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Utilisation of Energy Storage Technologies in Namibia

by Dr Detlof von Oertzen

Executive Summary

Background

In September 2020, the Economic Association of Namibia (EAN) and the Renewable Energy Industry Association of Namibia (REIAoN) commissioned Dr Detlof von Oertzen to prepare a high-level assessment of the utilisation of energy storage technologies in Namibia.

Energy Storage Systems

Energy storage systems are expected to play an increasingly important role in Namibia's electricity sector. A primary role will be to facilitate the integration of intermittent renewable power sources, such as solar and wind, into the country's electricity mix. Electricity storage systems are a key element in stabilising, smoothing and providing back-up to solar and wind generation and enhance their increased integration.

The relevance and applicability of energy storage systems depends on which services they provide. The main applications of large-scale energy storage technologies include time-shifting (using grid electricity to charge when supply exceeds demand), peak shaving (using stored energy to complement supplies in peak demand periods), load levelling (changing load in real time), low-voltage ride-through (using storage in low-voltage periods), voltage control, suppressing network fluctuations and as a spinning and standing reserve.

In the domestic end-user market, energy storage is relevant for grid-connected customers in behind-the-meter applications, creating access to electricity and for thermal energy services, including in off-grid settings. While not yet mainstreamed, electric vehicles are becoming more popular, including in Namibia. In time, they are expected to have a profound impact on the electricity industry.

Contemporary commercial and industrial energy storage applications are mainly centred around electric backup applications and hot water supplies. In future, large-scale users are likely to invest in own generation capacities and electricity storage systems, to reduce expenditure for electricity.

As yet, Namibia does not use electricity storage technologies as part of the operations of the national grid, despite the rapid uptake of intermittent generation sources across the country. In future, energy storage applications are expected to become more prevalent, especially where local networks are unstable or constrained, to control the grid frequency, to manage loads, regulate power flows and voltage levels.

Commercial Opportunities for Energy Storage Systems in Namibia

From the perspective of electricity end-users, the most promising value propositions of electricity storage systems lie in applications allowing time-shifting of supply and demand, uninterruptable power supplies and electric vehicles. From the perspective of IPPs operating intermittent supplies, electricity storage systems offer exciting prospects for an enhanced control of variable demand and supply. For electricity utilities, storage can be used to manage power quality, for time-shifting, to improve network efficiencies, as emergency supplies and to optimally match intermittent supplies with a variable demand.

To date, regulatory provisions for the integration of energy storage applications do not exist in Namibia, preventing the proper valuation of long-term costs and benefits associated with storage systems. However, in October 2020, the ECB commissioned the development of energy storage regulations and associated tariff approaches; this initiative is expected to be finalised in the latter part of 2021.

Applications of Energy Storage Systems in Namibia

Three typical energy storage applications are described to illustrate the application of such systems. Small-scale off-grid power supplies with storage are autonomous electrical systems supplying one or several end-users, and a large variety of such systems are already in use in Namibia. Medium-sized storage applications are of particular interest in remote areas, far away from the electricity grid. Off-grid systems that deliver grid-equivalent electricity include mini-grid systems, such as those in use at Tsumkwe, Gam and Gobabeb. IPP-scale energy storage technologies offer commercial opportunities, provided that the regulatory framework conditions render them viable. These are useful to extend supplies to beyond the generation intervals offered by intermittent sources, enhance the uptake and integration of additional variable sources, supply in peak demand periods, delay infrastructure investments and provide ancillary services.

Local Value Addition to Advance Energy Storage Technologies

Opportunities to use local mineral resources to advance the application of storage technologies exist. Namibia has many known mineral deposits, including those required for the production of electricity storage devices, including lithium, cobalt, copper, tin, nickel, tantalum, graphite and rare earth minerals.

Namibia's skills base, access to capital and manufacturing capabilities are unlikely to attract any of the major actors that are advancing storage technologies for now. On the other hand, Namibian mineral exploration and mining activities have a solid track record and the country is recognised as a premier mining destination. Market conditions offer considerable additional scope for advancement. While opportunities for value addition should be pursued further, Namibia's key attraction relevant to energy storage technologies is likely to remain being a reliable supplier of minerals and associated concentrates.

Hydrogen stores chemical energy and offers numerous potentials in transportation, mining, production, manufacturing and other endeavours. With many countries committing to reduce their carbon emissions, hydrogen could in time gain in significance in efforts to decarbonise industries. However, producing hydrogen at commercial scale and competitive cost remains a challenge. The most efficient use of hydrogen is to use it where it is produced. With Namibia's world-class solar and appreciable wind resources, producing hydrogen could become an attractive option to capitalise on local competitive advantages.

Conclusions

1. Namibia's renewable energy resource endowments, specifically its solar and wind resources, can offer significant benefits when combined with contemporary energy storage technologies.
2. The appetite shown by commercial, industrial and domestic end-users in adopting solar PV is indicative of what is likely to lie ahead in terms of the uptake of energy storage technologies.
3. Increasingly cost-effective energy storage technologies will further incentivise the uptake of intermittent renewable energy technologies, especially solar PV and wind. Provided that relevant legal and regulatory provisions enable business applications using storage, these are likely to advance storage uses by electricity utilities, IPPs, commerce, industry and for off-grid electrification.
4. Namibia's legal, regulatory and statutory provisions are currently developed to pave the way for the proper regulatory integration of such technologies in the country's electricity industry.
5. Declining costs of storage and renewable technologies have a significant impact on non-renewable energy generation assets, including conventional fossil-fuelled plant. Modern energy storage uses enable the viable supply of electricity that could in the past only be served by fossil-fuelled plant.
6. Storage technologies are expected to profoundly impact on the business models of electricity utilities as cost-effective storage incentivises grid defection and displacing grid electricity using own supplies.

7. Despite such looming challenges, operations of most local electricity utilities centre around continuing to do what has always been done. This creates a multitude of opportunities for suppliers and installers of renewable and storage technologies while incentivising new businesses for on- and off-grid supplies.
8. Namibia's contemporary market for storage remains small. The country's economic challenges necessitate solutions that enable end-users to reduce recurring costs, including for electricity supplies.
9. While the renewable energy business fraternity has been negatively affected by the current economic down-turn, some 40 local companies offer energy storage systems with 4 of them being considered to have the capacity to implement large(er)-scale utility, IPP, commercial and industrial storage systems.
10. Strengthening local capacities in research and development, as well as innovative vocational and business training relating to energy storage technologies remain essential and could form part of future activities of the Renewable Energy Industry Association of Namibia.

1 Purpose and Scope

In September 2020, the Economic Association of Namibia (EAN) and Renewable Energy Industry Association of Namibia (REIAoN) compiled Terms of Reference (refer to Annexure 1) and commissioned Dr Detlof von Oertzen to draft a high-level study on the "Utilisation of Energy Storage Technologies in Namibia".

This paper presents the results of the study and is structured as follows:

a. Section 2 provides a high-level introduction to Namibia's electricity industry;
b. Section 3 identifies Namibia's current electricity sources and local energy resource potentials;
c. Section 4 describes Namibia's electricity-related legal, statutory and regulatory provisions;
d. Section 5 provides a summary of the evolution of Namibia's electricity market model;
e. Section 6 introduces energy storage systems and their potential roles in the electricity industry;
f. Section 7 discusses potential opportunities for energy storage technologies and systems;
g. Section 8 presents applications to illustrate how energy storage technologies are used in Namibia;
h. Section 9 reflects on the opportunities to use local resources to advance the storage technologies;
i. Section 10 concludes the paper by providing key take-away messages of relevance to energy storage technologies in Namibia;
j. Annexure 1 presents the Terms of Reference that guided this assignment;
k. Annexure 2 provides a high-level summary of topics requiring further strengthening to enhance the value of energy storage technologies in Namibia; while the
l. References section provides the links to key references used in this paper.

2 Namibia's Electricity Industry in a Nutshell

This section provides a high-level introduction to Namibia's electricity industry, as at September 2020.

