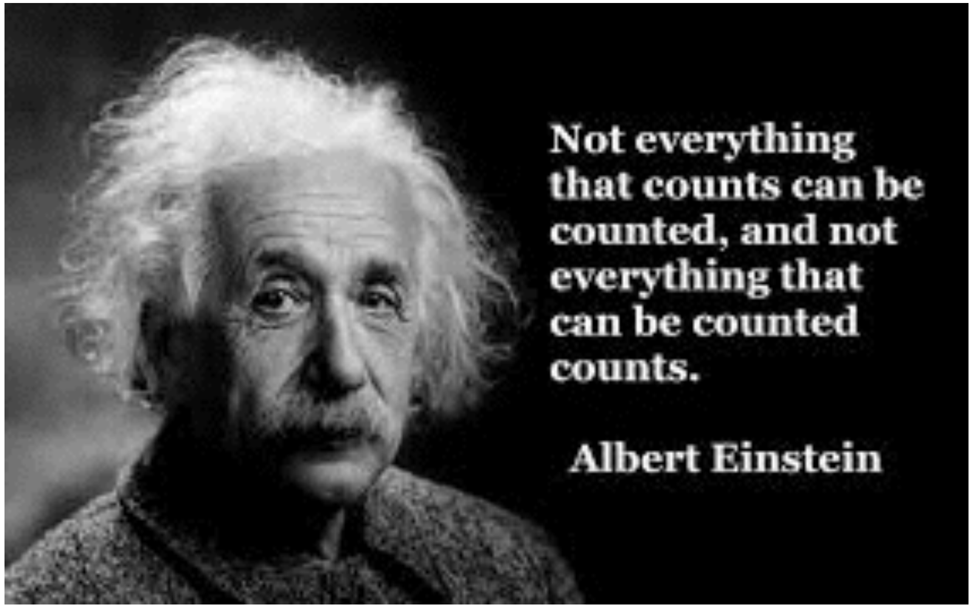
3. GLOBAL WARMING EFFECTS



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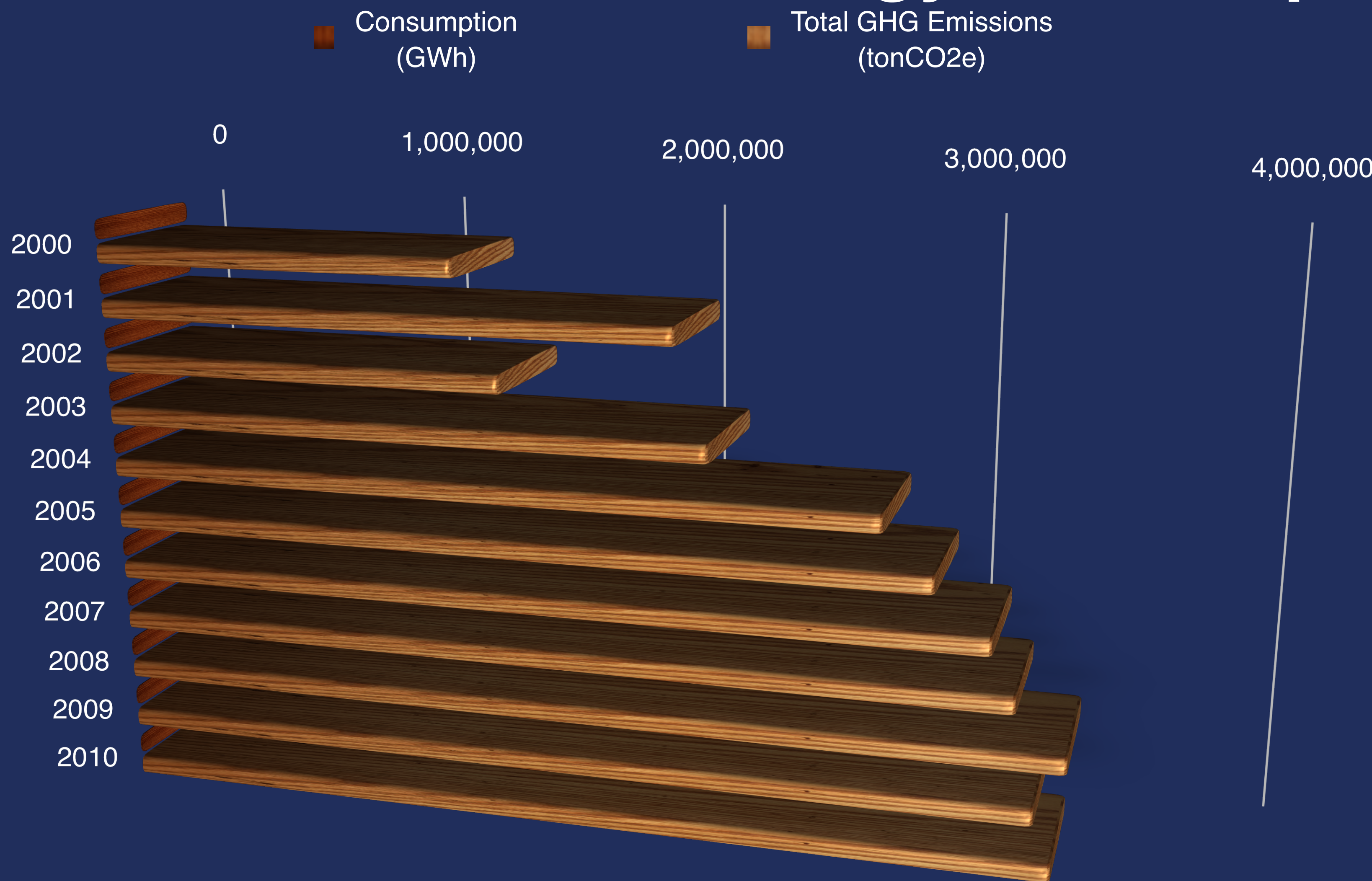
GHGs from Electrical Energy Consumption



