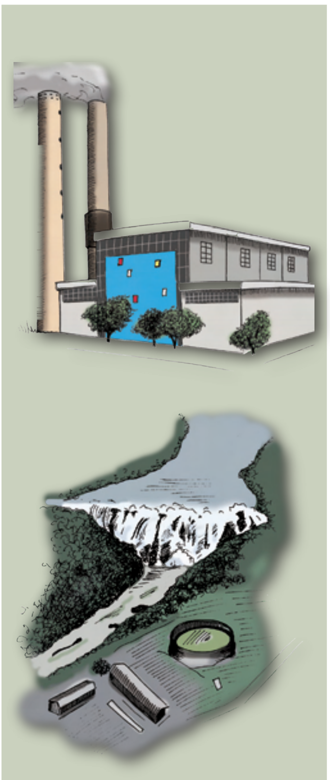
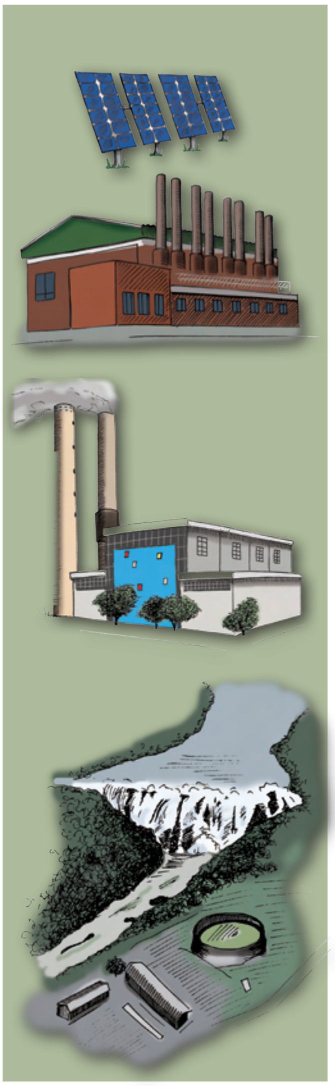
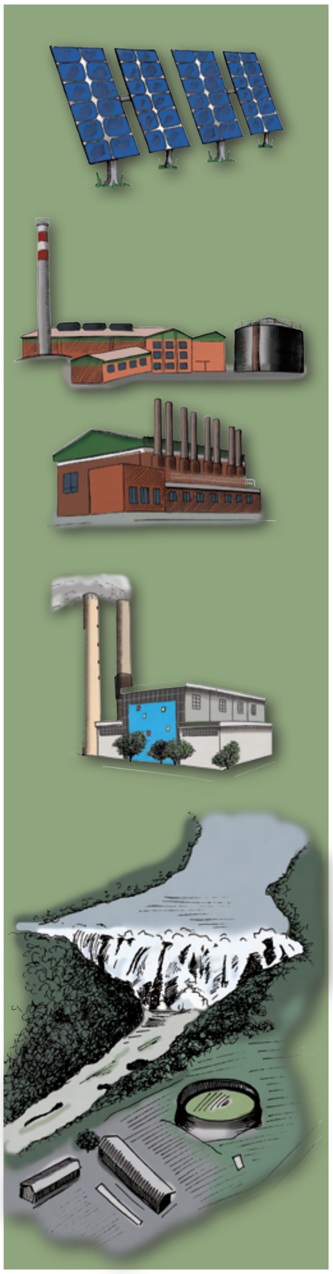
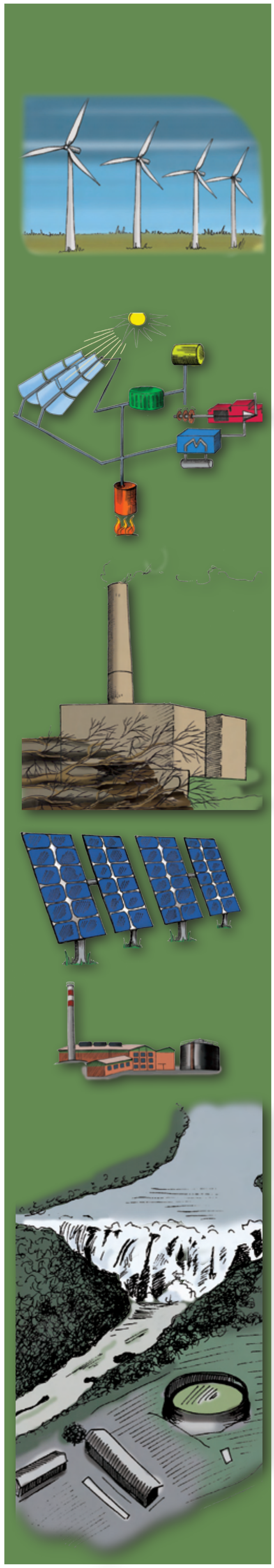
NAMIBIA'S ENERGY FUTURE

A CASE FOR RENEWABLES

Konrad Adenauer Stiftung

DISCLAIMER

The author has endeavoured to ensure that all data and information used in this Report and the associated numerical models is correct and up to date. However, due to factors beyond the control of the author, a number of assumptions had to be made in the compilation of this Report and the underlying models. These assumptions have an impact on the reliability of the Report's findings, recommendations and conclusions.

The findings, recommendations, conclusions and interpretations arising from this Report rely on information and data used, as well as the implicit and explicit assumptions made when drafting the Report, and the interpretation of such information and data as is implicitly or explicitly used in the numerical models.

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Conventions and Abbreviations

1.000	one
1,000	one thousand
1,000,000	one million
1,000,000,000	one billion
°C	degree Celsius
bn	billion
BTE	bush-to-electricity, power plant generating electricity using invader bush as fuel
ECB	Electricity Control Board
EE	energy efficiency
EWH	electric water heater
FY	financial year
GWh	gigawatt-hour; equal to 1,000 MWh, unit of energy
GRN	Government of the Republic of Namibia
kW	kilowatt; used as unit of electrical generation capacity, also denoted as kW_e
kW_{peak} or kW_p	kilowatt peak; unit of peak electrical generation capacity, often used in solar PV
kWh	kilowatt-hour; sometimes also referred to as "unit of electricity", unit of energy
LPU	large power user, such as a mine taking direct supplies from NamPower
MME	Ministry of Mines and Energy
MW	megawatt; used as unit of electrical generation capacity, also denoted as MW_e
MWh	megawatt-hour; equal to 1,000 kWh, unit of energy
MRLGHRD	Ministry of Regional and Local Government and Housing and Rural Development
NamPower	Namibia Power Corporation (Pty) Ltd
PV	solar photovoltaic technology that converts sunlight to electricity
RE	renewable energy
RED	Regional Electricity Distribution Company
SMEs	small- and medium enterprises
SWH	solar water heater
TWh	terawatt-hour; equal to 1,000 GWh or one billion kWh, unit of energy

Foreword

by Holger Haibach, Resident Representative of the Konrad-Adenauer-Stiftung, Namibia-Angola Country Office

Dear Reader,

When it comes to Climate Change, Namibia is not one of the big polluters of the Earth's atmosphere, but it is one of the countries most affected by it.

Sensible resource management has a big part to play in the sustainable development of a country, even more so when it is considered vulnerable to adverse environmental changes. This is especially relevant in the field of energy supplies and energy consumption.

Ever increasing energy prices, insufficient electricity supplies, and the dependency on foreign energy sources pose significant risks, not only to the Namibian people and economy, but even more so to the further development of the country. If Namibia is determined to achieve the development goals stipulated in the Vision 2030, sustainable energy supplies are a necessary cornerstone underpinning that vision, while being the basis for continued social peace and cohesion within society.

Namibia is most generously endowed with natural resources required for (renewable) energy supplies, especially in regard to the resources from the sun, wind and biomass from invader bush.

It is against this backdrop that the Konrad-Adenauer-Stiftung (KAS) has committed itself to contribute to the discourse on Namibia's energy future. Active in the country since 1989, KAS has cooperated with non-governmental and governmental institutions to further the development of the country in fields including the rule of law, governance, human rights and the social market economy, as well as sustainable development.

Sustainable development can only be safeguarded, if, amongst others, a country's energy supplies are and remain sustainable. Therefore the question arises why

Namibia, as of now, has not made more use of its natural resources, especially in regard to satisfying its own energy needs.

During close collaboration with different stakeholders over the last two years, it has transpired that, what is needed is a safe and sound basis of information as to what the future energy prices as well as the energy consumption patterns will be like, what role renewable energies could play in future, and which political decisions Namibia will have to take to increase the use of renewable energies, and render their uptake more attractive and economically viable.

KAS has therefore asked Dr Detlof von Oertzen, one of Namibia's leading consultants in this field, to carry out a study addressing the aforementioned questions. The study is an overview of the different aspects of Namibia's energy future, focusing on the country's electricity sector, and the role that renewable energies as well as energy efficiency measures could play.

The study aims to contribute to the ongoing general discussion about the future energy supply and efficient use of energy in Namibia. It is not meant to be an official policy document. Rather, it is hoped that the study will contribute to the deliberations of decision makers in the political and business arenas, as well as members of the media, planners, environmentalists, scientists and the population at large, to engage in the important discussion about the role and contribution that renewable energy and energy efficiency can and should play in the country's future energy supply and use. The study wishes to foster constructive debate and deliberation amongst all interested parties, and in this way contribute to informed decision making processes, which so vitally shape and contribute to the country's future.

Namibia's great potential, when it comes to renewable energies, should not go unnoticed and certainly should not go unused.

Resident Representative

Konrad-Adenauer-Stiftung

Namibia-Angola Country Office

Executive Summary

Energy is an essential pillar of any economy. The availability, affordability and security of energy supplies are necessary pre-requisites for development. This study focuses on Namibia's electricity sector, and the role and contribution that renewable energy and energy efficient technologies can play to sustainably power the nation into the future. The study aims to constructively contribute to a vibrant and robust debate, and thereby foster decisive action on Namibia's energy future, and with it influence the direction of our national development.

Namibia is blessed with substantial solar, wind and biomass resources. These renewable energy resources constitute a comparative national advantage that the country can use to its long-term socio-economic benefit. But despite the abundance of these natural blessings, their productive use remains limited. There is no compelling reason why the use of renewable energies and energy efficient technologies cannot be dramatically accelerated to contribute to Namibia's development.

In 2012, the challenges and constraints faced by Namibia's national electricity sector is apparent. The days of low-priced electricity are over. The country's current generation capacity is no longer able to meet the rising demand for electrical energy. In addition, Namibia's neighbours are not always able to export electricity as and when required locally. Unless deliberate and decisive action is taken, Namibia's economy will be negatively affected by electricity shortages. If this were to happen, even for short periods only, national development efforts will be undermined. This is most undesirable, and cannot be an option.

Renewable energy technologies that convert the country's abundant solar, wind and biomass resources into electrical energy, and the wide-scale adoption of energy efficient technologies, can significantly contribute to address short-term electricity supply gaps, while offering outstanding opportunities for the country's long-term development. Unsubstantiated statements about the alleged high cost of renewable energy technologies are misleading, and in many cases, simply incorrect. In fact, the cost of many renewable energy technologies has significantly declined in the past decade. Further improvements are anticipated as the scale and scope of renewable energy technology deployment increases around the world. This is good news for Namibia.

Given the outstanding renewable energy resource base that Namibia is blessed with, the large-scale roll-out of renewable energy and energy efficient technologies holds significant long-term socio-economic benefits: Advantages include long-term energy price stability, the creation of new local jobs through the establishment of innovative local value chains, and the decrease of non-productive currency outflows. At the same time, the increased uptake of renewable and energy efficient technologies will hedge the country against price escalations of imported fuels.

By deliberately embracing renewable energy and energy efficient technologies, Namibia stands to witness a significant change in the way that electricity is generated and used, and in this way, create long-term sustainable value. Investments in the use of local resources create local value chains generating local jobs, which are desperately needed. Investments that merely perpetuate import dependencies do not have such advantages.

Namibia's world-class solar regime can readily be utilised by solar water heaters, solar photovoltaic technologies, and concentrated solar power plants. These technologies can also contribute to reduce the country's immediate electricity supply gap. Small grid-connected solar photovoltaic plants are cost competitive, as are large-scale photovoltaic power plants, given suitable access to funding. In future, concentrating solar power plants will provide electric power at costs which are comparable to those of modern coal-fired plants.

Namibia's invader bush represents a significant and sustainable biomass energy resource. In addition to being a valuable and potentially sustainable energy crop, the use of invader bush could generate thousands of long-term jobs in rural Namibia. Power plants fuelled by biomass from this indigenous resource would have electricity generation characteristics similar to traditional coal-fired power plants. Bush-to-electricity power plants can serve as base load and mid-merit power plants, which are dispatchable on demand.

Value chains focusing on the processing of biomass in rural areas create new jobs, and new local business opportunities, while ridding rangelands from bush infestation. In addition, decentralised power production can contribute to further electrify rural Namibia, thereby creating new activities and opportunities that may also slow rural to urban migration. Few national opportunities offer so many value-adding propositions for rural Namibia as the sustained and environmentally sensitive use of the country's invader bush resource does.

Using abundant local renewable resources for the generation of electricity will create new value propositions in areas which have been decoupled from Namibia's predominantly urban focus on development. Local raw materials supplying domestic and regional markets can drive economic development, while creating jobs, mainly in rural Namibia. Strengthening rural communities through the creation of employment is essential. In this way, Namibia's renewable energy potentials, and in particular its bush resource can be utilised to make a meaningful contribution to development.

The study recommends policy initiatives to enhance the increased uptake of select renewable energy and energy efficient technologies, in turn adding value to the country's social, economic and environmental fabric, leading to improvement in the quality of life for Namibians. It outlines how private and public investments in green technologies can create new local value bundles. The deliberate roll-out of green technologies is expected to strengthen the foundation of the country's long-term development pathway, emphasising local value creation and local use, and with it ushering in a multitude of positive local social and environmental benefits.

The study identifies that the most significant social value from the increased deployment of renewable energy technologies, is developed in energy supply systems that create and sustain long-term local jobs. This can be achieved through targeted investments in human capacity development, and by creating and strengthening value chains that contribute to and invigorate the economy.

Economic value is created through, amongst many others, targeted investments in renewable energy and energy efficient technologies, the creation of employment, local value addition and beneficiation, and a reduction of currency outflows in the longer term.

Wide-spread application of energy efficient technologies, such as solar water heaters, reduces energy consumption and peak demand. It may also create new manufacturing opportunities in Namibia, and with it, a substantial number of additional jobs in the service sector. Solar photovoltaic and wind energy technologies create fewer direct jobs, but immediately contribute to reducing the country's electricity supply gap, while bringing much-needed diversity to Namibia's future energy supply mix.

Policy interventions will play an important role to turn Namibia's current electricity sector challenges into socio-economic growth opportunities. To more optimally position the country for concerted action in the energy sector benefitting from the abundance of our local renewable energy resources, policy must focus on the following:

- **address structural, regulatory and organisational impediments that continue to shackle the country's electricity sector**
- **define short-, medium- and long-term goals for the electricity sector, placing emphasis on the role and contributions that renewable energy and energy efficient technologies can play**
- **formulate a national renewable energy and energy efficiency strategy**
- **introduce a binding renewable energy and energy efficiency implementation plan with actual performance targets**
- **set national energy efficiency targets, with a focus on Government institutions, electricity utilities and the public building stock**
- **create a system of electricity tariffs that ensures affordability, availability, accessibility and investment certainty, while strengthening the security of our future energy supplies**
- **create a bundle of targeted tax and investment incentives that promote value adding activities in the local renewable energy and energy efficiency sectors**
- **create entrepreneurial incentives for the establishment of labour-intensive sustainable bush harvesting enterprises, and**
- **engage the public on the multiple roles and benefits associated with reliable energy supplies and the use of energy efficient practices so essential for the country's ongoing development.**

The study presents an electricity sector scenario to illustrate the likely impact of the bundled implementation of renewable energy and energy efficient technologies. It outlines the role in diminishing the electricity supply challenges faced by the country. The scenario is built on a 7-point action plan encompassing

1. **replacement of 100,000 electric water heaters by solar water heaters**
2. **introduction of a large-scale domestic energy efficiency program**
3. **roll-out of an energy efficiency program focusing on commercial and industrial entities, manufacturers and Government institutions**

4. roll-out of grid-connected solar photovoltaic systems to some 25,000 privately owned homes
5. establishment of multiple bush-to-electricity power plants
6. establishment of multiple wind farms, and
7. establishment of concentrating solar power plants incorporating storage and hybridisation technologies benefitting from our local biomass as well as natural gas resources.

The study concludes with key messages that require immediate attention:

1. Namibia's energy policy must explicitly recognise the pivotal role that renewable energy and energy efficient technologies can play in addressing the country's current electricity supply challenges, while creating *local* sustainable value chains underscoring economic development goals.
2. Namibia must more clearly spell out the roles, responsibilities and mandates of the participants active in the country's energy sector.
3. Namibia must develop a robust strategic approach for the long-term provision of electrical energy which benefits from available and abundant renewable energy resources, and
4. Namibia must create development-relevant value through the deliberate decentralisation of electricity generation facilities by incentivising the use and value addition of the country's renewable energy resources.

A compelling vision for Namibia's energy future must build on available and abundant renewable energy resources. There must be the realisation and recognition that we can, within our lifetime, create a sustainable energy future that leverages our national comparative advantages to create a better life, for all.

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. Namibia's national energy supplies and their long-term security will be strengthened by deliberately using renewable energy resources, because renewable energy resources are abundant, readily accessible, available, safe and clean, and will remain so in future.

Namibia has nature's blessings. Namibians can muster the required human resources to create a sustainable energy future. We must start immediately.

The time to act is now.

1 Background

Namibia has significant renewable energy potentials. However, despite the country's abundant solar, wind and biomass resources, their uptake and use for mainstream electricity generation remains slow. *Why?*

Renewable energy sceptics point out that wind and solar resources are intermittent. Also, it is often alleged that significant costs are incurred if renewable energy technologies were to be integrated more substantially into the country's electricity generation portfolio. *Are renewable energy technologies really more expensive?*

Both energy efficient (EE) and renewable energy (RE) technologies are experiencing dramatic price decreases in the past years, both internationally and in Namibia. This creates new and exciting opportunities for entrepreneurs, local authorities and utilities. A quiet renewable energy and energy efficiency technology revolution is taking place. Namibian decision-makers in policy, our electricity regulator, utilities and business must take note. *How can we best position ourselves to benefit from the rapid changes in the energy sector?*

" A quiet renewable energy and energy efficiency technology revolution is taking place."

Select renewable energy technologies are increasingly finding their way into day-to-day use, albeit slowly: in the early 1990's, few conventional engineers considered solar water heaters (SWH) a sufficiently reliable and viable proposition for the supply of domestic hot water. Today, the uptake of this technology can be witnessed all across the country, even in coastal towns of Namibia. Solar water heaters are no longer a novelty, their investment economics is outstanding, and banks, property developers and house-owners embrace them. *Increased SWH penetration is one of the tell-tale signs of the increased importance of renewable energy technology dispersion into the Namibian market.*

Source: [1.1]

Source: [1.2]

Today, in a slow and silent manner, similarly to how solar water heaters made their inroads during the past decade, Namibian investments in solar photovoltaic (PV) technology are increasing. PV converts sunlight to electricity. Most urban folk take electricity for granted, but users notice the regular and substantial cost increases on their electricity bills. Grid parity, which is the point where electricity generated from solar PV is cheaper than that supplied by the electricity grid, has arrived or is around the corner in most distribution areas in Namibia. Once grid parity is achieved, it has far-reaching implications, including for utilities. It will drive private investments, and change the way commercial and domestic users think about their own electricity use, and its supply.

Source: [1.3]

Other renewable energy technologies, for example those based on the sustainable use of biomass from Namibian invader bush, hold considerable promises, too. New value chains focusing on the processing of biomass in rural areas are likely, creating new jobs, new opportunities and substantial local benefits. Decentralised power production can contribute to further electrify rural Namibia. Bush use creates new value propositions in areas which have often been decoupled from Namibia's predominantly urban focus on development. Local raw materials supplying local and regional markets can drive such development, and create sustainable local jobs, mainly in rural Namibia, while reducing capital outflows caused by the import of fossil fuels. Strengthening rural communities through the creation of new and sustainable jobs is essential. Namibia's invader bush resource can assist, while powering development.

Source: [1.4]

Many energy efficient technologies and practices have short payback times, and also offer excellent non-financial benefits. For example, the use of energy efficient lighting reduces electricity costs immediately, and usually has a payback time of a few months only. Energy audits in buildings, and the incorporation of energy efficient technologies and practices in commercial and industrial settings are more commonplace in Namibia in 2012 than in previous decades. Such practices will gain in importance as a result of annual double-digit electricity rate increases. Individual and collective consumption behaviours influence the cost of electricity. Consumption behaviours can be changed. Behaviour change is often the most inexpensive way to deal with inevitable electricity price increases. Such change can be an important societal driving force – starting where we live, when and how we work, and how we can enhance the productive and cost-effective use of energy. Energy efficient technologies can assist and provide both immediate and long-term benefits to end-users.

However, despite some encouraging cases illustrating the contributions that RE and EE technologies can make in Namibia, the broad-based uptake of such technologies remains slow. The socio-economic benefits that a country that is as well-endowed with renewable energy resources as Namibia remain far less than what could be achieved. *There is no fundamental or compelling reason why the introduction and uptake of RE and EE technologies cannot be dramatically accelerated – for Namibia's development and long-term benefit.*

" The broad-based uptake of renewable energy technologies in Namibia remains slow. There is no reason why it has to remain that way."

Based on actual case studies, this study illustrates the potential contributions that select renewable energy and energy efficient technologies can make in Namibia.

Not in a decade or two, but starting today.

2 Introduction and Outline

This study highlights some low-hanging fruit offered in Namibia's fledgling renewable energy (RE) and energy efficient (EE) sectors and markets. It reflects on how targeted policy framework conditions could stimulate and enhance the increased uptake of select renewable energy and energy efficient technologies, and in this way add to the nation's social, economic and environmental fabric, whilst improving the quality of life in Namibia.

The study's departure point is NamPower's recent statement that Namibia will experience considerable electricity supply shortfalls starting in 2012 [2.1]. We focus on the role that solar energy can play, how Namibia's abundant invader bush resource can be used more beneficially, what contribution wind power can make, and how the large-scale introduction of solar water heaters could assist electricity users and NamPower, in bridging the gap between the demand for electricity and the available supplies.

The study describes how targeted private and public investments in green technologies in Namibia can create new value bundles. These include new jobs, increased revenues from taxation, and improved value addition to abundant local commodities. Individually and cumulatively, the deliberate roll-out of green technologies will strengthen the foundation of the country's long-term development, based on sustainable local value creation, and with it, a multitude of additional positive social and environmental spin offs.

The remainder of this study is structured as follows:

- **Chapter 3** provides an overview of Namibia's electricity sector, and the forces of change that shape this critical sector;

- **Chapter 4** discusses five focal areas where substantial new and additional value can be created in Namibia's renewable energy and energy efficiency sectors;

- **Chapter 5** summarises how certain renewable energy and energy efficient technologies can create social, economic and environmental value;

- **Chapter 6** reflects on the policy imperatives required to create the necessary momentum for change in Namibia's electricity sector;

- **Chapter 7** puts forward a 7-point action plan to roll out renewable energy and energy efficient technologies in Namibia;

- **Chapter 8** summarises the study's key messages; and

- A **reference section** provides select additional information, and lists the sources used and quoted in the study.

3 Namibia's Electricity Sector

3.1 Introduction

Namibia's electricity sector faces major challenges. Security of supplies, both nationally and regionally, are not guaranteed, demand is outstripping supply faster than replacements can be brought on line. Strategic planning has failed to deliver tangible results. This concerns all Namibians.

This study focuses on aspects relevant to the country's *electricity sector only*, even though electrical energy constitutes less than one-third of Namibia's total annual energy consumption [3.1]. Our focus does not imply that the electricity sector is considered more important than the liquid fuels sector. Rather, in our view, the structured development and rational management of both the liquid fuels *and* electricity sector are important, if vigorous development is to take place in Namibia.

Source: [3.2]

The supply of electricity to Namibia's consumers is increasingly under pressure. The country's demand for electrical energy is outstripping the available supply. Over the past years, Namibia has substantially relied on importing electricity shortfalls from its neighbours. However, regional electricity supply capacities have become substantially constrained. Without adequate electrical energy, local and regional development ambitions cannot be realised.

NamPower, as Namibia's monopoly electricity provider, faces particularly challenging times to ensure that the country's lights remain on. Recent investments, such as the new Anixas power station in Walvis Bay (shown on the left) and the addition of a fourth turbine at Ruacana have been preceded by more than three decades of non-investment in local generation capacity. In a country with moderate economic growth, the delay of much-needed investments in generation capacity is acknowledged to lead to supply bottlenecks. Regional capacities were often sufficient to bridge short-term supply gaps, and low

Source: [3.3]

electricity prices from fully depreciated generation assets made new investments unattractive. South Africa's erstwhile overcapacity may have helped prolong the belief that transmission systems alone would keep on powering the nation. Namibia's substantial reliance on South African electricity supplies had to come to an end eventually. Today it has.

Electricity prices have escalated significantly over the past years, and are expected to rise further for at least another few years, most likely at double-digit growth rates every year. This will continue to place pressure on consumers, especially those that are already struggling to make ends meet. Rapidly rising electricity prices will also negatively affect enterprises that use electrical energy for productive purposes. This is set to lead to a negative impact on the commercial, mining, industrial and manufacturing sectors.

Source: [3.4]

However, the following developments and factors can be turned into definite socio-economic growth opportunities: Namibia's electricity supply limitations and looming inability to meet the growing demand for electricity, the country's envisaged industrialisation policy, Namibia's to-be-revised energy policy, various green economy initiatives, and last but not least, the growing number of consumers and investors that recognise the increasing value of investments in RE and EE technologies. The above factors constitute a force that can create development opportunities that benefit from investments in Namibia's substantial renewable energy resources. Cumulatively, these factors beckon to be used more deliberately to create societal benefits and sustainable growth, while at the same time, addressing and resolving the country's energy security crisis. These are immense development opportunities.

This study aims to show that increasing electricity tariffs and the local and regional supply constraints offer significant opportunities, particularly for renewable energy and energy efficient technologies. Those who seize these opportunities, including suppliers and installers of RE and EE, investors, homeowners, electrical utilities, Independent Power Producers and institutions willing to provide funding for RE and EE investments, stand to benefit from new revenues that were previously largely inaccessible. This is an exciting time for Namibia's electricity sector, even if the current constraints seem daunting.

Before describing some opportunities waiting to be developed in Namibia's electricity sector, the remainder of this chapter provides a brief overview of some of the key elements characterising this important sector.

3.2 Units for Electrical Energy and Electrical Energy Generation Capacity

This section briefly explains some of the most common units and abbreviations used to express how much electrical energy is generated at power plants, or consumed by end-users, and the units used to quantify the electrical generation capacity of power plants.

Unit	In words	In relation to other units	Illustrative example
kWh	kilowatt-hour [kWh]	a basic unit of energy	It takes 1 kWh of electrical energy to heat 30 litres (roughly the amount of water required to take one shower) of water from 20°C to 48°C.
MWh	megawatt-hour [MWh]	1 MWh = 1,000 kWh	A household using 400 kWh of electrical energy per month will consume some 12 x 400 kWh = 4,800 kWh or 4.8 MWh of electrical energy per year.
GWH	gigawatt-hour [GWh]	1 GWh = 1,000 MWh = 1,000,000 kWh	Windhoek consumed more than 784,000 MWh or 784 GWh of electrical energy in the financial year 2011/2012, as shown in Table 5.
TWh	terawatt-hour [TWh]	1 TWh = 1,000 GWh =1,000,000 MWh =1,000,000,000 kWh	NamPower sold 3.543 TWh of electrical energy in the financial year 2010/2011 [3.5].

Table 1: Typical units used to express the quantity of electrical energy demanded or supplied

Unit	In words	In relation to other units	Illustrative example
kW	kilowatt [kW]	1 kW = 1,000 Watt	The electrical generation capacity of small mobile petrol-powered generators typically ranges between 3 kW and 30 kW. Under ideal operating conditions, such power plants can generate 3 kWh and 30 kWh of electrical energy per hour, respectively.
MW	megawatt [MW]	1 MW = 1,000 kW	In 2012, Namibia's Ruacana hydro-power station has an installed electrical energy generation capacity of 332 MW. The Anixas power station at Walvis Bay has an installed capacity of 22.5 MW.

Table 2: Typical units used to express the capacity of power plants generating electrical energy

3.3 Namibia's Electricity Sector in a Nutshell

Figure 1 illustrates the four main functions – i.e. generation, transmission, distribution and supply – on which the Namibian electricity industry is built.

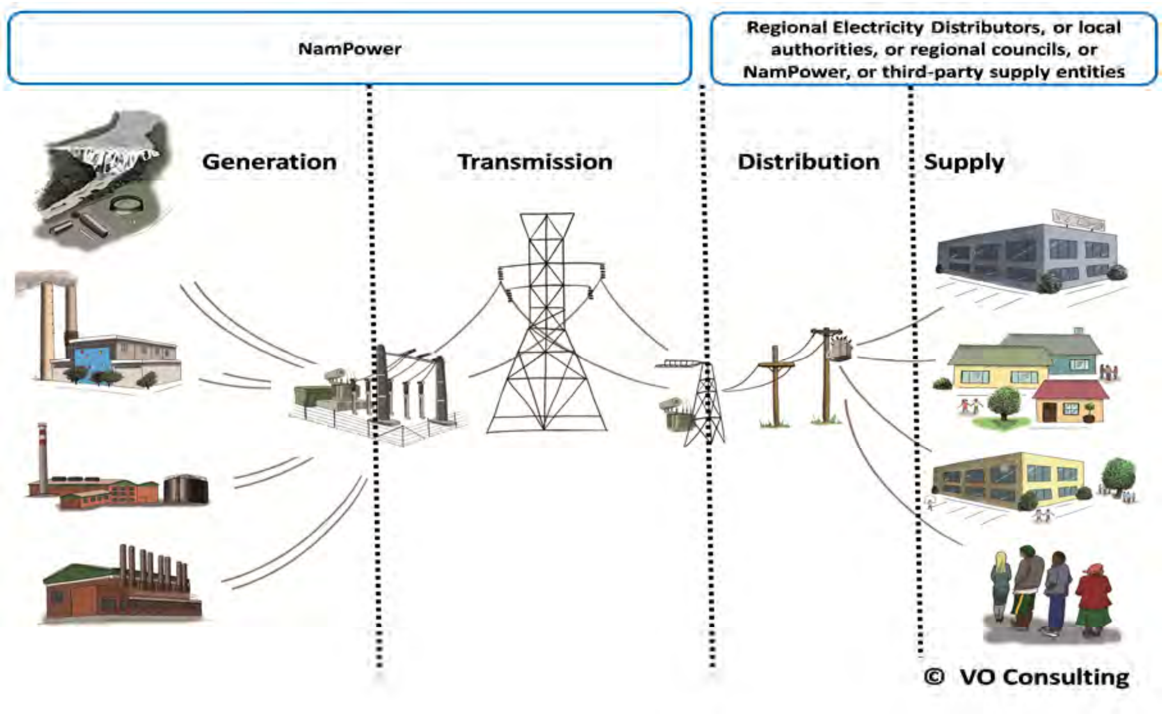
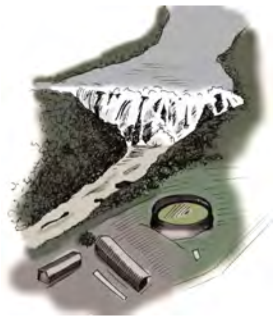


Figure 1: The four main functions of Namibia's electricity industry [3.6]

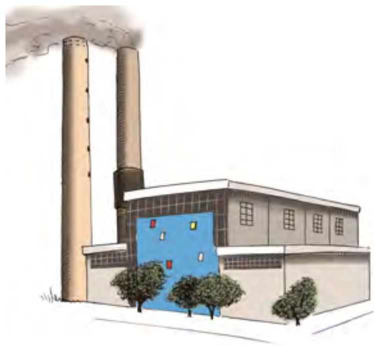
In Namibia, the electrical energy that is fed into the transmission grid is generated at four local power plants, in addition to the electrical energy imported from our neighbours:



Source: [3.6]

Ruacana is a hydro-electric power station on the Kunene River, which has a generation capacity of 332 MW. It is a run-of-river power station, meaning that its ability to generate electricity remains dependent on continuous water flows from Angola. In the absence of sufficient water flow, Ruacana cannot generate and feed electrical energy into Namibia's national electricity grid.

The coal-fired **van Eck** power station just north of Windhoek has a nameplate capacity of 120 MW. It was commissioned in 1972. Today it is expensive to operate, and due to ageing, it is no longer able to produce electricity at rated capacity. Van Eck is only used to bridge short-term supply gaps, and is likely to be refurbished to gain a few more years of life before being retired.



Source: [3.6]

Source: [3.6]

Paratus power station in Walvis Bay uses heavy fuel-oil, which has an electrical generation capacity of 24 MW. Similar to the van Eck power station, Paratus is mainly used to match short-term demand peaks, and due to ageing, is no longer able to produce at full capacity.

Anixas is a heavy fuel-oil power plant located in Walvis Bay. NamPower commenced with operations of the plant on 21 July 2011. Anixas has an installed capacity of 22.5 MW. The power station is mostly used to ensure that short-term peak demand can be adequately met, and it will remain an emergency standby electrical power plant for the foreseeable future.

Source: [3.6]

In addition to the local power generation capacity, electricity is imported from South Africa, Zimbabwe, Mozambique, Zambia and other regional countries. It enters Namibia by way of a network of high-voltage transmission lines. Assuming that our neighbouring suppliers have sufficient capacity, the electrical inter-connecting power lines to cross-border power stations have a south-north transmission capacity of some 600 MW. In addition, the Caprivi interconnector that links the Namibian transmission system with Zambia and Zimbabwe has a capacity of 300 MW. It allows NamPower to more readily trade electricity with our northern neighbours, making Namibia less dependent on imports from and wheeled through South Africa. As a risk mitigation measure, the Caprivi link reduces Namibia's exposure and dependence on the South African transmission grid, as well as its current constraints.

Source: [3.7]

In Namibia, the generation and transmission of electrical energy are NamPower's exclusive responsibility. As the country's single buyer, NamPower is also responsible for importing electrical energy as needed; NamPower exports electricity to Botswana and Angola. In addition, NamPower is the overall electricity 'system operator', i.e. the entity that ensures that the prevailing demand for electrical energy is met by sufficient supplies. The system operator ensures the stability of the Namibian electricity networks. This requires the careful balancing of all sources feeding into the national grid and matching them to those off-takers that take supply from the grid.

Namibia's transmission grid is connected to various distribution stations, where high-voltage electricity is transformed to medium voltages. A substantial distribution network criss-crosses the country. It is operated by Namibia's three regional electricity distributors (REDs), as well as NamPower, some local authorities and regional councils. These distribution entities are licensed operators, and responsible for the supply of commercial, industrial, institutional and domestic consumers in their areas of responsibility or jurisdiction.

Electricity users pay for the supply of electricity, as well as a portion of the electricity infrastructure required to provide such services. By the time an individual user flicks on a light switch, electricity has not only been generated, but has been transmitted, often over hundreds or even thousands of kilometres, has been transformed from high to low voltage, has been distributed, and has successfully been supplied. Every one of these distinct electricity sector value chain elements is costly, and is only reliable, accessible and affordable if each link in the complete supply chain operates effectively. This is by no means trivial, and explains why electrical energy is priced at the level it is. Table 3 summarises the main responsibilities of some of the main electricity sector actors in Namibia.

NamPower		Regional Electricity Distributors, or local authorities, or regional councils, or NamPower, or third-party supply entities	
Generation	**Transmission**	**Distribution**	**Supply**
Electricity is generated, e.g. in a hydro-electric power station such as Ruacana, or the coal-fired Van Eck power station outside Windhoek, or Paratus and Anixas in Walvis Bay. In future, new power stations using renewable energy sources, such as solar, wind and biomass are likely to come into operation in Namibia.	Electricity is fed into the national trans-mission grid and trans-ported from the place of generation to the places where it is used. Transmission takes place at high voltage to minimise losses.	Closer to the places where electrical energy is consumed, electricity is transformed to low voltages, and distributed to commercial, industrial, institutional and domestic end-users.	End-users are connected to the electrical distribution network. They take delivery of electrical energy, which is supplied and sold by a distribution entity, such as CENORED, Erongo RED or NORED, or a local authority or regional council or their agents, or in some cases, NamPower.

Table 3: Key responsibilities of some of the main electricity sector actors

Electrical energy is a high-quality form of energy. It is valuable, and expensive to generate, transmit, distribute and supply, and therefore best used productively. Many current uses of electrical energy are for consumptive rather than productive purposes. Some services, such as water heating, can be provided by alternative and less expensive forms of energy without compromising on quality or reliability. This holds many business and related opportunities, which will be discussed further in chapter 4.

3.4 Roles and Responsibilities in Namibia's Electricity Sector

The following entities – as shown in Figure 2 – have responsibilities in and for Namibia's electricity sector:

- **Cabinet** has approved Namibia's White Paper on Energy Policy of 1998.
- **Parliament** formalises relevant policies with appropriate legislation, amongst others the country's Electricity Act of 2007.
- **The Ministry of Mines and Energy (MME)** is the custodian of Namibia's energy sector, including the electricity sector, and principal energy policy initiator and implementer. The MME is responsible for overseeing and administering Namibia's electricity sector, in accordance with applicable policies and laws. Specifically, the authority to grant electricity licences, including their issue, transfer and renewal, rests with the Minister of Mines and Energy, who exercises such authority on recommendation of the Electricity Control Board.
- **The Electricity Control Board (ECB)** is Namibia's statutory electricity sector regulator, and oversees the licensing, standard of service and supply of all electricity industry participants, and regulates the country's electricity tariffs.
- **The Ministry of Regional and Local Government and Housing and Rural Development (MRLGHRD)** oversees Namibia's local authorities and regional councils. The Minister of MRLGHRD retains residual powers in regard to the electricity supply by local authorities and regional councils, and the ministry has a responsibility relating to the ongoing sustainability of these entities.
- **NamPower** is Namibia's state-owned electricity generation and transmission entity, and is also responsible for all electricity trading into and across the borders, and acts as the country's electricity system operator. NamPower is a shareholder of all Regional Electricity Distributors (REDs), and remains responsible for some residual electricity distribution activities in the country. As the single buyer, NamPower is solely responsible to source electricity outside Namibia, and to on-sell it in the country.
- **Regional Electricity Distributors (REDs) and other electricity distribution entities** are responsible for the distribution and supply of electricity, in accordance with the provisions of the Electricity Act and residual regulations under the Local Authorities and Regional Councils Acts. In 2012, three REDs are operational: NORED, CENORED and Erongo RED. Other electricity distribution entities include some local authorities, e.g. the City of Windhoek, regional councils and their agents, as well as select private entities, and in some cases, NamPower.
- **Electricity consumers** are end-users of electrical energy who include local and regional authorities, institutional users, commercial and industrial users, and domestic users of electricity.