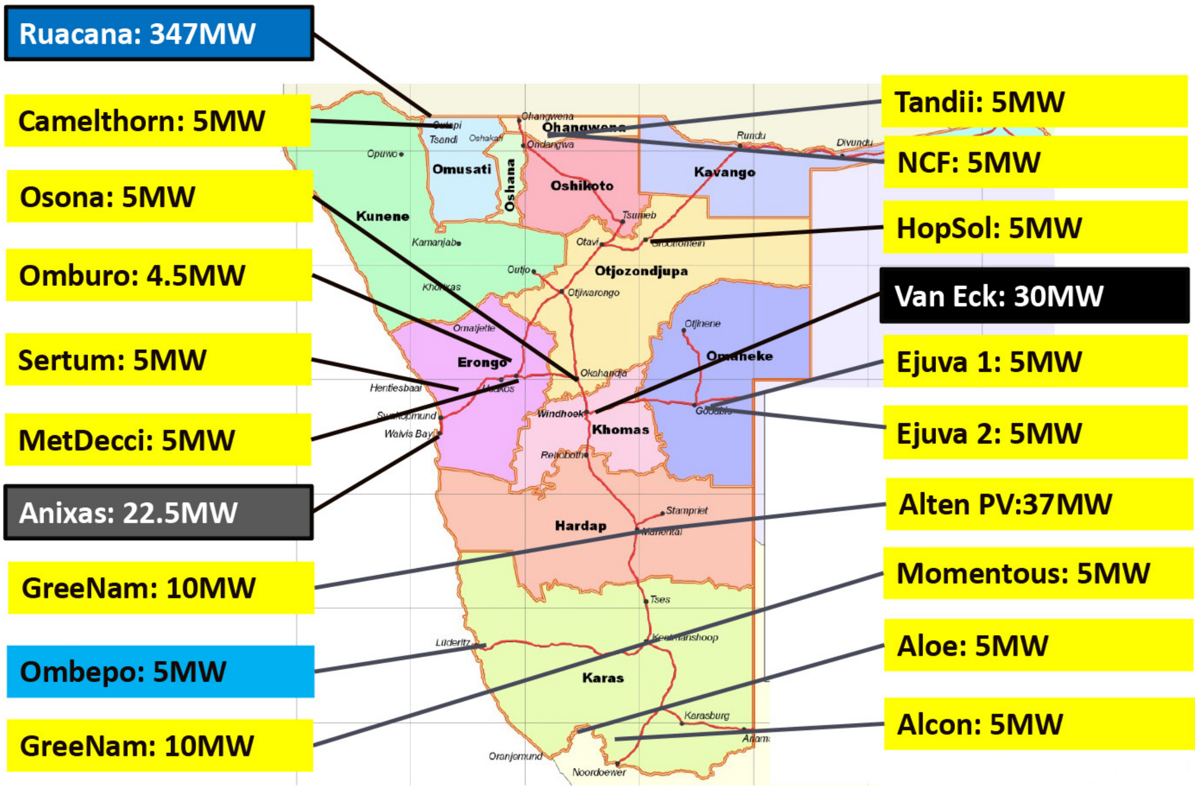
Electricity Supplies: Namibia's electricity requirements are sourced from twenty (20) local electrical energy generation plant (excluding embedded, behind-the-meter and off-grid generation plant) and various suppliers in neighbouring countries. Figure 1 depicts the local installed generating capacity which amounts to 526 MW; lined boxes indicate plant owned and operated by NamPower, yellow indicates the use of solar photovoltaic (PV) plant and blue indicates the use of wind energy.

Independent Power Producers: Seventeen (17) Independent Power Producers (IPPs) own and operate a total installed generating capacity of 126.5 MW, excluding all embedded, behind-the-meter and off-grid generating plant. Except for Ombepo, which is a wind farm, all other IPPs operating at the time use solar photovoltaic (PV) plant.

Embedded Generators: in addition to the above IPPs, several distributors and commercial operations procure electricity from IPPs that operate embedded generating plant. These include HopSol's 5 MW PV plant near Otjiwarongo selling to CENORED, OLC Arandis' 3 MW PV plant selling to Erongo RED and SunEQ's 5 MW PV plant supplying Ohorongo Cement.

Distributed Generating Capacity: an estimated 50 MW of grid-connected distributed generating plant are operational at the end of 2019. Some are for own use, including for example Windhoek's Grove Mall which operates a 2.8 MWp PV plant, Maerua Mall's 2 MW PV plant, Wernhil Park's 2.1 MW PV plant and Namibia Breweries 1 MW roof-mounted solar PV plant and others. Numerous smaller generating plant, such as roof-top PV systems operating as behind-the-meter generators, benefit from the national net metering rules and often have feed-in arrangements with a local electricity distributor.

Figure 1: Namibia's installed generating capacity, excl. embedded, off-grid and behind-the-meter plant (Source: VO Consulting)



Backup Generating Capacity: a large number and variety of backup generators are used throughout the country. Most mining operations have such generating plant on site. Examples include Langer Heinrich Mine's 16.5 MW diesel-powered plant, Ohorongo Cement's 7 MW diesel plant, Rössing Uranium Limited's 6.3 MW diesel plant and others.

Off-grid Generating Capacity: numerous off-grid generating plant, i.e. plant not connected to the national grid, are in operation. Prominent examples include B2Gold's 24 MW heavy fuel oil generating plant and its 7 MW solar PV plant, the off-grid installations at Tsumkwe, Gam and Gobabeb, as well as those on farms, lodges and small settlements not connected to the national grid.

Local Electricity Demand: during 2018/19, Namibia remained highly reliant on imported electricity, sourcing some 71% of total units into the system from suppliers in neighbouring countries. Taking transmission losses into account, imported electricity accounted for some 64% of NamPower's total local electricity sales in the period under consideration.

Electricity Purchases and System Maximum Demand: during 2018/19, some 4.4 TWh of electrical energy was injected into Namibia's transmission system, including just over 1.0 TWh from NamPower's generating assets. In the same period, a system maximum demand of 633 MW was recorded and excludes the Skorpion Zinc Mine and some 684 MW (in June 2019) when this mine is included.

Electricity Sales: during 2018/19, NamPower sold some 3.5 TWh to Namibian customers, excluding Skorpion Mine and the Orange River projects. Of this, the main distributors procured some 2.8 TWh, while NamPower's transmission customers – other than the distributors – procured some 0.7 TWh. Electricity distributors sold some 2.4 TWh to end-users. Of this, about 1.0 TWh was sold to domestic customers, as well as large power users and some 0.4 TWh was sold to commercial customers.

Electricity Customers: the electricity industry serves some 275 000 customers. Of these, some 251 000 are domestic, some 20 000 are commercial and industrial, some 2 500 are large power users and approximately 1 000 institutional customers including Government offices, ministries and agencies.