Conversion factor = 0.99 $kgCO_2e/kWh$; Source:ESKOM

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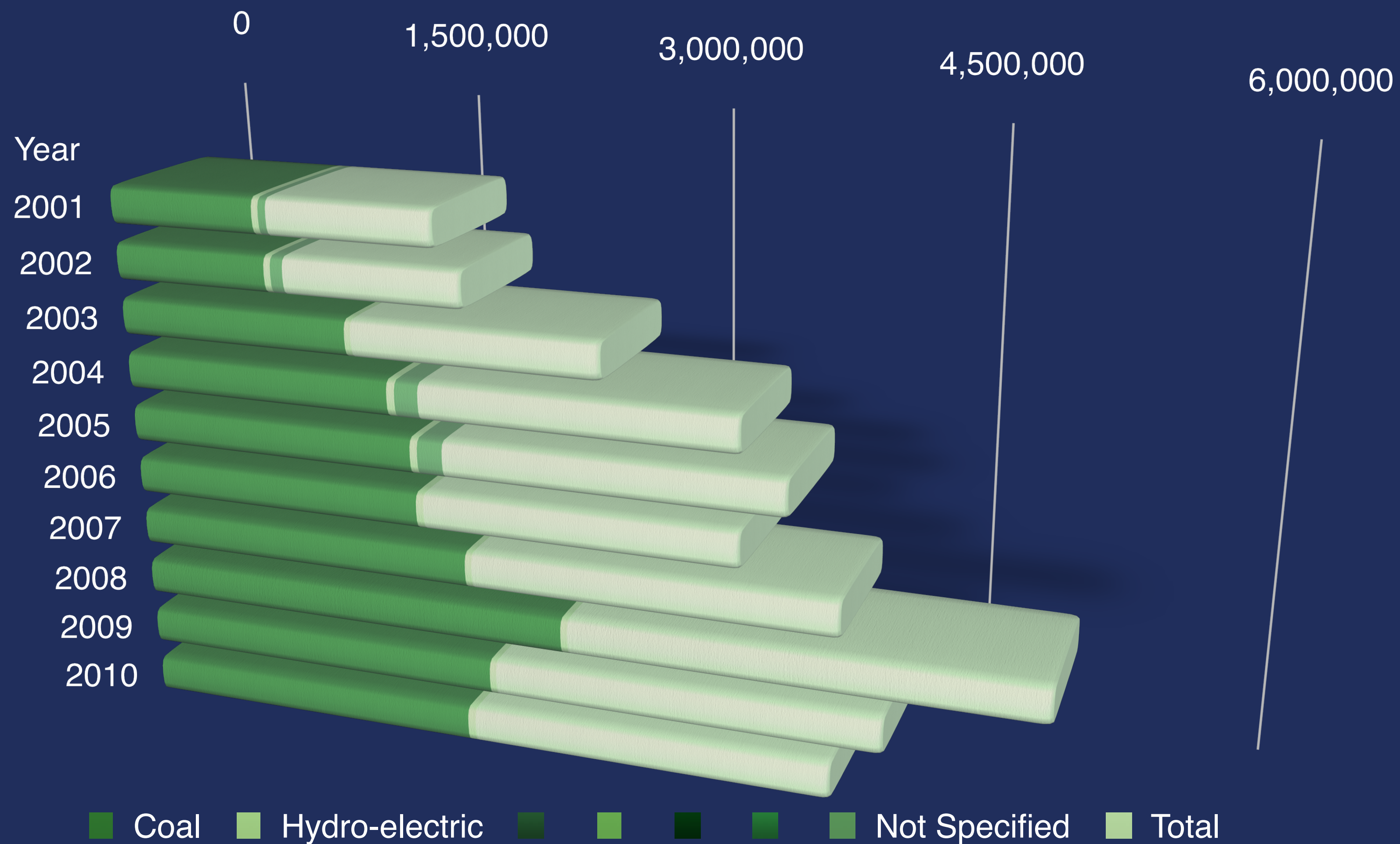
GHGs from Electrical Energy Consumption