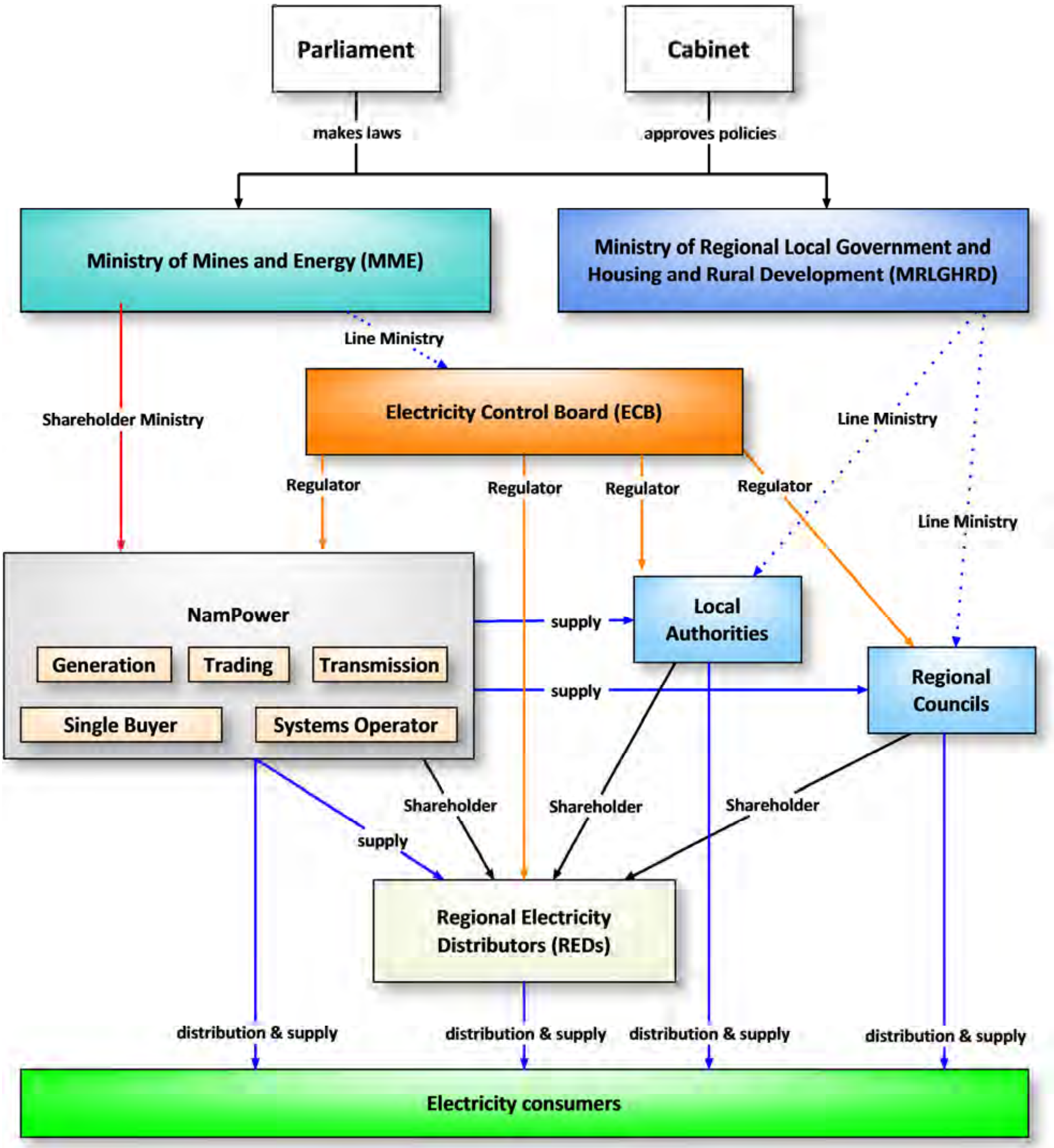


Figure 2: Responsibilities of the main actors in Namibia's electricity sector [3.8]

The roles and responsibilities of the various electricity sector actors are supported and set out in the relevant legislation. On a national as well as local policy level, the electricity sector is often plagued by confusion in regards to the duties and responsibilities of the different electricity sector entities. Examples of the ongoing uncertainties in the sector include the structural impediments faced by the sector as a whole, the multitude of challenges faced by the REDs, long-overdue reform of the sector, the ongoing debacle over the local authority surcharge, and a lack of adequate local authority funding.

Who is obviously missing from the above list of local electricity sector actors? For one, there are no active Independent Power Producers (IPP) in Namibia. These are entities that, in addition to NamPower, generate electricity for grid in-feeding. Although Namibia's White Paper on Energy Policy of 1998 is clear about the need to create a conductive investment climate in Namibia's energy sector, there are still no IPPs doing business locally. This is one of the indicators that structural and institutional impediments continue to constrain the country's electricity sector.

While a number of conditional electricity generation licenses have been issued by the Electricity Control Board, and a high-level IPP framework is in place, unresolved issues and barriers remain, and hinder the entry of additional power supply entities into the country. Of concern to any would-be IPPs is the independence of the single buyer, and the inherent conflict of interest between NamPower as the single buyer on the one hand and NamPower as the country's monopoly electricity generation entity on the other. For future IPPs, these considerations imply that power purchase agreements, as well as all aspects related to the access and use of the country's transmission grid, and the trading of electricity all take place under NamPower's direct control, and have to be negotiated before new electricity supply businesses can commence. Other IPP concerns, including the possible change of law and regulatory risks, make entry into the market difficult.

Namibia's system operator is also the country's single buyer, and at the same time, holds the national electricity generation and transmission monopoly. This combination of tasks endows NamPower with enormous responsibilities, and influence. At the same time, Namibia's electricity industry is structurally impeded by this constellation. Sector-wide leverage and bargaining powers should not be monopolised. Presently they are. Policy has to address this systemic weakness, or it will continue to burden the entry of new actors and supply sector participants, to the detriment of all electricity consumers in the country.

With the roles and responsibilities described, the question begging an answer is how much electrical energy is actually required in Namibia? This is covered in the next section.

3.5 Current and Future Demand for Electricity in Namibia

The total demand for electrical energy is determined by how much electricity all end-using consumers require at any point in time. Electricity users include large power users such as mines, end-users such as government ministries, commercial and industrial users, domestic users, farmers and rural dwellers connected to the country's electricity grid.

The different electricity users – through their collective consumption of electrical energy – determine the total national electricity demand. Demand for electrical energy has steadily increased over the years. As Namibia's economy grows and the country develops, the demand for electrical energy will escalate in terms of the total electrical energy required, as well as the peak electricity demand. Using demand or load forecasting methods, the electrical energy that is likely to be required in future can be projected. This is regularly done by NamPower, and has also recently been undertaken as part of the development of Namibia's Integrated Resource Plan [3.9].

For each calendar year in the period 1990 to 2010, Figure 3 shows the following:

a. blue bars depict the units of electrical energy acquired by NamPower, in TWh, either from local or imported generating plants;

b. red bars depict the units of energy actually sold by NamPower, in TWh; and

c. the black line depicts the units of electricity sold in Namibia, in TWh, excluding to Skorpion Zinc Mine, Orange River Projects, cross-border clients and line losses.

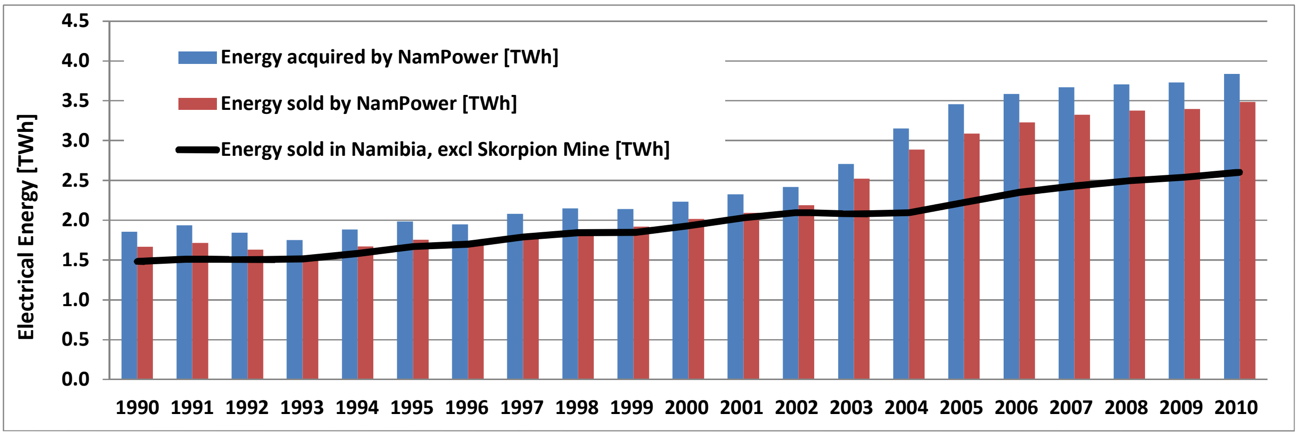


Figure 3: Historical growth of electrical energy per calendar year, between 1990 and 2010 [3.8]

Several interesting features are evident from Figure 3:

a. The units of electricity acquired by NamPower (blue bars) are always greater than those actually sold by NamPower (red bars). This is due to the losses in the electrical grid. Given Namibia's very extensive transmission system network, line losses cannot be avoided, and are of the order of 10% of the total energy supplied.

b. The units of electricity sold in Namibia (black line), especially from 2002 onwards, are substantially less than the units sold by NamPower, because electricity sales to Skorpion Zinc Mine, Orange River Projects, cross-border clients and line losses are explicitly excluded from this figure. Sales to the Skorpion Zinc Mine are usually dealt with separately because the mine's power supply is arranged through a back-to-back power purchase agreement with Eskom, and not covered by NamPower's usual power sourcing arrangements, as is the case for other electricity consumers in Namibia.

Units of electrical energy sold in Namibia between 1990 and 2010 grew by an average of 3.0% per year, while the system maximum demand (excluding Skorpion Zinc Mine) grew by an average of 4.1% per year between 1999 and 2012 [3.10]. In contrast, in the period 1990 to 2010, Namibia's gross domestic product (GDP) grew at an average of 4.1% per year, while Namibia's population grew by an average of almost 2.1% annually [3.11].

In order to project the expected demand for electrical energy for the period between 2011 and 2031, Namibia's Integrated Resource Plan assumes an annual growth rate of 4.25%. This implies that local electricity sales of almost 2.9 TWh in 2011 would increase to almost 6.6 TWh in 2031 [3.9]. In the same period, the country's peak electricity demand is expected to grow at 4.05% per year, which implies an increase from almost 500 MW in 2011 to about 1,100 MW in 2031 [3.9].

Figure 4 shows the projected demand for electrical energy between 2011 and 2031, expressed in TWh, based on a minimum annual average growth rate of 3.0% per year (black bars), a middle-of-the-road annual growth rate of 3.75% (combining black and green bars), and a maximum average annual growth rate of 4.5% (i.e. comprising the black, green and yellow bars).

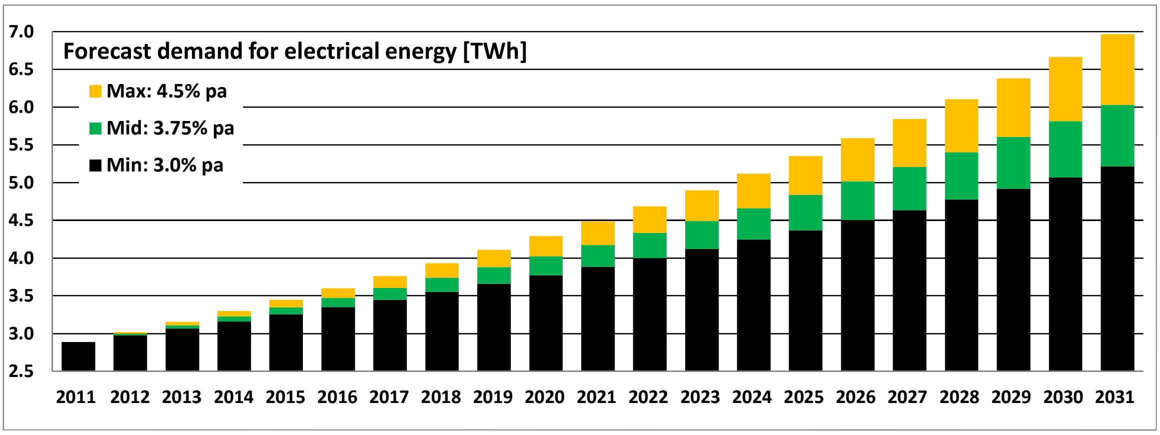


Figure 4: Projected demand for electrical energy in Namibia until 2031, in TWh [3.8]

Figure 5 shows the projected peak demand in MW required under a low, medium and high peak demand growth scenario of 3.5%, 4.0% and 4.5% per year respectively. Clearly, investments in generation capacity are urgently required if our lights are to remain on.

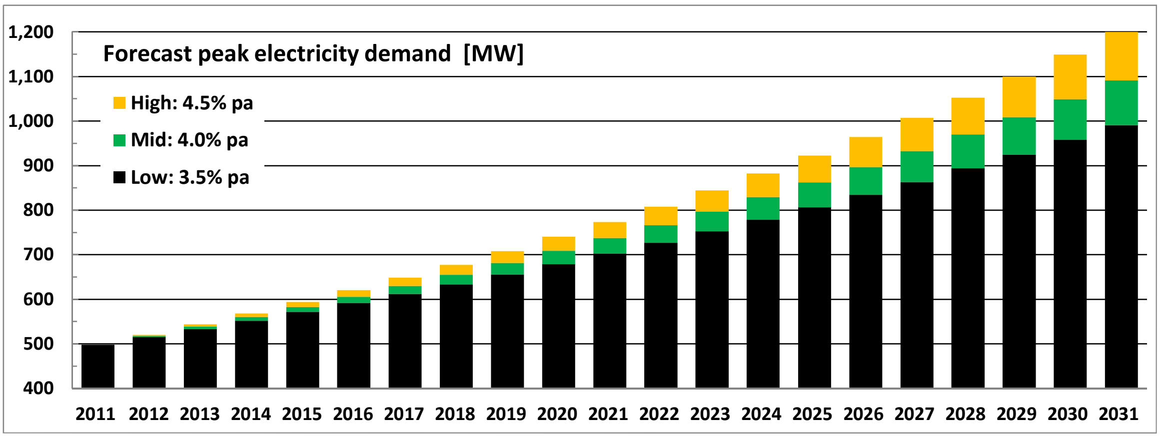


Figure 5: Projected maximum demand until 2031, in MW generating capacity required [3.8]

Namibia's historical annual aggregate load curves, for the years 2009 to 2011, are shown in Figure 6. The evening period between approximately 19h00 and 21h00 defines (on an annual basis) the national peak demand period. This period is significantly and substantially influenced by the electricity use of domestic consumers, through consumptive behaviours including the preparation of food, heating water, space heating or cooling, using lights, as well as for evening entertainment.

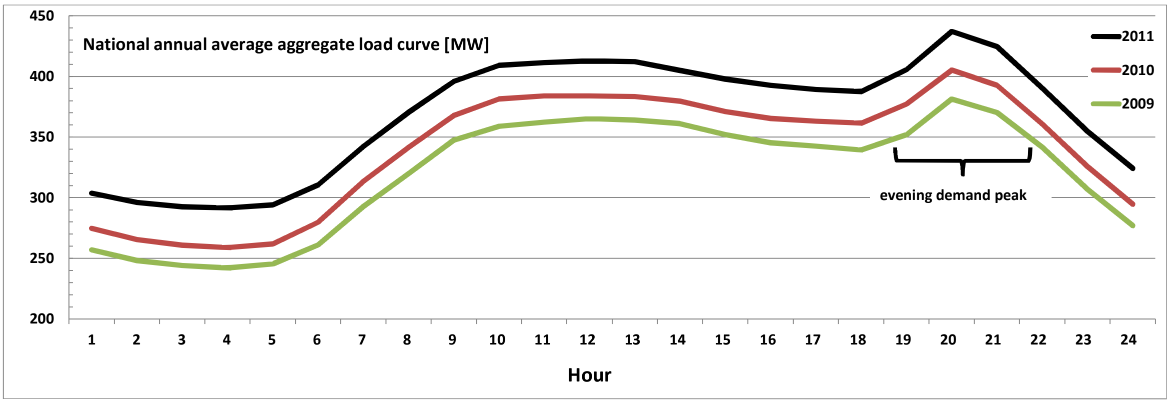


Figure 6: Namibia's annual aggregate load curves for 2009 to 2011, in MW [3.8]

The country's load duration curves for the years 2009 to 2011, as shown in Figure 7, quantify how much electrical energy was demanded for which percentage of time. Typical peak demand periods, as shown in Figure 6, often place particular pressure on utilities, both in terms of the availability of electrical energy and infrastructure, and the associated cost to supply the last unit of energy demanded by consumers in such times.

Peak demand periods are often of short duration, which implies that generation capacity to supply such demand only has to be available for a fraction of time in a given year. To illustrate this effect, Figure 7 shows that the national demand amounted to some 380 MW for 50% of the time in 2011, while electrical generation capacity meeting a load requirement of 450 MW or more was only required for 3.1% or 274 hours in that year.

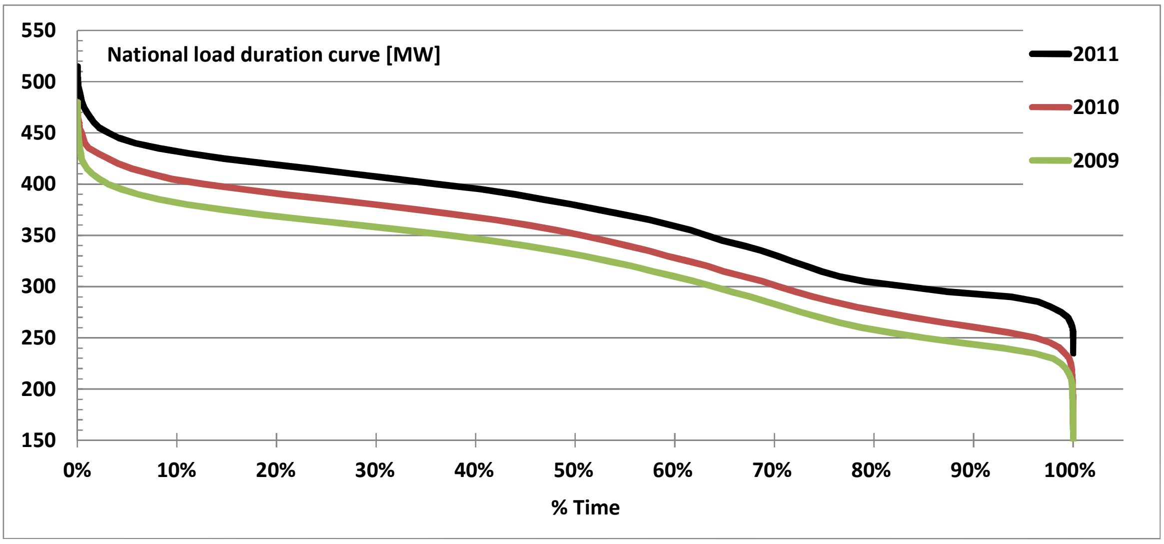


Figure 7: Namibia's annual load duration curves for 2009 to 2011, in MW [3.8]

Based on a middle-of-the-road peak demand growth of 4.0% per year, as shown in the black-and-green bars in Figure 5, and assuming that Namibia's population will continue to grow at some 2.05% per year, the country's population and expected demand per person is calculated. Figure 8 shows that the electricity demand per capita will increase from approximately 0.24 kW in 2011, to some 0.34 kW per person in 2031. Most of this increase in demand is likely to be due to productive uses of electricity, such as by new mining and commercial ventures taking place, and less so from strictly consumptive uses, such as an increase in the domestic use of electrical energy.

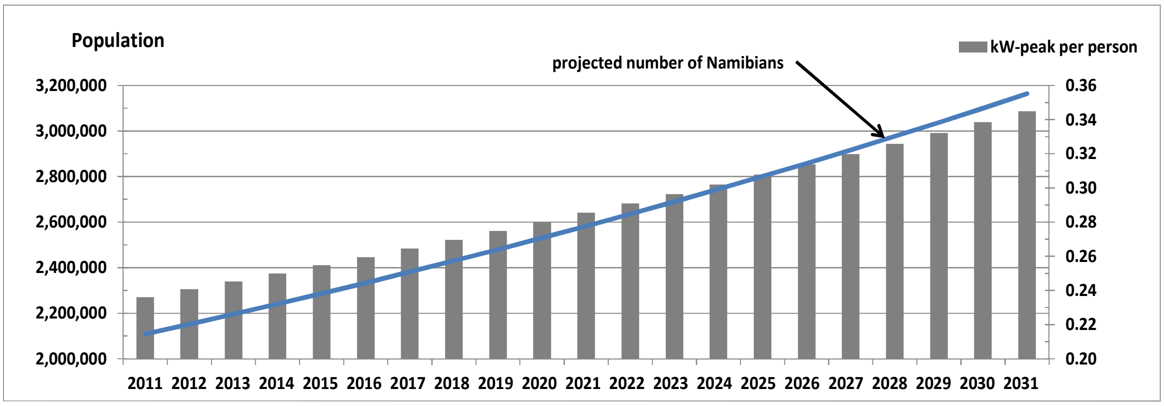


Figure 8: Projected population growth (shown as a blue line), and peak electricity demand per person (shown as grey bars, its scale is on the right hand side vertical axis), in kW [3.8]

It is instructive to contrast the electrical energy demand in select developing and industrialised countries in 2005 [3.12] and the demand per person in Namibia in 2011 expressed in kW, and the demand per Namibian as projected to 2031, based on an average peak demand growth rate of 4.0% per year between 2011 and 2031; this is shown in Figure 9.

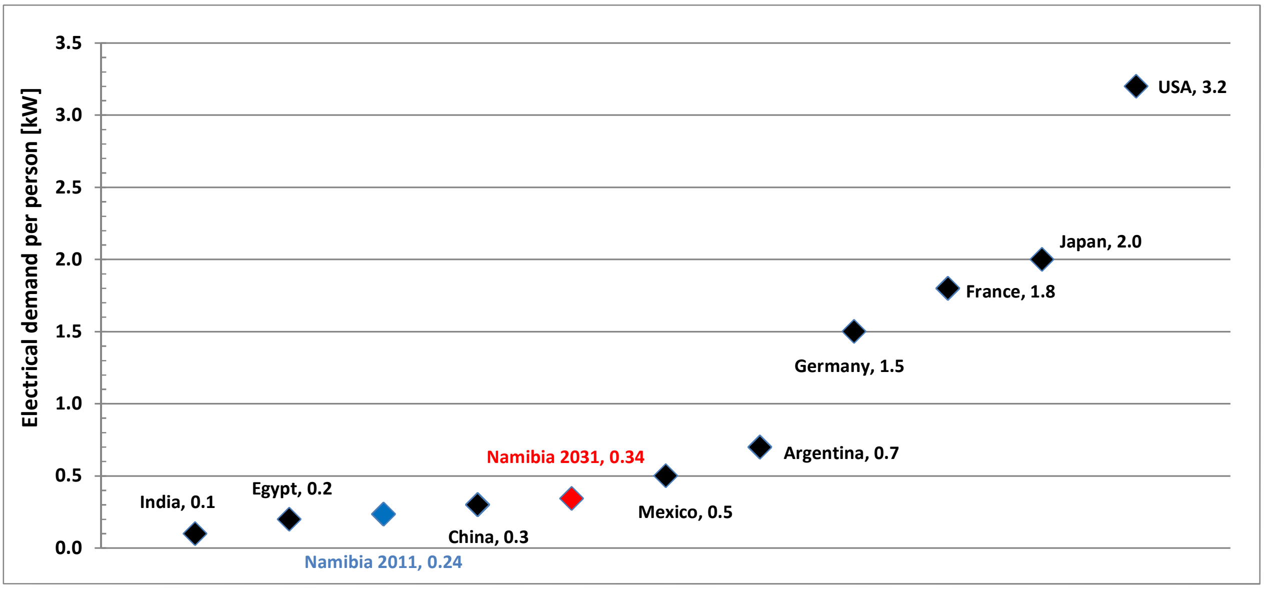


Figure 9: Demand per person in 2005, and Namibian demand per person in 2011 and 2031 [3.8] based on data from [3.12]

3.6 Sources of Electrical Energy

Electrical energy consumed in Namibia is generated locally at the Ruacana hydro-electric power station, the coal-fired van Eck power station near Windhoek, and Paratus and Anixas in Walvis Bay. The shortfall between the total electrical energy consumed and the quantity that can be generated locally is imported.

In the financial year 2010/2011 (abbreviated FY2010/11), local generation capacity contributed some 1,430 GWh of electrical energy, or 36.6% of the total energy traded by NamPower in that period [3.5]. The relative contribution to the electrical energy generated at the four local power stations in FY2010/11 is shown in Figure 10, and emphasises the pivotal role played by the Ruacana power station.

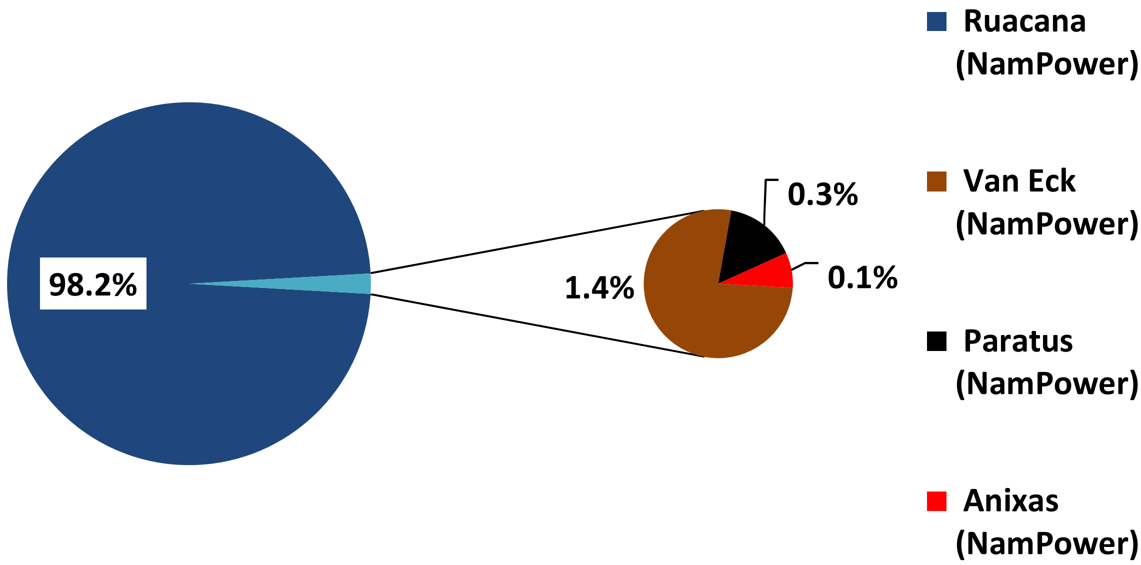


Figure 10: Contribution of local generation to the total electricity supplied in FY2010/11 [3.8]

The generation capacity of Ruacana depends critically on the availability of water in the Kunene River, which varies from month to month, and year to year. There is no large-scale dam at or near Ruacana; only a small reservoir is available to manage water over a 24-hour period. Consequently, there is no effective buffer that ensures water availability or can be used to regulate flow during the dry period. This implies that electricity generated at Ruacana will remain dependent on rainfalls and water use in south-western Angola; this may change as a result of long-term climate change as well as new and additional uses of Kunene River water in Angola.

The contribution of the four local generation plants to Namibia's electricity supply over the last decade is shown in Figure 11. Ruacana contributed between 88% and 99% of all local supplies, while van Eck's contribution ranged from 0.1% to more than 10%, and Paratus contributed between 0.1% and 0.6% to local supplies in the period under consideration [3.10]. Anixas only became available in 2011, so its contribution is small.

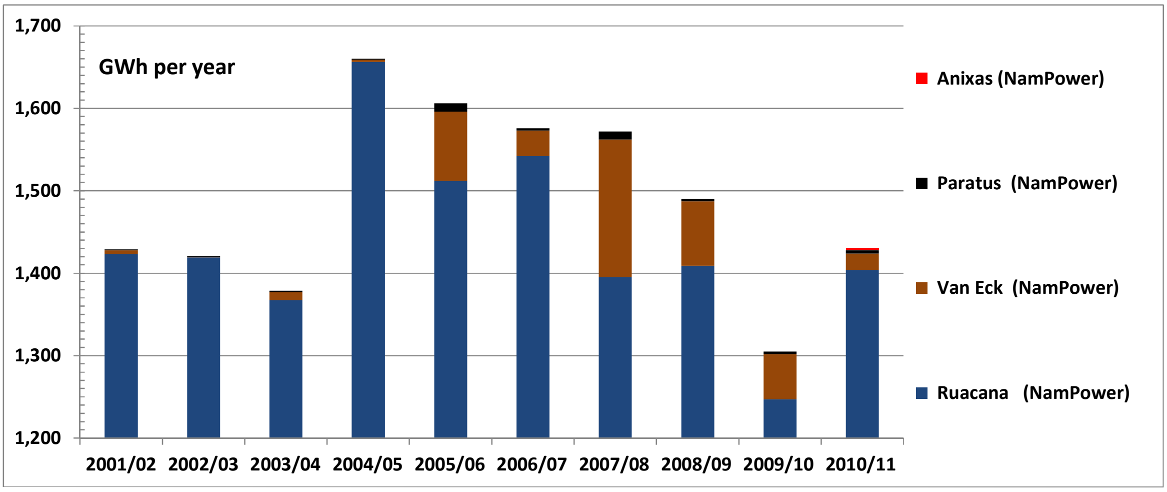


Figure 11: Electricity provided by local generation plant during the past decade, in GWh/a [3.8]

The difference between the demand for electrical energy and what local generation sources can supply has to be imported. Figure 12 shows the percentage of electrical energy that NamPower had to import from cross-border suppliers in the past decade. The percentage of imports has been increasing for eight out of ten years over the period 2001/02 to 2010/11 [3.10]. This illustrates that electricity imports are critically important, and that local generation capacity is desperately needed unless Namibia can identify regional suppliers willing and able to offer long-term supply contracts to Namibia. However, regional electricity supply capacities are stretched to the limit, and it becomes increasingly challenging to secure sufficient external supply contracts. This is a strategic risk, and may increasingly constrain the country's economic development.

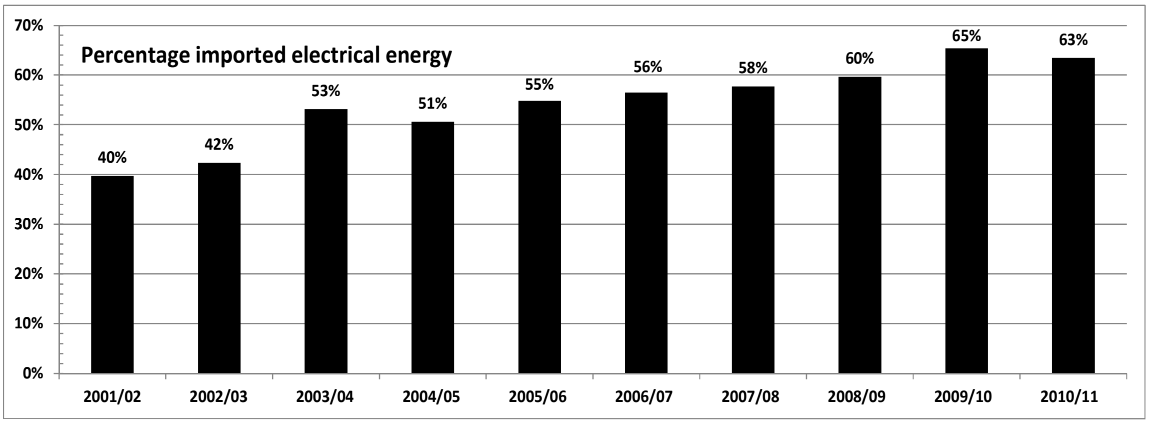


Figure 12: Percentage Namibian electricity imports during the past decade [3.8]

Figure 13 illustrates the contributions that all suppliers have made to Namibia's total electricity supply [3.10]. During the past decade, the single largest external contributor to Namibia's electricity supplies was Eskom, South Africa's electricity utility, which contributed between 38% and almost 53% to the total electrical energy sold by NamPower. This illustrates Eskom's pivotal role as critical supply partner. However, preferential supply agreements of the past with Eskom are no longer in place. Current supply agreements with Eskom include strict stipulations in regard to the timing, quantity, seasonal cost and load curtailment requirements to be adhered to by NamPower; these aspects have dramatically changed the playing field in which NamPower operates.

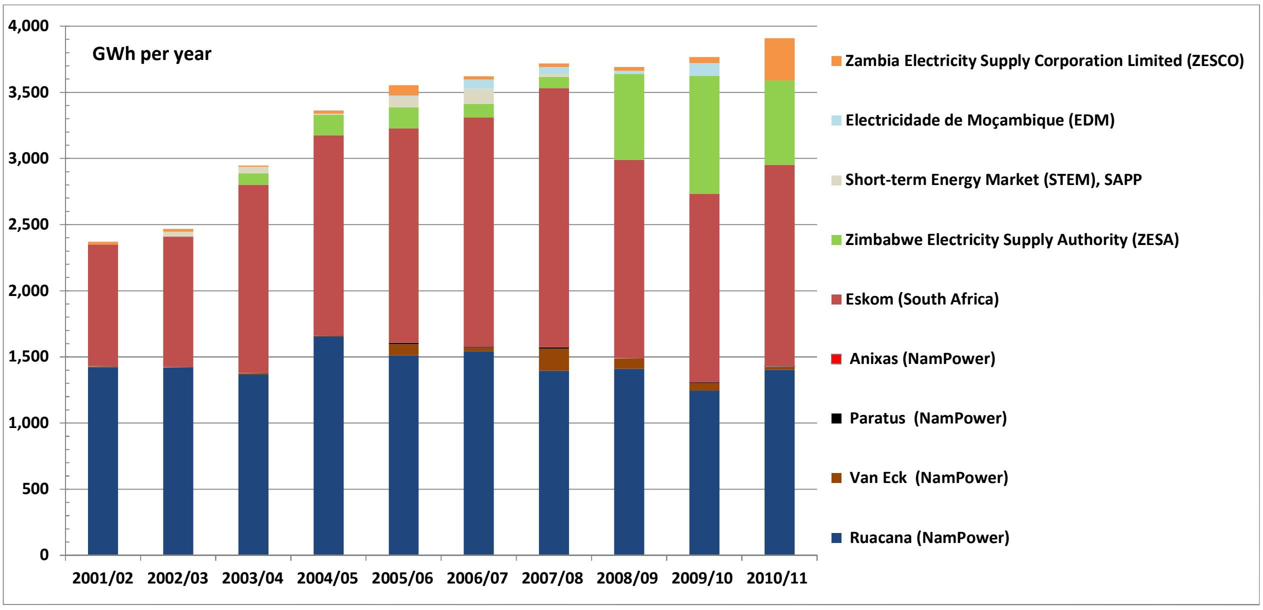


Figure 13: Sources of Namibia's electrical energy during the past decade [3.8]

The **Zimbabwe Electricity Supply Authority (ZESA)** provides up to 150 MW of base load power from the coal-fired Hwange station. The current supply contract runs between October 2008 and October 2013; and has just been extended to 2014. In 2009/2010, ZESA provided 23.7% of Namibia's total supplies, thus contributing significantly to Namibia's security of electricity supplies [3.10].

NamPower has a supply contract for up to 30 MW of supply with **Mozambique's Electricidade de Moçambique (EDM)**, which operates substantial hydro-power plants in the country. The contract is reviewed annually. EDM's maximum energy contribution amounted to 2.5% of total Namibian supplies in 2009/2010 [3.10].

NamPower's latest power supply agreement with the **Zambia Electricity Supply Corporation Limited (ZESCO)** came into effect in January 2010, and is for a 10-year duration for a firm capacity of 50 MW. ZESCO has contributed between 0.3% and 8.2% of Namibia's total electricity supplies, with a maximum of 637 GWH in 2010/2011 [3.10].

Occasionally and when available, NamPower acquires electrical energy on the **short-term energy market (STEM) offered through the Southern African Power Pool (SAPP)** [3.13]. STEM contributed up to 3.2% of the total electrical energy required in 2006/2007, but trading is constrained by a lack of sufficient power supply capabilities in the region, as well as the availability of adequate regional transmission capacities [3.10].

In the past years, even in crunch times where our South African neighbours had to learn to live with multiple and prolonged load shedding, Namibia has been largely spared such disruptions. This is a testament to the abilities of NamPower to keep the lights on, despite the regional constraints. Will this continue in future, and will last-minute provisions spare the country from unproductive and costly periods with no electricity?

Figure 14 and Figure 15 offer a glimpse into the future: Figure 14 shows the forecast electrical energy demanded per year, and how it may be met from the various Namibian and outside sources of supply, while Figure 15 shows the country's projected peak demand in the coming years, versus what our various in- and external supply options may be able to contribute during peak demand times.