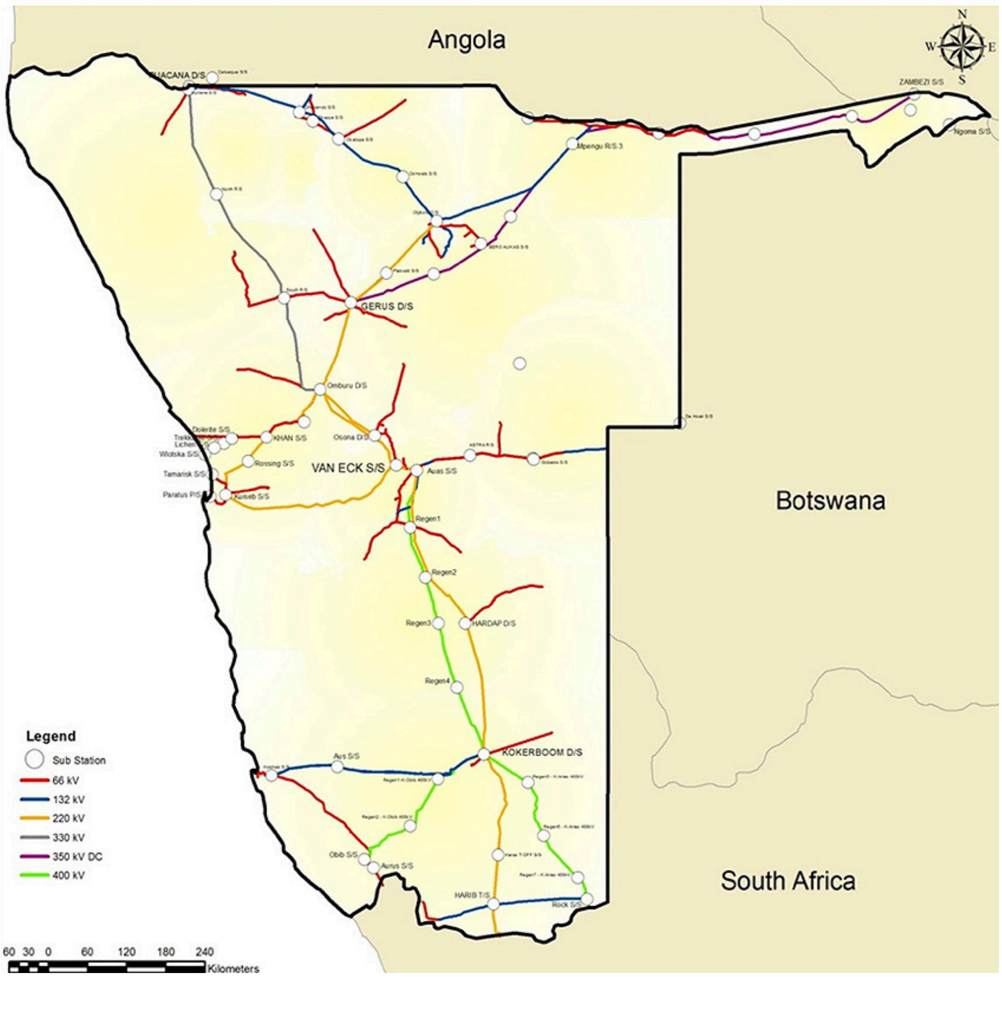
Electricity Distributors: some 83% of all grid-connected electricity customers are served by the three Regional Electricity Distribution companies and the City of Windhoek (CoW). NORED served some 30% of all electricity customers, the CoW served approx. 27% and 14% (11%) by Erongo RED (CENORED).

Distributor Sales: some 37% of total electricity sales by distributors were made in central Namibia, 19% in the areas served by Erongo RED and some 16% (8%) in the areas served by NORED (CENORED).

Revenues in Electricity Industry: during 2018/19, NamPower generated revenues of N$ 6.579 billion, with average revenues generated per kWh of electrical energy sold amounting to N$ 1.58/kWh. In the same year, the main distributors generated revenues of almost N$ 6.2 billion at an average of N$ 2.54/kWh sold. Sales to large power users other than distributors generated revenues of some N$ 2.7 billion, followed by revenues from sales to domestic customers amounting to some N$ 2.1 billion, some N$ 1.2 billion from commercial entities and about N$ 0.3 billion from institutional customers.

Electricity Prices: in 2018/19, NamPower's average local price per unit of electricity sold increased to approx. N$ 1.75/kWh from N$ 1.67/kWh in 2017/18. In 2018/19, the distribution industry's average price of electricity amounted to some N$ 2.46/kWh, up from about N$ 2.31/kWh in the year before.

Figure 2: NamPower's electricity transmission system, i.e. 66 kV and above (Source: NamPower)



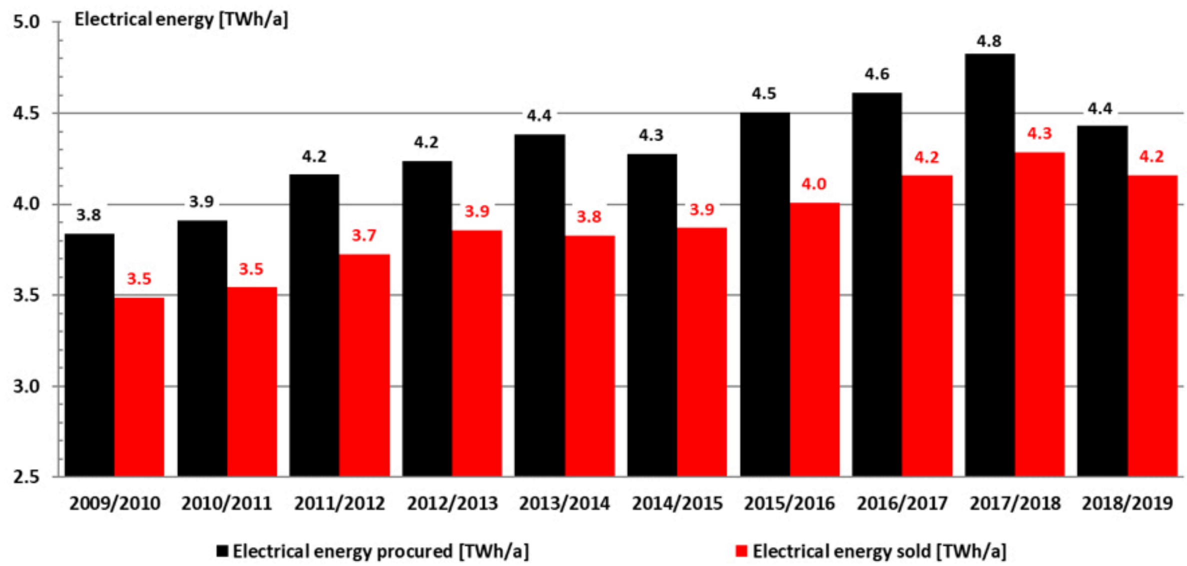
3 Electricity Sources and National Energy Resource Potentials

This section identifies Namibia's current electricity sources and local energy resource potentials.

3.1 Sources of Electrical Energy

Electrical energy procured by NamPower increased from some 1.9 TWh in 1990 to 4.6 TWh in 2018, i.e. an increase by a factor 2.5. In this period, the year-on-year change in electricity procured ranges between –5.3% and +16.6% per year, with an average annual growth of +4.1% between the calendar years 1990 and 2018. Figure 3 shows the total electrical energy procured and sold by NamPower (which is the result of transmission losses), in TWh per year (abbreviated TWh/a), in the decade between the financial years 2009/10 and 2018/19.

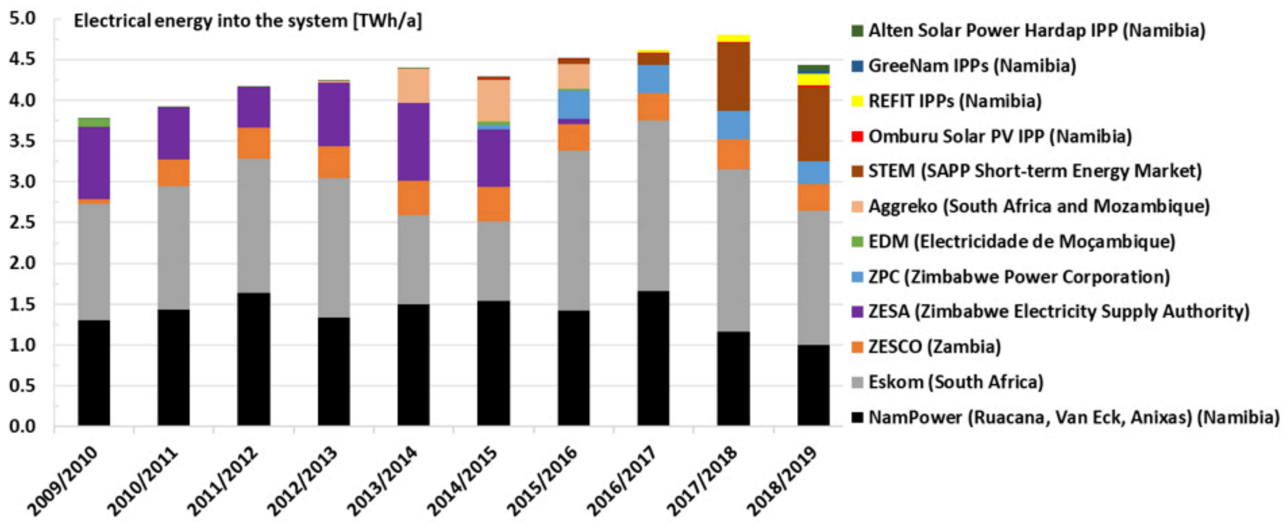
Figure 3: **Electricity procured and sold by NamPower from 2009/10 to 2018/19 (Source: VO Consulting)**