Consideration of Actual Electrical Fuel Mix



Conversion factor units: tonCO2e/GWh; Source: IAEA

Coal = 888; Hydroelectric = 6; NB: Unspecified source was assumed to be coal

GHGs from Electrical Energy Consumption

- Need to delineate:
- Direct and Indirect Emissions (Scope 1 &2)
- Contribution of Renewables
- Specific Emissions (e.g. CO2, NH4, N20, SF6)

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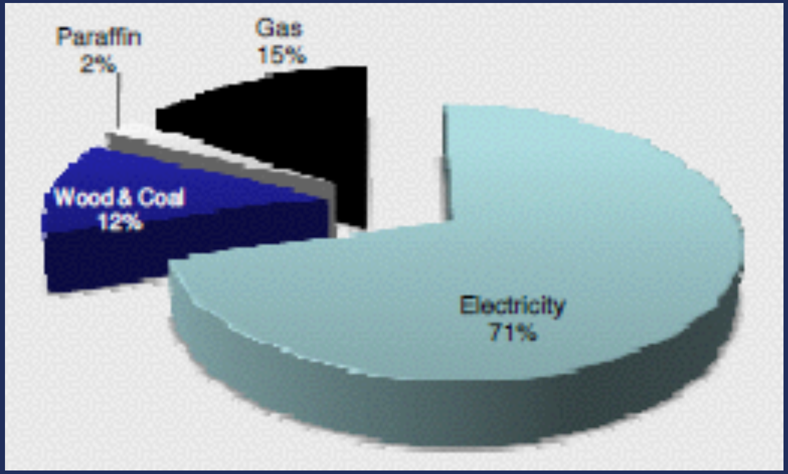
GHG Emissions - Domestic Energy



Household/Domestic fuel mix for the three towns (Kgabi et al, 2013)

Town	Location (Latitude; Longitude)	Population	Number of Households	Main Economic Activities
Karibib	21°56' 16.97"S; 15°51' 16.47"E	13300	3700	No major enterprises or industries. Only Aragonite marble quarries and the Navachab Gold Mine. Economic status: Low income.
Lüderitz	26°38' 45.00"S; 15°9' 14.00"E	13700	4400	Tourism, hospitality, fishing industries, mining and a port/harbor. Economic status: Mainly Medium - low income.
Ondangwa	17°54' 47.01"S; 15°58' 40.12"E	36800	7500	No major enterprises or industries. Only local and regional businesses. Economic status: Mainly Medium - low income.