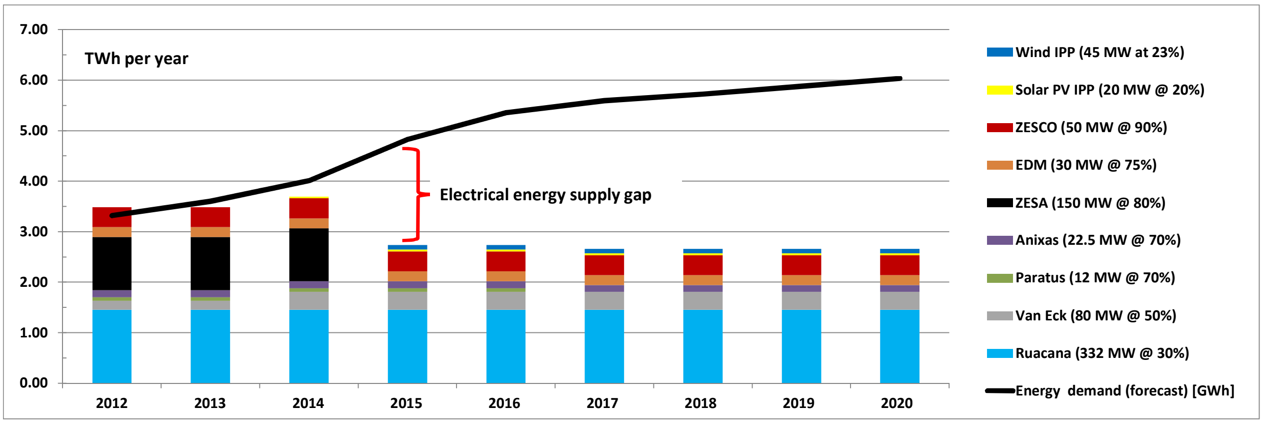


Figure 14: Forecast electrical energy demand and associated sources of supply, in TWh [3.8]

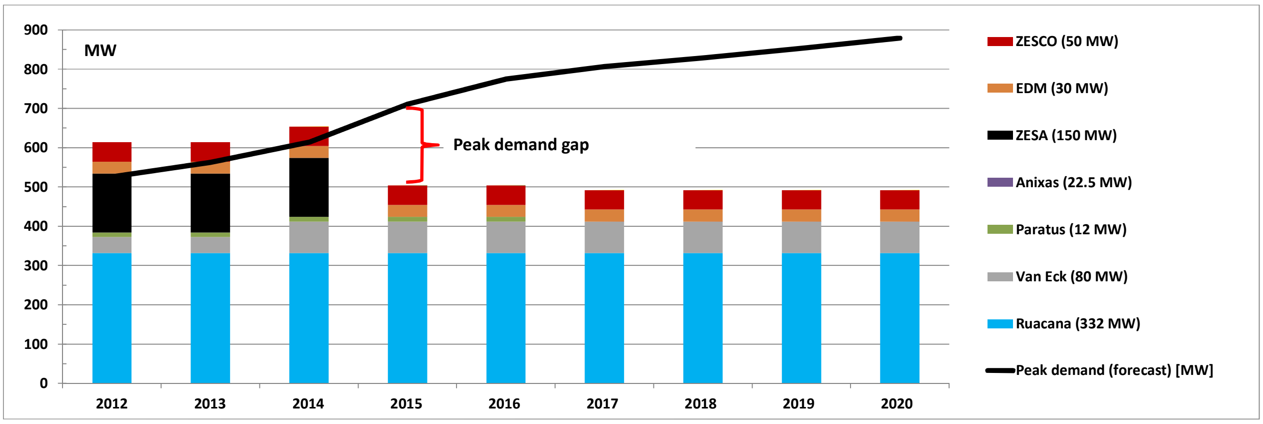


Figure 15: Forecast annual peak demand and associated sources of supply, in MW [3.8]

It is evident that a worrying and sizeable energy supply gap is developing, which requires decisive and immediate action. Unless Namibia can find reliable and affordable sources of electricity supplies in the near future, electrical energy supplies will not meet the expected national demand. This would have very serious consequences for the country. Figure 15 shows the corresponding peak demand situation, and how both in- and external sources may assist to meet the peak demand for electrical power. A serious peak demand gap needs to be filled. We conclude that decisive action is urgently required.

3.7 Domestic Use of Energy in Namibia

The Namibian Census of 2001 reveals that 68% of consumers living in urban areas used electricity for lighting; only 10% of rural households used electricity [3.14].

The Namibian Household Income and Expenditure Survey of 2009/2010 found that almost 42% of households used electricity for lighting while some 38% of respondents used candles [3.15]. Findings of the 2001 and 2009/2010 assessments are compared in Figure 17, Figure 18 and Figure 19 below.

Figure 16: Candles for lighting remain essential for more than 38% of Namibians [3.16]

Figure 17 to Figure 19 show that the use of electricity for lighting, cooking and heating has increased as a percentage of households interviewed in 2001 and 2011 respectively. This increase has occurred in rural as well as urban areas.

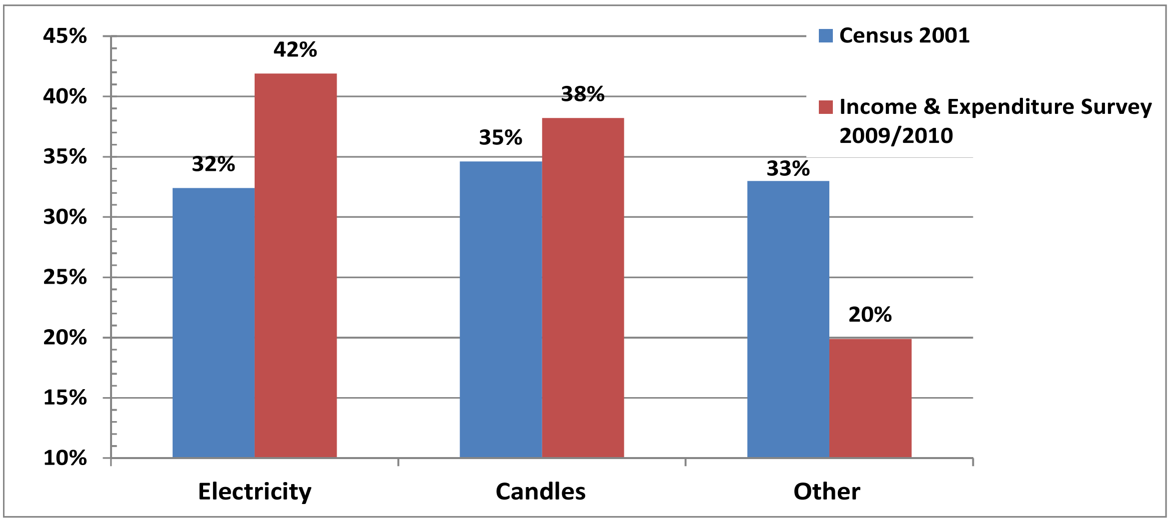


Figure 17: Energy for lighting - percentage households using different forms of energy [3.8]

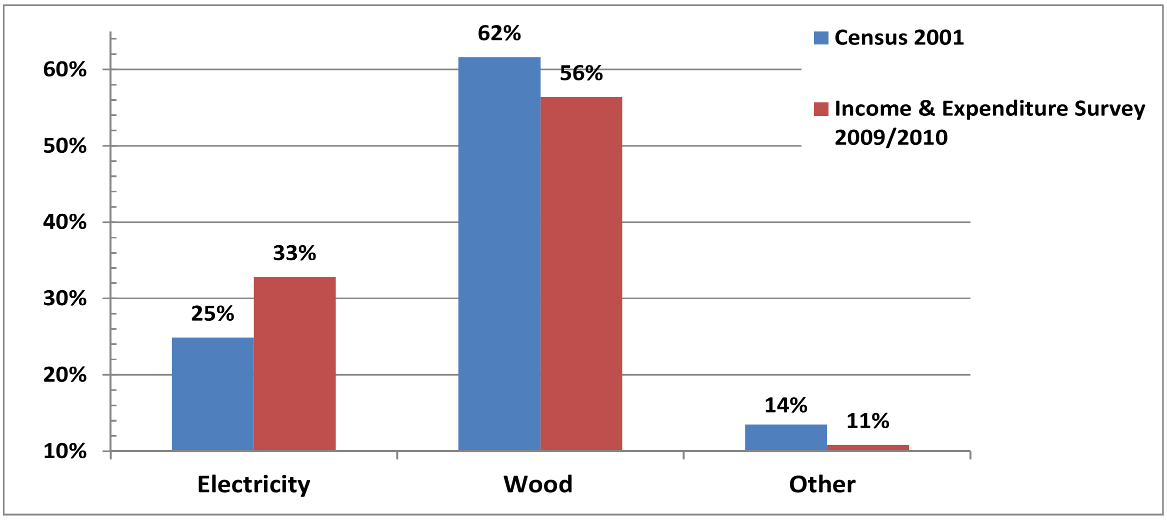


Figure 18: Energy for cooking - percentage households using different forms of energy [3.8]

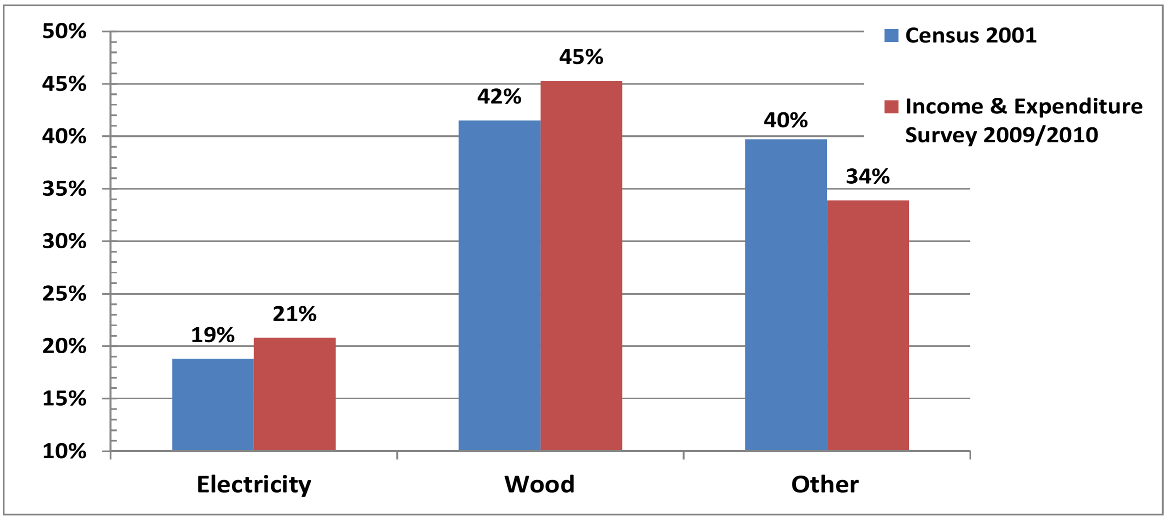


Figure 19: Energy for heating - percentage households using different forms of energy [3.8]

3.8 Electricity Use in Namibia

In the financial year 2010/2011, NamPower fed a total of 3.91 TWh[1] into the national system [3.5]. Of this, 2.48 TWh or 63.4% were imported from cross-border suppliers. Eskom was the single largest supplier, providing some 1.52 TWh or almost 39% of the total electricity going into the Namibian system in that year [3.5].

In the same period, the country's total electricity consumption amounted to 2.65 TWh, including rural consumption and mining, but excluding Skorpion Zinc Mine (0.69 TWh), Orange River projects (0.13 TWh) and exports to neighbouring countries (0.07 TWh). Losses, including transmission losses and electricity not sold to end-users amounted to some 0.37 TWh, or 9.4% in 2010/2011 [3.5].

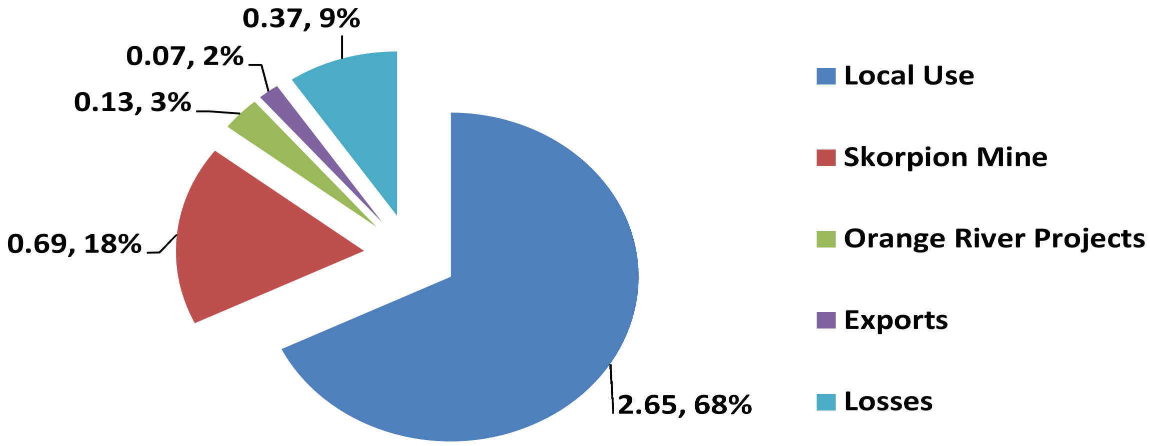


Figure 20: Components of total electricity use of 3.91 TWh in 2010/2011, in TWh and % [3.10]

The total electrical energy consumed in the various distribution and supply areas for 2010/2011 is summarised in Table 4.

SUPPLY AUTHORITY Unit	Total electricity consumption [MWh]	Domestic consumption [MWh]	Commercial consumption [MWh]	Bulk/LPU consumption [MWh]
Windhoek	752,392	328,604	148,916	274,872
Erongo RED	375,508	149,667	56,815	169,026
NORED	206,145	110,520	31,926	63,699
NamPower Distribution	196,766	0	82,659	114,107
CENORED	148,455	39,283	55,974	53,198
Southern regions	135,541	56,560	27,761	51,219
Oshakati Premier Electric	50,221	11,263	9,993	28,965
Central regions (excl. Windhoek)	49,330	21,111	8,069	20,150
TOTAL	**1,914,357**	**717,008**	**422,113**	**775,236**

Table 4: Electricity consumption in Namibia's distribution and supply areas in 2010/2011 [3.17]

[1] TWh – terawatt-hour, which is one million megawatt-hour (MWh), or one billion kilowatt-hour (kWh). The most common unit used to indicate domestic electricity consumption is the kWh. Many commercial and bulk users use the MWh as a unit to quantify the amount of electrical energy used.

Figure 21 shows the domestic, commercial and bulk/large power use in 6 distribution and supply areas in 2010/2011; while Figure 22 shows the percentage use in the same year.

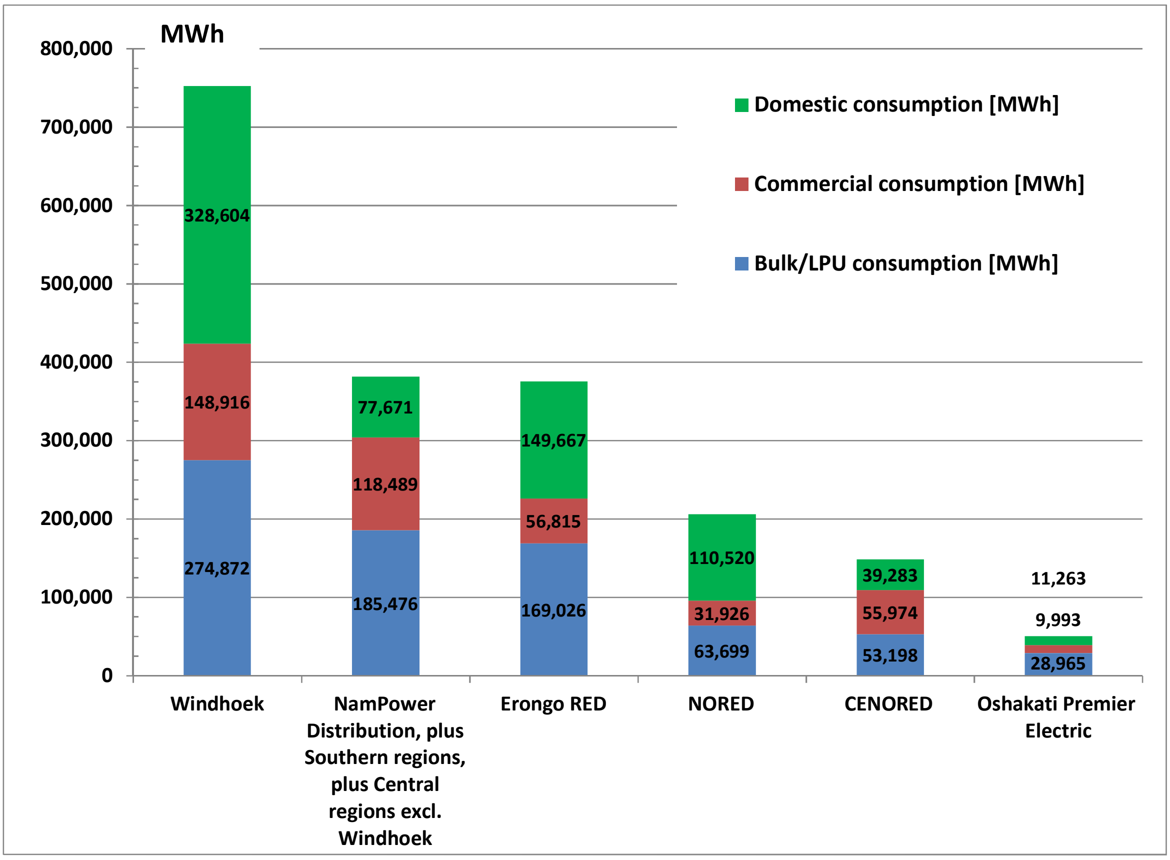


Figure 21: Electricity use in Namibia's main supply areas in 2010/2011; data as per Table 4 [3.8]

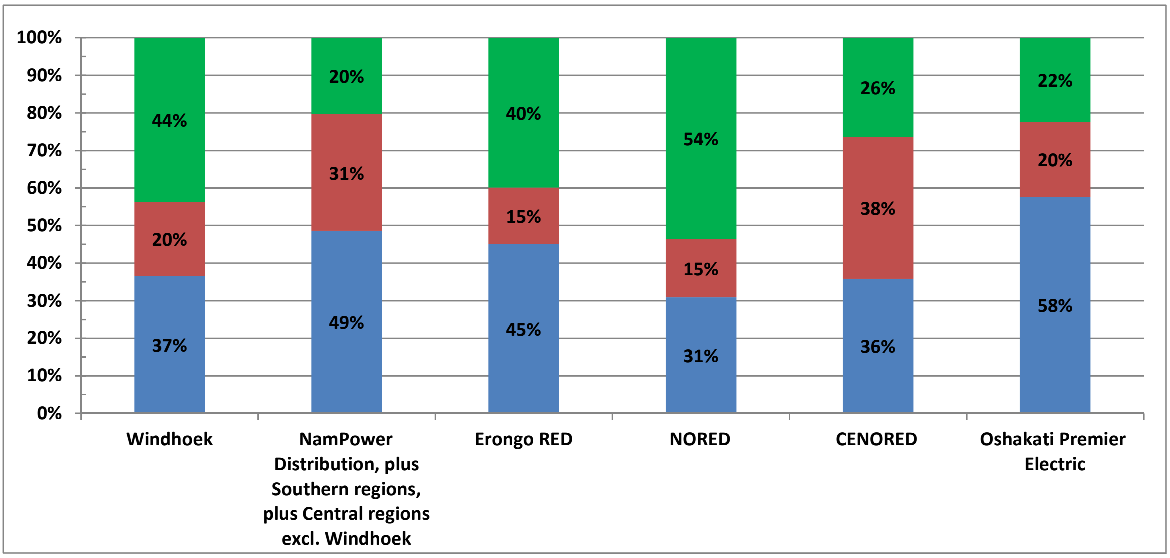


Figure 22: Percentage domestic (green), commercial (red) and bulk/large power user (blue) consumption in 2010/2011 [3.8]

The total electrical energy consumed in the 8 main distribution and supply areas in 2010/2011 amounted to some 1.91 TWh[2]. NamPower sold less than 0.74 TWh[3] to transmission clients, including select large power users and other bulk users who have direct off-take arrangements with the utility. Such users include mines, water pumping schemes and select commercial and industrial consumers. For 2011/2012, the total electrical energy consumed in the 8 main supply areas increased to 2.01 TWh; this is an increase of some 5% in the energy used in these areas between 2010/11 and 2011/12.

SUPPLY AUTHORITY / Unit	Total electricity consumption [MWh]	Domestic consumption [MWh]	Commercial consumption [MWh]	Bulk/LPU consumption [MWh]
Windhoek	784,570	341,266	179,933	263,371
Erongo RED	392,390	153,881	58,519	179,990
NORED	237,916	116,420	34,358	87,138
NamPower Distribution	200,132	0	72,644	127,488
CENORED	149,279	39,620	56,194	53,465
Southern regions	143,732	65,222	27,909	50,600
Oshakati Premier Electric	52,521	11,676	10,432	30,413
Central regions (excl. Windhoek)	49,593	18,728	9,533	21,332
TOTAL	**2,010,133**	**746,813**	**449,522**	**813,797**

Table 5: Electricity consumption in Namibia's distribution and supply areas in 2011/2012 [3.17]

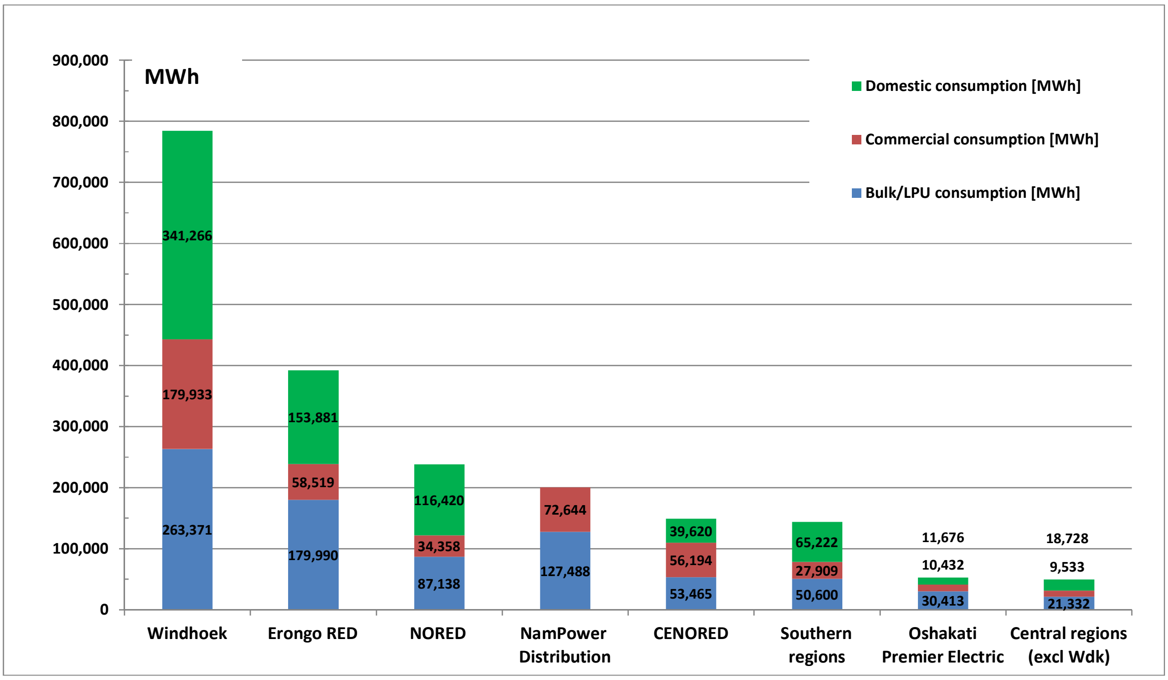


Figure 23: Electricity use in Namibia's main supply areas in 2011/2012; data as per Table 5 [3.8]

[2] There are inevitable losses in both the transmission and distribution networks. In practice, this implies that NamPower has to acquire of the order of 10% more electrical energy than can eventually be sold.

[3] For 2010/2011, the total national electricity consumption amounted to 2.65 TWh, which excludes Skorpion Zinc Mine, the Orange River Projects, exports and network losses. A consumption of 1.91 TWh in distribution and supply areas leaves 2.65 – 1.91 ≈ 0.74 TWh of electrical energy, that NamPower supplied directly to transmission clients, *excluding* associated network losses.

3.9 Domestic Electricity Consumption in Namibia

The domestic electrical energy consumption in MWh in FY2010/11 is shown in Figure 24.

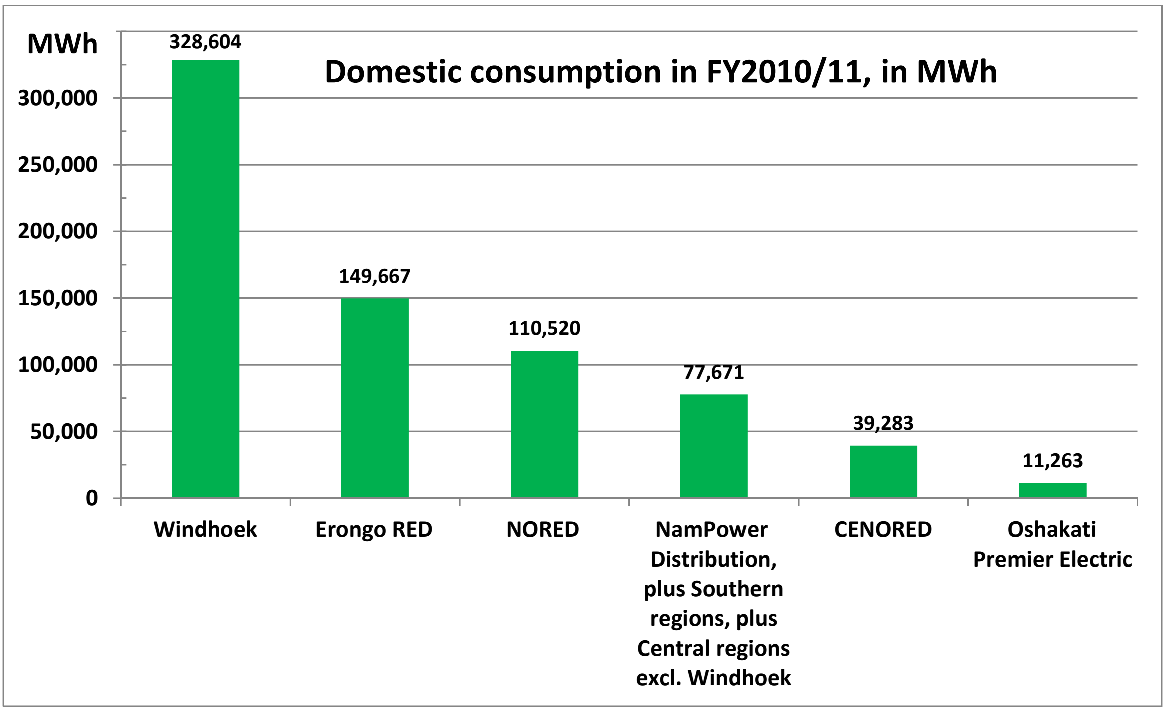


Figure 24: Domestic electricity consumption in Namibia's main supply areas in FY2010/11, in MWh [3.8]

Figure 25 shows the percentage domestic consumption of the total electrical energy consumption per supply area in FY2010/11.

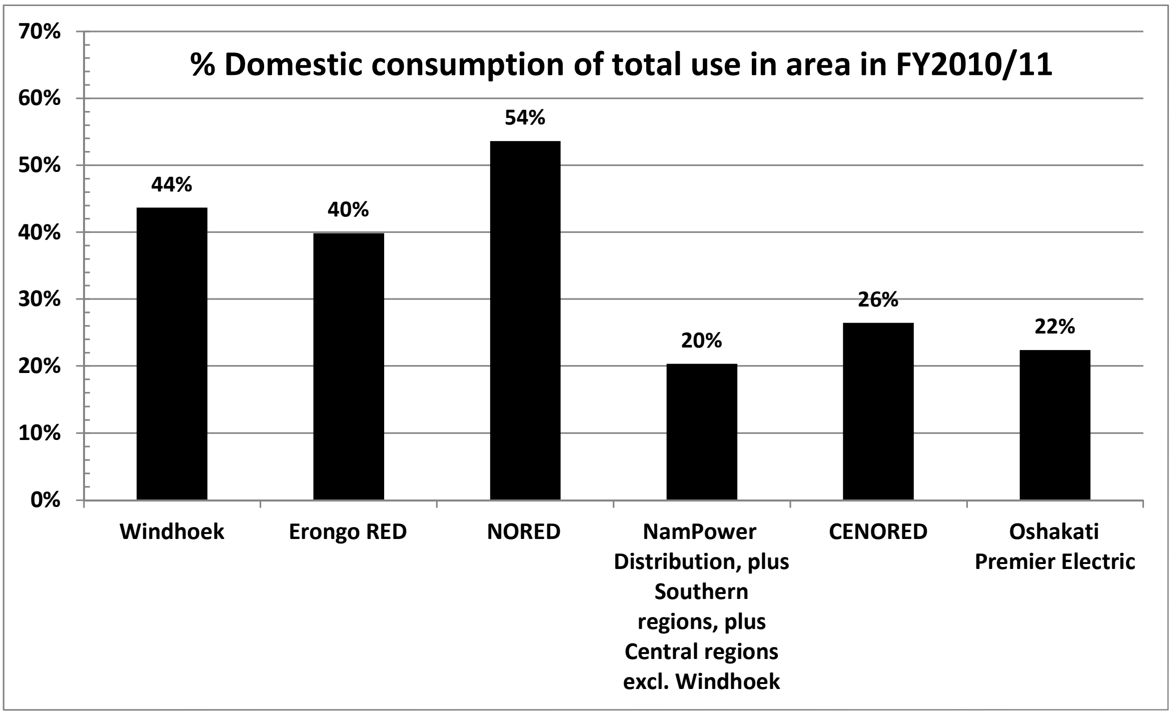


Figure 25: Percentage domestic electricity consumption of the total electricity consumption in each of Namibia's main supply areas in FY2010/11 [3.8]

As shown in Figure 26, Namibia's domestic electricity consumption amounted to 37.5% of the total electrical energy consumed in 2010/2011, while commercial consumption constituted some 22% of the total consumption, and bulk/large power user consumption provided by and through the supply and distribution authorities accounted for some 40.5% of the total electricity used in these areas. It is evident that Namibia's domestic consumption of electrical energy – at some 37.5% of the total electricity used – is an important component of the total electricity consumed nationally.

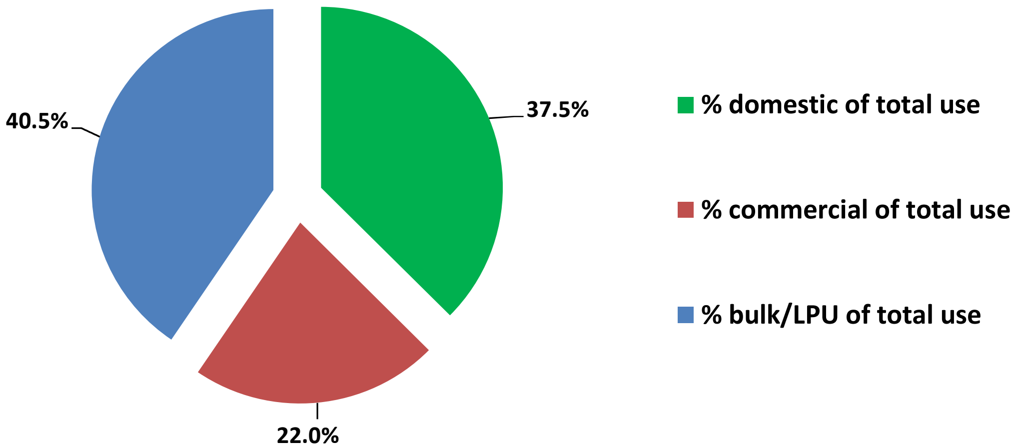


Figure 26: Main uses of electricity in Namibia's supply & distribution areas in FY2010/11[4] [3.8]

At almost 50% of the total domestic consumption of electricity in Namibia in 2010/2011, the City of Windhoek was the most significant user of domestic electrical energy. If the city's domestic users were to be supplied by a dedicated power plant, such a hypothetical plant would have to have a capacity of almost 50 MW when operated throughout the year[5]. Similarly, if the country's total domestic electrical energy consumption of some 717,000 MWh in 2010/2011 was to be generated by a single power plant, such a generator would require an installed capacity of almost 110 MW if it was operated throughout the year[6].

The domestic sector accounts for more than one-third of Namibia's total electricity consumption in urban areas in Namibia. It is therefore important to consider how the consumption in the domestic sector will change as a result of rural-to-urban migration, the delivery of formal housing having grid or grid-like electricity connections, as well as changing household incomes, and the resultant increase in the uptake of electrical appliances in the years to come. This is the topic covered in the next section.

[4] Excluding Skorpion Zinc Mine, the Orange River Projects exports and line losses as well as NamPower's direct supplies to bulk and large power users, such as mines and water pumping schemes.

[5] A hypothetical 50 MW power plant with a capacity factor of 75% would supply some 328 GWh per year. It is to be noted, however, that domestic consumption has a load factor of less than 75%, because most consumption is during the evening peak period, with limited consumption during the remainder of a typical day.

[6] A hypothetical 110 MW power plant with a capacity factor of 75% would supply some 722 GWh per year; also refer to the discussion of the underlying assumption as presented in the previous footnote.

3.10 Energy Efficiency Potentials in Namibia's Domestic Electricity Sector

Past and projected future electricity demand trends were discussed in section 3.4. Considerable energy efficiency opportunities exist in the domestic sector. These can cost-effectively reduce the consumption of electrical energy on a household level, thereby contributing to mitigate the increases in domestic energy expenditure and use. Here, the use of energy efficient appliances and greener technologies, as discussed in chapter 4, are of particular importance, and hold considerable domestic electricity savings potentials, while cost-effectively enhancing the services from energy efficient appliances.

Informed by international and local experience with the introduction of energy efficient technologies, potential domestic electricity savings often lie between 20% and 60% of the total consumption, without the loss of amenities or comfort [3.18]. The introduction and use of such technologies however depends critically on the awareness and willingness of domestic users to systematically identify and embrace technologies and activities that have energy savings potentials.

It is recognised that Namibia has a substantial stock of existing residential properties, as well as consistent housing backlog in both urban and peri-urban areas [3.19]. These create a demand for housing development, which in turn necessitate that new domestic construction adds thermally and light-efficient buildings to reduce costs arising from unnecessary or easily avoidable expenditures on energy. The timing and factors that most significantly influence the demand for electrical energy consumption in the domestic sector in Namibia are summarised in Table 6 below.

Timing	Key factors influencing the domestic electricity demand
Morning	• electric water heater • number of members in the household
Evening	• number of rooms in the household • cooking habits and cooking technology • use and setting of electric water heater • air conditioner use in summer and electric heating in winter
All-day consumption	• floor area of the household • user behaviour • use of fridge/freezers • use of air conditioners, pool pumps and other semi-permanent loads

Table 6: Domestic factors influencing household electrical energy consumption [3.18]

International experience (see for example [3.19]) shows that the most effective approaches to energy efficiency in the domestic sector include:

- energy efficiency awareness programmes, including ready access to information
- housing design, and specifically the thermal efficiency of houses
- regulatory requirements for energy efficiency planning approvals for new and refurbished housing stock
- energy labelling of appliances
- energy efficiency and demand side management programs, and
- a supportive regulatory environment, enabling supply authorities to set electricity tariffs based on energy efficiency performance rather than traditional consumption-based revenues only.

However, while energy efficient technologies are important in the domestic sector, the uptake and productive use of energy efficient technologies in the commercial and industrial sector is often more readily achieved, and frequently holds more savings opportunities than those witnessed in the domestic sector [3.19]. This is mainly because

1) commercial/industrial facilities are often characterised by their larger and more concentrated electrical energy consumption patterns, while domestic consumers are more numerous, but have smaller individual energy consumption requirements;
2) the financial and economic benefits of energy efficient technologies are often more pronounced and readily demonstrated for commercial buildings and industrial settings than they are for individual domestic users; and
3) commercial and industrial entities generally have better access to finance to allow for technology upgrades yielding energy savings.

3.11 Electricity Prices in Namibia

This section briefly describes the electricity tariffs that are paid by end consumers in Namibia.

End-user tariffs are regulated by the ECB, and are calculated using the ECB's electricity tariff determination methodology [3.20]. To this end, electricity distribution entities, who sell electrical energy to end-users, compile an ´operating and reporting manual` (ORM). The ORM summarises the entity's total sales, costs and revenues, and is the basis from which the revenue requirement necessary to ensure the entity's sustainable operations is calculated. Based on the calculated revenue requirement and a given regulated return on investments in electrical infrastructure, each utility and distribution entity determines end-user electricity tariffs. These are submitted to the ECB, who assess the entity's tariff application. If the proposal meets the ECB's requirements, the end-user tariffs as submitted by the distribution entity are approved, and published by the utility.

The above electricity tariff determination methodology applies to all distribution and supply entities that provide electricity to end-users, i.e. all REDs, local authorities, regional councils, NamPower distribution as well as private entities undertaking electricity distribution and supply functions in Namibia.

Figure 27 shows the average end-user electrical energy prices in N$ per kWh between 2008/09 and 2012/13, for post-paying domestic clients using conventional electricity meters in select distribution areas [3.21]. The electricity price shown *excludes* any additional charges such as demand, basic, capacity, rental, ECB levy and other charges, as may appear on an end-user's electricity bill, and are therefore energy charges only.