Electrical energy consumed in Namibia is either generated locally, or imported from regional suppliers. Local electricity supplies are sourced from plant owned and operated by NamPower as well as local IPPs. NamPower's generation assets include the 347 MW Ruacana hydro-electric plant in the Kunene River, the 120 MW coal-fired van Eck plant in Windhoek (actual operational capacity is currently limited to approx. 90 MW in total and 30 MW at any given time) and the 22.5 MW heavy fuel oil-fired Anixas plant at Walvis Bay, which is only used as a peaking plant.

Figure 4 identifies the sources from which Namibia procured electrical energy between the financial years 2009/10 and 2018/19. Both regional and local suppliers contributed to meet the demand for electricity. In addition to the regional supply entities from whom electricity was procured, several new local supply entities (other than NamPower) commenced operations from 2015 onwards. The first commercial IPP, i.e. InnoSun's 4.5 MW Omburu solar PV plant near Omaruru, started grid in-feeding in May 2015. Other IPPs joined later, including the so-called REFIT IPPs that benefit from the Interim Renewable Energy Feed-in Tariff (REFIT) programme.

Figure 4: Local and regional contributors to NamPower's electricity supply portfolio (Source: VO Consulting)

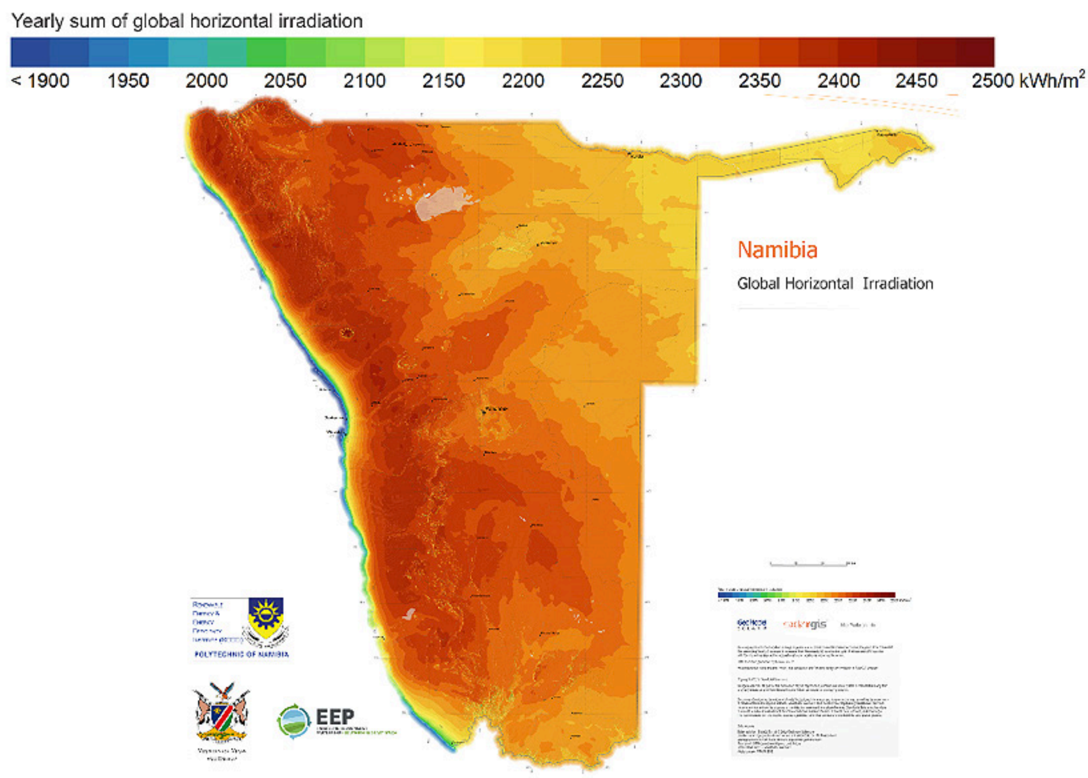


3.2 Local Energy Resource Potentials

Namibia is abundantly endowed with indigenous energy resources, including the following:

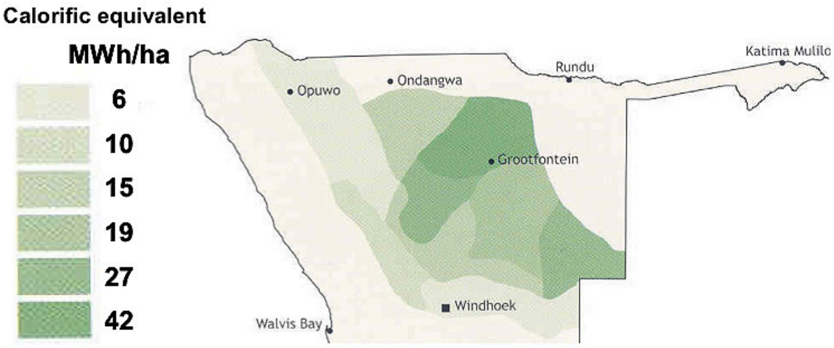
- **Solar resource:** Namibia has one of the very best solar irradiation regimes in the world, as is illustrated in Figure 5. This renewable resource is most suitable for solar electricity generation, for example by way of solar photovoltaic plant and concentrated solar plant (with large-scale storage possibilities), as well as for solar thermal applications. The commercial use of Namibia's solar resource is increasing rapidly, most notably by way of solar PV (electricity generation) and thermal uses (e.g. to heat water).

Figure 5: Namibia's world-class global horizontal solar resource (Source: Namibia Energy Institute)



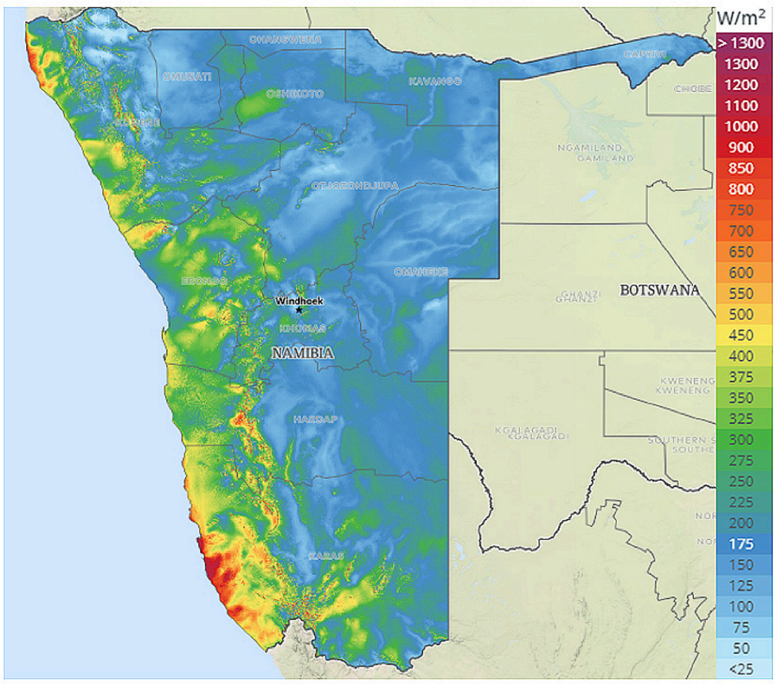
• **Biomass resource:** More than one-half of all Namibian households continue to use wood as a fuel source for cooking and/or space heating. This nationwide use of biomass implies that biomass remains a significant and import national energy source. Biomass from invader bush is ubiquitous in northern Namibia, refer to Figure 6, and has important agricultural uses and as a renewable fuel source in the electricity industry as well as in commerce and industry. Biomass also serves as a primary feedstock to the charcoal industry, is used as an animal fodder, as soil additive in the form of biochar and as a fuel source that can displace coal and various liquid fuels.