GHG Emissions - Domestic Energy

The energy used by residents in each of the three towns:

- KARIBIB - Electricity (66.89%), Wood and coal (17.93%), Gas (13.8%), Paraffin (1.38%)
- LÜDERITZ - Electricity (76%), Gas (19%), Wood and coal (4%), Paraffin (1%)
- ONDANGWA - Electricity (70.59%), Gas (14.71%), Wood and Coal (10.29%), Paraffin (4.41%) (Kgabi et al, 2013)

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GHG Emissions - Domestic Energy

		Consumption (kg/day)	Emission Factor (CO_2e/kg)	Emissions (tons CO_2e/day)	Emissions (tons CO_2e/year)
Karibib	Coal	244	2.8814	0.703	256.6
Lüderitz		290		0.836	305.1
Ondangwa		495		1.426	520.5
Karibib	Wood	244	1.9060	0.465	169.7
Lüderitz		290		0.552	201.5
Ondangwa		495		0.943	344.2
Karibib	LPG	166.5 kg (329.7 L)	1.4917 CO_2e/L	0.492	179.6
Lüderitz		198 kg (392 L)		0.585	213.5
Ondangwa		337.5 kg (668 L)		0.996	363.5

GHG emissions from energy consumption by households

Kgabi et al (2013)

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GHG Emissions - Domestic Energy

	Consumption (kWh/year)	Emission Factor	Emissions (tons CO2e/ year)
Karibib	11380164	0.99 kg/kWh	11266
Lüderitz	13533168		13398
Ondangwa	23067900		22837

GHG emissions from electricity consumption by households

Kgabi et al (2013)

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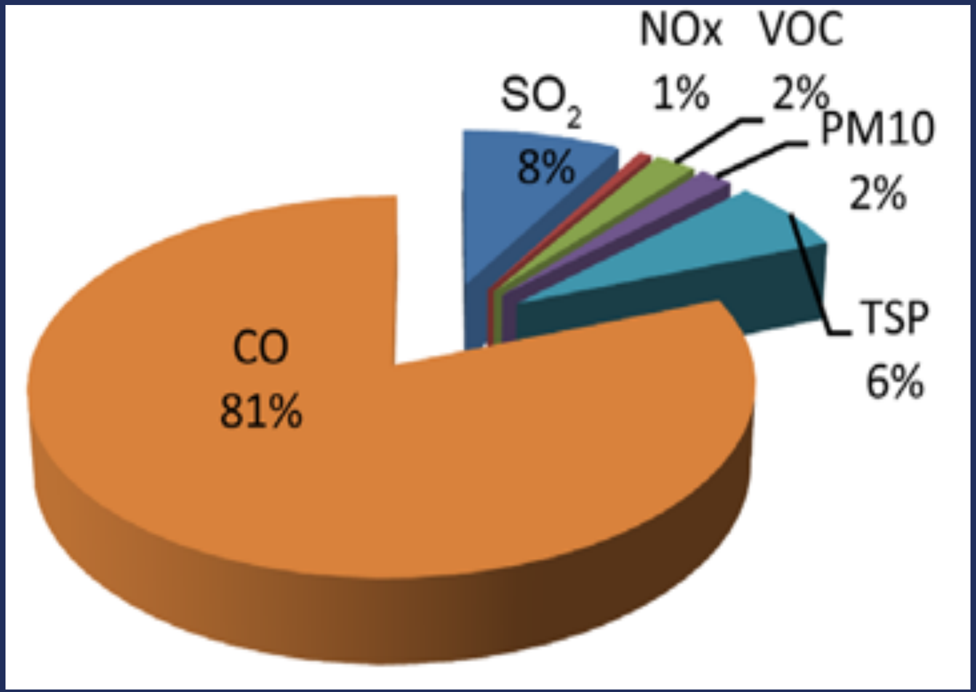
4. AIR QUALITY EFFECTS