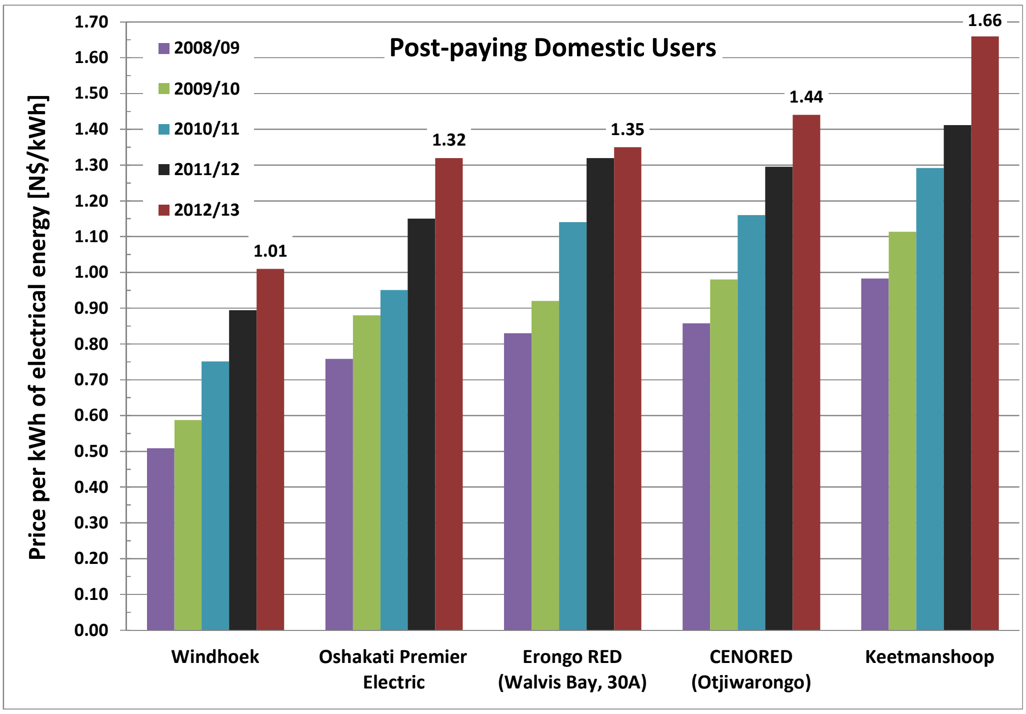


Figure 27: Price per unit of electricity for post-paying electricity users, in N$ per kWh [3.8]

Figure 28 shows the average electrical energy price in N$ per kWh for pre-paying domestic users having pre-paid electricity meters, in select distribution areas, between 2008/09 and 2012/13. The pre-paid tariff for electricity as shown in Figure 28 includes all charges levied by the distribution entity, except the ECB levy which amounts to an additional N$ 0.014 per kWh in 2012/13.

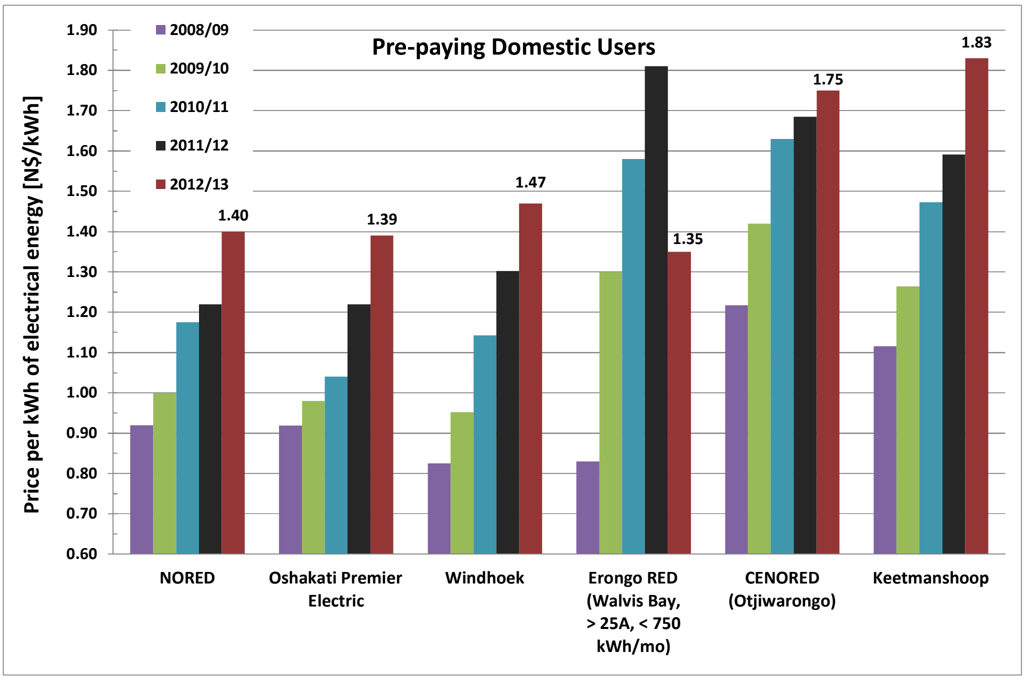


Figure 28: Price per unit of electricity for pre-paying electricity users, in N$ per kWh [3.8]

Each distribution entity's operating circumstances are unique [3.22]. Factors that significantly influence an entity's end-user tariffs include:

- the condition of the electricity distribution and supply network, and investments requirements for its upkeep
- the scale of network extensions, upgrades and ongoing maintenance required
- the growth of the energy consumption in a specific supply area
- the amount of energy sold per network kilometre
- the required average network length required per customer, and
- the energy sales per customer.

As shown in Figure 27 and Figure 28, the price paid by end-users for electrical energy has (in many instances) almost doubled over the past five years. Tariff increases by distribution entities are mainly determined by:

- the annual NamPower tariff increases, as approved by the ECB and passed through to electricity distribution entities

- systematic increases to achieve cost-reflective tariffs, and
- network maintenance and upgrade costs [3.22].

It is instructive to consider the total monthly electricity bill that a domestic user would have to pay. Assuming an electricity consumption of 300 kWh per month through a conventional credit meter, with a 30 Ampere circuit breaker (if relevant), the total monthly cost including energy charge, ECB levy, local authority surcharge (if applicable), basic monthly service charge and circuit breaker charge for select distribution areas in 2012/2013 is shown in Figure 29.

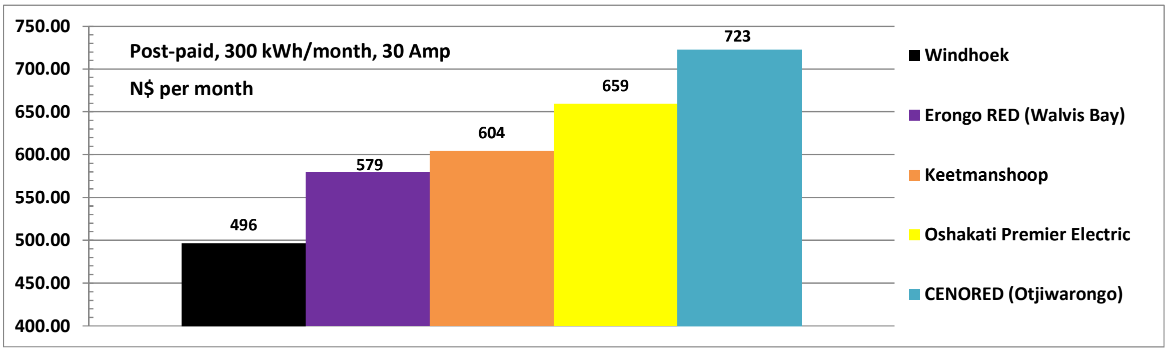


Figure 29: Total monthly electricity charge for post-paying consumers, 300 kWh/month [3.8]

For end-users having a pre-payment electricity consumption meter, the total monthly electricity bill when using 300 kWh of electrical energy per month is shown in Figure 30.

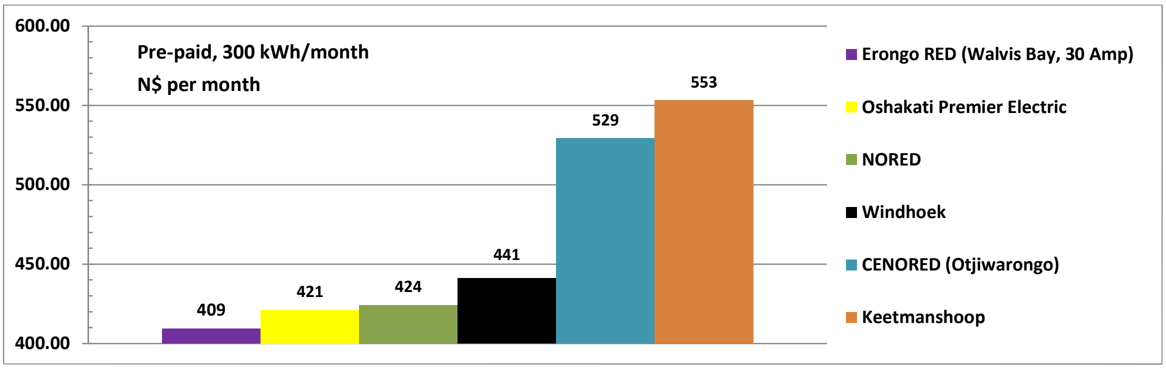


Figure 30: Total monthly electricity bill for pre-paying consumers, 300 kWh/month [3.8]

Southern African electricity tariffs have historically been far below cost-reflectivity. The recent shortage of electricity, massive investment requirements in the electricity sector and the drive towards cost-reflectivity of tariffs has resulted in a substantial escalation of end-user electricity prices. At about the same time as regional supply gaps emerged, Namibia's REDs were established. This has contributed to the widely-held view that the REDs have been a major reason for hefty electricity price increases. There is little evidence that supports such allegations.

While arguments that the REDs have contributed to the rapid escalation of end-user electricity prices has provided political mileage for some, such debates conveniently ignore the fundamental challenges faced by Namibian electricity utilities. The principal challenge facing Namibia is a shortage of electricity generation capacity, coupled to historically low consumer tariffs that are inadequate to ensure that electrical infrastructure can be adequately maintained and extended.

Figure 31 shows that the average price per unit of electricity sold by NamPower has escalated from 10.98 cents per kWh in 1993/94, to about 90 cents per kWh in 2012/13.

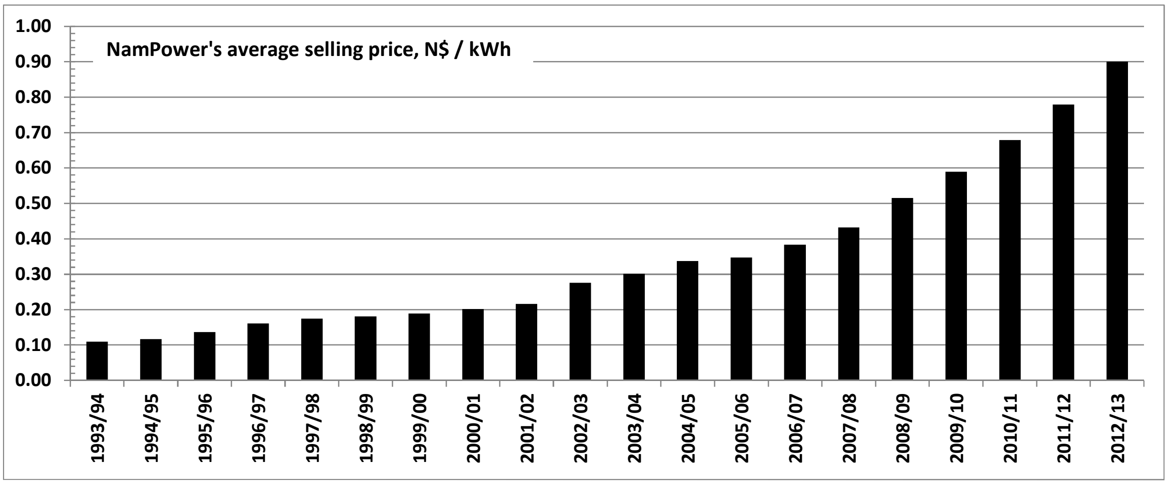


Figure 31: Average NamPower price of electricity in the past two decades, in N$/kWh [3.10]

Figure 32 shows the Namibian consumer price index, and the index for NamPower's average price of electricity relative to the base year 2000/01. While inflation has brought about a doubling (factor 2) of the cost of a basket of goods, electricity prices have escalated by factor 3.4 over the period 2000/01 to 2010/11. Wholesale electricity prices are, and will continue to be, a significant electricity price driver, irrespective of the distribution entity that supplies end users.

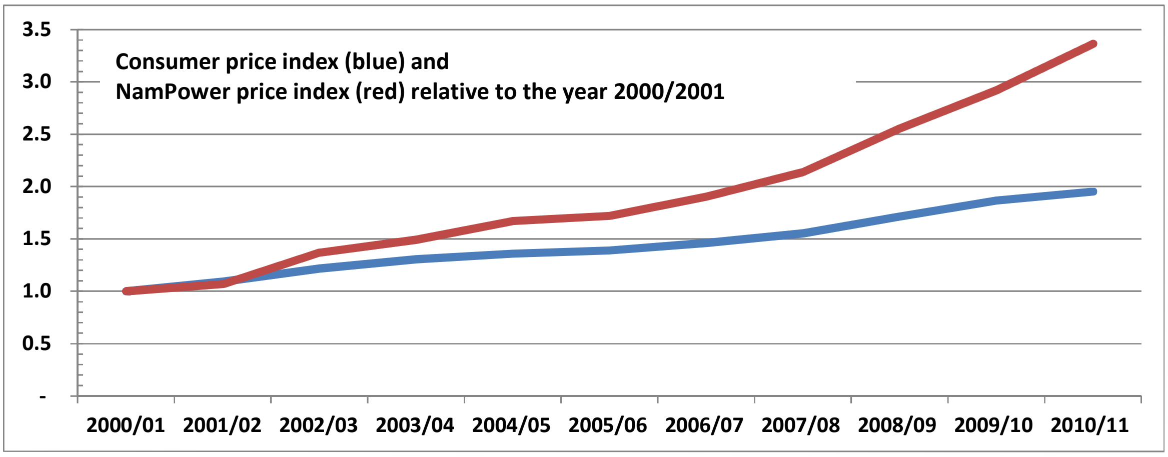


Figure 32: Consumer price index (blue) & NamPower price index (red) relative to 2000/01 [3.10]

In the years to come, Namibia's electricity prices will continue to escalate substantially. NamPower expects that the wholesale price of electricity will increase from the current N$ 0.90/kWh in the financial year 2012/2013, to an estimated N$1.60/kWh in 2016/2017 [3.5]. The expected path for the wholesale price of electricity is shown in Figure 33, assuming an annual price increase of 15.5% on the previous year's cost per kWh.

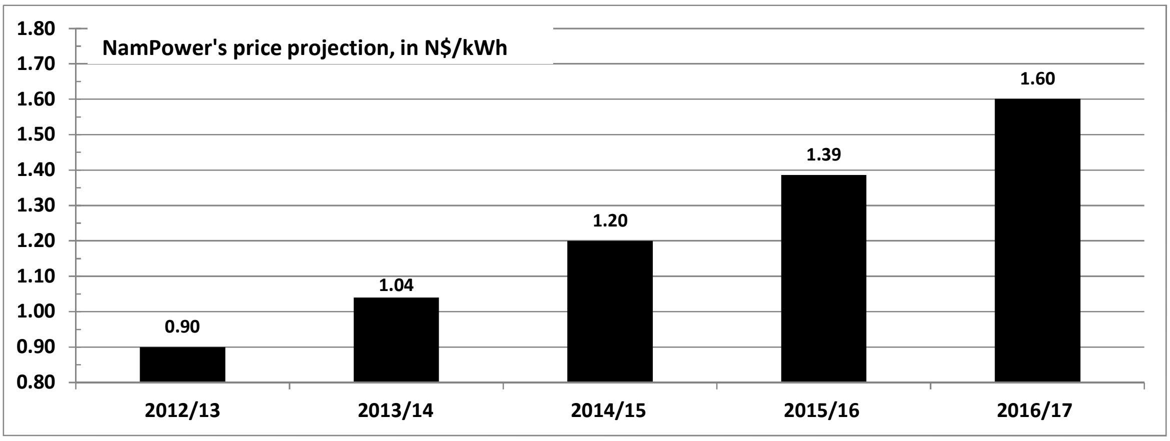


Figure 33: Average wholesale price projection anticipated by NamPower, in N$/kWh [3.5]

Based on the increase of the wholesale electricity price shown in Figure 33, the end-user tariffs in coming years can be estimated. End-user tariffs are always higher than the wholesale price charged by NamPower, because the distribution of electricity incurs additional costs which are not part of the electricity tariffs charged by NamPower (unless the supply is taken directly from NamPower).

In 2011/12, end-user electricity tariffs charged in Namibia broadly ranged between a few percentage points and more than 80% higher than the average wholesale price charged by NamPower, which was N$ 0.78/kWh. This illustrates the substantial price difference per kWh between the different distribution entities, and highlights the important cost contribution to the wholesale price introduced through the distribution function. One can therefore comfortably assume that the future price increases anticipated by NamPower will – at least on average – be passed through to the end consumer.

The median pre-payment consumer price of the various distribution entities discussed in this section amounts to N$ 1.44/kWh in 2012/2013. Based on this end-user energy price, three price escalation scenarios are formulated:

- a sub-par 10% increase per year price escalation scenario, which will successively under-recover the increases due to projected wholesale price increases
- a simple cost pass-through price escalation of 15.5% per annum, to ensure that the NamPower price increases are at least covered, and
- a high price escalation scenario, in which the end-user tariff is escalated at 20% each year until the financial year 2016/2017.

The three separate scenarios discussed above are depicted in Figure 34. For the low escalation scenario, Figure 34 shows a cumulative escalation of more than 46% between 2012/13 and 2016/17. End-user electricity prices more than double if an annual end-user price escalation rate of 20% per year occurs between 2012/13 and 2016/17.

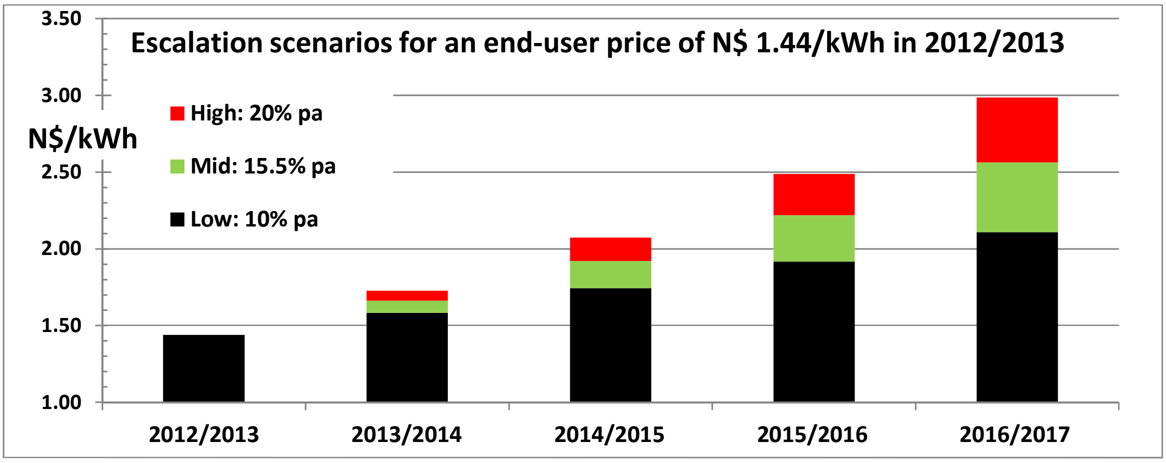


Figure 34: End-user electricity price escalation in low, medium and high growth scenarios [3.8]

End-user prices are not only dependent on the wholesale price of electricity. Other important cost drivers have and will in future cause an increase of end-user rates, escalating at least in line with the prevailing inflation rate.

The scenarios above illustrate the sobering fact that Namibian electrical energy end-users will be facing steep electricity price escalations over the coming years. This will be unpalatable to most.

At the same time, rapidly increasing electricity prices present significant opportunities to introduce technologies that will allow Namibia to secure its own energy supplies, and implement a strategy where energy systems create local value while becoming more sustainable. This will be the topic of the next chapter.

4 Technologies for Namibia's Sustainable Energy Future

4.1 Introduction

This chapter provides a brief introduction to renewable energy and energy efficient technologies that can contribute to the development of Namibia's sustainable energy future.

Following a general introduction to green energy technologies, the chapter describes five technologies that show immediate and substantial potential to alleviate Namibia's current electricity shortage while at the same time pave the way for the large-scale introduction of such technologies. These five technologies include

- the use of Namibia's invader bush resource to generate electricity
- the introduction of solar photovoltaic technologies to fully or partially meet the electricity requirements of select end-users
- the large-scale introduction and roll-out of solar water heaters
- the use of concentrated solar power technologies to generate electricity, and
- the introduction of wind power plants to contribute to Namibia's electricity supply.

There are many other renewable energy and energy efficient technologies that can and undoubtedly will make a contribution in Namibia in future. In the context of this study however, the present overview focuses only on the five options identified above.

4.2 Green Technologies

This section provides a brief introduction and rationale for some energy-relevant "green technologies" which offer significant benefits for Namibia's development. Generally, the bouquet of the so-called green technologies are understood to *provide services that have no or only minimal negative impacts on the environment, while sometimes even improving the quality of the environment as a result of their use*. While the potential scope for the application of green technologies and practices in Namibia is substantial, this section focuses solely on those energy-relevant technologies that reduce the footprint and impact, which the more conventional energy technologies and energy appliances have.

A considerable number of technologies exist that are purported to have no negative effects on the quality of water, soil, air and other essential constituents of the earth's biosphere. Often challenges of net benefits arise because of the limited frame of reference in which specific advantages are evaluated, and because marketing departments rather than actual technical evidence, frame the "greenness" of products or services.

Energy technologies that are considered "green" – while being relevant in Namibia – are technologies that are affordable, readily available, and offer short financial and environmental payback periods. For financial benefits to accrue, advantages arising as a result of the acquisition and use of green technologies rapidly outweigh the associated financial cost. For environmental benefits to accrue, green technologies offer one or several advantages and benefits when compared to the requirements of the more conventional or explicitly "non-green" technologies. Specifically, environmental benefits offered by green technologies can include their low manufacturing footprint, use of low toxicity components and manufacturing process, low carbon dioxide and other greenhouse gas emissions, during their manufacturing process and subsequent operations, ability to be substantially recyclable.

While it is not always readily recognised in a sparsely populated country such as Namibia, most economic development endeavours place strains on natural resource base, and increasingly limit the availability of ecosystem services that are so readily taken for granted. In Namibia, the non-availability of electricity is likely to increasingly constrain the country's development choices.

The natural limits to what an ecosystem can sustainably deliver are often not adequately reflected in the price paid for commodities. The pricing of goods and services must include a premium to reflect the cost on the environment. As an example, while Namibia is a non-Annex 1 country under the UNFCCC classification of developed and developing nations, and therefore does not have binding carbon dioxide emission limits, the cost of producing carbon dioxide in the country's energy sector, and by implication the goods and services produced using such energy, will become more relevant in future. This implies that investments in energy-relevant green technologies, to generate electricity or use in energy efficient technologies, will increasingly have to consider the impact created on the environment, such as the carbon generated and other "green" attributes.

Technologies, such as most renewable energy and energy efficient technologies that reduce the total resource usage and carbon footprint will become increasingly important. This is particularly so, if Namibia is to build on its international reputation as a clean and unpolluted country, offering products and services that are created in a largely intact and well-managed environment. This is as relevant for the tourism industry as it is for Namibia's fishing and beef industries, and other sectors essential for economic development.

Underpinning the development and growth of most economic sectors in the country is Namibia's energy sector, specifically the electricity industry. While the benefits of producing clean energy are important, affordability, reliability and accessibility remain the principal imperatives. Energy-relevant green technologies, which allow the user to reduce costs over the lifetime of the product while being more environmentally benign than conventional energy technologies, are increasingly part of the contemporary consumer's purchase decision. These create new opportunities, and offer long-term growth potential that Namibia can ill afford to ignore.

By focusing on the increased adoption of green technologies, Namibia can embrace an economic growth paradigm that incentivises responsible consumption while providing more people with an equitable and sustainable standard of living. In this way, national development and environmental sustainability become inseparable performance criteria for economic growth, rather than being traded off against each other. Namibia has the natural resource base and potential to integrate green technologies into national development strategy, especially when choices are deliberately focusing on creating jobs, including in the country's energy and green technology sectors. Aligned to a national green and pro-development growth plan would be a focus on establishing a more climate-proof society, enhancing the productive use of energy, conserving the country's precious natural resources, and minimising biodiversity loss in all economic activities.

A Namibian green growth plan must include the country's energy, agriculture, transport, fishing and tourism sectors. As part of the country's greening of the energy sector in particular, local resource potentials in the solar and wind sector offer substantial opportunities, as do the country's biomass resources locked in the abundant invader bush in north-central Namibia. This study covers applications in solar photovoltaic and solar thermal technologies, and also reflects on the costs and benefits of their wider use. The study also introduces a concept for the wider and more deliberate use of invader bush to fuel decentralised bush-to-electricity power plants, which would significantly contribute to attaining energy, job creation and local value addition goals, in addition to realising local growth imperatives. The study also considers concentrated solar and wind power to contribute to the country's electricity needs, while greening the supply of electrical power provided to the nation.

An aspect which is not substantially covered in this study is the application of energy efficient appliances. These include, amongst others, the wide-scale introduction of energy savings bulbs, which reduce energy consumption for lighting while offering short payback times and improved product lifetimes. Here, the replacement of incandescent lamps with light emitting diode (LED) bulbs offer significant savings potentials, both from the national as well as private user perspective. Energy audits, to identify the main electricity guzzlers in a commercial or domestic setting, and improve the thermal performance of buildings, are also important. They may lead to the introduction of energy efficient technologies and end-user behaviour change, thus contributing to electricity savings as well as an increasingly productive use of electricity.

Investments in green energy technologies in the building sector, from passive design measures to active energy-efficient heating, ventilation and air-conditioning systems, and the improvement of energy efficiency in the manufacturing and commercial sectors offer substantial savings, and plentiful greening potentials. Although important, these will not be discussed in this study. The reader is referred to a study on the subject which was recently completed [3.19].

A changing natural climate, increasingly mobile investment funds and escalating resource and commodity prices make it important that developing nations such as Namibia develop green growth strategies. The Government can and should be a significant facilitator in this endeavour, and create framework conditions including binding national green energy targets, attractive energy tariffs and regulatory provisions for net metering for embedded green generation capacity, green energy tax incentives, and more pronounced efforts to raise awareness about adaptation strategies as a cost-efficient way to alter end-users energy consumption behaviours.

The country's electricity sector offers substantial scope to become more future-oriented and sustainable. Here, green technologies building on the considerable local renewable energy resource base can become the main driving force. Change is enabled through solid policy. While Namibia's White Paper on Energy Policy has created some momentum in the late 1990's and early 2000, a revised policy focusing on local competitive advantages such as those offered in the country's renewable energy sector is desperately needed.

Policy must pronounce itself on the long-elusive levelling of the playing field in the country's electricity sector, creating opportunities for access to our electricity market, attracting innovative sector participants and those willing to invest in green technologies, investing in the explicit greening of the sector by way of the adoption of renewable energy technologies, and the systematic inclusion of a national energy efficiency road map. The private sector has access to technology, know-how and capital. It would infuse its creativity and embrace green technologies where their benefits outweigh the costs provided that national policy and regulatory framework conditions allow for such opportunities. There are definite value propositions in the country's renewable energy and energy efficiency sectors; some of them are discussed in further detail below.

Opportunities are most readily developed if their potential value is recognised, and green technologies offer many value propositions. Value recognition goes beyond the realisation of any immediate monetary rewards that may be achieved by way of the introduction of such technologies. Forward-looking energy policy should explicitly embrace the creation and extension of local value chains that recognise the sustainable potential of the country's plentiful renewable energy potentials, and their pivotal role in Namibia's ongoing economic development.

Undoubtedly the long-term value locked in the country's renewable energy sector has not been recognised. Views on what constitutes sustainable value creation in and through the energy sector will have to change if Namibia is to realise long-term social and economic development in an environmentally sustainable manner. The next sections present examples on how this could be achieved.

4.3 Namibian Invader Bush: From Nuisance to Sustainable Energy Source

Substantial areas in northern Namibia are covered by so-called invader bush [4.1]. Thorny bush and shrub species grow in such abundance that they have a significant effect on the growth of grasses and less prevalent species of bushes and shrubs. Such vegetation also dramatically reduces the essential recharge of underground water resources [4.1, 4.2].

It is commonly accepted that Namibian bush encroachment affects some 26 million hectares of farmland [4.1, 4.3]. Bush infestation is said to be responsible for substantial annual losses in agricultural output, estimated at "one billion Namibian dollars per year" (Minister of Agriculture, Water and Forestry, Hon. John Mutorwa, 11 September 2012, 16th National Rangeland Management Forum, Windhoek). As such, bush encroachment directly affects the livelihoods of communal and commercial farmers, and their employees. Amongst the many side-effects of bush infestation is the steady reduction in the total number of livestock in Namibia, and with it, the decrease of jobs in the rural agricultural sector [4.3]. *This is highly undesirable, but can be changed.*

While numerous studies undertaken in the past years have attempted to find the causative agents driving bush encroachment, far less has actually been achieved to address the problems caused by and associated with this phenomenon. Many commercial and communal livestock owners consider invader bush a mere nuisance, which is expensive and often not economically viable to remove from the land. While various bush reduction, bush thinning and bush eradication approaches are undertaken, mainly to enhance the livestock carrying capacity of the land [4.1, 4.4], the returns of increased livestock production alone will often not offset the costs of such endeavours [4.5]. However, the creation of new value chains may tilt the balance in favour of a long-term economical and ecologically sound use of the country's bush resource.

Examples of activities benefitting from invader bush encroachment include Namibia's charcoal industry, which uses invader bush as a resource with definite economic value [4.6]. It is pointed out though that this industry's impact on the overall volume of invasive biomass in northern Namibia is small [4.3]. Also, the bushblok project under the auspices of the Cheetah Conservation Fund, uses invader bush to produce wood briquettes, which can replace fire wood. More recently, the Energy for Future "Bush-to-Fuel Project" providing wood chips for the Ohorongo Cement plant has encouraged a wider audience to view bush encroachment as a renewable resource that can add long-term value [4.7].

Most previous bush-clearing efforts have neither recognised nor directly benefitted from the energy content of Namibia's invader bush resource. The concept of creating *sustainable energy farming using invader bush*, rather than fighting the invasive growth, has not taken hold. Yet, on-farm revenue generating activities could be substantially extended if the value chains in which invader bush is used are further developed. As such, invader bush remains a substantially untapped and potentially sustainable resource that –

if adequately managed – could in time provide thousands of new jobs in rural areas. Using invader bush for its energy content – either in the form of wood logs, pellets, briquettes, wood chips or feedstock for combustion, pyrolysis or gasification processes – can also be a replacement for wood products in building materials and composite wood products, and as an additive in animal feeds. Invader bush is more than a nuisance for farmers, it remains a largely untapped business opportunity awaiting development.

This section focuses on the biomass resource locked in Namibia's invader bush, and broadly quantifies the potential rural job creation potentials that could be realised when decentralised energy provision based on the use of local biomass commences.

Where is invader bush found? Figure 35 shows that the main areas infested by excessive bush growth are found in northern and north-eastern Namibia [4.9].

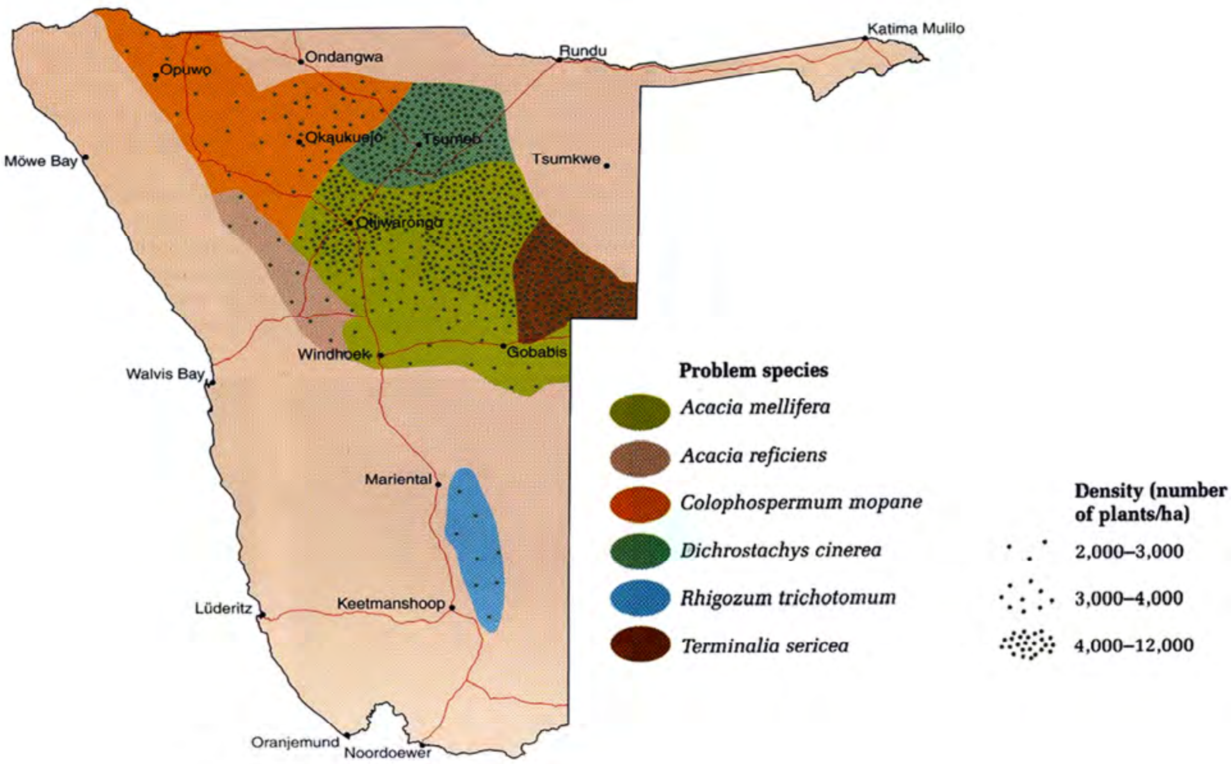


Figure 35: Spatial distribution and bush densities in Namibia [4.9]

How much invader bush is out there? It is estimated that some 26 million hectares of natural rangelands are currently affected by moderate to high infestations of invader bush [4.1]. Between 8 and 20 tons of biomass from invader bush can be harvested per hectare [4.1, 4.3], as quantified in Figure 36. Bush densities of up to several thousand plants per bush-encroached hectare are common [4.1, 4.3, 4.9]. The amount of biomass that can be harvested per hectare depends on the actual harvesting method and approach used: The choices are between manual harvesting, semi-mechanised, or fully mechanised bush harvesting, complete bush removal, selective removal and bush thinning. Whether the resource offers a once-off yield or allows for multiple or even sustainable harvesting depends on the type of harvesting used, and the aftercare regime applied following such harvesting.

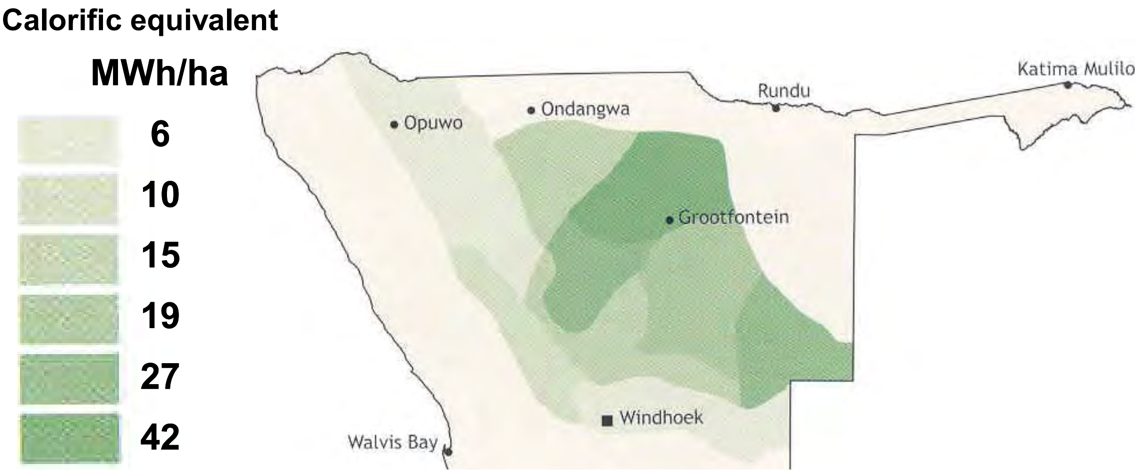


Figure 36: Indicative energy content per bush-encroached hectare in northern Namibia [4.3]

How is invader bush harvested? Several harvesting methods are known, the three most widely used methods include

- **mechanised harvesting**, using track-mounted harvesters or skid steers equipped with cutter blades, as shown in Figure 37 below.

  Mechanised harvesting is often less specific in terms of which bushes and/or bush species are harvested, but this method achieves high harvesting yields per hour.

  Mechanised harvesting usually requires only few operators, and therefore creates only a limited number of jobs, for example for equipment operators (semi-skilled) and maintenance personnel (skilled).

Figure 37: Track-mounted harvesters (left, [4.10]) and skid steer bush harvester (right, [4.11])

- **semi-mechanised harvesting**, using chain saws and small mechanical brush or bush cutters, as shown in Figure 38 (right), and
- **manual harvesting**, using axes, pangas and machetes, as shown in Figure 38 (left).

Figure 38: Manual bush harvesting using an axe (left) and semi-mechanised harvesting using a mechanical brush cutter (right) [4.11]

Most manual and semi-mechanised equipment allows the harvester to be very selective in terms of bush species harvested, and the size of bush cut down. The environmental footprint caused by such harvesting methods is therefore much smaller than that created through fully mechanised harvesting, and surface soil disturbances can usually be kept to a minimum using these labour-intensive techniques.

Manual and semi-mechanised harvesting is labour intensive. Because qualifications are not important for such a job, harvesting methods relying on substantial manual work present significant opportunities for rural job creation for unskilled persons.

Value chains involving biomass from invader bush usually commence with the harvesting process, as shown in Figure 39. It is this first step in the value addition process from invader bush that has the potential to create substantial numbers of new rural jobs, provided that suitable labour and bush-use framework conditions are in place.

Figure 39: First steps in the value and production chain for biomass use from invader bush

How many jobs can be created through the harvesting of invader bush? The number of persons involved in harvesting or felling of invader bush critically depends on whether the process is undertaken manually, semi-mechanised or fully mechanised. This section differentiates between the complete manual harvesting by axe, panga or machete, the semi-mechanised harvesting by motorised brush cutter, and the fully mechanised harvesting using a skid steer. Table 7 below compares the number of persons required to harvest some 4,400 tons[7] of wet biomass per year using axes / pangas, brush cutters, or a single skid steer equipped with a heavy-duty cutting blade.