Figure 6: Indicative calorific biomass energy densities in northern Namibia (Source: VO Consulting)



• **Wind resource:** Along most of the country's coastline, as well as in select inland locations, Namibia boasts some good to significant wind energy potentials which are useful for electricity generation. This is illustrated in Figure 7, showing the power density at 100 metres hub height.

Figure 7: Mean wind power density in W/m2 at 100 m above ground level (Source: Global Wind Atlas)



• **Hydropower:** NamPower's Ruacana hydro-power station is located in the Kunene River. It is a run-of-river plant and its outputs are highly variable. Without large-scale storage, and noting that there is only a small reservoir to manage water levels over a 24-hour period, Ruacana's output remains largely dependent on rainfall. Additional hydro-potentials exist in the Kunene, including for the envisaged 600 MW Baynes hydropower plant, and to a lesser degree, in both the Okavango River and Orange River.

- **Uranium resource:** since 1976, Namibia produces uranium concentrate for export. The country is one of the four largest uranium producers, contributing more than 10% to global supplies in 2018.
- **Natural gas:** The Kudu gas field, discovered in 1974, has proven and potentially exploitable natural gas reserves of some 1.3 trillion cubic feet. The field has been extensively explored, including the drilling of eight exploration wells and undertaking 3-dimensional seismic surveys in 1993 and 1996. However, despite decades of exploration and development work and hundreds of millions of Namibian dollars in investments, the commercial development of the field remains elusive.
- **Waste:** Namibia has several municipal waste disposal sites as well as other sources of waste that could potentially be utilised for the generation of heat and electricity. Prime candidates for future development include the main waste disposals located near Windhoek, Walvis Bay and Swakopmund.
- **Oil:** Indications of the existence of potentially exploitable resources exist. However, no commercial oil discoveries have been recorded to date.
- **Coal:** Although select coal deposits exist, none are considered suitable for commercial development.
- **Geothermal potential:** Some evidence of geothermal potentials exists around the country. However, these have not been properly explored, nor quantified and none of the known resource fields are currently considered to be exploitable for power generation.
- **Ocean and wave energy potentials:** Namibia has a long coastline which offers the likely potential to harvest energy from waves and the ocean. Its resource potential, however, awaits to be quantified.

4 Electricity-related Legal, Statutory and Regulatory Provisions

This section summarises Namibia's electricity-related legal, statutory and regulatory provisions.

The Ministry of Mines and Energy (MME) is responsible for the development of policies that shape Namibia's electricity industry. The Electricity Control Board (ECB) is the industry's regulatory authority, responsible for the rules and regulations that guide the electricity supply and distribution industry.

4.1 National Energy Policy (2017)

The National Energy Policy of 2017 defines the Government's strategic intent relating to the energy industry. The Policy recognises the value of energy storage, especially to reduce the firm power back-up requirements of intermittent renewable supplies. It emphasises the Government's intent to "create the relevant provisions in the country's legal, regulatory and tariff framework to enable the use of both large and small-scale energy storage technologies", and "ensure that the design of new generation, transmission and distribution infrastructure accommodates the integration of energy storage systems."

4.2 National Renewable Energy Policy (2017)

The National Renewable Energy Policy of 2017 guides the Government on the development of the country's renewable energy sector. Amongst others, the Policy aims "to enable access to modern, clean, environmentally sustainable and affordable energy services for all Namibian inhabitants" and "to meet [Namibia's] short-term and long-term national development goals and to assist Namibians climb the development ladder, empowered by access to energy at levels that facilitate engagement in productive activity".

4.3 National Independent Power Producer Policy (2018)

The National Independent Power Producer Policy (IPPP) of 2018 expresses Government's intent and commitment to broaden private-sector participation in the electricity industry. Policy statement 1 is critical in that it states that "All IPPs shall be afforded equal access to the Namibian power generation market under a clear policy framework and a market structure and shall operate under the same fair and transparent rules and regulations."

4.4 Electricity Act (Act No. 4 of 2007)

The Electricity Act, 2000 (Act No. 2 of 2000) established the Electricity Control Board (ECB) and described its key mandate and functions. This Act has since been repealed and replaced by the Electricity Act, 2007 (Act No. 4 of 2007), which details the current roles and responsibilities of the ECB and the conditions and requirements for licenced activities in Namibia's electricity industry. The Act lays the foundation for the licensing of electricity-related activities, including for the generation, trading, transmission, supply, distribution, import and export of electricity which necessitate separate licences.

4.5 Net Metering Rules (No. 471 of 2016)

The Net Metering Rules were developed under the Electricity Act, 2007 and were promulgated in 2016. The Rules stipulate that all distribution licensees must offer net metering to customer-generators, subject to applicable laws, rules and regulations. All renewable energy technologies are eligible for net metering. In addition, all distribution customers are allowed to install net metered facilities, subject to the provisions of the Electricity Act and stipulations under the Act.

5 Namibia's Electricity Market Model

This section provides a brief summary of the evolution of Namibia's electricity market model from the Single Buyer to the Modified Single Buyer market framework that is expected to become fully operational towards the end of 2020.

5.1 The Single Buyer Market Model

In November 2000, Cabinet approved the single buyer (SB) electricity industry market model for the restructuring of the country's electricity supply industry. The SB made it compulsory that all entities wishing to supply electricity to or within the country were to sell to NamPower. In turn, NamPower would be the only supplier of bulk power, to distributors and select large power users, while also retaining responsibilities in the distribution sector, notably in areas where other distributors did not provide services. In time, even the most ardent supporters of the SB recognised the lack of investments in national generation capacities. NamPower's slow pace of change and near-absolute domination of the industry could also not readily be argued away. The SB model was to change, and in 2015, InnoSun established the first commercial IPP at Omburu and embedded plant began operations in CENORED's and Erongo RED's supply areas. Others started supplying select large power users.

5.2 Modified Single Buyer Market Model

From 2018 onwards, the so-called modified single buyer (MSB) market model was extensively workshopped with a large number of stakeholders. The MSB is a modification of the SB market model, allowing IPPs to directly supply electricity to select customers without having to involve the SB, while also allowing private generators to operate plant to export electricity.

The MSB is expected to become fully operational during 2020, which was not the case at the time of writing.

6 Energy Storage Systems

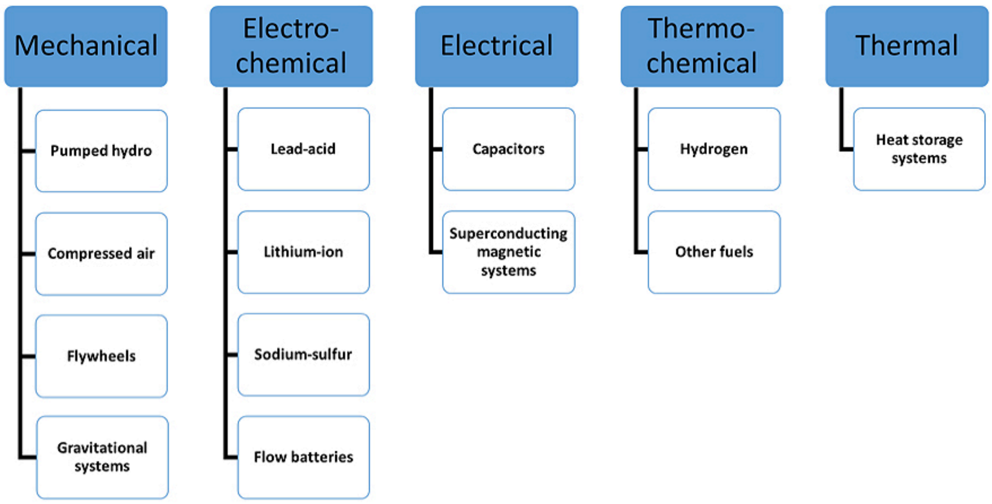
This section introduces energy storage systems and their potential roles in the electricity industry.