Global Warming & Air Pollutants

- Trace gases and aerosols impact climate through their effect on the radiative balance of the earth
- Trace gases such as greenhouse gases absorb and emit infrared radiation which raises the temperature of the earth's surface causing the enhanced greenhouse effect
- Aerosol particles have a direct effect by scattering and absorbing solar radiation and an indirect effect by acting as cloud condensation nuclei
- Atmospheric aerosol particles range from dust and smoke to mists, smog and haze (IPCC, 2001)

Coal Combustion During Electricity Production



Kgabi et al (2014)

- Emission of GHGs during fuel combustion affects air quality
- Combustion of 1 kg of coal results in emission of 19 g SO2, 1.5 g NOx, 5 g VOCs, 4.1 g PM10, 14.7 g TSP, 187.4 g CO and 0.0134 g benzene (Friedl, et al 2014)
- 231.71g = 23.17% Pollutants

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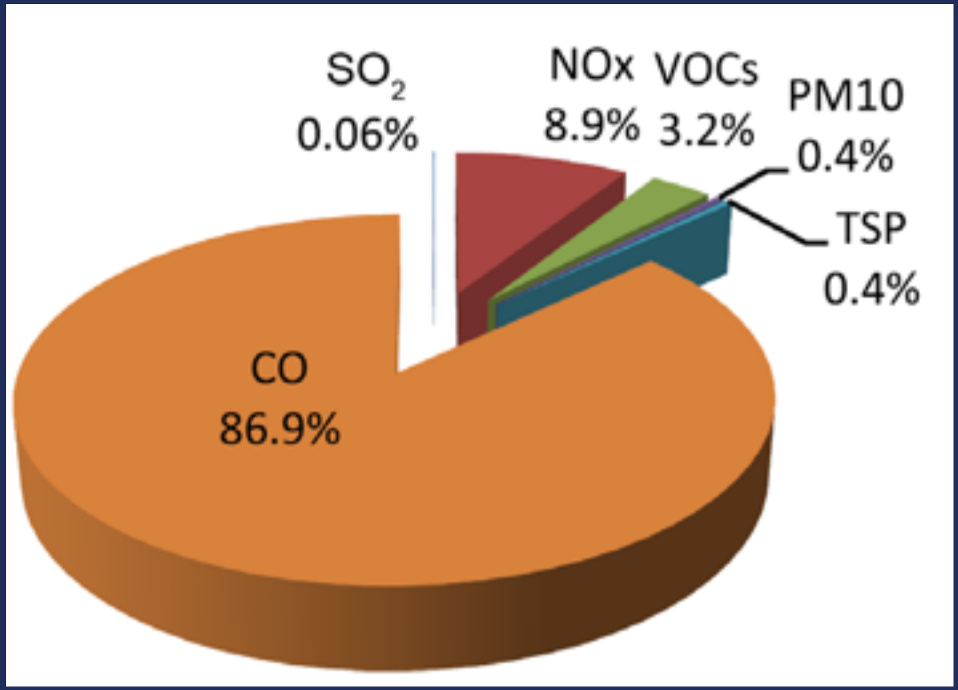
Fuel Oil Combustion During Electricity Generation

- 1 kg of petroleum products emits 0.01 g SO2, 1.4 g NOx, 0.5 g VOCs, 0.07 g PM10, 0.07 g TSP, and 13.6 g CO into the atmosphere (Friedl et al, 2014)
- 15.65g = 1.56% Pollutants



Kgabi et al (2014)

NB: The need for quantification of each fuel type used in the electricity production