Harvesting invader bush – persons required	Axe/panga	Bush cutter	Skid steer
Persons required to harvest 4,400 tons per year	42	13	1

Table 7: Number of persons required to harvest 4,400 tons of wet biomass in one year [4.12]

Table 8 summarises the associated cost per ton of harvested invader bush.

Harvesting invader bush – indicative cost per ton	Axe/panga	Bush cutter	Skid steer
Cost per ton of wet biomass harvested [N$/t]	132	119	89

Table 8: Indicative cost per ton of wet biomass harvested, in N$ per ton [4.12]

It is evident that manual harvesting creates many more jobs than semi-mechanised or fully mechanised harvesting would. However, given the current labour dispensation in Namibia, few farmers and/or entrepreneurs are likely to employ substantial numbers of manual harvesters when more cost-effective and efficient methods of harvesting are indeed available. When a single person plus machine can do a job requiring 42 manual harvesters while being two-thirds more cost-effective per ton of material harvested, creating large-scale manual harvesting programs requires policy interventions that reduces current labour hiring barriers and offers labour-focused incentives.

It is instructive to reflect on the other value created when comparing manual and different mechanised harvesting. Table 9 illustrates that manual harvesting implies the lowest outflow of value from the country, while an increasing degree of mechanisation creates substantial and ongoing financial flows across the borders of Namibia.

[7] This quantity was deliberately chosen because it corresponds to the approximate annual yield using a single skid steer equipped with a bush-cutting blade.

	MANUAL	SEMI-MECHANISED	FULLY MECHANISED
Equipment import requirements	N$ 750 per harvester per year	N$ 9,000 per harvester per year	~ N$ 200,000 per harvester per year
Fuel import requirements	None	> N$ 17,500 per harvester per year	> N$ 120,000 per harvester per year
Harvesting jobs created per 4,400 wet ton harvesting operation per year	42	13	1
Salaries generated per 4,400 t harvesting operation per year	~ N$ 554,000 per year	~ N$ 200,000 per year	~ N$ 24,000 per year

Table 9: Comparative value created: manual, semi-mechanised & mechanised harvesting [4.12]

Investments in local value chains using local labour and minimal equipment and fuel requirements therefore minimise cash outflows, especially if all or most of the subsistence requirements of labourers are met locally too. While the manual productivity expressed in harvesting rate per hour is not competitive with semi- or fully mechanised harvesting, both local value creation and currency preservation are optimised. A job as a manual labourer harvesting bush may not seem desirable to all, but having no job and no job prospects is worse. Jobs are scarce in rural Namibia. Large-scale bush harvesting initiatives could change this. Current debates on local job creation and a rigid labour policy could be infused with realism.

What would biomass from invader bush be used for? This study focuses on energy technologies that could contribute to Namibia's energy future. While numerous bush use applications are possible, this section considers only the use of invader bush for its energy content. Products that use biomass because of its energy content include

- wood logs for heating and the preparation of food
- wood chips used in combustion chambers in electricity power plants, as well as for pyrolysis and gasification plants, and
- wood briquettes and pellets for heating and use as feedstock in combined heat and power (CHP) and similar electricity power plants.

The energy content of Namibian invader bush broadly ranges between 4 and 6 kWh/kg [4.3, 4.12]. Biomass from Namibian invader bush is therefore a valuable source of locally grown energy, which can be used to generate electricity. Table 10 summarises the biomass requirements, the amount of electricity that can be generated, potential jobs created through harvesting, and the capital infused into the local economy through salary payments for a small (0.1 MW capacity) to mid-sized combustion power plants using stoker boilers of up to 10 MW capacity. In principle, power plants using invader bush could have generating capacities larger than 10 MW, however the cost of transport increases rapidly when medium to large plant have to be supplied. Decentralised bush-to-electricity power plants are therefore a more sensible option rather than a few centralised ones, and effectively integrate and create value in existing local structures.

Bush-to-electricity power plant capacity	0.1 MW	0.5 MW	1 MW	5 MW	10 MW
Electricity generated per year [GWh/a]	0.6	3	6	30	60
Wood required per year [wet tons wood/a]	800	3,700	7,300	36,100	72,200
Jobs created – manual harvesting	8	36	70	342	684
Jobs created – semi-mechanised harvesting	3	11	21	103	206
Jobs created – mechanised harvesting	1	1	2	9	17
Salaries paid per year if harvesting is done manually only ['000 N$/a]	106	475	924	4,514	9,029

Table 10: Comparison of requirements of stoker boiler bush-to-electricity power plants [4.12]

Could invader bush alleviate Namibia's power shortage? Yes. Small power plants have a higher cost per MW installed than their larger equivalents, as shown in reference [4.13]. On the other hand, small plant can readily be connected to Namibia's distribution networks, and thus be placed where water, labour and bush resources are available. In this way, decentralised bush-to-electricity power plants would stimulate investments in rural Namibia, and counteract the rural to urban migration experienced for many years.

Larger power plants may require a connection to the national transmission network, which allows power to be transmitted to all corners of the land. However, localities for larger plant – at or close-to existing transformer stations – are not as readily available in bush-infested areas as are suitable sites at which a grid connection to the extensive distribution network within electricity distribution areas.

The cost of transport and logistics increases as the distance between the harvesting sites and the power plant increases. This implies that, even if the transport of wood fuel to the power plant is organised on a near-industrial scale, shorter transport routes to the power plant always imply cheaper wood fuel delivery, as shown in Table 11 below.

Bush-to-electricity power plant capacity	0.1 MW	0.5 MW	1 MW	5 MW	10 MW
Area required over 20 years [ha]	1,600	7,400	14,600	72,200	144,400
Average return trip to plant [km]	6	13	18	38	54

Table 11: Area required for harvesting & average transport distance to the power plant [4.12]

While it is beyond the scope of this study to present a detailed techno-economic analysis of the viability of bush-to-electricity power plants, some order of magnitude estimates of the revenue requirement per kWh of electricity produced in different plants are provided in Table 12.

Bush-to-electricity power plant capacity	0.1 MW	0.5 MW	1 MW	5 MW	10 MW
Revenue required per kWh in year 1 [N$/kWh]	1.95	1.47	1.31	1.16	1.09

Table 12: Indicative revenue requirement per kWh for bush-to-electricity power in year 1 [4.13]

The indicative levelised cost of energy, i.e. the present value of the total cost divided by the present value of the power plant's total energy produced in its lifetime is summarised in Table 13. It shows that – from a cost perspective – bush-to-electricity combustion power plants (e.g. stoker boiler technology) can be competitive with other dispatchable power generation options that may be considered for Namibia, as is also further elaborated in Figure 54 on page 81.

Bush-to-electricity power plant capacity	0.1 MW	0.5 MW	1 MW	5 MW	10 MW
Levelised cost of energy [N$/kWh]	2.55	1.89	1.70	1.50	1.43

Table 13: Indicative levelised cost of energy of bush-to-electricity power plants [4.13]

To conclude: Bush-to-electricity power plants are a real possibility in Namibia, and can generate significant local value using an abundant local resource. This untapped Namibian opportunity has not yet enjoyed the political recognition and support it requires to make a contribution to Namibia's development.

4.4 Solar Photovoltaics: Capitalising on Namibia's Prime Solar Resource

This section discusses Namibia's outstanding solar photovoltaic (PV) potential, and the role that solar PV technology can play in narrowing the country's electricity supply gap. The section also elaborates on the opportunities that PV can create in bringing modern electricity services to the furthest corner of the land.

Solar photovoltaic technology converts sunlight into electricity. PV technology is mature, ultimately reliable and often backed by 20-, 25- or even 30-year product warranties. Solar PV is highly suitable for a country as well-endowed with sunshine days as Namibia. PV technology can be used in urban grid-connected systems, whereby the electricity generated by the PV modules is fed into the local distribution network. It can also be used in larger more centralised solar power plants, feeding electricity into the national grid, or power entire villages, or homesteads in stand-alone island applications.

In Namibia, PV technology is already used for numerous off-grid applications, to provide electricity to farms, lodges, off-grid homes and businesses as well as for pumping water in rural-related applications and uses. In this way, solar PV technology provides access to modern electrical energy services in areas far away from the conventional electricity distribution system.

Solar PV technology and diesel-powered or other electricity generators can be used jointly, in which case they are called hybrid systems. In January 2012, Namibia's largest solar PV-diesel hybrid system was inaugurated at the north-eastern village of Tsumkwe, as shown in Figure 40.

Figure 40: Solar PV array of Namibia's largest solar-diesel hybrid system at Tsumkwe [4.14]

It is often alleged that PV technology is expensive, and therefore unsuitable for applications in developing countries. In view of the dramatic price decreases that have taken place in the solar PV sector worldwide over the the past years, such opinions are outdated, and simply no longer valid. As will be shown in this section, solar PV has a definite and cost-effective contribution to make in Namibia, both in urban grid-connected applications, as well as for the provision of off-grid electricity in rural settings.

The cost per kWh of electricity from solar PV generated in select locations in Namibia *is already less expensive today* than a unit of electricity provided by a distribution entity, provided that access to long-term finance is available. Once this so-called *grid parity point* is reached, i.e. the point where electricity generated by solar PV technology costs as much or less than conventionally supplied grid electricity, the uptake of solar PV is bound to increase dramatically. This is an ingredient of the quiet RE revolution taking place in Namibia today.

Solar PV is packaged in units called PV panels. Such panels have a maximum power rating, for example 55 W_p, or 150 W_p, or even 240 W_p (peak Watt is abbreviated W_p). From a few to hundreds of PV panels are connected to form a PV array. During sunshine hours, the array produces a direct current electrical output. Once converted into alternating current in an inverter, the electrical output is no different than what is supplied by an electricity utility or stand-alone electricity generator, and can be used to power standard off-the-shelf electrical appliances.

Figure 41: Roof-mounted solar PV system in Windhoek's southern industrial area [4.15]

Namibia's excellent sunshine regime allows annual energy yields of between 1,600 kWh/kW_p in coastal areas, up to about 2,100 kWh/kW_p in select locations in southern Namibia. While the specific yield per installed W_p depends on the type of PV technology used, Namibia's outstanding solar resource implies that a hypothetical PV array with a capacity of one kW_p will produce between 1,600 and 2,100 kWh of electrical energy per year [4.16]. This is a considerable energy yield and ranks amongst the best in the world.

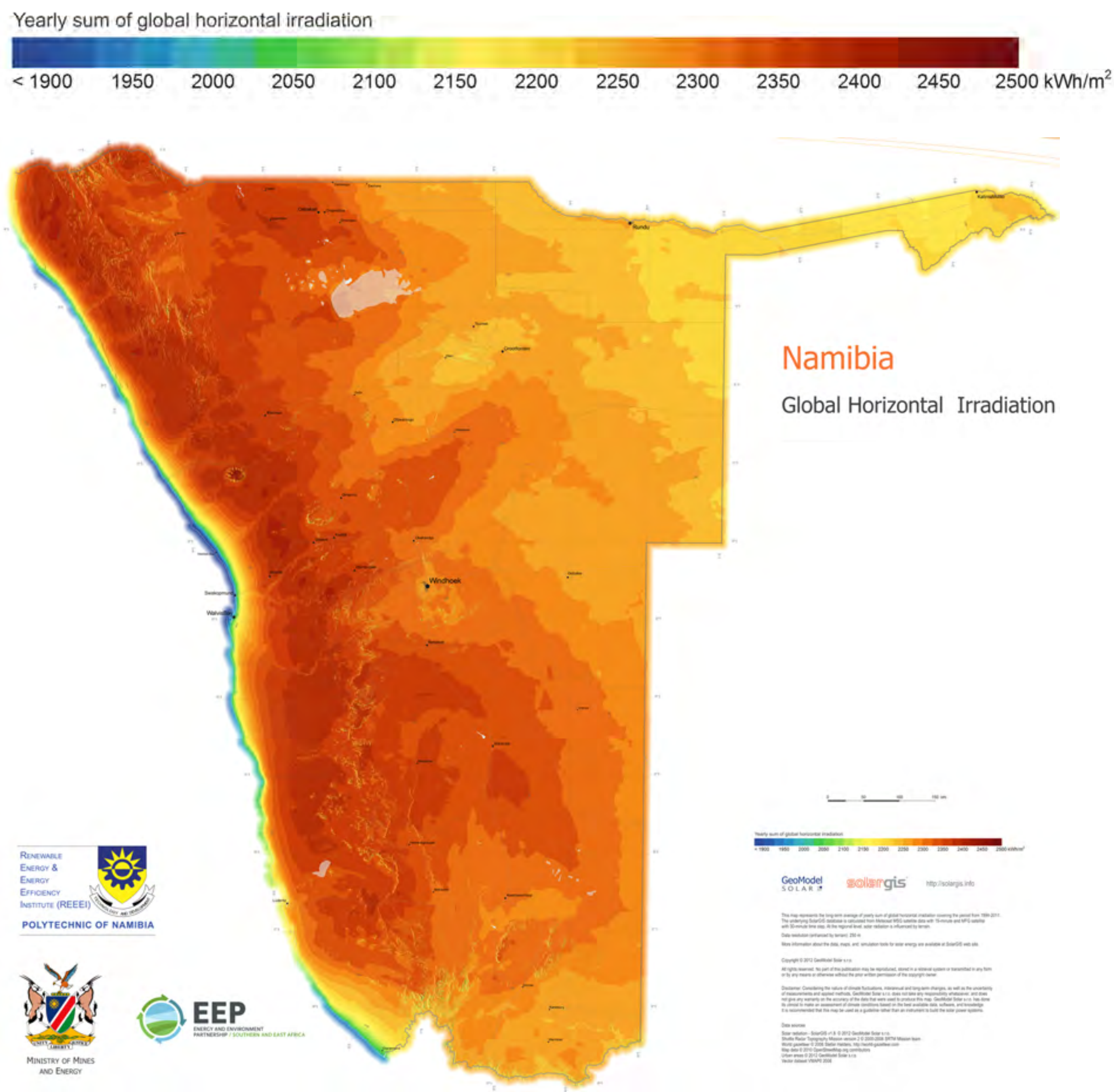


Figure 42: Namibia's world-class global horizontal solar resource [4.17]

Namibia's solar resource is one of the country's prime sustainable assets, and is an energy form that is and will remain entirely free of charge. Energy from the sun requires no fossil fuel imports, no lengthy negotiations for power purchase agreements, and no foreign exchange hedging. Today's solar PV plants use the free energy supplied by the sun to produce high-value conventional electricity on which most contemporary economic activities depend. Solar PV technology produces few greenhouse gases (during the manufacturing process), and is amongst the most environmentally benign energy generation technologies available. Solar PV also offers excellent long-term investment opportunities for those interested in guaranteed yields delivered over several decades. No fossil-fuel power plant offers similar long-term value propositions.

In view of the many claims made about the alleged high cost of solar PV technology, it is instructive to delve a bit deeper. Consider a typical 1 kW_p roof-mounted grid-connected system installed in an urban area in central Namibia. It is assumed that the location has a sunshine regime allowing the PV array to produce some 1,850 kWh of electrical energy in the first year of operations [4.16], and has a total installed cost ranging between N$25,000 to N$30,000 [4.18].

The system's electrical energy output is used by a domestic owner and user, while excess electricity not consumed is fed into the existing electrical grid. The solar electricity displaces grid electricity when the PV array produces electrical energy, i.e. the user will not have to purchase grid electricity when sufficient solar electricity is available. In times where insufficient solar electricity is available, for example at night, grid electricity is used.

The system is provided with an output warranty for at least 20 years. This time period is assumed to coincide with the period over which a mortgage bond is repaid for the residential property where the system is installed. It is assumed that the owner decides to add the cost of the solar PV plant to the existing mortgage.

At a fixed interest rate of 12.5% per year for a loan over 20 years, the repayment for a system costing N$27,500 amounts to some N$3,800 per year, which is indicated by grey "Repayment" bars in Figure 43. The nominal value of the displaced electrical energy, indicated by blue "Saving" bars in Figure 43, increases from N$2,775 in year 1, to N$12,174 in year 20. The above assumptions imply that the income generated by the PV array – in form of savings – outweigh the costs from year 4 onwards. The break-even point at which the total cumulative savings minus repayments are positive (refer to the "Cumulative saving" line in Figure 43) occurs shortly after year 5 of operations.

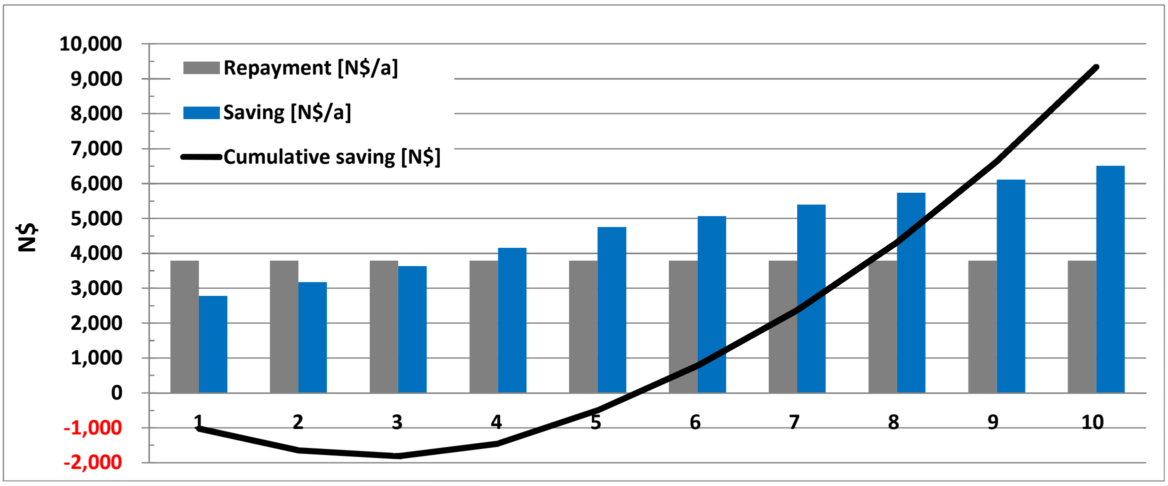


Figure 43: Repayments and savings: grid-connected 1 kW_p PV system in central Namibia [4.19]

The solar PV system described in the paragraph above is small. Domestic users would likely decide to install a larger system, which in turn would decrease the cost per installed kW, and thus lead to a shorter payback period, and more significant cost savings. Clearly, a reduction in capital cost or interest rates would also accelerate the accrual of benefits.

Using a discount rate of 15%, the present value of the financial benefits of the above model system amount to approx. N$32,169 (assuming 20 year use), while the present value of all costs (in form of repayments for the system) amount to some N$23,771. This implies a benefit-to-cost ratio of 1.35, which means that for every one dollar spent today, there is a benefit of N$1.35 in today's money. This is a worthwhile investment.

The levelised cost of energy, i.e. the present value of the total cost divided by the present value of the system's total energy produced over its lifetime is N$2.11/kWh [4.20]. In view of NamPower's recent statement that the utility expects that the average wholesale price per kWh of electricity is to increase to N$1.60/kWh in 2016/17, a firm end-user electricity price guaranteed for a period of at least 20 years at N$2.11/kWh is low, and price competitive, and readily available in Namibia without any subsidies or special feed-in tariffs. Savings from grid-connected solar PV systems result from the displacement of conventionally supplied grid electricity. As such, grid-connected solar PV is a definite ingredient of Namibia's quiet renewable energy revolution, and it is happening today.

Could solar PV make a contribution to Namibia's electricity balance? Unreservedly *yes*. While solar PV does not produce electricity when the sun is not shining, it can make a significant contribution to reduce the electrical energy requirements during the day. On the other hand, without storage devices, such as large-scale battery systems or other technologies, the contribution that large-scale solar PV can make to reduce the country's peak demand, especially the evening peak, is insignificant. This implies that the role that solar PV can play is most pronounced during the day, peaking at midday. Domestic loads, such as ironing and washing, can be shifted into this peak output period. Many ordinary evening activities on the other hand, including electric cooking and entertainment using electrical energy are more challenging to shift. As such, solar PV without additional technological assistance in the form of energy storage cannot solve Namibia's electricity bottlenecks entirely, but can make a sizeable and sustainable contribution to the reduction of the country's day-time electricity needs.

Figure 44 and Figure 45 illustrate the contribution that a grid-connected solar PV system can make on the electricity demanded by a domestic and commercial user respectively: The black curve illustrates the power demand pattern, expressed in kW, over a typical 24-hour period. The green line shows the power supplied by the solar PV system, while the red line depicts the resultant net demand curve. When the user's demand is "negative", i.e. where the red line is below the main horizontal, the solar PV system feeds net electrical energy into the distribution grid. Such exports are then available for use by other electricity users connected to the electricity grid. In times where the red line is above the horizontal, the user draws net electricity from the grid. During the day, when the output of the solar PV system exceeds the requirements of the user, the user is a net producer of electrical energy, while at night and in times of heavy demand, electricity is drawn from the grid.

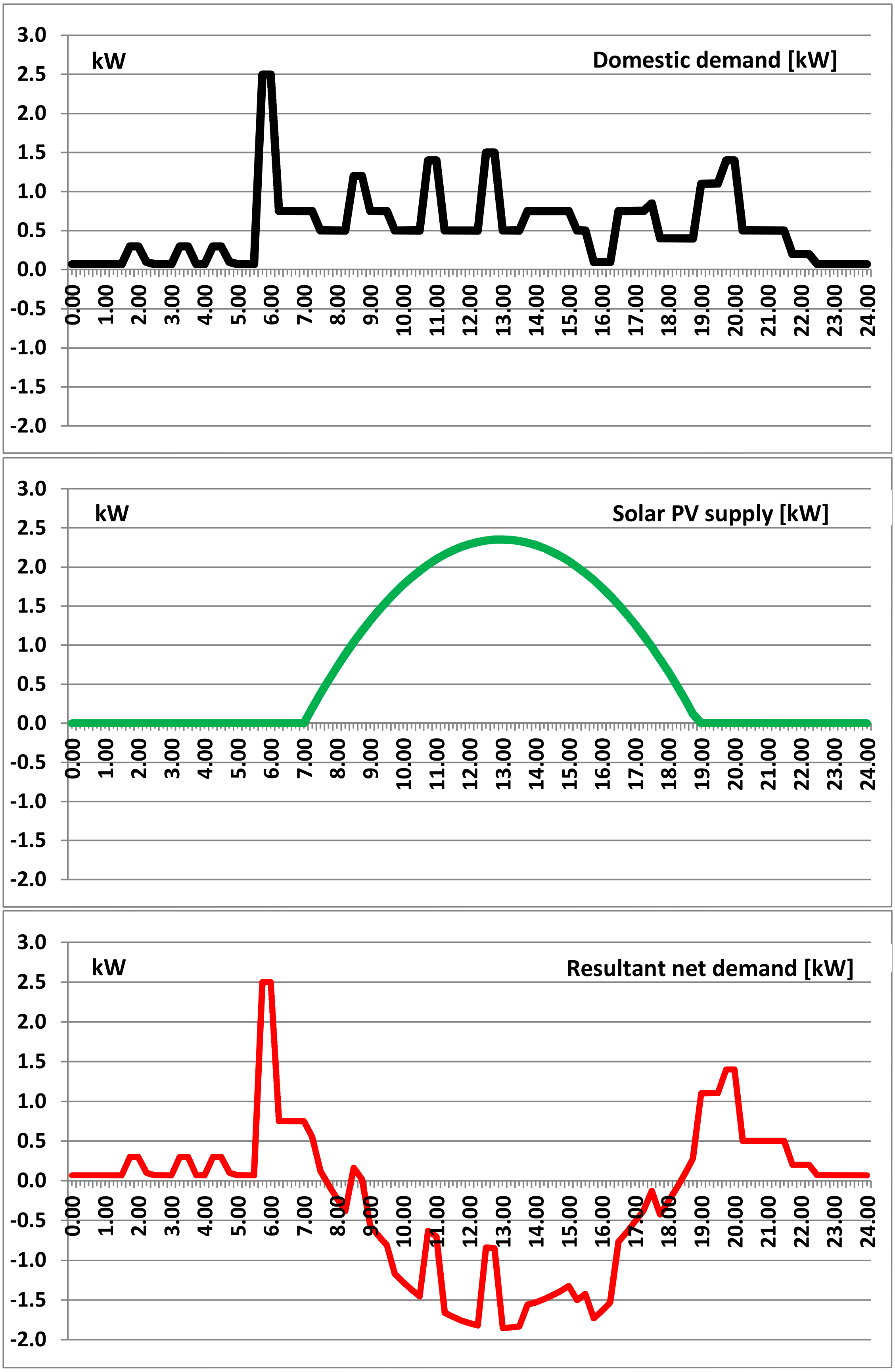


Figure 44: Indicative domestic demand (black line), supply by the solar PV system (green) and resultant net demand curve (red) over a typical 24-hour period [4.19]

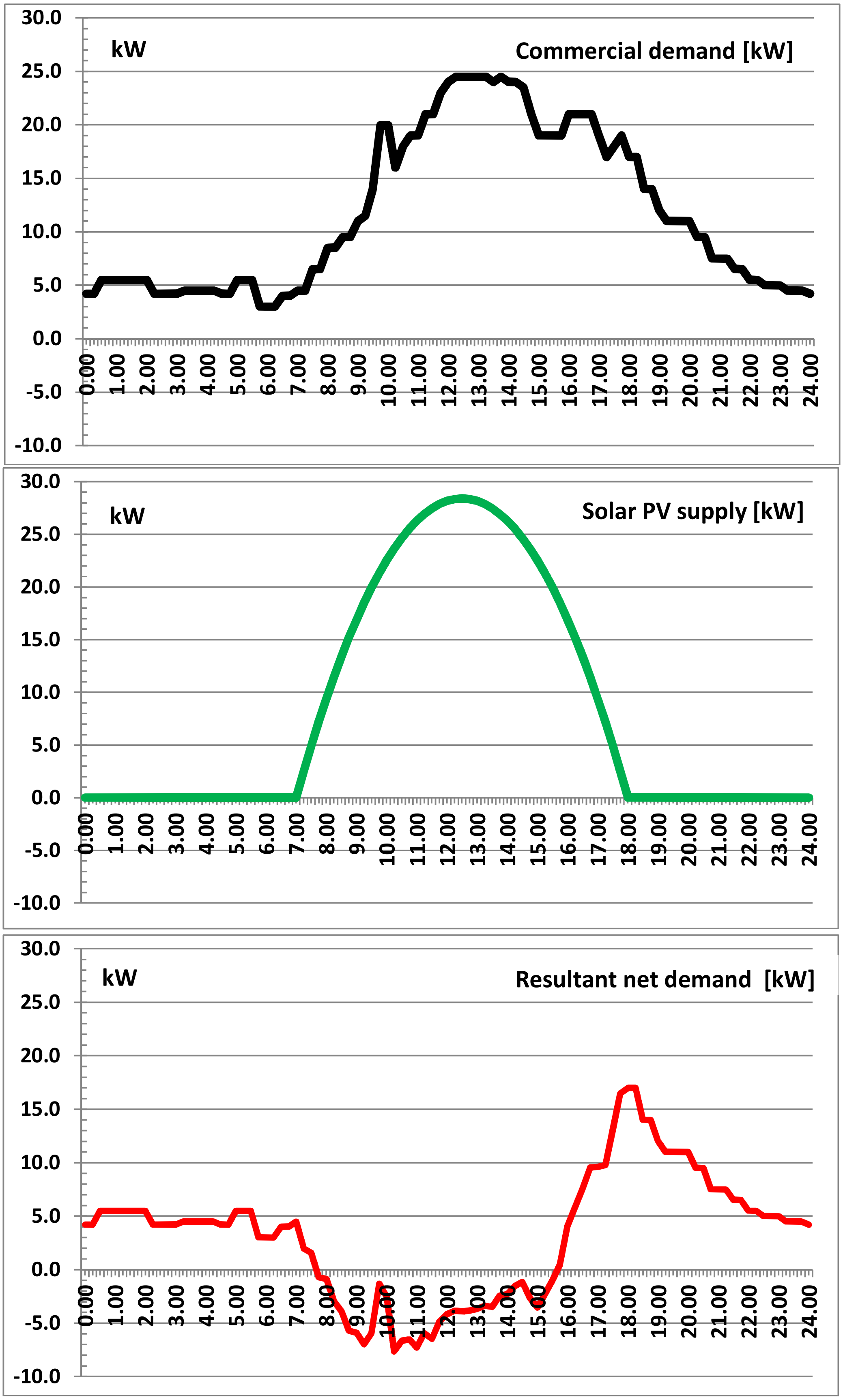


Figure 45: Indicative commercial user demand curve (black line), supply by the solar PV system (green) and resultant net demand curve (red) over a typical 24-hour period [4.19]

How much electrical energy could solar PV contribute to Namibia's electricity supply? The answer to this question depends on the scale of a solar PV roll-out. A few possible scenarios include:

- if 5,000 grid-connected users invested in a 3.6 kW_p solar PV plant, these would produce a total electrical energy of some 33.3 GWh in year 1, assuming an average yield of 1,850 kWh/kW_p. To put this in perspective, if the new Anixas power station at Walvis Bay would run for 1,850 hours per year, and produce electricity for 80% of this up-time, it would produce approximately the same amount of electrical energy as generated by the above solar PV installations.
- if 25,000 grid-connected users invested in a 3.6 kW_p solar PV plant each, these would in total produce some 166.5 GWh in year 1. Provided that the Van Eck power station could utilise its complete nameplate capacity of 120 MW for 1,850 hours per year, and produce electricity for 75% of this up-time, it would produce the same amount of electricity.
- if 75,000 grid-connected users invested in a 3.6 kW_p solar PV plant each, these would produce some 499.5 GWh in year 1. The Ruacana hydro-electric plant in the Kunene Region would have to generate electricity for some 1,584 hours at 95% availability to produce the same amount of electrical energy.

What would it cost to introduce solar PV on a large scale? The answer lies in differentiating between the total cost of installation, and how this is financed. Given a multi-MW uptake of solar PV in Namibia, the local price for large fully-installed roof-mounted systems which ranges between N$18/$W_p$ and N$25/$W_p$ in mid-2012, could be reduced. Assuming that a fully installed price of N$18/$W_p$ could be achieved as a standard, 5,000 solar PV systems of 3.6 kW_p each would cost N$324 million (N$51 million less than Anixas); 25,000 systems would cost N$ 1.62 billion, and 75,000 systems would cost some N$ 4.86 billion. This may sound substantial, but actually depends entirely on *who* would finance such expenditure, and *how* they could be financed.

Realising that the cost of grid-connected urban systems could in most instances be borne directly by those who benefit from such an installation, the above scenario offers much scope and opportunity, and has many potential beneficiaries. The example of a 1 kW_p solar PV system was deliberately chosen to illustrate some principles of grid-connected solar PV systems: It is evident that the repayment required for the system exceeds the actual savings generated by the system for only three years, as shown in more detail in Figure 46 below. This is the result of conservative estimates, and could be considerably improved if a national large-scale roll-out commences in which capital costs are lowered, and/or interest rates are decreased, and/or the repayment period could be favourably extended.

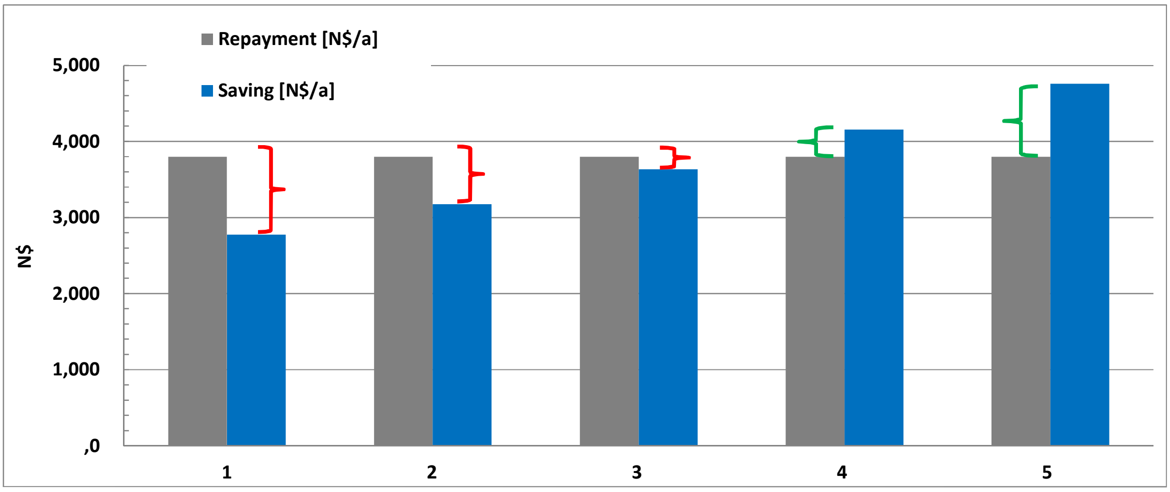


Figure 46: Annual repayments & savings from a grid-connected 1 kWp solar PV system [4.19]

The gap between repayments and savings is significantly determined by the capital cost of the equipment, the interest rate of the loan, and the cost per kWh of electrical energy displaced by the solar PV system. If capital costs are reduced, for example by realising national economies of scale, or by way of incentives, or the creation of a carbon reduction income, or if electricity prices escalate more rapidly than assumed [4.20], the initial minor funding gap (i.e. the difference between repayments and savings) could be closed even quicker than is shown in Figure 46. A national incentive scheme, which bridges the difference between cash outflows in the form of repayments and cash savings, is a tangible and sensible proposition. This is what most commercial banks do, provided they are aware of the opportunity.

Amongst the many options, an incentive could be offered in the form of a once-off purchase rebate, or interest rate subsidy, or a cash-neutral guarantee provided by a special-purpose funding vehicle, or a combination of capital reduction, interest rate reduction and cash-neutral guarantee. The cost of each of these options is summarised in Table 14, assuming a national roll-out of 25,000 solar PV systems of 3.6 kW_p capacity each.

	Upfront capital reduction	Interest rate reduction	Cash-neutral guarantee	Combination: capital, interest & guarantee
Cost [million N$]	666	620	163	22

Table 14: Cost of incentives for a 25,000 solar PV system roll-out, in million N$ [4.21]

As is evident from Table 14, the "combination" approach is the least expensive, and includes factors that the local market can and very likely will favourably respond to provided that an opportunity is available. Market responses are expected to include: a) the reduction of the capital costs as a result of increasing the economies of scale, and b) a reduction of the interest rate in response to a substantial increase in low-risk loan volumes. This implies that a large-scale roll-out of solar PV would require only a minimum of intervention and expenditure by Government, and yield long-term sustainable value for many, including the utilities. In addition, and very importantly, such a program would make a decisive and long-term contribution to address Namibia's electricity supply gap, while allowing many Namibians to benefit from the current electricity sector impasse. This is an attractive political and financial value proposition.

Who are the actual beneficiaries of a large-scale roll-out of solar PV systems in Namibia? Assuming that only grid-connected systems are used, the main beneficiaries of a 25,000 system roll-out are

- consumers – through the reduction of their annual electricity costs
- distribution entities – by reducing the requirements for grid and distribution network expenses
- NamPower – through the reduction of energy demanded during sunshine hours
- financial service providers and insurance companies – by way of an increase of loan value and volumes, and improved client risk portfolio, and
- investors – through the creation of new long-term investment opportunities.

In addition, solar PV supply companies and their staff, and the service industry associated with such suppliers will benefit as the scope and scale of a national roll-out of solar PV systems accelerates. Employment and new job opportunities, specifically amongst solar installers and through small- and medium enterprises (SMEs) providing goods and services to solar companies, are expected to be substantial.

In 2012, it is estimated that the local solar PV industry has a capacity to install some 2,000 medium-scale PV systems per annum. This capacity would have to be increased by a factor 3 to 5 to meet a medium to large increase in demand for such technologies. This would imply an increase in local capacity from an estimated 120 persons to more than 500 persons who could become active in the sector, even before the roll-out has commenced in in rural areas. Is this substantial? Yes, creating some 400 new jobs in Namibia's low-voltage electricity supply industry, many of which can be for graduates of vocational training centres, and in a future-oriented green growth sector, is a long-term investment where Namibia has and will keep a real comparative advantage: her excellent solar regime.

Figure 47: Roof-mounted grid-connected solar PV system in Omaruru [4.15]

Can solar PV be used for off-grid applications? Solar PV is both cost effective and useful for rural off-grid applications. These can range from large solar-diesel hybrid installations for villages and remote localities, such as the power plant that was recently inaugurated at Tsumkwe, or the Gobabeb hybrid installation, to single dwelling stand-alone units or even mobile telephone charging units. Off-grid applications usually require batteries to provide electrical energy after sunset, which render such systems more expensive than their grid-connected counterparts. However, when comparing the cost per kWh supplied by conventional diesel or petrol generating systems, or the cost of bringing electricity networks to remote localities, to the cost of locally installed solar PV systems it becomes obvious that the very long component life offered by contemporary solar PV technologies renders them cost effective, reliable and cost competitive.

The indicative revenue requirements per kWh of electricity produced in three differently sized solar PV plants are provided in Table 15. Medium to large solar PV plants produce electricity below the domestic electricity tariff charged by many distributers in Namibia in mid-2012. The indicative levelised cost of energy is also shown in Table 15: From a cost-per-kWh perspective, medium to large solar PV power plants are close to becoming competitive with dispatchable power generation options, as is further elaborated in Figure 54 on page 81.

Solar PV power plant capacity	1 MW_p	5 MW_p	10 MW_p
Revenue required per kWh in year 1 [N$/kWh]	1.56	1.45	1.35
Levelised cost of energy [N$/kWh]	1.70	1.59	1.48

Table 15: Indicative revenue requirement per kWh for solar PV power plants in year 1, and levelised cost of energy, both in N$/kWh [4.22]

To conclude: a national initiative that enables domestic and commercial users to invest in solar PV systems is both attractive and feasible, and can effectively assist in reducing Namibia's electricity shortage. Even without subsidies, the large-scale introduction of solar PV systems, especially for urban grid-connected users, holds excellent benefits. Distributed solar PV generators not only reduce the amount of electricity that has to be provided by NamPower, but they also enable domestic users to invest in future-oriented technologies that harvest what Namibia is blessed with, i.e. abundant sunlight.

Economically, the country's fragmented and highly individualised solar supply industry stands to benefit tremendously from an increased uptake of such systems. Banks and other providers of long-term loans will benefit from an increase in their loan value, volumes and diversification of the loan portfolio risk. The long-term prospects of solar PV in Namibia are excellent. Considering that contemporary PV technologies offer a useful service life often in excess of 20 years, investments in these technologies are sensible and hedge the owner against escalating electricity prices.