6.1 Classification of Energy Storage Systems

Figure 8 classifies the main energy storage systems currently in use globally, including

1. mechanical systems, including pumped hydro-electric storage, compressed air storage, flywheels, gravitational energy storage and related systems;
2. electro-chemical systems, including lead-acid batteries, lithium-ion batteries, sodium-sulphur batteries and flow batteries;
3. electrical systems, including capacitors and superconducting magnetic systems;
4. thermal systems, such as heat storage systems; and
5. thermo-chemical and chemical systems, including those producing hydrogen and other fuels.

Figure 8: Classification of contemporary energy storage systems (Source: VO Consulting)



6.2 Energy Storage Technologies and their Potential Roles in the Electricity Industry

Energy storage systems are expected to play an increasingly important role in Namibia's electricity sector. A primary role will be to facilitate the integration of intermittent renewable power sources, such as solar and wind power, into the overall electricity supply mix. Energy storage systems are therefore considered to be a key element in stabilising, smoothing and providing the necessary back-up to solar and wind generation sources, thereby enhancing their increased uptake and integration.

The relevance and applicability of energy storage systems depend on which services they are to provide. As such, large-scale grid integration has different requirements than those necessary for domestic behind-the-meter applications. This is further illustrated by considering the main applications of large-scale energy storage technologies which can provide services including the following:

- **Time-shifting:** time-shifting refers to the use of grid electricity to charge an energy storage system when supply exceeds demand or when electricity is cheap and the use of such stored energy in peak demand periods. To be useful grid energy management tools, storage capacities must be of the order of several MW, to several tens of MW. Applications include the use of pumped hydro and compressed air systems, as well as the use of conventional battery systems. In future, hydrogen and other fuels, inexpensive flow battery technology and thermal energy storage technologies are expected to become important and could potentially become relevant in Namibia, provided these are actively developed.

- **Peak shaving:** peak shaving refers to the use of electrical energy stored during off-peak periods, to compensate generation deficits during periods peak demand periods. Energy storage – depending on the scale of peak shaving necessary – can provide definite benefits and in this way, reduce the requirement to invest in expensive peak electricity generation plant. However, for time-shifting and peak shaving to work, electricity supplies in off-peak periods must exceed the prevailing demand.
- **Load levelling: l**oad levelling is a supply-side support measure to level or follow changing load patterns in real time, i.e. a method to balance fluctuations associated with a rapidly changing electricity demand.
- **Low-voltage ride-through:** low-voltage ride-through is the capability to mitigate low-voltage periods when these occur and is a voltage control measure necessary when external voltage fluctuations occur. Such applications necessitate a near-instant response capacity and thus ideally suited for fast-response energy storage technologies. For example, voltage fluctuations associated with having various intermittent renewable energy technologies feeding into the grid, such as for example solar PV and wind energy generation, necessitate the system operator to smoothen the power variations because of such sources, while having the necessary capacity to respond to momentary low-voltage periods.
- **Transmission and distribution stabilisation:** energy storage systems can be used to support the synchronous operation of components on a power transmission line, or to regulate the power quality in the distribution grid. These require instant response capabilities and power capacities to match the prevailing grid demand.
- **Black-start**: energy storage systems can provide the capability to start up generation operations, e.g. from a shutdown condition, without having to take supplies from the grid.
- **Voltage regulation and control:** electric power systems react dynamically to changes in active and reactive power, thus influencing the magnitude and profile of the voltage in networks. In this regard, energy storage systems can be used to control dynamic voltage behaviours.
- **Suppression of network fluctuations:** while power fluctuations occur permanently on the electricity grid, their existence threatens modern power electronics components and must therefore be minimised. Energy storage systems can provide the necessary functionality to protect such sensitive system components, especially those associated with fluctuations that require fast responses, high cycling times and short-term high-power inputs.
- Spinning reserve refers to additional capacity that can be made available by increasing the power output of grid-connected generating plant, spinning reserve is important where there is a rapid decrease of the load, or a fast increase of additional on-line generation facilities. In such conditions, energy storage systems can assume the role and function of a spinning reserve and maintain the power output until more conventional load control measures can be applied.
- **Standing reserve:** standing reserves are used to deal with network constraints arising when the electricity demand exceeds the supply, which can happen when load forecasts are inaccurate, or in case unexpected plant outage occurs. In this way, energy storage systems are used to re-balance the demand with the prevailing supply, by providing a temporary service until other demand- and/or supply-side measures are applied.

While the above are mostly applicable in the management of the electricity grid, the following applications of energy storage systems are pre-dominantly applicable on the end-user side:

- **Emergency back-up power and uninterruptible power supply:** in case of a power failure, energy storage units have traditionally been used to provide emergency back-up power services, including those needed to ensure the short-term provision of uninterruptible power supply (UPS). Applications include, amongst others, computers and related information technology, telecommunication systems, broadcasting systems and emergency lighting systems. Such applications are usually time-limited in nature and necessitate that energy storage systems provide supplies until the main grid supply is restored, or, in the case of UPS systems, until a system can be properly shut down. For emergency back-up power systems, instant-to-medium response times are required, as are long discharge times. In contrast, typical UPS systems offer near instantaneous power supplies, but usually do so for a very limited time only.

- **Transport applications:** increasingly, energy storage systems are finding their way into a variety of transport applications, ranging from hybrid-drive vehicles to fully electric vehicles. The increasing energy density of contemporary energy storage systems, the limited size and fast response times render them increasingly popular. In addition, health- and climate-related concerns provide political leverage to incentivise the switch from fossil-fuelled transport to cleaner alternatives, not only for individual travel, but also for applications in future mass transport systems.

6.3 Applications of Energy Storage Technologies and Associated Systems

The following energy storage applications are of immediate relevance to the electricity industry.

6.3.1 Domestic Energy Storage Applications

Three main energy storage applications are important in the domestic end-user market, namely support of grid-connected customers, creating access to electricity and thermal energy services.
In so-called behind-the-meter applications, domestic end-users use a variety of battery storage systems, to augment the grid electricity supplies and to store energy generated from own electricity generation equipment, such as solar photovoltaic installations. In addition, and more prevalent in rural than in urban Namibia, are a variety of backup power supply supplies. Some of these include electrical energy storage, which allows end-users to draw electricity even without the main electricity supply source being in operation, i.e. when the generator is not running, or in case of renewable energy installations, when the sun is not shining or the wind is not blowing. Lastly, thermal energy storage devices have been in use for several decades and contemporary applications include electrically-powered hot water devices, solar thermal hot water systems, as well as systems heated by biomass, diesel or heavy fuel oil and volatile waste materials.

The above uses of the various energy storage devices are most likely to continue. Future trends may likely include the increasing use of solar thermal hot water installations, instead of using electrically-powered hot water systems. In addition, middle- to high-income earners may increasingly wish to gain control over their own electricity supply and invest in grid-connected renewable energy generation plant, e.g. solar PV technologies. This development will shift the more traditional use of energy storage systems in the domestic sector away from merely being a convenient backup supply, into becoming a more integral part of the country's future electricity supply systems. This is likely to be accompanied by a general shift towards a more decentralised provision of power generation, with domestic end-users, businesses and commercial entities producing more of their own electricity in response to declining technology costs and ever-rising tariffs of grid-supplied electricity.