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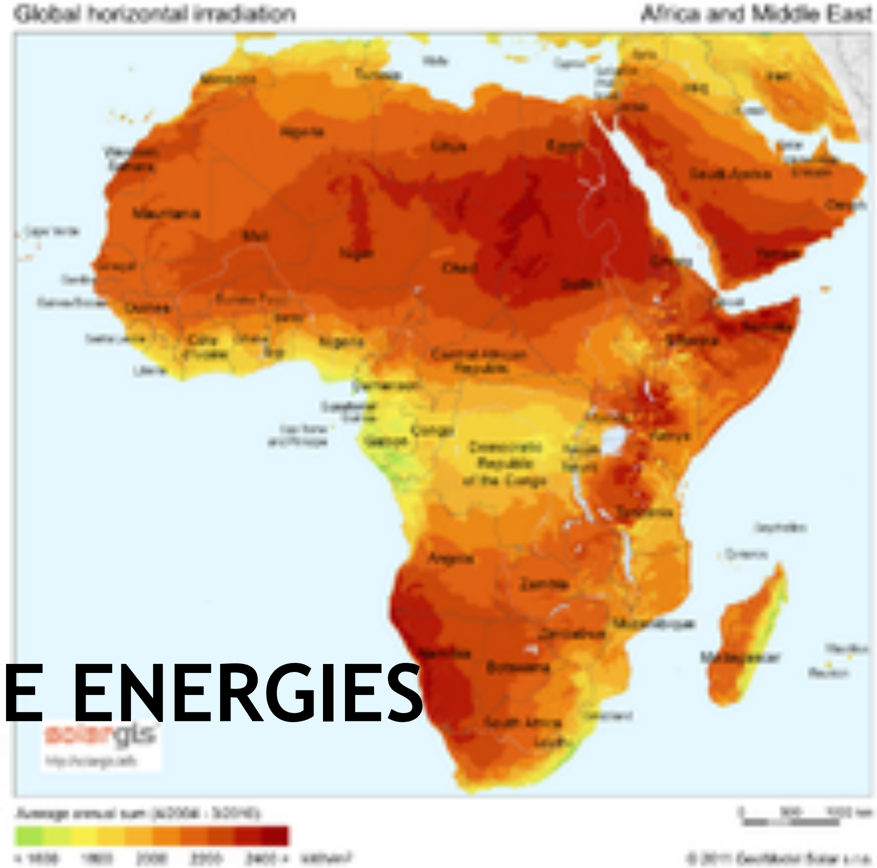
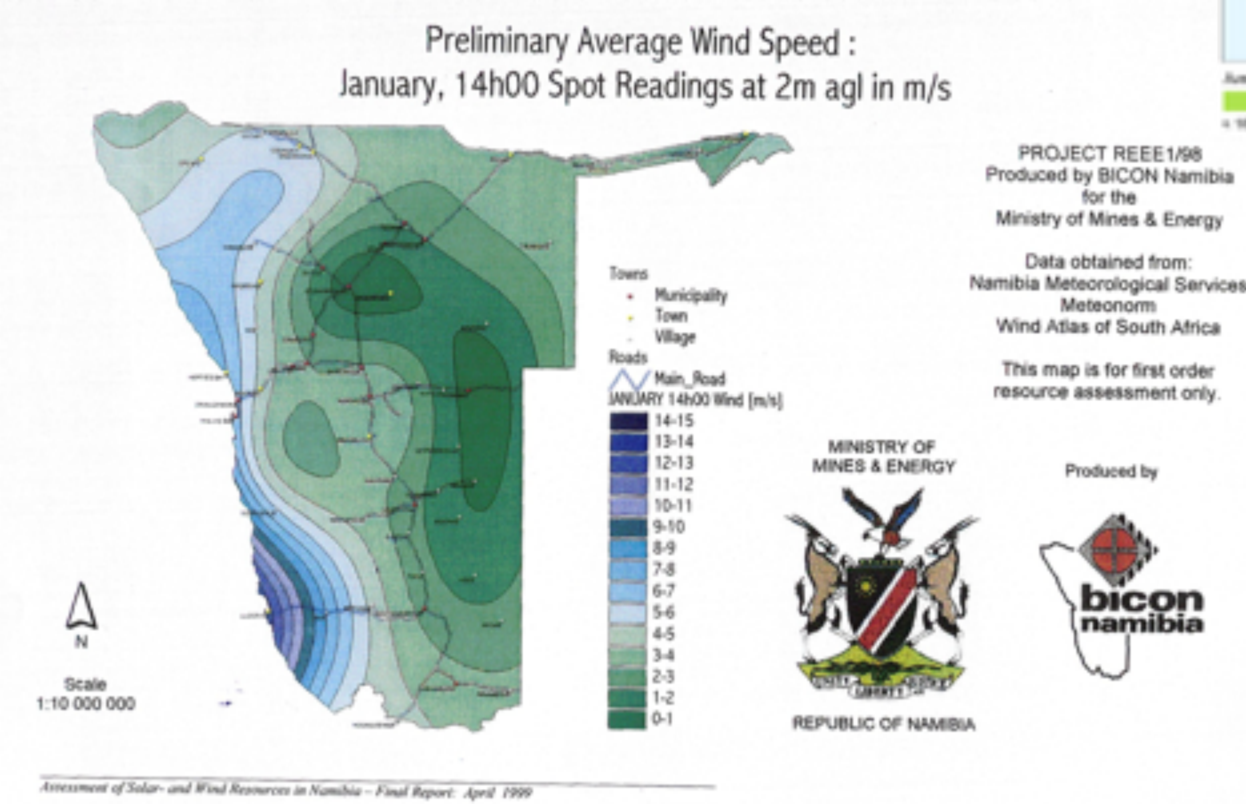