4.5 Solar Water Heaters: Saving Dollars Litre By Litre

Water for domestic, commercial and industrial use can be heated by solar water heaters (SWH), electric water heaters (EWH), heat exchangers or heaters using the combustion of wood or other inflammable materials. Many Namibian households, particularly those in urban areas benefitting from a permanently installed water heater, use electricity to heat water. In view of Namibia's abundance of free solar energy, the widespread use of electric water heaters to heat water for showers, bathing, cleaning and washing of clothes and dishes is perplexing. Would it be sensible to replace EWH by SWH? What are the costs and benefits if Namibia was to embark on a large-scale replacement of EWH and roll-out of SWH? This section addresses these important questions.

Source: [4.25]

In 2012, an estimated 130,000 EWH are installed in the domestic sector in Namibia [4.23]. Assuming that each of these devices is equipped with a heating element with a rating of 2.5 kW, the total connected load of all EWH amounts to some 325 MW. When compared to the peak demand of 516 MW in June 2012 [4.24], the total load due to EWH is very substantial, yet non-essential. Of course, not all EWH are switched on and used all the time. Even if the times during which EWH use electricity are shifted from the peak electricity demand periods, such as the evening demand peak, as is done using ripple control systems, Namibia's electric load due to the installed EWH remains sizeable, and unnecessary in the face of cost-effective and smarter alternatives.

The connected load due to EWH is not the only aspect that matters. What is also important is the actual consumption of electrical energy by EWH. This consumption varies from hour to hour, and depends critically on the thermostat setting, hot water use, and the level of insulation covering EWH storage cylinders. However, realising that a single shower of 30 litres uses some 1.1 kWh of electrical energy, while a single bath of 100 litres uses some 3.7 kWh of electrical energy [4.26], a daily 5-person household electricity use exceeding 10 kWh for hot water services alone, and excluding clothes and dish washing, is quite realistic [4.27]. This is a substantial quantity of high-value energy.

Taking all domestic hot water requirements into account, the total electrical energy use of EWH typically lies between 20% and 40% of a household's total electrical energy consumption [4.28]. EWH therefore represent a significant domestic as well as national electrical energy savings opportunity. As such, EWH are a legacy of an era where electricity prices were low. That era is over, new approaches to provide cost- and environmentally sensible hot water services are necessary. SWH offer one such solution. This section discusses how this could be achieved.

Cabinet introduced a resolution on the installation of electric water heaters in government buildings in 2007 [4.29]. Additional significant savings opportunities exist in both the domestic and commercial sectors in Namibia. One such savings opportunity is realised when EWH are replaced by SWH. A national roll-out focusing on the domestic sector is therefore a particularly attractive option for Namibia, and would significantly reduce the use of valuable electrical energy that is currently squandered in the preparation of hot water. A large-scale national approach would also reduce the country's maximum demand peak, while saving substantial electrical energy, create entrepreneurial opportunities that benefit from small- and medium-scale commercial opportunities, and create manufacturing as well as carbon trading opportunities.

A national roll-out of SWH, in which 15% of the existing and remaining stock of electric water heaters was to be replaced every year, requires some 10 years to replace 80% of the entire EWH stock in the country, assuming that no or few additional EWH are installed during the implementation of such a national program. Assuming a cost of N$15,000 per EWH-to-SWH upgrade, such a replacement program would cost some N$300 million in year 1, while saving 70 GWh of electrical energy, and reduce the peak electricity demand by some 24 MW. In year 10, when only 20% of the existing EWH remain installed, such a program would have cost some N$ 1.6 billion, saved 2.6 TWh of electrical energy, and reduced the peak demand by up to 131 MW, as is summarised in Table 16.

Year	SWH installed per year	EWH remaining installed	% EWH remaining installed	Roll-out cost per year [m N$]	Energy saving per year [GWh]	Peak demand reduction [MW]
1	19,500	110,500	85%	293	70	24
2	16,575	93,925	72%	249	130	45
3	14,089	79,836	61%	211	181	63
4	11,975	67,861	52%	180	224	78
5	10,179	57,682	44%	153	260	90
6	8,652	49,029	38%	130	291	101
7	7,354	41,675	32%	110	318	110
8	6,251	35,424	27%	94	340	118
9	5,314	30,110	23%	80	360	125
10	4,517	25,594	20%	68	376	131

Table 16: National EWH-to-SWH replacement costs N$12m/MW of peak demand reduced [4.30]

From the perspective of a Namibian electricity utility, both the energy saving and peak demand reduction potentials of SWH are substantial, and should be of considerable interest to utilities, investors and members of the public. In order to put the required investment into perspective, it is useful to contrast the capital cost required to build the Anixas power station at Walvis Bay with the EWH-to-SWH replacement program described above. While the Anixas plant cost some N$375 million for a generation capacity of 22.5 MW, i.e. some N$ 16.7 million per MW, the envisaged EWH-to-SWH program costs approximately N$ 12 million per peak MW saved. Considering that SWH will not require any additional fuel to yield ongoing savings, while Anixas will continue to consume imported diesel and heavy fuel-oil with a highly uncertain future price development, and continue to incur ongoing operation and maintenance costs, an investment in MW demand reductions constitutes a national savings opportunity that cannot and should not be ignored. There are few national bargains to be had which are as obvious as the replacement of EWH with SWH.

In principle, the national SWH roll-out scenario summarised in Table 16 could be accelerated, for example by installing more units each year. In this way, by for example installing 20,000 units each year, a national campaign would require less than 6 years to replace more than 90% of all EWH, again assuming that only a few additional EWH would be installed during such a program. In year 6, when less than 10% of the previous EWH stock remains, the program will have cost N$ 1.8 billion, cumulatively saved some 1.5 TWh of electrical energy, and reduced the peak demand by approximately 150 MW, as summarised in Table 17.

Year	SWH installed per year	EWH remaining installed	% EWH remaining installed	Roll-out cost per year [m N$]	Energy saving per year [GWh]	Peak demand reduction [MW]
1	20,000	110,000	85%	300	72	25
2	20,000	90,000	69%	300	144	50
3	20,000	70,000	54%	300	216	75
4	20,000	50,000	38%	300	288	100
5	20,000	30,000	23%	300	360	125
6	20,000	10,000	8%	300	432	150

Table 17: Accelerated national solar water heater roll-out scenario [4.30]

The scenarios illustrated in Table 16 and Table 17 show that a national EWH-to-SWH replacement program and roll-out could quickly and cost-effectively reduce the national peak electricity demand, and contribute substantially in saving electrical energy. *How could such a national program be financed?* It could be financed through a combination of private and public loans. This will be a mutually beneficial arrangement for both loan providers and beneficiaries. As an incentive, property owners who finance the replacement of their EWH with a SWH through an existing mortgage bond facility can have a SWH installed at their residence *without incurring any additional expenses*, and repay the loan for the SWH refurbishment solely through the savings on electricity not used. This is an investment with few equals.

A scenario for a typical Namibian mortgage bond holder is illustrated in Table 18 below. The scenario assumes that an existing loan facility, such as a mortgage bond for a house, is extended by N$15,000, at an interest rate of 12.5% per annum, for a repayment period of 10 years. For each such new loan, the scenario results in a *net cumulative saving* realised after the full repayment of the loan for the EWH replacement, amounting to more than N$67,000 after 10 years. Savings could be reinvested, to accelerate the repayment of the remainder of the loan, or used for other purposes. Few clients would be unhappy with realising such savings. Banks would embrace this extension of loan facilities for green technologies, which increases loan volumes while improving loan repayments through savings on the expenditure for electricity.

Year	% escalation of electricity tariff [% per year]	Electricity tariff [N$/kWh]	Energy saving [kWh/a]	Loan repayment [N$/a]	Cost of electricity saved [N$/a]	Cumulative savings [N$]
1	-	1.50	3,600	2,709	5,400	2,691
2	15%	1.73	3,600	2,709	6,210	6,191
3	15%	1.98	3,600	2,709	7,142	10,624
4	15%	2.28	3,600	2,709	8,213	16,127
5	15%	2.62	3,600	2,709	9,445	22,862
6	7%	2.81	3,600	2,709	10,106	30,259
7	7%	3.00	3,600	2,709	10,813	38,362
8	7%	3.21	3,600	2,709	11,570	47,223
9	7%	3.44	3,600	2,709	12,380	56,894
10	7%	3.68	3,600	2,709	13,247	67,431

Table 18: Indicative loan repayment and savings schedule for a domestic SWH upgrade [4.31]

Table 18 also illustrates that the replacement of an EWH with a SWH is a financially viable proposition resulting in immediate and overall cost savings. This is the case irrespective of whether the beneficiary is a domestic user, or a commercial user, or an industrial or institutional user.

Considering the potential for domestic savings, these are of national significance and the implications of such investments are most considerable: From the perspective of an individual household, immediate cost-savings can be realised as soon as a SWH is installed. This investment pays for itself *and* generates additional funds for further investments. In most cases, no additional funding is required to realise such savings. For any consumer, this is highly desirable.

From a national perspective, large-scale investments in energy efficient technologies, such as SWH, introduce even more advantages as summarised below:

- reduces the total demand for electrical energy
- reduces the peak demand for electricity, which is especially important during evening peak consumption times in Namibia
- reduces the amount of electricity that Namibia has to import or generate using expensive diesel- or coal-fired power stations, and
- reduces the impact on the environment by decreasing greenhouse gas emissions from coal, diesel or heavy fuel-oil fired power stations.

The large-scale introduction of SWH also holds numerous potentials for small- and medium enterprise (SME) development and employment creation. Importing SWH is almost always necessary if the number of units sold nationally is small. However, significant new business opportunities can be created in an investment climate where entrepreneurs establish SWH manufacturing plant locally. The wide-scale introduction of SWH can also create additional value streams, for example in terms of carbon credit payments. While individuals cannot readily benefit from the international trade in carbon credits, which are for example created when SWH replace EWH, a bundled national approach would create scope to additionally benefit from such revenues.

From the utility perspective, investments in technologies which significantly reduce the peak demand while costing much less than the capital required for additional power stations are significant. The sceptic may ask: are NamPower or the distribution entities not in the business of selling electricity? The answer is: yes, they are. However, one needs to ask whether it is not more advantageous to use a valuable and scarce resource such as electrical energy for productive purposes while letting the sun assist in providing clean and cost-free energy for hot water services. Few will disagree with such a notion.

The cost of a national roll-out and accelerated roll-out program are summarised in Table 19, and shows the actual and present value costs and benefits of the "standard" and "accelerated" SWH roll-out programs discussed in this section, using a discount rate of 15%.

Year	Cost of standard national roll-out [million N$ / a]	Cost of acc. national roll-out [million N$ / a]	Benefit of standard roll-out [million N$]	Benefit of acc. roll-out [million N$]
1	293	300	52	54
2	249	300	126	140
3	211	300	222	266
4	180	300	342	440
5	153	300	487	674
6	130	300	599	888
7	110	-	716	972
8	94	-	838	1,063
9	80	-	966	1,160
10	68	-	1,100	1,264
Present Value:	**N$ 0.93 bn**	**N$ 1.14 bn**	**N$ 2.07 bn**	**N$ 2.65 bn**

Table 19: Comparison of costs and benefits of two national SWH roll-out programs [4.30]

The benefit-to-cost ratio of the standard roll-out program is 2.2, while that of the accelerated SWH roll-out is 2.3. This implies that the financial benefits of such programs far outweigh their costs. *Not even taking non-financial benefits into account, this is highly desirable.* Based on the very favourable benefit-to-cost ratios, the large-scale implementation of a SWH roll-out is amongst the most obvious smart investments that can be made, both for domestic users of hot water, as well as nationally. The wide-scale introduction of SWH also allows a more effective use of electricity, in order to enhance the value addition from each unit of electricity consumed. While hot water services are essential for a modern society, providing hot water by using high-grade forms of energy such as electricity is neither smart nor effective. EWH are easy and profitable to substitute, and an EWH-to-SWH exchange program creates new local job opportunities, especially in the small and medium enterprise sector.

To conclude: A national roll-out of SWH replacing EWH makes financial sense, and can quickly and effectively contribute to address Namibia's short-term peak demand and electricity supply challenges.

Several models of how local authorities and/or utilities can initiate large-scale SWH roll-out programs are possible. Such programs can be initiated and implementation could commence in a matter of months, rather than years, i.e. they are much faster than increasing the national energy generation capacity. National program drivers could be the Ministry of Mines and Energy, local and international investment funds, commercial banks, local authorities, or NamPower. These entities would likely benefit if they are supported by an agile business-oriented implementation team acting without political constraints and/or interference. National programs do raise issues, including the question of local capacity to undertake installations, sustainability, income reductions for local authorities, ensuring the quality of the roll-out, component warranties and many others. These have to be addressed by the project champions driving such a program. A long-term institutional commitment to a national roll-out of SWH is equally important. A Government entity such as the Ministry of Mines and Energy may have to put in place measures to ensure the long-term success.

Policy can be more pro-active in regard to the wide-scale uptake of solar water heaters in Namibia. A national policy limiting or even outlawing the continued installation of electric water heaters is certainly possible. Such a policy would likely create opportunities for manufacturers of solar water heaters, to the benefit of consumers, and in promotion of the productive use of electricity in Namibia.

SWH can be a new source of revenues from investments in energy-related infrastructure in Namibia. One would expect that astute investors will not forgo this sizeable opportunity, which in addition to its energy efficiency benefits, will realise substantial social and environmental benefits, and can tangibly and immediately contribute to make Namibia's energy future smarter and more sustainable.

4.6 Concentrated Solar Power: Dispatchable Power from a World-class Resource

Concentrated solar power (CSP) plants use direct sunlight focused on receivers to harvest heat energy. A heat-absorbent medium in absorber tubes transfers to heat exchanger units, where steam is generated. Conventional steam turbines connected to off-the-shelf generators drive such electrical generators, feeding electricity into the national electricity transmission system. Schematically, this process is shown in Figure 48.

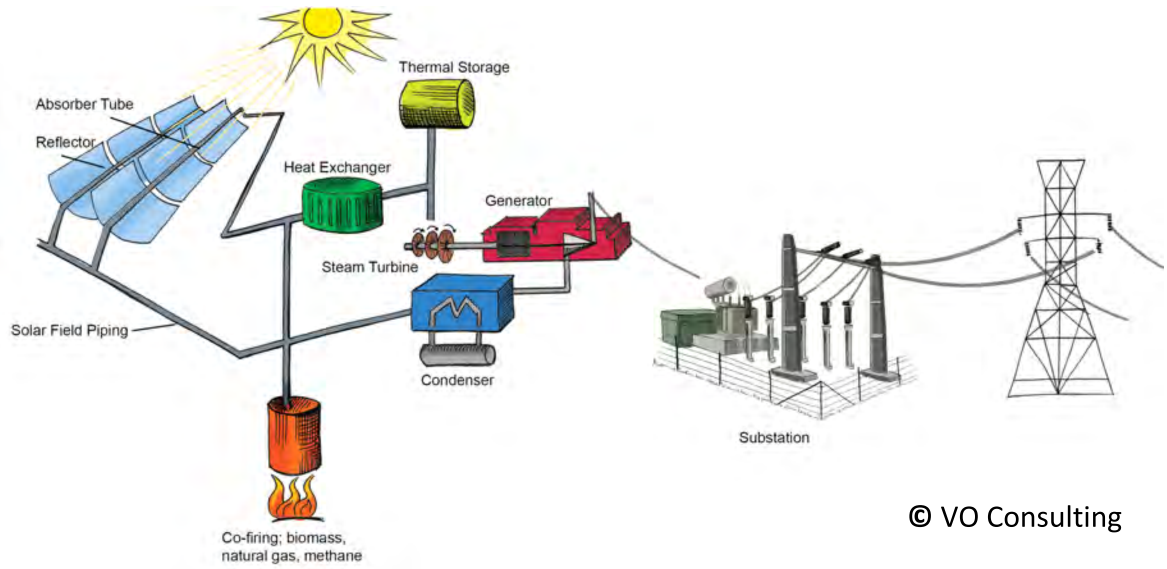


Figure 48: Conversion of direct radiation from the sun into electricity in a CSP plant [4.32]

A variety of CSP technologies exist, including solar trough systems, Fresnel systems, power towers and parabolic dishes; these are shown in Figure 49.

Figure 49: From left to right: solar parabolic trough system [4.33a], Fresnel system [4.33b], power tower [4.33c], and a parabolic dish system [4.33d]

Namibia has a world-class solar resource that is ultimately useful for CSP applications [4.34]. A recent study commissioned by the Renewable Energy and Energy Efficiency Institute at the Polytechnic of Namibia has confirmed that the direct normal irradiation component of the country's national solar resource, which is the "solar fuel" for CSP plants, is amongst the world's best [4.34]. A world-class resource is awaiting further use.

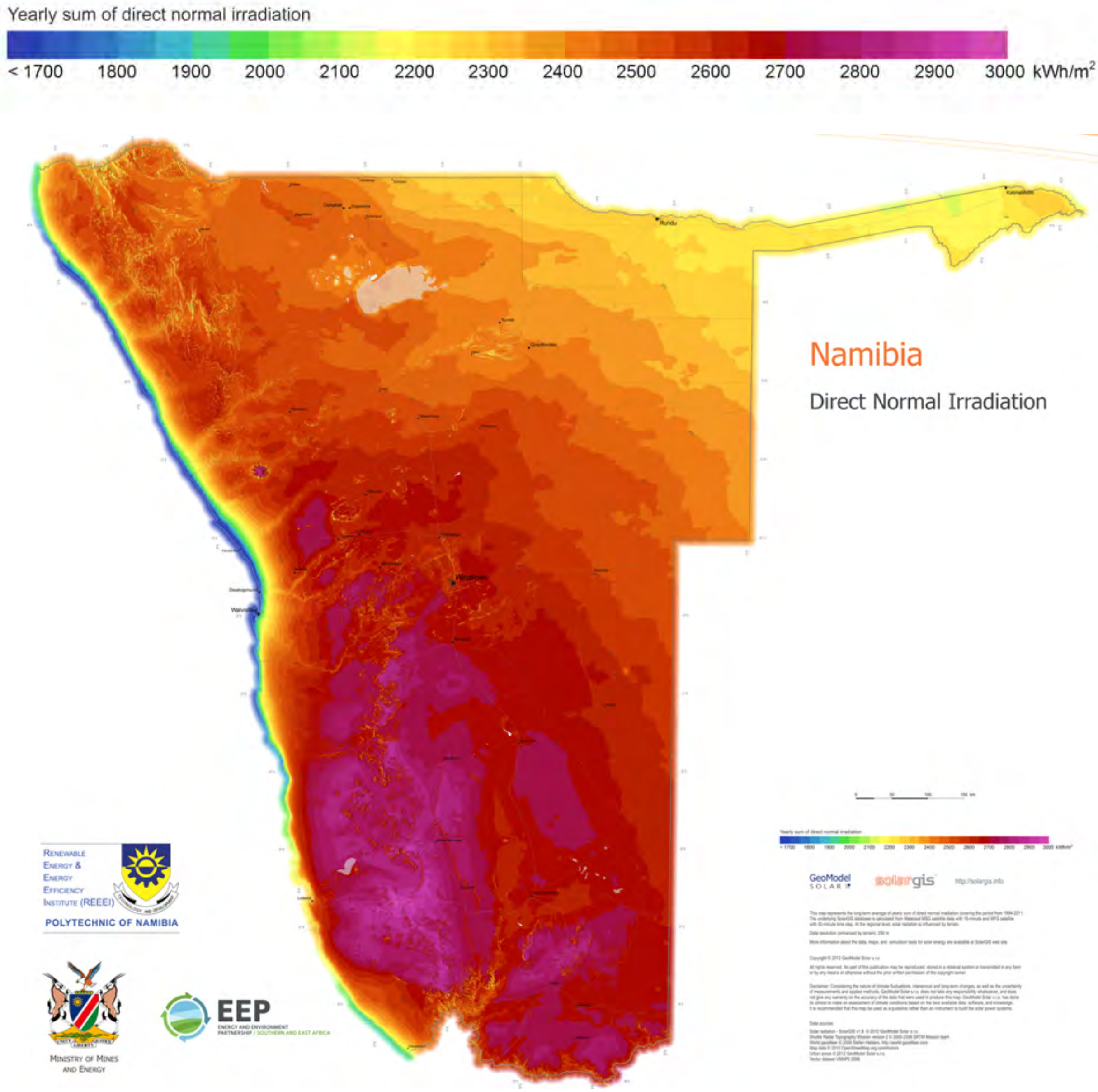


Figure 50: Namibia's world-class direct normal irradiation resource [4.35]

Concentrated solar power plants have a number of distinct advantages that render them particularly useful for operations in Namibia. Importantly, their output depends on the solar resource. With a solar direct normal irradiation resource as outstanding as Namibia is endowed with, the resource is abundantly available. This resource base constitutes a Namibian comparative advantage that is without many equals – and yet, it remains largely untapped. Our solar resource is an entirely free commodity, and as shown in Figure 50, is excessively abundant in many parts of Namibia.

"Namibia's solar resource constitutes a national comparative advantage having few equals."

CSP plants can be equipped with energy storage technologies, which allow them to provide power long after sunset. In particular, storage systems allow CSP plants to

"Namibia's solar resource is an entirely free commodity, and excessively abundant in most parts of the country."

produce electrical energy during the Namibian evening peak consumption time. Storage also renders CSP plants readily dispatchable. In addition, because many CSP plant designs are based on well-established steam technology, the required heat can be generated from a combination of solar and other fuels such as natural gas, biomass or methane. Such co-firing allows CSP to be a bridge technology, utilising gas or biomass resources when the solar resource is either insufficient or unavailable, and in times in which there is insufficient heat storage capacity. Another clear advantage is the modularity of CSP plants, which implies that they can be built and extended in units of a few to tens of MW capacity, as and when required.

Investments in CSP capacity can be staggered to cater for the growing national or regional demand, rather than having to finance a single large plant. Modularity thus allows the owner-operator of a CSP plant to minimise capital outlays, and match plant size to the national demand and the local resource availability. In this way, modularity is most valuable, as it hedges against excessive investments, and also allows the plant operator and Namibian electricity systems operator to gain experience with one or several strategically located CSP plants before embarking on large-scale investments.


Source: [4.36]

With the exception of parabolic dish systems, which can provide electrical power to remote area settlements or farms, the CSP options discussed in this section are best suited for larger-scale applications, for example for village or town electrification, and to feed electrical energy into the national grid. The decentralised establishment of several mid-sized multi-MW CSP plants reduces the risk of local cloud cover or other external factors influencing the electricity generation capability of a plant, but also increases the cost per MW. For local authorities wishing to invest in electricity generation capacities, CSP plants may offer an attractive long-term proposition, especially when additional fuels such as natural gas, biomass or methane are available to allow for hybrid plant operations. Provided that the necessary access to electrical infrastructure is available, system establishment costs can be minimised. This implies that a local CSP plant close to an existing transmission system may readily supplement a town's electrical requirements.

It is beyond the scope of this study to present a detailed techno-economic analysis of the viability of CSP plants. This section therefore only presents order of magnitude estimates of the revenue requirement per kWh of electricity produced in typical parabolic trough CSP plants. Table 20 shows the indicative revenue requirement per unit of electricity in year 1 of operations of three differently sized CSP plants.

CSP power plant capacity	5 MW	10 MW	50 MW
Revenue requirement per kWh [N$/kWh]	2.01	1.64	1.35

Table 20: Indicative revenue requirement for parabolic trough CSP power plants in year 1, in N$ per kWh [4.37]

Table 21 summarises the energy output of solar trough CSP plants, assuming that operations are extended by 6 hours per day using hybrid operations and/or storage.

CSP power plant capacity	5 MW	10 MW	50 MW
Energy output [GWh per year]	16.8	37.4	207.4

Table 21: Indicative energy output per year for parabolic trough CSP power plants equipped with 6-hour hybrid operation and/or storage capacity, in GWh per year [4.38]

Table 22 summarises the levelised cost of energy (LCOE) for three typical concentrated solar trough plants, in N$ per kWh, assuming a plant life of 20 years.

CSP power plant capacity	5 MW	10 MW	50 MW
Levelised cost of energy [N$/kWh]	2.19	1.78	1.44

Table 22: Indicative levelised cost of energy for parabolic trough CSP power plants, in N$ per kWh [4.40]

To conclude: CSP can provide much-needed dispatchable power generation capacity fuelled by an abundant local commodity. This renders investments in local generation capacity using local resources attractive, and adds value where Namibia has unlimited and sustainable capacity to power the nation into the future.

There are no fuel cost escalations for CSP, while the cost of coal or natural gas will remain an international commodity in which Namibia remains a price taker. This implies that investments in CSP provide long-term price stability and independence of foreign exchange fluctuations and international markets.

Early adoption of CSP technology – for example by way of investing in several mid-sized plants – is recommended to build utility experience while limiting unfavourable initial end-user cost increases.

4.7 Wind Power: The Power's in the Air

Wind energy converters, also called wind turbines, transform the wind's kinetic energy into electrical energy. In this way, wind turbines located in positions with a good wind regime, as for example found at sites along the Namibian coast, can generate electricity using the prevailing wind regime.

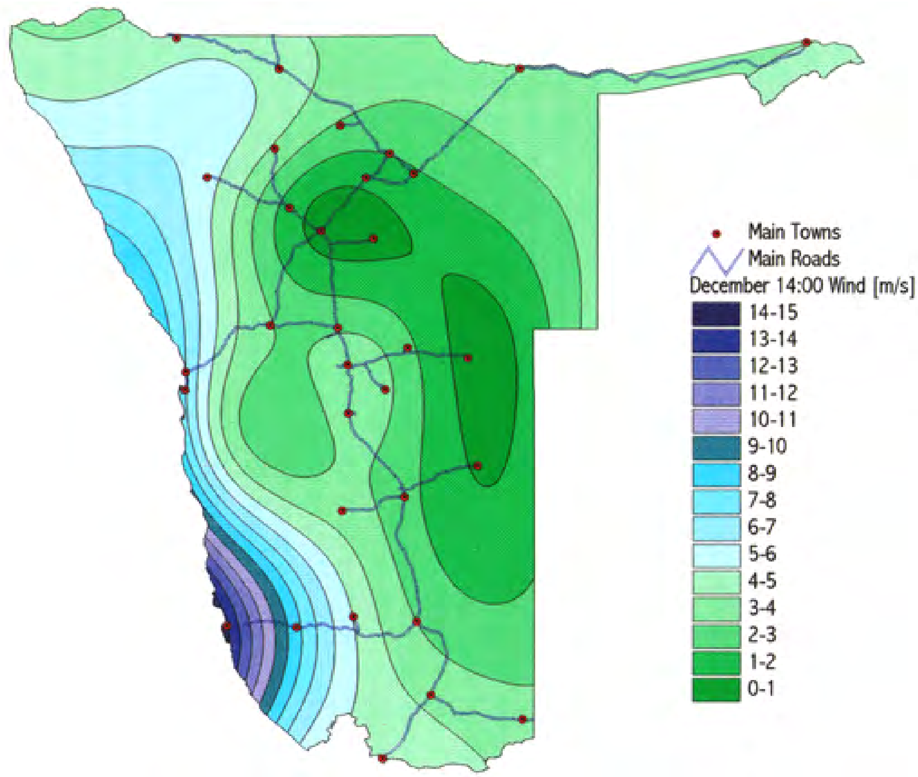


Figure 51: Indicative Namibian wind speeds at 14h00 in December, in metres per second [4.41]

Wind resources along the Namibian coast are considerable. It is well-known that the wind energy potential in the greater Lüderitz area is excellent [4.42]. The Diaz Wind Power company plans to establish a 44 MW wind farm south of Lüderitz [4.43]. Additional sites in this area would be worthwhile for further development, provided that the investment conditions and grid connection requirements become more attractive than at present. Innowind and Electrawind hold conditional licenses for the establishment of wind farms close to Walvis Bay; these may eventually have a capacity in excess of 60 MW [4.44].

As is evident from the indicative wind speed map shown in Figure 51, the coastline north of Henties Bay offers additional sites having moderate to good wind regimes, which may in time make it attractive to establish wind farms. It is to be noted however that the availability of a good wind regime is not the only pre-requisite for the development of a site to become a wind farm. In particular, the site's proximity to the national electricity transmission system is a crucial determinant to render a site viable for wind farm development. While Namibia offers many windy spots, especially along the coast, only few of them are adequately connected to the national electricity network at present.

Source: [4.46]

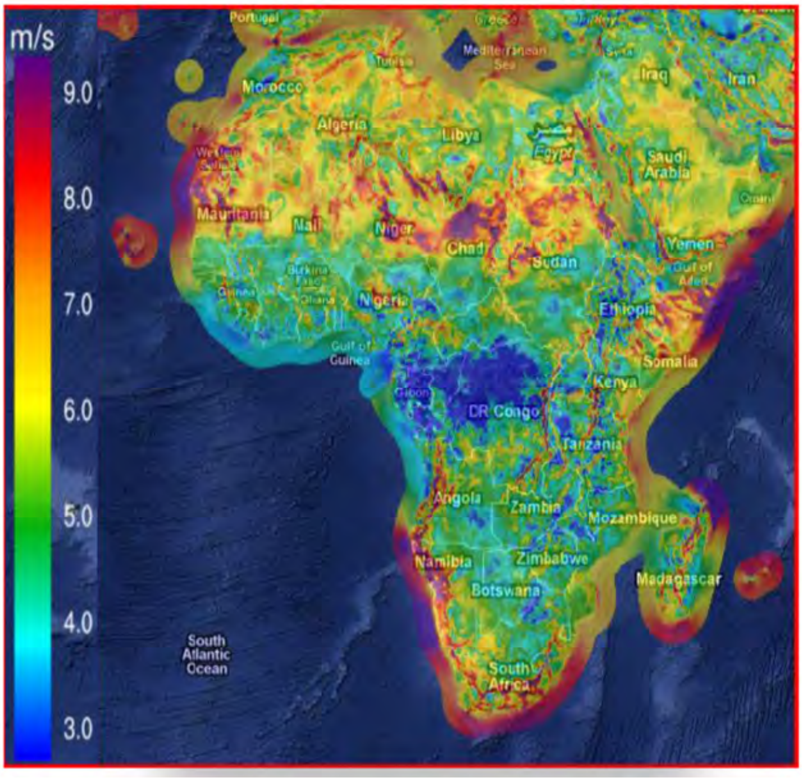
Typically, a 50 MW wind farm positioned on Namibia's southern coast can be expected to yield in excess of 96 GWh of electrical energy each year [4.45].

Assuming that most sites which offer reasonable connectivity to the national transmission grid can be developed in time, a total installed wind energy capacity in access of 100 MW is considered realistic for the future.

Off-shore sites may one day add to such capacity, but would also substantially increase the cost of supply, as the installation of off-shore generators and connection to the national grid is more demanding than comparable on-shore site developments.

Figure 52: Namibia's only wind energy converter in July 2012, a 220 kW turbine at Walvis Bay

Few site-specific wind resource assessments have been undertaken in Namibia so far. These are essential to optimally position, size and design a wind farm. The absence of credible wind data is one reason why potential investors remain hesitant to pursue wind farm development projects in Namibia. While there is little doubt that viable wind sites exist, some of which will offer a world-class wind resource, not all such sites are sufficiently close to be readily connected to the national transmission system. If they were to be connected, the developer would face substantial additional costs which reduce the viability of such ventures.



Source: [4.47]

Figure 53: Comparison of wind regimes across the African continent, scale in metres per second

Wind energy plants are increasingly economical to establish. However, their output depends on the characteristics of the available wind resource. Wind is notoriously intermittent, which implies that wind energy converters are not 'dispatchable'. This implies that wind energy systems cannot supply power as and when demanded by system requirements. While wind is a resource that can increasingly be predicted well ahead of time, the number of meteorological stations in the region remains very limited. This has a negative impact on the quality and predictive reliability of wind regime forecasts, which in turn makes it more challenging to integrate larger wind capacity into the national grid.

Similar to many other renewable energy technologies, wind farms can be developed modularly, and expanded as and when the national demand requires. This is an attractive feature of wind farm development, and allows the owner-operator to save on capital outlays by sizing the wind farm to most optimally meet the prevailing demand. As noted before, the modularity of many renewable energy technologies has value, as it hedges the developer against premature investments.

On the other hand, given the limited number of potential wind farm locations that are close to the existing transmission grid in Namibia, potential wind farm developers sometimes focus on securing land access rights and conditional generation licenses without the intention to develop the site any time soon. This has already happened in Namibia, and while the early-movers now hold such conditional licenses, they are blocking access to land by other developers. This is neither desirable nor does it promote investments. It emphasises a particular structural problem inherent in Namibia's electricity industry: Approaches that have been used to grant conditional licenses to potential investors have not yielded tangible results, implying that not a single kWh generated at a wind farm in Namibia has yet been fed into the national grid. This is certainly not only due to an unwillingness or inability on the side of investors.

Source: [4.48]

This study does not present detailed techno-economic analysis of the viability of wind power. However, some estimates of the revenue requirement per kWh of electrical energy produced at Namibian wind farms are presented below. Table 23 summarises the order of magnitude revenue requirement for wind farms having three different generation capacities.

Wind energy power plant capacity	20 MW	50 MW	100 MW
Revenue requirement per unit of electricity [N$/kWh]	1.55	1.33	1.08

Table 23: Indicative revenue requirement per unit of electricity for wind farms in year 1, in N$ per kWh [4.49]

Table 21 summarises the energy output for the typical wind farms introduced in Table 23.

Wind energy power plant capacity	20 MW	50 MW	100 MW
Energy output [GWh/a]	35.0	94.1	201.4

Table 24: Indicative energy output per year for differently sized wind farms, in GWh/a [4.50]

Table 22 summarises the levelised cost of energy for three typically sized wind farms, assuming a plant life of 25 years.

Wind energy power plant capacity	20 MW	50 MW	100 MW
Levelised cost of energy [N$/kWh]	1.69	1.45	1.17

Table 25: Levelised cost of energy for three differently sized wind farms, in N$/kWh [4.51]

To conclude: The levelised cost of energy of the wind farms considered in Table 25 is favourably comparable to that of coal-fired power plant if these were to be built in Namibia in 2012 [4.39]. Realising that there are no fuel cost escalations for wind power generators, and only inflation-related increases in operation and maintenance costs, investments in wind power provide long-term price stability and independence of foreign exchange fluctuations and international fossil fuel markets. This makes wind power a most useful and important ingredient in Namibia's national electricity generation mix.

As in the case of bush-to-electricity plants, CSP or solar photovoltaics, investments in local generation capacity using local resources are attractive, and can add value to Namibia's long-term development. If resources such as solar or wind are used, ever-rising fuel-costs will have lost their bite.

Intermittent power generation technologies, such as wind power, would benefit substantially if the Baynes hydropower station is established. The ability to call upon readily dispatchable power plants, for example a hydro-power station with storage, considerably increases the value of wind power in our national energy mix.

4.8 Reflections on the Cost of Energy

Figure 54 shows the levelised cost of energy (LCOE) of the various renewable energy power plant options considered in this study. For comparison, the LCOE of coal-fired power plants with / without taking carbon taxes into account have been included [4.39].

Figure 54 makes it clear that conventional coal-fired power without carbon taxes remains the overall least-cost option (ignoring natural gas), provided that fuel costs do not escalate more than the underlying inflation rate, which was assumed to be 6% per year over the life-of-plant. In view of international commodity price developments in the past decades, and the expected pressures on coal resources, it seems overly optimistic to assume that the real coal price will remain constant over the coming 30-year period.

It is noted that there are numerous cost dimensions *other* than fuel cost. Also, there are many benefit dimensions other than providing a least-cost energy supply option. Energy options that are to form part of Namibia's future energy mix therefore should have *more benefits than merely being the cheapest option at a given time*.

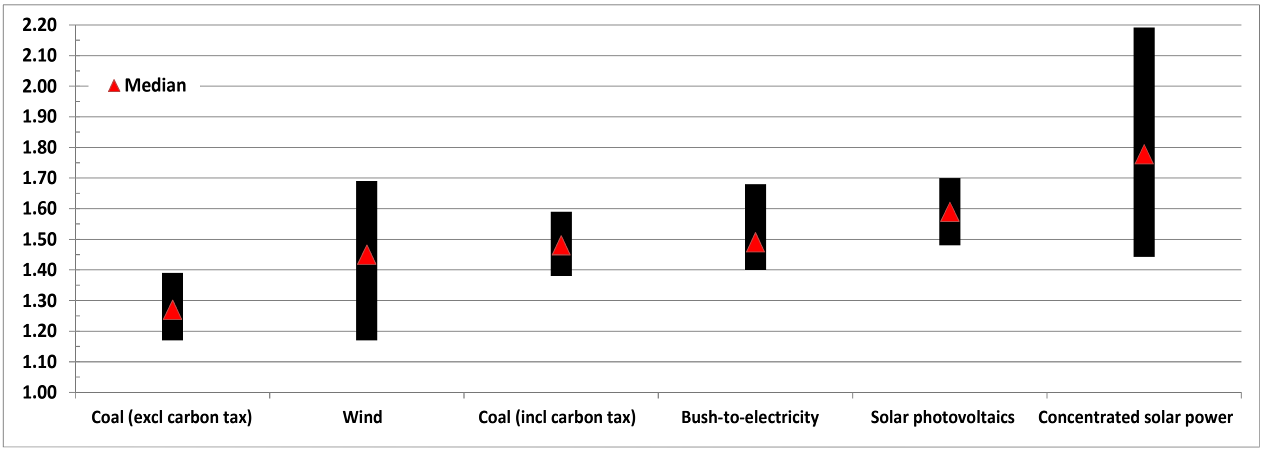


Figure 54: Levelised cost of energy (LCOE) of the supply options discussed in this study, in comparison with coal-fired power [4.39]

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 supplies allows us to recognise the short-, medium- and long-term implications of our energy supply choices, and emphasises the pivotal and value-contributing role that renewable energy technologies can and should play in Namibia's future electricity supply mix.

The next chapter identifies some important **value potentials and value dimensions** used to assess and rank future energy supply options. These provide a comparative framework for a more integrated assessment of the advantages and disadvantages of energy options, guided by the real costs and real benefits provided by new generation capacity and thus avoiding a singular focus on least-cost options.