While not yet mainstreamed, electric vehicles are increasingly becoming more popular around the world. When such vehicles are further mainstreamed in Namibia, they may, in time, have a profound impact on domestic electricity consumption by way of the use of their on-board storage systems.

Another development that is expected to become increasingly more popular is the application of mini- and micro-grids, which rely on a variety of electricity supply technologies as well as energy storage systems. Developments of this nature, driven amongst others by the rapid adoption of solar technologies throughout the domestic electricity user sector, are expected to lay the foundation for more interactive and flexible distribution supplies and in its wake, enhance the resilience of the electricity supply and distribution industry.

International experience, especially in countries having a similar solar regime to that of Namibia, show that self-generation and investments in storage technologies need more than willing consumers: targeted incentives and regulatory provisions are essential ingredients, without which many of the above trends are likely to remain stifled.

6.3.2 Commercial and Industrial Energy Storage Applications

Currently, commercial and industrial energy storage applications are mainly centred around hot water supplies and electric backup applications, such as uninterruptible power supplies. In future and in response to escalating grid-supplied electricity prices, commercial and industrial consumers are expected to increasingly invest in their own renewables-based power generation, to reduce their electricity bills. In some instances, commercial and industrial actors may also invest in electricity storage systems, for example to lower their maximum demand and thereby lower associated charges by the supplier and for emergency backup purposes. Motivation for such investments would increase if the duration of grid outages or grid instability were to rise in future.
However, as commercial and industrial uses of storage applications may be more bottom-line oriented than those in the domestic sector, it is important to note that current petrol- or diesel-powered stand-by generation technologies offer many of the above services, at a fraction of the cost that would be incurred by investing in contemporary energy storage technologies. This implies that storage costs must decrease further before the scale and scope of commercial and industrial investments in electrical energy storage systems will significantly increase in Namibia.

As the uptake of intermittent generation sources increases, a situation could arise whereby commercial and industrial actors would only be allowed to grid-connect additional intermittent plant if it included storage capacity. For example, a recent assessment undertaken for the ECB suggested that grid instability could arise if the percentage of intermittent capacity exceeded 50% of total supplies. This implies that the further penetration of intermittent capacity is likely to stimulate the gradual uptake of electricity storage technologies throughout the industry.

6.3.3 Energy Storage Applications and the National Electricity Grid

As yet, Namibia does not use electricity storage technologies as part of mainstay grid applications. This is despite the rapid rise of intermittent renewables across the country. In future, energy storage applications are expected to become more prevalent, especially in network locations that may become temporarily unstable, or be constrained. Energy storage systems are also expected to play a role in the control and management of the network frequency, to rapidly manage load and generation profiles and to regulate power flows and voltage levels, mostly at the distribution network level.

While domestic, commercial and industrial uses of energy storage are expected to increase in future, utility-scale storage projects at the local and national level are necessary to manage and respond to the impacts brought about by the rapid uptake of intermittent generation technologies. In this way, storage facilities become the tools to manage and mitigate risks at local or national level. This approach, however, necessitates a shift in how Namibia's grid is supplied and managed: traditionally, grid constraints were addressed by strengthening infrastructure, e.g. by upgrading transmission lines, or upgrading distribution networks and associated infrastructure, or similar. As large-scale energy storage becomes more readily available, traditional approaches to strengthen grid infrastructure, including grid capacity upgrades and expansions, are increasingly likely to compare these to the costs, benefits and speed of impact associated with the installation of storage facilities in the network. Here, the modularity and ease of implementation of modern energy storage systems are of importance, as such measures can readily and flexibly respond to a given challenge while offering cost and time advantages. In contrast, many conventional investments in large-scale grid infrastructure upgrades are inflexible, site specific, expensive and challenging to implement.

Irrespective of whether electricity storage is connected on the consumer side, or within the network on the utility side, it affects network-wide power flows. These need to be managed. It is for this reason that utility-scale storage is likely to be the most responsive to address overall network challenges and in this way, create the necessary operating circumstances for the meaningful integration of domestic, commercial and industrial users in a smartened grid of the future.

6.4 Namibian Projects using Storage Systems

Numerous small-scale, mainly domestic behind-the-meter applications exist and use energy storage systems. Often, these include off-grid systems on farms, lodges and in off-grid settlements, where storage systems are an integral part of (mostly) hybrid solar PV and diesel electricity supply systems.

Contemporary storage applications include a few larger off-grid systems, such as those used in the telecommunications industry (powering repeater stations and similar) and at a variety of farming and lodge facilities. For illustration purposes, the following specific examples are highlighted:

- Gam is in the Otjozondjupa Region’s Tsumkwe constituency and is powered by a 292 kWp solar PV plant and 2.5 MWh storage facility, delivering a maximum demand of 200kW.
- Tsumkwe is powered by a solar PV-diesel hybrid plant (202 kWp solar PV array supported by a 150kVA and 350kVA diesel generators) and a storage facility of 1.05 MWh.
- Sesriem is powered by a 253 kWp solar PV plant coupled to a containerised 1 MWh storage facility, producing an output of up to 240 kW.
- The Gobabeb Namib Research Institute is supplied by a 63.4 kWp solar PV generator and diesel backup generator of 60 kVA capacity coupled to a lead-acid storage system of 670 kWh capacity.
- Many stand-alone farm and lodge systems exist, often utilising solar-diesel hybrid systems coupled to battery systems to ensure the continues availability of supplies.

6.5 Procurement

The procurement and installation of storage systems by private entities is executed via local suppliers and installers and must meet the requirements that govern the connection of renewable energy systems to the local electricity grid. For systems which are not connected to the grid, installation requirements only pertain to ensuring that health and safety provisions are met and that they do not endanger end-users or the public.
Procurement for public entities is subject to the rules and regulations under the Public Procurement Act. These are administered and enforced by the Central Procurement Board (CPB), which operates under the Ministry of Finance. Systems are advertised, and potential suppliers bid by way of tender and bidding documents submitted to the CPB for evaluation, adjudication and award. To date, this procurement process continues to delay the implementation of projects in the electricity industry.

7 Commercial Opportunities for Energy Storage in Namibia

This section provides a high-level discussion of some of the commercial opportunities for energy storage technologies and associated systems in Namibia.

While energy storage systems are primarily made to store energy, their actual value depends on the end-user's requirements. These can be differentiated between the requirements of electricity end-users, those by IPPs and those of electricity utilities, each of which are briefly summarised below.

7.1 Needs and Requirements of Energy Storage Users

7.1.1 Electricity Storage Applications for End-Users

From the perspective of an electricity end-user, the value proposition of electricity storage systems is greatest for the following applications:

a. **Time-shifting:** for end-users on time-of-use electricity tariffs, electricity storage systems can effectively be employed to reduce total electricity costs by reducing consumption in high-cost peak demand periods and recharging such storage systems in off-peak times.
b. **Emergency power supply/uninterruptable power supply:** some end-users may rely on equipment that necessitates continuous electricity supplies, including those using critical information and telecommunications technologies. In such cases, electricity storage systems may be useful and substitute emergency stand-by generators, or be used as uninterruptible power supplies.
c. **Electric vehicles:** increasingly, electric vehicles are entering the market space and begin to be cost-competitive with petroleum-powered vehicles. This development is the result of intense research and development efforts and the mainstreaming of high-performance electrical energy storage systems such as lithium-ion, nickel-cadmium and other battery storage systems used in such mobile applications. Increasingly, such energy storage technologies are expected to find additional applications, for example contributing to power domestic or commercial uses while being connected to the power grid, known as vehicle-to-home and vehicle- to-grid applications.