5. THE CASE FOR RENEWABLE ENERGIES



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Renewable Energy – GHG Emissions

Technology	Low	High	Mean
	Tonnes CO		
Lignite	790	1372	1054
Coal	756	1310	888
Oil	547	935	733
Natural Gas	362	891	499
Solar PV	13	731	85
Biomass	10	101	45
Nuclear	2	130	29
Hydroelectric	2	237	26
Wind	6	124	26

(Data Source: IAEA, 2009)

Wind Energy

- Namibia is one of the countries with long coastlines measuring 1,572 km
- Wind resources along the Namibian coast are considerable
- The wind energy potential in the area south of Lüderitz is outstanding
- A typical 50 MW wind farm positioned on the southern coast would yield some 0.12 TWh every year (von Oertzen, 2009)

Solar Energy

- Namibia's annual solar radiation average exceeds 6 kWh per square meter per day
- Presently, solar energy for power generation remains mostly untapped – except for the photovoltaic electricity and water pumping installations throughout the country
- Under prevailing conditions, a generation output of some 0.08 TWh per annum per 50 MW of installed capacity is possible (von Oertzen, 2009)

Solar Energy

- Hazardous emissions connected to PV technology are primarily related to energy consumption in the manufacturing process
- Direct process emissions are almost zero
- Risks from the use of cadmium telluride in modules appear to be quite low, provided that the material is kept well-encapsulated
- PV systems have life-cycle greenhouse gas emissions in the range of 25-35 g/kWh

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Solar Energy Systems

- PV energy systems have a very good potential as a low-carbon energy supply technology
- Important considerations to make when discussing the environmental impacts of PV technology (Alsema, 2006):

✓ Energy Pay-Back Time
✓ Greenhouse gas (GHG) mitigation
✓ Toxic emissions
✓ Resource supply
✓ Health & Safety risks

6. CONCLUDING REMARKS

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Summary

- Increase in energy consumption and production yields increase in GHGs and other major pollutants
- The choice of fuel mix determines the success of GHG emissions reduction
- There is no single fuel which is not associated with GHG or other environmental implications (Kgabi et al 2014)
- Current Energy Mix: Coal → Hydro-electric → Fuel Oil

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Summary

- Sustainable energy choices are about deliberately deciding for long-term benefits, for local sustainable value creation, and against import dependencies and non-sustainable resource use
- A balanced view of the actual benefits and costs of our energy supply choices
- Future Energy Mix: Renewable energy technologies should play an important role in Namibia's future electricity supply mix.

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Proposed Fuel Mix

Future Energy/power projects (as per National Development Plan (NDP4)

- Baynes Hydro Power - 660 MW
- Kudu Gas to Power - 800 MW
- Concentrated Solar Power (CSP) - 50 MW
- Wind Power - 44 MW (Independent Power Producer (IPP) project)
- Solar PV - 20 MW (IPP)
- Solar PV - 30MW (through tender) (Isaacks, 2013)

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