5 Value Potentials of RE and EE in Namibia

The previous chapters included case studies on select renewable energy and energy efficient technologies. What they have in common is that they would – if they were introduced more widely – reduce Namibia's dependence on electricity imports and the country's reliance on fossil fuels including coal and heavy fuel oil.

Additional value can be created through the deliberate large-scale introduction of renewable energy and energy efficient technologies in Namibia, most notably through

- local employment creation
- reducing currency outflows
- reducing Namibia's dependence and vulnerability to foreign exchange fluctuations for energy-related expenditures
- increasing private investment in the country's energy sector, and
- strengthening Namibia's reputation as a country offering an intact environment, where smart policies ensure that environmental costs are minimised through the targeted roll-out and application of green technologies.

This section highlights how local renewable energy and energy efficiency opportunities can create social, economic and environmental value. While this section cannot be considered comprehensive, it illustrates the importance of some of the key value drivers at work in the country's energy sector.

For the purposes of the present analysis, ***social value*** is indicated by the

- local job creation potential offered by a specific energy technology
- income generation potential, and
- local capacity development potential.

This study recognises ***economic value*** through the

- contribution to the national electricity supply, or the reduction of demand
- cost savings per kWh generated or saved, and
- foreign exchange savings.

This study recognises ***environmental value*** through the

- reduction of carbon dioxide emissions, as well as particulate matter (PM), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) emissions
- reduction of water use, and
- minimisation of the total environmental footprint brought about by the use of a specific energy technology.

Value indicator ↓ Technology →	COAL	SOLAR PV	SWH	SOLAR CSP	WIND	BUSH-TO-ELECTRICITY
Local job creation potential	low	medium	medium	low	low	high to very high
local skilled workers	low	medium	medium	low	low	medium
local unskilled workers	low	low	medium	low	low	high to very high
Broad-based income generation potential	low	medium	high	low	low	high to very high
Local capacity development potential	low	high	high	medium	medium	high to very high
Contribution to electricity supply / demand	very high	medium	high	high	medium	high
Cost savings per kWh generated / saved	medium	very low	very high	very low	medium	low to medium
Foreign exchange savings	very low	medium	high	medium	medium	medium to high
Carbon dioxide emissions	very high	very low	very low	very low	very low	medium [8]
PM, SO_2 and NO_2 emissions	high	very low	very low	very low	very low	medium
Water use	medium	very low	very low	medium	very low	medium
Total environmental footprint	very high	low	very low	medium	low	medium

Table 26: Qualitative comparison of social, economic and environmental value created by different energy supply options [5.1]

[8] The combustion of biomass liberates carbon dioxide which was previously absorbed during the growth of plant material. However, fossil fuels in the form of petrol and diesel are used in the harvesting, transport and fuel preparation, which implies that a bush-to-electricity plant is not entirely carbon neutral, but contributes to national carbon savings when compared (for example) to a conventional coal-fired power plant which is not equipped with carbon sequestration technology.

Based on the qualitative comparison of different energy technologies presented in Table 26, the overall social, economic and environmental value dimensions are derived. These are summarised in Table 27 below.

Value dimension	COAL	SOLAR PV	SWH	SOLAR CSP	WIND	BUSH-TO-ELECTRICITY
Social	low	medium	high	low	low	very high
Economic	medium	medium	high	medium	medium	medium
Environmental	low	high	high	high	high	medium

Table 27: Overall social, economic and environmental value created by different energy supply options [5.1]

It is important to recognise that there are additional **technical value dimensions** that are of importance when comparing different energy options and their potential contribution to Namibia's electricity sector, including

a. the effective electrical capacity that could realistically be contributed to the total electricity supply system

b. the actual amount of electrical energy produced or saved per year

c. the degree of dispatchability, indicating how readily and predictably the technology can be called upon in times of peak demand or energy supply bottlenecks

d. the ability to reduce Namibia's current electricity supply deficit

e. the contribution to reduce or meet the country's peak electricity demand

f. the number of jobs directly created, and

g. whether the total life-cycle cost – as for example expressed through the levelised cost-of-energy (LCOE) – can be calculated with a high degree of certainty, taking future foreign exchange fluctuations, the cost of fuels to be used in future, and other essential future cost elements into account.

Based on the case studies presented in sections 4.3 to 4.7 of this study, the above technical value dimensions are further quantified in Table 28 below.

Value indicator ↓ Technology →	COAL	SOLAR PV	SWH	SOLAR CSP	WIND	BUSH-TO-ELECTRICITY
Approximate capacity addition / reduction	150 MW [9]	90 MW_p [10]	100 MW [11]	150 MW [12]	100 MW [13]	150 MW [14]
Electrical energy produced / saved per year	1,050 GWh	160 GWh	530 GWh	850 GWh	193 GWh	920 GWh
Jobs directly created	200 [15]	300 [16]	500 [17]	150 [18]	200 [19]	500 / > 10,000 [20]
Can it reduce Namibia's supply gap?	yes	yes	yes	yes	yes	yes
Can it supply / save during maximum demand periods?	yes	inter-mittently	yes [21]	yes	inter-mittently	yes
Is it dispatchable on demand?	yes	no	yes [22]	yes	no	yes
Can LCOE be computed with high certainty?	no [23]	yes	yes	yes	yes	no [24]

Table 28: Comparison of critical technical value dimensions of select energy and energy efficient technologies relevant in Namibia [5.1]

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[9] Larger coal-fired plants are certainly possible. In 2012, a single coal-fired plant of 150 MW capacity would most likely be the smallest feasible base load plant for Namibia [5.2].
[10] Assuming that 25,000 households would each be equipped with a 3.6 kW_p solar photovoltaic plant. Larger solar PV plants, from a few MW to tens of MW capacity are certainly possible, and it is very likely that such power plants are added to Namibia's electricity supply system from 2013 onwards. Solar PV plants have a capacity factor of the order of 20%.
[11] Assuming that some 100,000 households were to each replace one 2 kW electric water heater with a solar water heater system, 50% of which are switched on at any given time.
[12] Assuming that three CSP plants of 50 MW capacity each with 6-hour storage capacity were to be installed.
[13] Assuming that the greater Lüderitz area will eventually host wind farms of some 50 MW capacity, while sites between Walvis Bay and Henties Bay offer locations for an additional capacity of some 50 MW.
[14] Assuming that 15 bush-to-electricity plants based on simple combustion technology of 10 MW capacity each were to be installed across north-central Namibia.
[15] The environmental and socio-economic impact assessment undertaken for NamPower's proposed coal-fired power station in Erongo estimates that between 2,000 and 3,000 jobs will be available in a 2-year construction period, of which some 70% will be unskilled or semi-skilled, and between 200 and 300 jobs will be created in the operational phase.
[16] Assuming that 5,000 solar PV rooftop systems are installed per year, requiring 5 full-time persons (including for technology supply) to install 2 systems every 5 working days.
[17] Assuming that 20,000 SWH systems are installed per year, requiring 5 full-time persons to install one system every working day.
[18] Literature suggests that the total jobs created per installed MW of solar thermal plants is between 0.3 and 19 persons; here it is assumed that one job is created per installed MW.
[19] Literature suggests that the total jobs created per installed MW ranges between 3.8 and 5.9 persons; here it is assumed that two direct jobs are created per installed MW.
[20] A fully mechanised biomass processing approach requires some 250 persons per 150 MW capacity, versus more than 10,000 persons if harvesting is mainly done manually.
[21] Solar thermal water heaters having an electric backup element can be set to avoid using electricity in peak demand periods, which in turn reduces peak demand.
[22] Solar thermal water heaters are not dispatchable as such, but their electric backup element can, if required, be set to avoid using electricity in peak demand periods.
[23] Unless forward contracts and/or price hedging covers for the supply of coal are in place for the full life-of-plant, the LCOE can only be determined probabilistically.
[24] Unless forward contracts and/or a price hedging covers for the supply of diesel fuel as required for harvesting, transport and fuel preparation for the full life-of-plant are available.

To conclude: Energy systems can create significant social value – other than by providing access to energy – if they lead to long-term local job opportunities, result in investments in local capacity development, and contribute to build and strengthen local value chains.

Economic value in energy supply systems is created – amongst others – by increasing technology and human efficiencies, new investments, establishing new and permanent industries and jobs, and minimising non-productive cash outflows from Namibia.

Environmental value in energy supply systems is created if the use of limited local natural resources is optimised for their productive value, and by employing technologies having a minimal environmental footprint. If environmental processes can be enhanced by employing a particular energy technology, such as in the case of bush-to-electricity plants, where agricultural land can be reclaimed and underground water resources are enhanced through the select harvesting of invader bush, additional environmental value is created, while at the same time improving and strengthening environmental services from the land. Such value propositions yield benefits over and above the common environmental values (if any) created by other energy supply options. A national program for the sustainable use of invader bush therefore holds massive value potentials, both for Namibia's agricultural and labour sectors, as well as the environment. Here, forward-looking policy is essential.

Of the energy technologies compared in Table 26, bush-to-electricity power plants are expected to create the most local jobs, and lead to the development of a variety of new rural value adding services. Such service and support activities are expected to include contracting for bush harvesting, the transportation of harvested biomass, and the preparation of biomass before its use in power stations. The degree of mechanisation of harvesting however significantly determines the type and number of jobs actually created.

Considerable local value addition potentials are also locked in the more wide-spread application of solar water heaters. A national program which successively replaces electric water heaters with SWH would create a substantial number of additional jobs in various service sectors as well as new manufacturing opportunities.

Similar to conventional coal-fired power plants, both concentrated solar power (CSP) plants and bush-to-electricity (BTE) plants offer dispatchable power. While coal remains an imported commodity with uncertain future cost increases which remain exposed to future foreign exchange fluctuations, both CSP and BTE use abundant local resources in the form of sunshine and invader bush and have no or very little future foreign exchange exposure. *Value arising from investments in the use of local resources creates local value, local jobs and local expertise.* Conventional power planning often ignores these important local value contributors and merely focuses on least-cost options. This is too narrow a view.

Take away message: Policy drives investment. Namibian policy frequently deliberates on the need for local value addition. However, policy does not adequately recognise the value locked in Namibia's renewable resources. The absence of policy-led initiatives incentivising the development of local sustainable value propositions built on Namibia's abundant renewable resources is obvious. Policy must bring about a more balanced focus on local value creation. In this way, Namibia's energy future could be placed on a secure footing.

6 Creating Momentum for Change – The Policy Imperative

This chapter offers a perspective on how Namibia's current electricity sector challenges can be turned into socio-economic growth opportunities by, amongst others, the focused creation of sustainable jobs and targeted local value addition in the country's renewable energy sector. To this end, this chapter presents an action list describing the high-level tasks to set in motion a process for the wide-scale roll-out and adoption of renewable energy and energy efficient technologies.

To address and resolve the current electricity sector challenges facing Namibia, the following steps are of critical importance:

1. re-write Namibia's energy policy to position the country for investments in the energy sector, and deliberate value creation from our abundant renewable energy resources

2. address the structural, regulatory and organisational impediments that plague Namibia's electricity sector

3. define specific, realistic and measurable short-, medium- and long-term sectoral goals for the electricity sector as a whole, emphasising the role and contributions of renewable energy and energy efficient technologies in the country's future electricity mix

4. formulate a national renewable energy and energy efficiency strategy, clearly articulating the country's strategic intent in regard to its substantial renewable energy resources

5. introduce a binding renewable energy and energy efficiency implementation plan as an integral part of the country's new energy policy, backed by appropriate legislation and regulation

6. set national renewable energy and energy efficiency targets, focusing on Government institutions, electricity utilities and the public building stock

7. create a system of electricity tariffs that ensure continued affordability and accessibility, create investment certainty, and security of energy supplies

8. create a bundle of targeted tax and investment incentives focusing on value adding activities in the renewable energy and energy efficiency sectors

9. create incentives for labour-intensive sustainable bush harvesting and bush use enterprises, and

10. systematically engage the public on the multiple roles and benefits associated with reliable energy supplies needed for the country's ongoing development.

The above steps require, first and foremost, an in-depth understanding of how the country's electricity sector operates. Quick-fixes and political manoeuvring, as for example witnessed in debates about the electricity distribution industry, will not address the fundamental challenges faced by Namibia's electricity sector.

Policy needs to recognise that Namibia is richly endowed with natural renewable resources that constitute an important national comparative advantage.

Policy needs to resolve *how* the electricity sector is to be structured to promote investment and growth, while at the same time ensuring the security of energy supplies and affordability, accessibility and the sector's ongoing reliability.

Policy needs to decide how the electricity sector can more effectively promote development through investments in local resources, local job creation and local sustainable value addition.

Policy needs to recognise the value and incentivise the productive use of energy.

Policy needs to establish benchmarks for the efficient and beneficial long-term use of local resources, including the country's renewable energy resources.

Policy needs to create the framework conditions for national and international partnerships that can transform the country's electricity supply sector from being import-dependent to a local use and value-adding sector, benefiting from the country's renewable energy resources.

Policy needs to ensure that energy initiatives have an overall positive impact on Namibia's economy – focused on job creation, development and the protection of the country's brittle environment.

As for Namibia's immediate electricity supply challenges, these cannot be addressed over night. However,

- decisively tackling the structural impediments in the electricity sector
- creating electricity tariffs that incentivise investments, including the regulated and unfettered access to the transmission and distribution grids
- incentivising demand side management measures, including the rapid roll-out of solar water heaters, and
- incentivising energy efficiency measures, including the provision of energy audits, especially in Government buildings, commerce and industry

will lead to electricity savings from year one onwards, while creating the necessary momentum for change to embark on a sustainable national energy future.

New value bundles await to be unpacked, and *it is for policy to initiate this critical process*. Namibia's sustainable resource base, specifically our solar, wind and biomass resources, can be the backbone on which a broad-based sustainable and environmentally benign development can be built. *The time has come to act.*

7 A 7-Point Action Plan for Namibia's Electricity Sector

This chapter briefly presents an electricity sector scenario that illustrates the impact that the bundled implementation of renewable energy and energy efficient technologies would have on the Namibian electricity sector, and the role these technologies can play in relieving the country's current electricity supply challenges.

The purpose of the 7-point action plan is to stimulate debate by illustrating what could be achieved if a more pro-active approach to the introduction of renewable energy and energy efficient technologies were to be pursued nationally.

A word of caution: The content of this chapter, in all fairness, remains conceptual in nature, and has definite limitations. The author wishes to point out that the content of this chapter cannot be considered a final blueprint for how Namibia's electricity sector challenges can be overcome in their totality. The intention, however, is to put forward a scenario that showcases the multiple opportunities that can be created if renewable energy and energy efficient technologies are employed more deliberately.

The 7-point action plan for Namibia's electricity sector is based on a bundle of initiatives that are undertaken in the next 6 years, comprising the following [7.1]:

1. **Initiative 1:** the systematic replacement of electric water heaters by solar water heaters, leading to the replacement of 100,000 EWH with SWH over 6 years
2. **Initiative 2:** the execution of a domestic energy efficiency program, leading to electricity savings of some 20% in each of 80,000 targeted homes over 6 years
3. **Initiative 3:** the roll-out of an energy efficiency program focusing on Government buildings, commercial and industrial entities and manufacturers, leading to electricity savings of some 15% in each of 1,200 participating entities over 6 years
4. **Initiative 4:** the introduction of a grid-connected solar photovoltaic roll-out program, leading to the establishment of 25,000 grid-connected solar PV systems of 3.6 kW_p each over 6 years (IPP development is not included here)
5. **Initiative 5:** the establishment of multiple wind farms, mainly along the country's coastline, leading to the establishment of wind farms with a total generation capacity of 90 MW over 6 years
6. **Initiative 6:** the establishment of multiple mid-sized (between 5 and 10 MW each) bush-to-electricity power plants, leading to a total generation capacity of 100 MW over 6 years, and
7. **Initiative 7:** the establishment of multiple concentrating solar power plants with storage and/or co-firing capabilities using biomass and/or natural gas, leading to a total generation capacity of 100 MW over 6 years.

The individual and total contribution of the 7-point action plan described above, when related to Namibia's total projected electricity demand, is shown in Figure 55. The impact that the 7-point action plan would have on the country's projected peak electricity demand is shown in Figure 56.

Figure 57 shows how Namibia can meet its demand for electrical energy, by including the following generation plants:

1. Ruacana hydro-electric power plant contributing 332 MW at an average of 30%
2. Van Eck contributing 50 MW at 30%, and retiring from year 5
3. Paratus contributing 10 MW at 10%, and retiring from year 4
4. Anixas contributing 22 MW at 15%, and used as peaking power plant only
5. establishing an additional 150 MW base load plant at 80% availability, which is to become operational from year 4 onwards
6. generating electricity as well as energy savings through the implementation of the 7-point action plan as introduced above, and
7. plugging supply shortfalls with imports, which are essential in years 1 to 3, while creating some surplus capacity for exports between years 5 to 10.

How and by whom could the 7-point action plan be implemented? A key pre-requisite to the initiation of an electricity action and savings plan as diverse as the 7-point action plan presented in this chapter is the willingness to show leadership in the country's energy sector. Here, key role-players are the Ministry of Mines and Energy, the Electricity Control Board, NamPower, the three operational REDs, and other distribution entities. A project concept based on the 7-point action plan must include inputs from the Ministry of Finance, and may best be coordinated from and through the National Planning Commission, or possibly as a high-priority national program directly from the Office of the President.

Namibia's electricity sector in 2012 is shown in Figure 60. The existing generation capacity cannot meet the country's future demand for electricity. The sector is in need of bold, courageous and expeditious action. A visionary energy plan for Namibia's future is urgently required, to allow us to create a national sustainable energy future. The 7-point action plan introduced in this chapter may provide some food for thought for what can and should be done.

A diverse and multi-faceted future electricity sector, as depicted in Figure 61, may serve as inspiration. Realising the immense potentials that the accelerated use of local renewable energy resources can play in the country's socio-economic development, the time has now come that Namibians afford the country's energy future the urgency it must enjoy if the lights are to remain on. ***The time to act is now.***

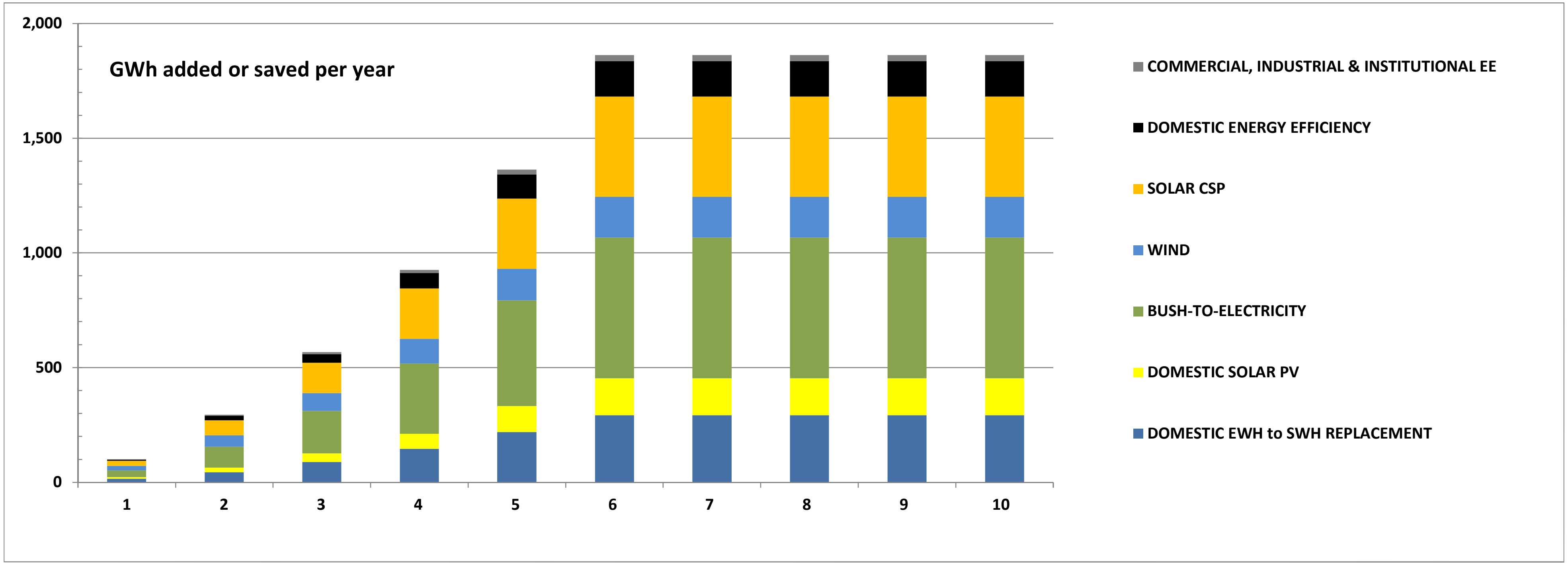

Figure 55: Individual and cumulative electrical energy provided by way of the implementation of the 7-point action plan, in GWh per year [7.1]

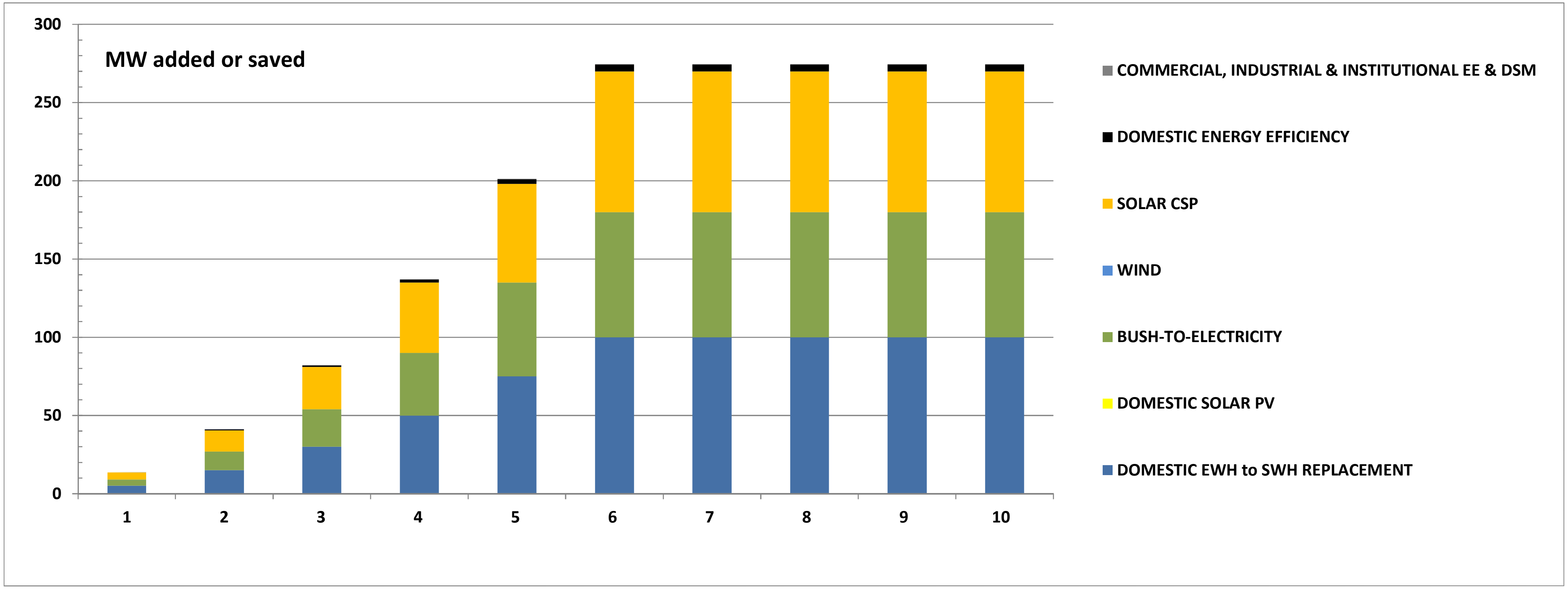

Figure 56: Individual and cumulative contribution to the peak electricity demand provided through the implementation of the 7-point action plan, in MW [7.1]

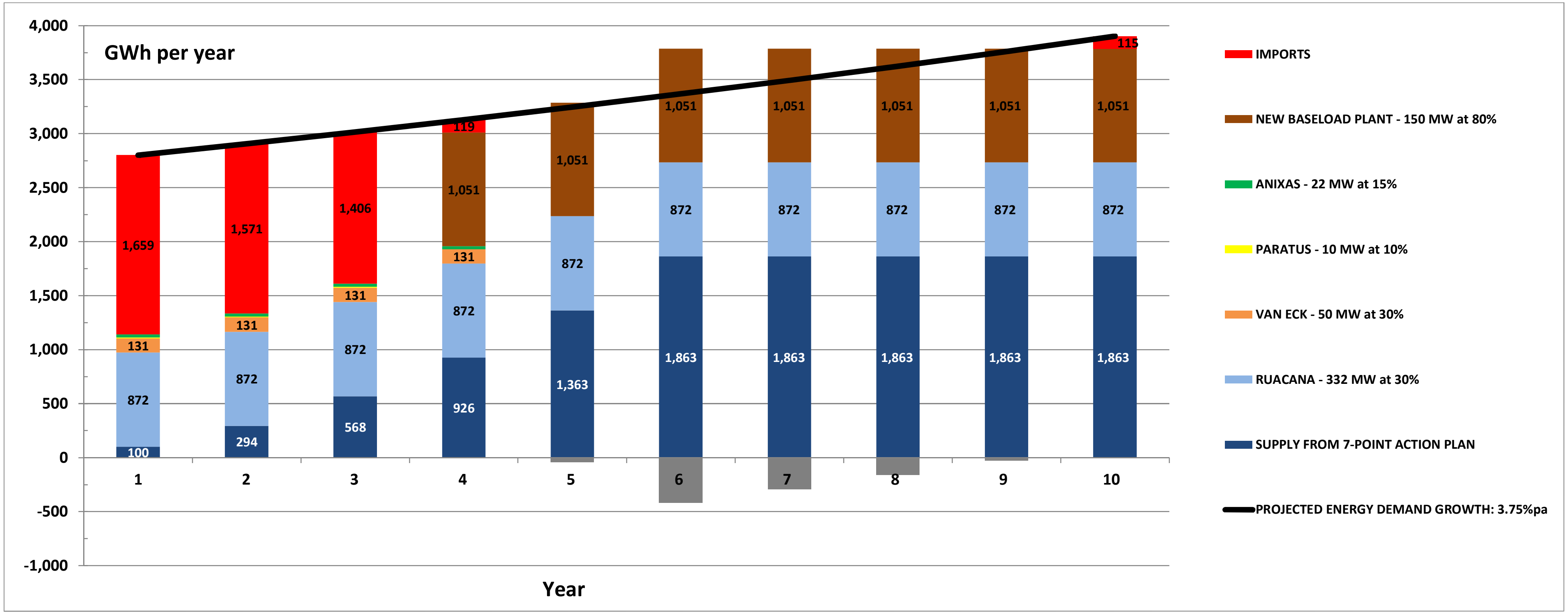

Figure 57: Projected electricity supply scenario, showing the forecast demand for electricity (excluding Skorpion Zinc Mine, Orange River projects and exports) increasing at a hypothetical rate of 3.75% per year (black line), and highlighting the role of electricity imports required (red bars), showing new base load capacity (brown) as well as existing power plants including Anixas (green), Paratus (yellow), van Eck (orange), Ruacana (light blue), and the cumulative supply / savings realised by way of the implementation of the 7-point action plan (dark blue). Years in which local generation and savings exceed the projected local demand allow for exports, which are indicated as grey bars in years 5 to 10 [7.1]

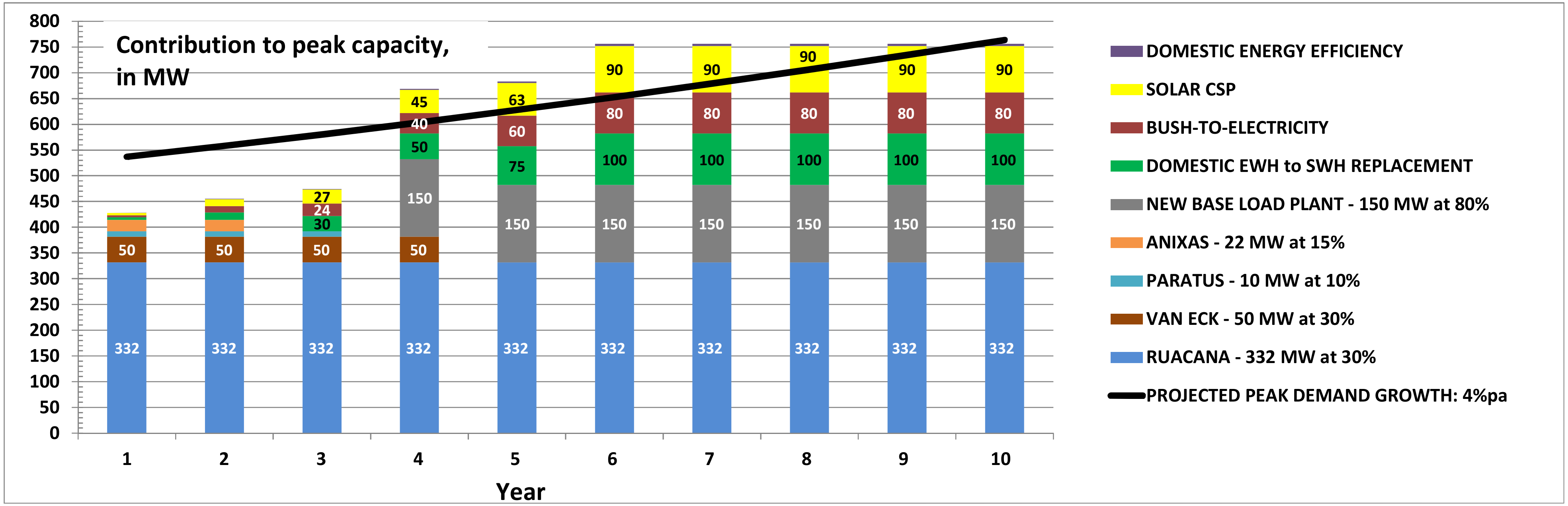

Figure 58: Projected growth of peak demand, at a hypothetical rate of 4% per year (black line), relative to the peak demand contributions from the four local generation power plants plus the individual impact of actions implemented through the 7-point action plan. It is evident that the capacity added by way of the 7-point action plan can make for a sizeable contribution to the country's peak electricity demand. Note that the above figure conservatively assumes that generation capacity added by way of solar PV and wind power contributions, and commercial EE measures coming on stream through the 7-point action plan, will not contribute to meet the country's peak demand [7.1]

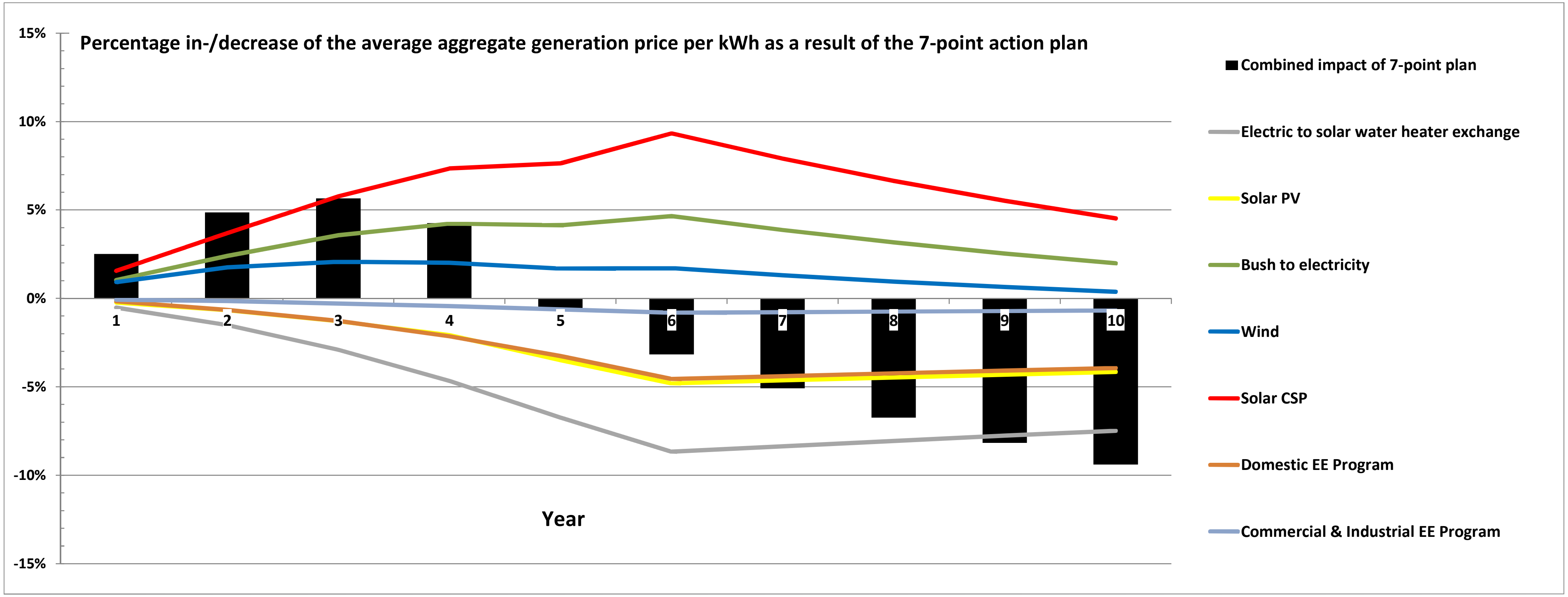

Figure 59: Indicative impact of the individual actions and combined impact of all actions which are part of the 7-point action plan on the average aggregate generation price for electricity in Namibia. As shown, the introduction of solar CSP (red), bush-to-electricity (green) and wind power (blue) is expected to lead to an increase in the aggregate national generation price per kWh, while the combined impact of all actions included in the 7-point action plan is expected to reduce the average aggregate generation price from year 4 onwards, as indicated by the black bars. It is assumed that the EWH-to-SWH exchange program, the solar PV roll-out and the domestic and commercial energy efficiency programs which are part of the 7-point action plan will not be funded through the electricity generation price charged by generators, and the cost of these programs would therefore not have to be recovered through the aggregate national generation price for electrical energy as they are likely to be funded through a combination of private investments, select public sector funding programs as well as potential contributions from development funding entities that do not influence the aggregate electricity price [7.1]

A simplified illustration of Namibia's electricity sector in 2012 is shown in Figure 60.

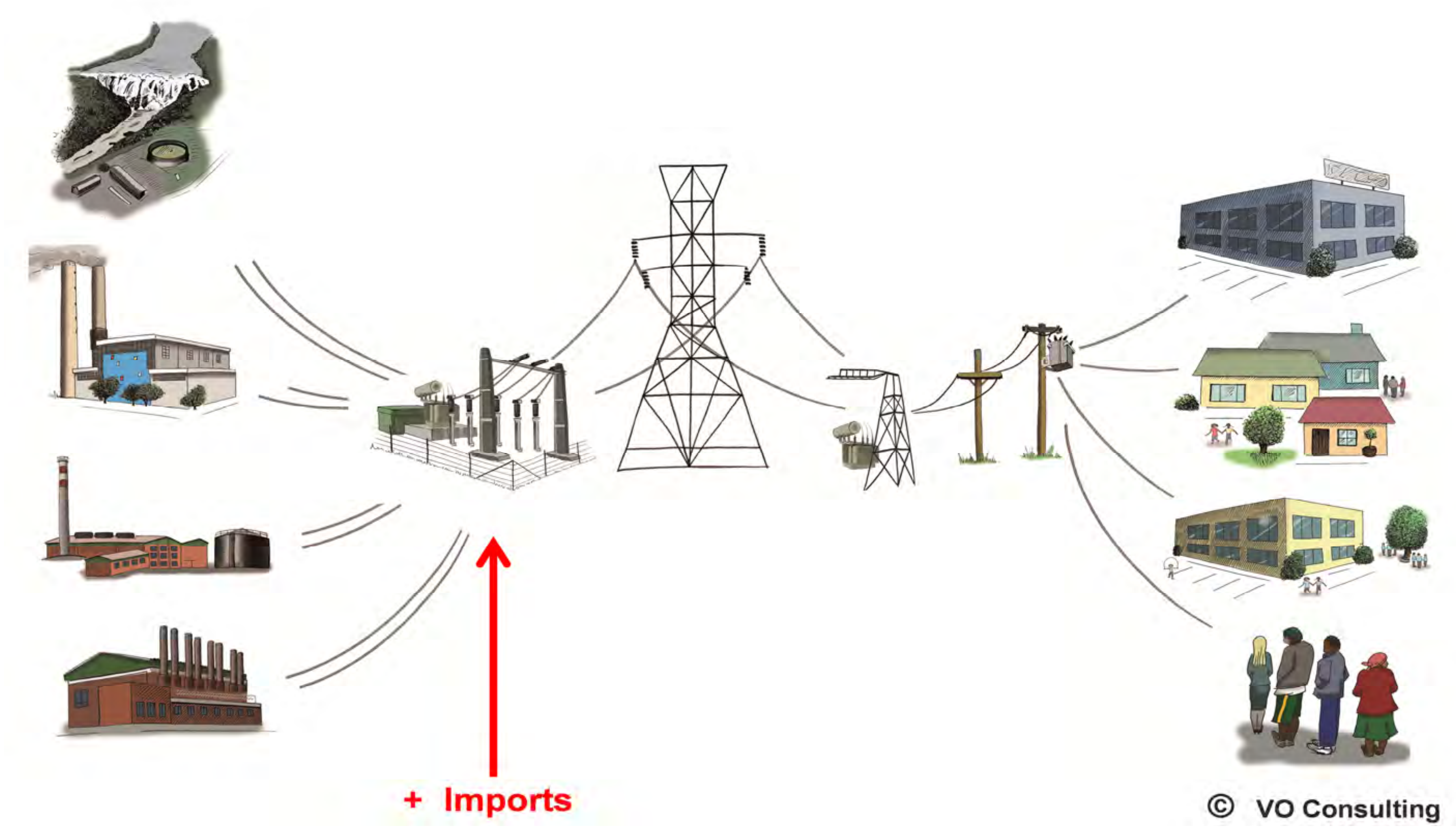

Figure 60: Namibia's electricity sector in 2012 [7.2]

In future, if the lights are to remain on, the country's electricity sector will need to embrace renewable energy generation technologies, as well as energy efficient technologies. In the medium to long-term, the sector is likely to transform as depicted in Figure 61.

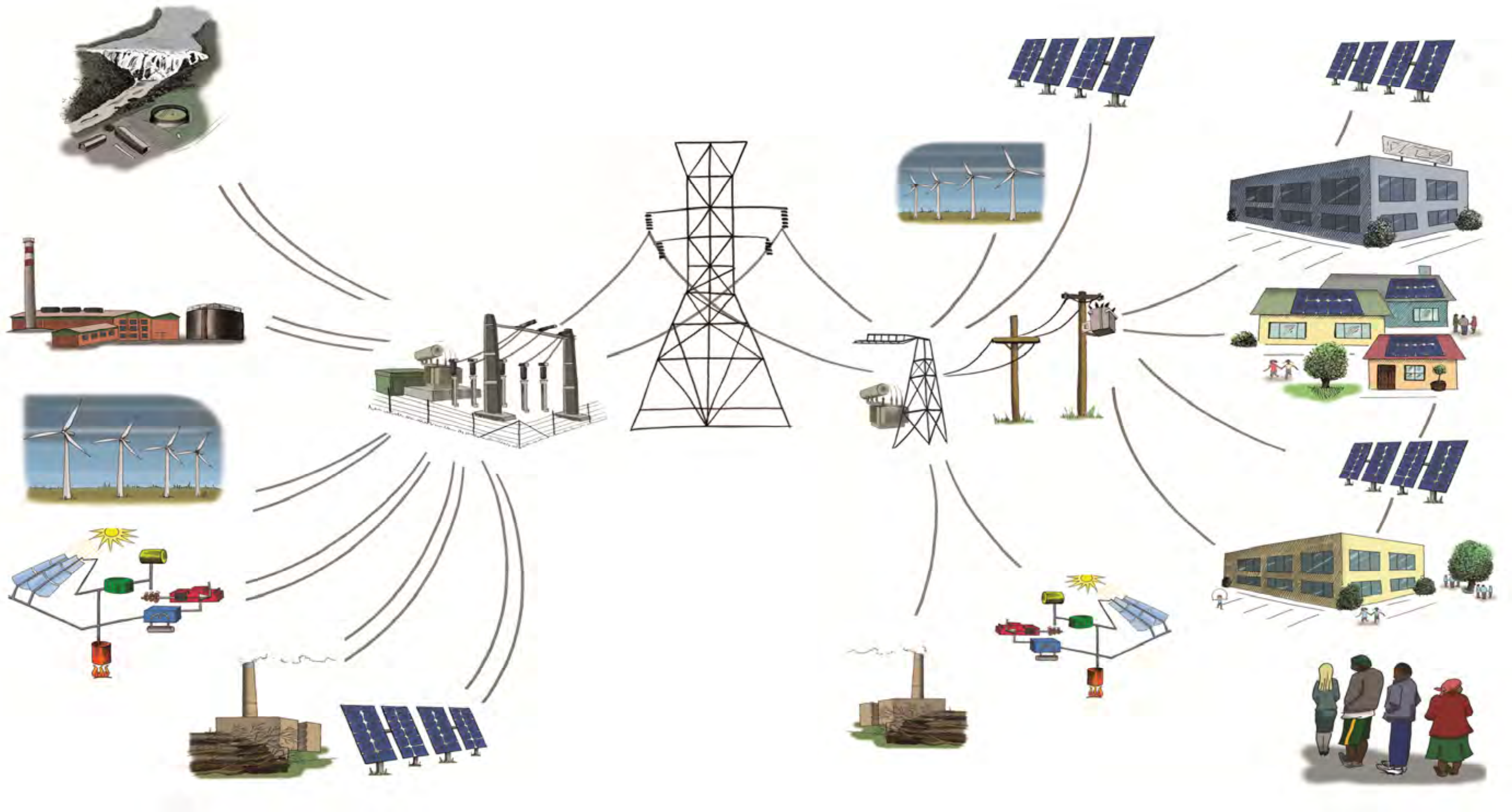

Figure 61: Namibia's future electricity sector, substantially including renewable energy technologies, and benefitting from the widespread use of energy efficient technologies, a smart grid on the consumer side, and numerous demand management practices [7.2]

8 Key Messages

This chapter summarises the study's key messages, and shares a vision on how Namibia's electricity sector can be transformed into a broad-based development machine that can power the nation into the 21st century and beyond.

1. Namibia's abundant solar, wind and biomass resources constitute a national comparative and sustainable advantage.
2. Namibia must more deliberately exploit its renewable energy riches to create long-term socio-economic benefits.
3. The productive use of Namibia's renewable energy resources remains limited. There is no compelling reason why this must continue. Change is necessary.
4. Namibia's energy policy must explicitly recognise the pivotal role that renewable energy and energy efficient technologies can play in powering the nation into the future.
5. Policy has to clearly identify and pronounce the roles, responsibilities and mandates of the various participants in the country's energy sector.
6. Namibia's current electricity sector challenges offer unique opportunities and must re-orient national energy policy towards sustainability, by focusing the sector's long-term development on the deliberate inclusion, targeted use and incentivised beneficiation of local renewable energy resources.
7. Namibia must create development-relevant value through the deliberate decentralisation of electricity generation capabilities, by incentivising the uptake and use of the country's renewable energy resources.

Policy plays a critical role in focusing the electricity sector's role players on the transformation towards sustainability. It is essential to re-visit how Namibia supplies its electricity. A diversification of supplies is needed. New market entrants can infuse much-needed dynamism, innovation, capital and technology know-how.

Improving the clarity of roles and responsibilities in the sector is essential. Ministerial leadership must provide policy direction. Sector-wide integrated planning must shape the country's sustainable energy future. Ad hoc decision-making will not deliver long-term value. A focus on costs *and* benefits is essential.

A vibrant electricity sector which is able to supply affordable and reliable electricity is *the* pre-requisite to power the country's development. Such vibrancy needs to be created by the sector's participants, must be shaped by vision, and implemented by bold, courageous and expeditious action.

A vision of a sustainable energy future that leverages Namibia's renewable energy blessings to the advantage of all can become reality. Not in a decade or two, but starting today. *The time to act is now.*

9 Acknowledgements

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[3.1] Ministry of Mines and Energy, www.mme.gov.na.

[3.2] Photo by AP Photo/Charlie Riedel, http://news.discovery.com/earth/power-lines-contaminants-pcb.html, accessed on 1 August 2012.

[3.3] Photo by VO Consulting, www.voconsulting.net, info@voconsulting.net

[3.4] Photo from NamPower, www.nampower.com.na, as quoted in http://www.investinthecommonwealth.com/?p=713, accessed on 1 August 2012.

[3.5] NamPower, *Energy Plans for Industrialisation*, Presentation by Paulinus Shilamba, Managing Director of NamPower, to the Namibian Chamber of Commerce and Industry Business Summit, 15 June 2012.

[3.6] Artwork by Jenny Beresford, Vocal-Motion, Graphic Design and Illustrations, Swakopmund, Copyright VO Consulting, info@voconsulting.net.

[3.7] Photo from NamPower, showing a new high-voltage transmission line between Zambia and Namibia that allows electricity imports from countries including Zambia, the DRC and Mozambique to Namibia, www.nampower.com.na, accessed on 1 August 2012.

[3.8] Image by VO Consulting, copyright VO Consulting, info@voconsulting.net.

[3.9] Namibia´s Integrated Resource Plan, Electricity Control Board, 2012.

[3.10] Based on analysis and information contained in NamPower's Annual Reports, refer to www.nampower.com.na, accessed on 1 August 2012.

[3.11] At Independence the National Planning Commission estimates the number of Namibians to be 1,377,500, while they were some 2,066,000 Namibians in 2010. This equates to an annual average population growth rate of 2.05% per year over the 20-year period between 1990 and 2010, www.npc.gov.na/census/index.htm, accessed in August 2012.

[3.12] United States Energy Information Administration, www.eia.gov; United States Census Bureau (International Database), www.census.gov/population/international/data/idb/informationGateway.php, accessed in August 2012.

[3.13] http://www.sapp.co.zw/docs/P3_-Overview_of_the_SAPP_Day_Ahead_Market_Trading_Platform_AUGUST_2010.pdf, and http://www.narucpartnerships.org/Documents/3%20Beta%20Energy%20Trading%20in%20SAPP-%20JULY%202009.pdf, accessed on 29 June 2012.

[3.14] Namibia Census, 2001, National Planning Commission, www.npc.gov.na/census/index.htm, accessed on 25 June 2012.

[3.15] Namibian Household Income and Expenditure Survey of 2009/2010, National Planning Commission, www.npc.gov.na, accessed throughout June 2012.

[3.16] Photo provided by Harald Schütt, Amusha Consultancy Services.

[3.17] Data provided by the Electricity Control Board, www.ecb.org.na, accessed in July and August 2012.

[3.18] Estimates are based on work undertaken by VO Consulting, info@voconsulting.net.

[3.19] Glenn Howard, Glynn Morris and Detlof von Oertzen: *Baseline Study on Energy Efficiency in Buildings in Namibia*. Namibia Energy Efficiency Programme (NEEP) in Buildings, Renewable Energy and Energy Efficiency Institute, Polytechnic of Namibia, August 2011.

[3.20] Electricity Control Board, www.ecb.org.na, accessed in August 2012.

[3.21] Data provided by the Electricity Control Board, see [3.20].

[3.22] Discussions with Uli von Seydlitz, Emcon Consulting Group, are gratefully acknowledged.

[4.1] N. de Klerk: *Bush Encroachment in Namibia*. Ministry of Environment and Tourism, Windhoek, Namibia, 2004,
B. Bester: *Major Problem – Bush Species and Densities in Namibia*. Agricola 10: 1-3, 1998.

[4.2] Colin, Christian and Associates: *The Effect of Bush Encroachment on Groundwater Resources in Namibia: A Desk Top Study*. Namibia Agricultural Union, December 2010.

[4.3] Hager, Claus, Robert Schultz and Detlof von Oertzen: *Turning Namibian Invader Bush into Electricity: The CBEND Project*. 12th Congress of the Agricultural Scientific Society of Namibia, Neudamm, Namibia, 2007.

[4.4] Combating Intruder Bush - the Financial Decision, Namibia Agricultural Union: 10, 2000.

[4.5] Honsten, Dagmar and David Joubert: *Incentive Scheme for Invader Bush Management. A Cost Benefit Analysis*, Namibia Agronomic Board, 2009.

[4.6] Dieckmann, U. and T. Muduva: *Namibia's Black Gold? Charcoal Production, Practices and Implications*. Land, Environment and Development Project, Legal Assistance Centre, 2010.

[4.7] Colin, Christian and Associates: *Energy for Future: Bush-to-Fuel Project*, Environmental Impact Assessment, 2010.

[4.8] Strategic Environmental Assessment for Combating Bush Encroachment for Namibia's Development, National Planning Commission Secretariat, Rural

Poverty Reduction Programme 9 ACP Nam 012, Southern African Institute for Environmental Assessment, 2009

[4.9] Mendelsohn, John, Alice Jarvis, Carole Roberts and Tony Robertson: *Atlas of Namibia*. Published by the Ministry of Environment and Tourism by David Philip Publishers, 2002.

[4.10] Ohorongo Cement, Schwenk Group, "*The Development of the Ohorongo Cement and Energy for Future Projects*", Presentation given to the Namibian Manufacturers Association, 16 June 2011, page 86.

[4.11] Leinonen, Arvo: *Wood chip harvesting technology and costs*, VTT, 2007.

[4.12] Based on bush harvesting activities only, under the following assumptions:

Input parameters for bush harvesting & power plant characteristics	Model input
Salary – manual harvester [N$/a]	13,200
Salary – semi-mechanised harvester [N$/a]	15,400
Salary – fully mechanised harvester [N$/a]	24,200
Harvesting yield per person per year - manual only [t/a]	106
Harvesting yield per person per year - semi-mechanised only [t/a]	352
Harvesting yield per person per year - fully mechanised only [t/a]	4,400
Calorific value of dry wood [kWh/kg]	4.0
Average capacity factor of power plant [%]	70%
Gross conversion efficiency [%]	25%
Boiler efficiency [%]	85%

[4.13] Based on the following input variables and model assumptions:

Bush-to-electricity Power	Input Variables & Assumptions					Units
Plant capacity	**0.1**	**0.5**	**1**	**5**	**10**	MW
Plant life	25	25	25	25	25	years
Capital cost	40	35	30	27.5	25	N$ million per MW
Number of staff	6	10	18	22	30	direct employees
Direct staff cost			60,000			N$ per person in year 1
O&M fixed	2.75%	2.75%	2.75%	2.5%	2.25%	of capex per year
O&M variable	120	110	100	95	90	N$/ton of wood in year 1
Fuel – excl. chipping and transport	130	130	130	130	130	N$/ton of wood in year 1
Transport	9.00	9.00	8.00	6.00	5.00	N$ per ton per km in year 1
Av. transport distance	6	13	18	38	54	km to plant
Tons of wet wood required	800	3,700	7,300	36,100	72,200	tons of wet wood per year
Capacity factor	70.0%	70.0%	72.5%	75.0%	77.5%	%
Cost of chipping			50.00			N$/ton of chipped wood
Cost of capital (nominal)	10%	10%	10%	10%	10%	% per year
Discount rate (nominal)	15%	15%	15%	15%	15%	%
Annual inflation rate	6.0%	6.0%	6.0%	6.0%	6.0%	% per year

[4.14] Photo provided by Harald Schütt, Amusha Consultancy Services.

[4.15] Photo provided by Dr Robert Hopperdietzel, HopSol.

[4.16] The electric output from solar photovoltaic plants in Namibia depends on the type of PV panels used, their orientation and location. Based on the experiences of some of the larger solar PV plant installed and operating in Namibia, the output is in the range between 1,600 kWh/kW$_p$ and

approximately 2,100 kWh/kW$_p$, where kW$_p$ refers to the solar PV plant's nameplate peak output capacity in kW.

[4.17] Map prepared by GeoModel Solar, and provided by the Renewable Energy and Energy Efficiency Institute, Polytechnic of Namibia on 30 July 2012.

[4.18] Based on personal interviews with leading suppliers of solar technology in Namibia, in June and July 2012; names are withheld to ensure the confidentiality of different pricing policies applied by local suppliers.

[4.19] Graph by VO Consulting, info@voconsulting.net.

[4.20] Assuming a 1 kW$_p$ model PV plant costing N$27,500, purchased through a loan over 20 years with an annual interest rate of 12.5% per annum, in an area yielding 1,850 kWh/kW$_p$, displacing electricity of N$1.50/kWh in year 1, escalating as described below. The LCOE is calculated using a discount rate of 15%; PV panel output degradation is assumed to be 0.5% per year. Domestic electricity prices are assumed to escalate at 15% per year for four years, and thereafter 7% per year for the remainder of the loan period.

[4.21] If the complete installation of a 1 kW$_p$ system costs N$27,500, then a once-off rebate of N$ 7,400 would reduce the upfront capital requirement to N$ 20,100, which render the model solar PV system cash-positive from year 1 onwards.

An interest rate subsidy, from a commercial rate of 12.5% per annum on the outstanding loan amount to 7.85% per annum renders the model solar PV system cash-positive from year 1 onwards.

A cash-neutral guarantee of N$ 1,809 covers the funding gap between repayment and savings from the model solar PV system during years 1 to 3 of operations; with the year 1 shortfall being N$ 1,023, year 2 of N$ 622 and year 3 of N$ 164.

A combination of the above could entail the lowering of capital costs from N$27,500/kW$_p$ to N$24,000/kW$_p$ (which the market would quite likely achieve through an enhancement of the economies of scale), a lowering of the loan interest rates from the commercial rate of 12.5% per annum to 11% per annum (which is realistic as increases in loan volumes are substantial), and a year 1 cash-neutral subsidy of N$ 239.

[4.22] Based on the following input variables and model assumptions:

Solar PV Power	Input Variables & Assumptions			Units
Plant capacity	**1**	**5**	**10**	MW
Plant life	25	25	25	years
Capital cost	23.0	21.5	20	N$ million per MW$_p$
O&M fixed	1.5%	1.5%	1.5%	% of total capital cost
O&M variable	0.0%	0.0%	0.0%	% of total capital cost
Yield	1,850	1,850	1,850	kWh/kWp/annum
Insurance	0.00%	0.00%	0.00%	% of total capital cost
Interim replacement cost	0.00%	0.00%	0.00%	% of total capital cost
Cost of capital	10.0%	10.0%	10.0%	% per year
Discount rate	15.0%	15.0%	15.0%	%
Inflation	6.0%	6.0%	6.0%	% per year

[4.23] The number of electric water heaters in Namibia is estimated as follows: in 2011, Namibia had a population of almost 2,200,000. Assuming a household size of 5 persons per household, the approximate number of households amounts to 2,200,000/5 = 440,000 households. Of these, some 55% or 242,000 households are classified as rural, many of which would either not use electric water heaters at all because they are not connected to the electricity grid, or do not regularly use such technologies. Assuming that some 70% of urban households use electrical energy including electric water heaters regularly or occasionally, and that one electric water heater is installed per such household, one finds the approximate number of domestic electric water heaters installed in 2011 is of the order of 130,000.

[4.24] Peak demand – according to NamPower, a national peak demand of 516 MW was recorded at 19h00 on 07 June 2012; Paulinus Shilamba, Managing Director: NamPower, Energy Plans for Industrialisation, Presentation to the Namibian Chamber of Commerce and Industry Business Summit, 15 June 2012 Paulinus Shilamba, Managing Director: NamPower, Energy Plans for Industrialisation, Presentation to the Namibian Chamber of Commerce and Industry Business Summit, 15 June 2012.

[4.25] Photo provided by Heinrich Steuber, SolTec cc.

[4.26] Shower: heating 30 litres of water from an inlet water temperature of 18°C to 50°C requires 1.1 kWh of energy, excluding losses.
Bath: heating 100 litres of water from an inlet water temperature of 18°C to 50°C requires 3.7 kWh of energy, excluding losses.

[4.27] Assuming that a typical 5-person household will use a shower three times per day at 30 litres each, and two baths at 100 litres each day, thus requiring 3 x 1.1 + 2 x 3.7 kWh = 10.7 kWh per day.

[4.28] A 5-person household can expect to use some 300 kWh of electrical energy per month for hot water services alone. Of course, this figure varies very substantially from one domestic setting to another one, and therefore only provides an order of magnitude ball-park figure rather than an exact Namibian average value.

[4.29] Ministry of Mines and Energy, Annual Report 2007/8, Period of Review 1 April 2007 to 31 March 2008, accessed in August 2012, www.mme.gov.na/pdf/mme-annualreport-r08-low-res2.pdf.

[4.30] VO Consulting, info@voconsulting.net.

[4.31] The annual price escalation of electricity tariffs is based on regional trends as well as direct indications from the Electricity Control Board and NamPower as to the most likely price path of electricity prices in Namibia. Based on a recent NamPower presentation, refer to [4.24], the cost per kWh of electrical energy is expected to rise from N$0.90/kWh in 2012 to N$1.60/kWh in 2016, i.e. an average wholesale price escalation of 15% per annum. Usually, retail prices of electricity, such as those by the Regional Electricity Distributors, local authorities and others who are engaged in the sale of electricity to end consumers, escalate on average at least as much as wholesale prices do.

[4.32] Artwork by Jenny Beresford, Vocal-Motion, Graphic Design and Illustrations, Swakopmund, Copyright VO Consulting, info@voconsulting.net.

[4.33a] Solar trough system: parabolic trough at Kramer Junction in the Mojave desert in California, USA, http://whatwow.org/parabolic-trough/a-broad-view-of-parabolic-trough-solar-collectors-at-kramer-junction-in-the-mojave-desert-in-california/ , accessed in August 2012.

[4.33b] Fresnel system: Ausra, http://www.energy.ca.gov/reti/steering/2008-06-18_meeting/SOLAR_FS-Compact_Linear_Fresnel_Reflector.pdf.

[4.33c] Power tower: Abengoa Solar, http://www.abengoasolar.com/corp/web/es/galeria/ , accessed in August 2012.

[4.33d] Parabolic dish: http://1.bp.blogspot.com/-pjkZ3Z17QvA/T6YmNP7J4aI/AAAAAAAAAGU/1GP87yD2YeI/s1600/image_pv.jpg, accessed in August 2012.

[4.34] Pre-feasibility Study for CSP in Namibia, Gesto Energy, Renewable Energy and Energy Efficiency Institute at the Polytechnic of Namibia, July 2012.

[4.35] Map prepared by GeoModel Solar, and provided by the Renewable Energy and Energy Efficiency Institute, Polytechnic of Namibia on 30 July 2012.

[4.36] See for example: http://www.thesolardryer.com/su/concentratingsolarpower/concentratingsolarpower.htm, accessed in August 2012.

[4.37] Indicative cost per kWh for parabolic trough CSP power plants in year 1, refer to model input variables and assumptions listed in [4.40].

[4.38] Indicative energy output per year for parabolic trough CSP power plants equipped with co-firing capacity and storage allowing for energy generation for an additional 6 hours per day, refer to model input variables and assumptions listed in [4.40].

[4.39] The indicative levelised cost of energy (LCOE) for coal-fired power plants, if built in Namibia in 2012, are

Coal-fired Power Plant	50 MW	100 MW	200 MW
Levelised cost of energy – no carbon tax [N$/kWh]	1.39	1.27	1.17
Levelised cost of energy – including a carbon tax of N$200/$t_{carbon}$ [N$/kWh]	1.59	1.48	1.38

The above-mentioned LCOE calculations are based on the following input variables and assumptions:

Coal-fired Power Plant	Input Variables & Assumptions			Units
Plant capacity	**50**	**100**	**200**	MW
Plant life	30	30	30	years
Capital cost - plant	20	17.5	15	N$ million per MW
O&M fixed	3.00%	2.75%	2.50%	% of total capital cost
O&M variable	3.50%	3.25%	3.00%	% of total capital cost
Interim replacement cost	0.300%	0.275%	0.250%	% of total capital cost

Fuel - cost of coal per ton	1,200	1,200	1,200	N$ per ton in year 1
Energy content of coal	27.91	27.91	27.91	GJ/ton_{coal}
Net heat rate	11,600	11,600	11,600	kJ/kWh
Capacity factor	78.0%	80.5%	83.0%	%
Carbon tax	*1	*1	*1	$N\$/ton_{carbon}$
Carbon emission	88.4	88.4	88.4	kg_{carbon}/GJ
Cost of capital	10.0%	10.0%	10.0%	% per year
Discount rate	15.0%	15.0%	15.0%	%
Inflation	6.0%	6.0%	6.0%	% per year

*1: A fixed nominal amount of N$200/ton of carbon is assumed in the LCOE calculation for coal-fired plants that take a carbon tax into account, refer to Figure 54 on page 81.

[4.40] Indicative levelised cost of energy calculations for parabolic trough CSP power plants are based on the following input variables and assumptions:

CSP Power Plant	Input Variables & Assumptions			Units
Plant capacity	5	10	50	MW
Plant life	20	20	20	years
Capital cost - plant	45	42.5	40	N$ million per MW
O&M fixed	2.0%	1.75%	1.5%	% of total capital cost
O&M variable	1.0%	0.75%	0.5%	% of total capital cost
Hybrid addition / storage	6	6	6	hours per day
Solar to electric efficiency	10.0%	11.0%	12.0%	%
DNI solar resource	2,400	2,400	2,400	$kWh/m^2/year$
Aperture of plant	42,000	84,000	420,000	m^2 of solar field
Interim replacement cost	0.25%	0.25%	0.25%	% of total capital cost
Plant availability	80.0%	85.0%	90.0%	%
Cost of capital (nominal)	10.0%	10.0%	10.0%	% per year
Discount rate (nominal)	15.0%	15.0%	15.0%	%
Inflation	6.0%	6.0%	6.0%	% per year

[4.41] von Oertzen, Detlof, Reimo Bauer, REEE 1/1998, Assessment of Solar and Wind Resources in Namibia, Ministry of Mines and Energy.

[4.42] Deutsche Energie Consult Ingenieursgesellschaft mbH, 1999, Project Studies for Wind Parks in Walvis Bay and Lüderitz, Project No 97.2119.4-001.02, Terna Namibia, VN 81015042, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ).

[4.43] http://www.united.com.na/Projects.htm, accessed on 1 August 2012.

[4.44] http://www.namibian.com.na/news/marketplace/full-story/archive/2012/june/article/nampower-considers-agreements-with-independent-power-producers/ states that
"[…] Electrawind, a 60-megawatt farm at Walvis Bay, informed NamPower in June last year that the power outputs were disappointing. It said it will explore the possibility of a smaller wind plant at Lüderitz and a larger one at Oranjemund with coordinated operation with the Kudu gas project. It has, however, not yet confirmed whether it will abandon the Walvis Bay site. Innowind, also a 60-megawatt plant near Walvis Bay, has approved an energy tariff of N$1.14 per kilowatt-hour, but according to Katali is not

willing to accept a number of risks. NamPower is willing to pay the fee, but is also not willing to stand for the risks.", accessed in August 2012.

[4.45] A wind farm with an installed capacity of 50 MW and average annual capacity factor of 22% generates some 96 GWh of electrical energy per year.

[4.46] Image by VO Consulting, info@voconsulting.net.

[4.47] http://www.vortex.es/africa-wind-map, accessed on 1 August 2012, and Vestas, WindTalks Namibia, 2 November 2011, page 17.

[4.48] Artwork by Jenny Beresford, Vocal-Motion, Graphic Design and Illustrations, Swakopmund, Copyright VO Consulting, info@voconsulting.net.

[4.49] Indicative revenue requirement per unit of electricity for wind farms in year 1, based on model input variables and assumptions listed in [4.51].

[4.50] Indicative energy output per year for wind farms, in GWh per year, based on model input variables and assumptions listed in [4.51].

[4.51] Levelised cost of energy for three different wind farms, expressed in N$/kWh, is calculated using the following inputs and assumptions:

Wind Power Plant	Input Variables & Assumptions			Units
Plant capacity	20	50	100	MW
Plant life	20	20	20	years
Capital cost - plant	18.0	17.0	15.0	N$ million per MW
O&M fixed	3.00%	2.75%	2.50%	% of total capital cost
O&M variable	0.00%	0.00%	0.00%	% of total capital cost
Interim replacement cost	0.30%	0.275%	0.25%	% of total capital cost
Capacity factor	20.0%	21.5%	23.0%	%
Cost of capital (nominal)	10.0%	10.0%	10.0%	% per year
Discount rate (nominal)	15.0%	15.0%	15.0%	%
Inflation	6.0%	6.0%	6.0%	% per year

[5.1] VO Consulting, info@voconsulting.net.

[5.2] Environmental and Socio- Economic Impact Assessment: Proposed Coal-Fired Power Station in Erongo, http://www.nampower.com.na/pages/erongo-coal-fired-power-station-eia-downloads.asp, accessed on 18 July 2012.

[7.1] The 7-point action plan is based on the following model assumptions:

7-point energy plan – ENERGY PERSPECTIVE	Assumptions
Domestic EWH to SWH replacement	Replacement saves 8 kWh per benefitting household per day
Domestic solar photovoltaics	Install a 3.6 kW_p solar PV plant per participating household, each yielding 1,800 kWh/kW_p/year
Bush-to-electricity generation	Plants have an average annual capacity factor of 70%
Wind energy generation	Plants have an average annual capacity factor of 22.5%
Solar CSP generation	Plants include storage and/or co-firing capacity and have an average annual capacity factor of 50%

Domestic energy efficiency program, over and above the replacement of EWH with SWH	Reducing consumption by 20% in each participating household, each consuming 9,600 kWh per month before the intervention
Commercial, industrial and institutional energy efficiency and demand side management program	Reducing consumption by 15% in each of the targeted entities, each consuming 150 MWh electrical energy per year before the intervention

		YEAR	1	2	3	4	5	6	7	8	9	10
	INITIATIVE PER YEAR	CUMULATIVE INITIATIVE	GWh electrical energy contributed or saved									
DOMESTIC EWH to SWH REPLACEMENT [households]	5,000	5,000	15									
	10,000	15,000		44								
	15,000	30,000			88							
	20,000	50,000				146						
	25,000	75,000					219					
	25,000	100,000						292	292	292	292	292
DOMESTIC SOLAR PV [households]	1,000	1,000	6									
	2,000	3,000		19								
	3,000	6,000			39							
	4,000	10,000				65						
	7,500	17,500					113					
	7,500	25,000						162	162	162	162	162
BUSH-TO-ELECTRICITY [MW plant capacity]	5	5	31									
	10	15		92								
	15	30			184							
	20	50				307						
	25	75					460					
	25	100						613	613	613	613	613
WIND [MW plant capacity]	10	10	20									
	15	25		49								
	15	40			79							
	15	55				108						
	15	70					138					
	20	90						177	177	177	177	177
SOLAR CSP [MW plant capacity]	5	5	22									
	10	15		66								
	15	30			131							
	20	50				219						
	20	70					307					
	30	100						438	438	438	438	438
DOMESTIC ENERGY EFFICIENCY [households]	2,500	2,500	5									
	7,500	10,000		19								
	10,000	20,000			38							
	15,000	35,000				67						
	20,000	55,000					106					
	25,000	80,000						154	154	154	154	154
COMMERCIAL, INDUSTRIAL & INSTITUTIONAL EE & DSM [participating entities]	100	100	2									
	100	200		5								
	200	400			9							
	200	600				14						
	300	900					20					
	300	1,200						27	27	27	27	27
		ENERGY [GWh]	100	294	568	926	1,363	1,863	1,863	1,863	1,863	1,863

7-point energy plan – CAPACITY PERSPECTIVE	Assumptions
Domestic EWH to SWH replacement	50% of EWH would have been on during the evening peak, and are now off as a result of the replacement with SWH; 2 kW per EWH
Domestic solar photovoltaics	no firm contribution to evening peak demand
Bush-to-electricity generation	80% of installed capacity is available and can be dispatched during the evening peak

Wind energy generation	no firm contribution to evening peak demand
Solar CSP generation	90% of installed capacity is available and can be dispatched during the evening peak
Domestic energy efficiency program, over and above the replacement of EWH with SWH	20% of the load required before the program was undertaken is removed from the evening peak
Commercial, industrial and institutional energy efficiency and demand side management program	10% of the load required before the program was undertaken is removed from the evening peak

YEAR	1	2	3	4	5	6	7	8	9	10
	MW peak demand contributed or saved									
DOMESTIC EWH to SWH REPLACEMENT [MW saved in peak time]	5									
		15								
			30							
				50						
					75					
						100	100	100	100	100
DOMESTIC SOLAR PV [MW added]										
BUSH-TO-ELECTRICITY [MW added]	4									
		12								
			24							
				40						
					60					
						80	80	80	80	80
WIND [MW added]										
SOLAR CSP [MW added]	5									
		14								
			27							
				45						
					63					
						90	90	90	90	90
DOMESTIC ENERGY EFFICIENCY [MW saved in peak time]	0									
		1								
			1							
				2						
					3					
						4	4	4	4	4
COMMERCIAL, INDUSTRIAL & INSTITUTIONAL EE & DSM [MW saved in peak time]	0.0									
		0.1								
			0.1							
				0.2						
					0.3					
						0.4	0.4	0.4	0.4	0.4
CONTRIBUTION TO PEAK [MW]	**14**	**41**	**82**	**137**	**201**	**275**	**275**	**275**	**275**	**275**

To assess the ***order of magnitude*** **of the impact of the proposed 7-point plan on the average aggregate selling price per kWh in Namibia**, it is assumed that:

- demand for electrical energy excludes the use by Skorpion Zinc Mine, the Orange River Projects, exports and losses
- the annual average aggregate electricity generation price is N$0.67/kWh in year 1
- the annual average aggregate electricity generation price per kWh increases by 15% per year between years 1 to 5, while increasing by 7% per year between years 5 to 10, and
- that a revenue requirement of zero is assumed for all action plan activities which do not have to be funded through the national generation price.

	YEAR	1	2	3	4	5	6	7	8	9	10	Unit
	Total energy demanded *1	2,801	2,906	3,015	3,128	3,246	3,367	3,494	3,625	3,761	3,902	GWh/a
	Assumed annual average aggregate generation price	0.67	0.77	0.89	1.02	1.17	1.25	1.34	1.44	1.54	1.64	N$/kWh
Electric to solar water heater exchange	Energy contribution	15	44	88	146	219	292	292	292	292	292	GWh/a
	Revenue requirement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N$/kWh
	Weighted price	0.667	0.759	0.860	0.971	1.093	1.145	1.229	1.320	1.417	1.521	N$/kWh
	% in/decrease	-0.5%	-1.5%	-2.9%	-4.7%	-6.7%	-8.7%	-8.4%	-8.1%	-7.8%	-7.5%	%
Solar PV	Energy contribution	6	19	39	65	113	162	162	162	162	162	GWh/a
	Revenue requirement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N$/kWh
	Weighted price	0.668	0.765	0.875	0.998	1.131	1.194	1.279	1.371	1.470	1.575	N$/kWh
	% in/decrease	-0.2%	-0.7%	-1.3%	-2.1%	-3.5%	-4.8%	-4.6%	-4.5%	-4.3%	-4.2%	%
Bush to electricity	Energy contribution	31	92	184	307	460	613	613	613	613	613	GWh/a
	Revenue requirement	1.31	1.35	1.41	1.46	1.51	1.57	1.64	1.70	1.78	1.85	N$/kWh
	Weighted price	0.677	0.789	0.918	1.062	1.220	1.312	1.394	1.481	1.575	1.676	N$/kWh
	% in/decrease	1.0%	2.4%	3.6%	4.2%	4.1%	4.6%	3.9%	3.2%	2.5%	2.0%	%
Wind	Energy contribution	20	49	79	108	138	177	177	177	177	177	GWh/a
	Revenue requirement	1.55	1.57	1.59	1.61	1.63	1.66	1.69	1.72	1.75	1.78	N$/kWh
	Weighted price	0.676	0.784	0.904	1.039	1.192	1.275	1.359	1.449	1.546	1.650	N$/kWh
	% in/decrease	0.9%	1.8%	2.1%	2.0%	1.7%	1.7%	1.3%	1.0%	0.6%	0.4%	%
Solar CSP	Energy contribution	22	66	131	219	307	438	438	438	438	438	GWh/a
	Revenue requirement	2.01	2.03	2.06	2.09	2.12	2.15	2.19	2.22	2.26	2.31	N$/kWh
	Weighted price	0.680	0.799	0.937	1.094	1.261	1.371	1.448	1.531	1.621	1.718	N$/kWh
	% in/decrease	1.6%	3.7%	5.8%	7.3%	7.6%	9.3%	7.9%	6.6%	5.5%	4.5%	%
Domestic EE Program	Energy contribution	5	19	38	67	106	154	154	154	154	154	GWh/a
	Revenue requirement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N$/kWh
	Weighted price	0.669	0.765	0.875	0.997	1.134	1.197	1.283	1.375	1.473	1.579	N$/kWh
	% in/decrease	-0.2%	-0.7%	-1.3%	-2.1%	-3.3%	-4.6%	-4.4%	-4.2%	-4.1%	-3.9%	%
Commercial & Industrial EE Program	Energy contribution	2	5	9	14	20	27	27	27	27	27	GWh/a
	Revenue requirement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N$/kWh
	Weighted price	0.669	0.769	0.883	1.015	1.165	1.244	1.331	1.425	1.525	1.632	N$/kWh
	% in/decrease	-0.1%	-0.2%	-0.3%	-0.4%	-0.6%	-0.8%	-0.8%	-0.7%	-0.7%	-0.7%	%
Combined impact of 7-point plan	Energy contribution ALL	100	294	568	926	1,363	1,863	1,863	1,863	1,863	1,863	GWh/a
	Revenue requirement ALL	1.14	1.14	1.15	1.17	1.15	1.18	1.21	1.25	1.28	1.32	N$/kWh
	Weighted price	0.687	0.808	0.936	1.062	1.164	1.214	1.273	1.339	1.411	1.489	N$/kWh
	% in/decrease	2.5%	4.9%	5.6%	4.3%	-0.7%	-3.2%	-5.1%	-6.7%	-8.2%	-9.4%	%

*1 excluding Skorpion Mine, the Orange River Projects and electricity exports

[7.2] Artwork by Jenny Beresford, Vocal-Motion, Graphic Design and Illustrations, Swakopmund, Copyright VO Consulting, info@voconsulting.net.

Appendix A: Terms of Reference of the Study

This Study is guided by Terms of Reference (ToR). The scope of the Study is to include:

- an introduction to the Namibian electricity sector, sketching out the most important developments in regard to the country's national demand and supply situation;
- an overview of how electricity is generated, distributed and sold in Namibia;
- an exposition of the electricity industry, and its current challenges and opportunities;
- a description of the customer category profiles, their use of electricity and the opportunities offered by way of a targeted introduction of energy efficient technologies;
- a brief overview of the electricity sector's main role players, and their potential contribution in promoting the advancement of RE and EE technologies;
- an overview of "green technologies" in general, and specifically RE and EE technologies that could be developed to offer benefits to a broader section of the Namibian society;
- a discussion on electricity tariffs, and their expected future development; and
- a reflection on where and how Namibia's much-needed energy sector transformation can afford local entrepreneurs and job seekers to turn the many existing challenges into tangible and sustainable value-adding opportunities.

Specifically, the Study is to provide *informed laypersons* with four focal area perspectives:

1. the significant renewable potential locked in the country's invader bush resource, and the numerous rural growth, job creation and environmental benefits leveraged when decentralised energy provision based on the use of local biomass is incentivised;
2. Namibia's solar photovoltaic potential, and the role that PV technology can play in narrowing the country's electricity supply gap, and the opportunities that can be created in bringing modern electricity services to the furthest corner of the land;
3. the benefits and costs of embarking on a national roll-out of solar water heaters, to reduce the country's supply gap, and create meaningful near-industrial job opportunities in Namibia's fledgling RE industry and the creation of secondary jobs;
4. a brief introduction to Concentrated Solar Power (CSP) technology, outlining the technology's potential to supply local authorities, municipalities and medium-sized commercial and industrial entities with sustainable electric power.

Finally, the Study is to highlight how local RE and EE opportunities can create social, economic and environmental value, and is to explore value propositions arising through the concerted strengthening of the country's RE and EE sector. It is to offer perspectives of how Namibia's current electricity sector challenges can be turned into socio-economic growth opportunities, mainly by targeted local value addition and the creation of sustainable local jobs. The Study is to conclude with a summary of key messages, specifically framed for non-specialist decision-makers.

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