7.1.2 Electricity Storage Applications for Independent Power Producers

From the perspective of Independent Power Producers generating electricity using intermittent supply sources, electricity storage systems hold the following main development prospects:

a. **Time-shifting:** when generating electricity using intermittent sources, the timing of supplies may be out of step with the prevailing demand. For an IPP, storage technologies can store electrical energy when supply exceeds demand, providing additional power where demand exceeds supply, while also creating opportunities to sell in peak demand periods and benefitting from high time-of-use tariffs, while limiting or curtailing sales in low-demand periods.
b. **Demand-supply response control:** the electrical output of intermittent generation capacities varies significantly throughout any given day, as such sources are determined by prevailing weather patterns. Here, energy storage systems can be useful, to store electrical energy during maximum supply periods and provide additional power when the supply of electrical generators does not meet the given demand. It is worth mentioning that the MSB's operating requirements emphasises the importance of reliable supplies, which incentive the use of energy storage to strengthen the predictability and reliability of a generation plant's outputs.

7.1.3 Electricity Storage Applications for Electricity Utilities

From the point of view of an electricity utility such as NamPower or the various main electricity distribution entities operating in the country, electricity storage systems hold the following main development prospects:

a. **Power quality management and control:** one of the important functions undertaken by an electricity utility, such as NamPower, is the control of voltage and frequency. This is generally achieved by adjusting supplies to the changing demand patterns. Specifically, voltage is generally controlled by taps of transformers and reactive power with phase modifiers, frequency is controlled by adjusting the output of generating units. Here, electricity storage systems can provide frequency control functions and control voltage fluctuations in networks.

b. **Time-shifting:** in some instances, temporary changes in the peak demand may best be addressed by using suitable storage, including amongst others, pumped hydro-electric storage systems. By time-shifting electricity supplies, overall generation costs can be reduced. This is achieved by storing energy at off-peak times, for example at night and having this available for dispatch in peak demand periods.

c. **Network efficiency improvements:** occasionally, power networks can be congested, which may occur when transmission/distribution lines are not sufficiently sized to be able to convey electrical energy as demanded. In such cases, large-scale storage systems installed at strategic locations reduce congestion and can be used to delay network reinforcements and upgrades.

d. **Emergency power supply for protection and control equipment:** a reliable power supply for protection and control is of critical importance for electricity utilities and backup battery storage systems are frequently used as an emergency power supplies.

7.2 Barriers Facing Energy Storage Systems

Amongst the most pronounced barriers faced by energy storage technologies in Namibia is the absence of regulatory guidance or provisions. This also implies that the proper valuation of long-term costs and benefits of various storage systems remains incomplete, which hides their potential benefits while singularly focusing on their (often considerable) capital cost requirements.

In addition, several technical questions remain, which perpetuate the economic uncertainties associated with storage technologies. These barriers remain considerable and must form part of the strategic considerations by businesses wishing to mainstream such technologies in Namibia.

In October 2020, the ECB commissioned the development of energy storage regulations, including associated tariff approaches. At the time of writing it is expected that this important assignment will be finalised in the latter part of 2021.

7.3 Value Proposition of Energy Storage Systems in Namibia's Electricity Industry

As yet, Namibian policy and regulatory provisions are not focusing on the potential roles and benefits that energy storage systems could have for the electricity industry. Also, end-users remain sceptical as to the benefits of energy storage systems, while being cognisant of the considerable capital investment requirements associated with the installation of such systems.

However, broad consensus exists in the electricity industry that energy storage technologies are essential if intermittent renewable energy sources are to play a more pronounced role in the country's electricity mix. This realisation is considered critical and businesses wishing to bring energy storage systems to market in Namibia should recognise this element as a key to unlock local energy storage opportunities. Section 8 explores the value proposition of storage using specific case studies.

7.4 Hydrogen

Hydrogen has the potential to become a fuel used for transport, mining, production, manufacturing and other industries. As countries commit to reduce their carbon emissions, hydrogen could significantly contribute to current efforts to decarbonise industries.

Amongst other processes, hydrogen is produced by an electrically-powered electrolyser that splits water into hydrogen and oxygen. If the electrical energy required is produced from carbon-neutral sources, the resulting hydrogen is termed "green hydrogen". However, most hydrogen currently produced originates by way of steam reforming, using fossil fuels such as natural gas, liquid petroleum or coal, as well as high temperature steam and a catalyst, to produce hydrogen, carbon monoxide and some carbon dioxide. Hydrogen from this process is termed "grey hydrogen", while "blue hydrogen" is produced when the carbon dioxide arising from the steam reforming process is captured and stored.

The European Union intends to invest $430 billion in green hydrogen production by 2030 to help achieve its Green Deal. Japan, Germany, Saudi Arabia, Chile, Australia and the United States (after re-joining the Paris Agreement in 2021) are committing major investments to enhance their green hydrogen capacities.

Producing competitively priced hydrogen remains challenging. The most optimal use of hydrogen is to use it where it is produced. Hydrogen is highly versatile and can be used in gaseous or liquid forms, be converted to electricity or used as a fuel or feedstock in industries as diverse as mining (e.g. for "green iron"), manufacturing (e.g. fertilisers, chemicals and as a fuel), in transport and others.
To date, national greenhouse emissions targets and placing a cost on carbon emissions determine whether business cases exist to develop hydrogen production and distribution infrastructure and applications. For Namibia, having world-class solar and appreciable wind resources, producing hydrogen could be an option to create local industrial capacities that capitalise on the country's national sustainable endowments.

7.5 Energy Storage Systems and Namibia's Electricity Future

Namibia is well-endowed with solar, wind and biomass resources. The optimal development, integration and increased use of these resources render it necessary that energy storage technologies and associated systems are introduced. The rapid decline of the cost of storage systems is likely to boost the fledgling interest in self-generation plus storage solutions, which is an essential pre-requisite for further market development.

The following aspects are important to develop the Namibian energy storage market and are a sub-set of issues and topics requiring further strengthening to enhance the value of energy storage technologies, as further addressed in Annexure 2:

1. relevant provisions in the country's legal and regulatory system must enable the use of both large- and small-scale energy storage technologies, which are currently being developed;
2. a pricing mechanism for services from energy storage technologies does not yet exist;
3. local technical and performance standards guiding energy storage technologies do not exist, noting that suppliers usually refer to South African provisions where these are available;
4. incentives for the procurement of energy storage systems do not exist, implying that such systems must be able to generate profits entirely from the services they provide; and
5. the recognition that infrastructure upgrades can be delayed or are not required if suitable energy storage systems are introduced has not taken hold amongst most local utilities.

8 Applications of Energy Storage Systems in Namibia

This section presents three real-world energy storage applications to illustrate how energy storage technologies are used in Namibia.

8.1 Small-scale Off-grid System with Storage

This section introduces a small-scale off-grid stand-alone power supply system with energy storage. Off-grid electricity end-users are typical users of small-scale stand-alone power supply systems that often include energy storage technologies. Typically, such off-grid systems are not connected to the national electricity grid, even when they are used in the immediate proximity to it.

Small-scale off-grid systems, as referred to in this section, are autonomous electrical power systems supplying one or several end-users. A large variety of such stand-alone systems are in use in Namibia, ranging from hand-held lanterns to systems providing electricity to entire communities.

A small-scale off-grid system supplying an average 575 kWh per month for household end-use would for example comprise of a solar photovoltaic (PV) plant of some 3.9 kWp and a lithium-ion storage system with a capacity of 9 kWh. In October 2020, such a stand-alone power supply systems that can feed one large or several small households, has an indicative cost of some N$ 260 000, excluding value added tax. With a life expectancy of about 20 years, it has a levelised cost of electricity (LCOE) over the full life-of-plant of approx. N$ 4/kWh , excluding tax-related benefits, such as asset depreciation charges that are allowable for select income tax categories.

Considering that grid-supplied electricity prices for domestic end-users are of the order of N$2.85/kWh, the price development of grid electricity may motivate end-users to invest in a grid-connected solar PV system to benefit from net metering, or entirely defect from the grid. In 2020, about one-fifth of all grid-connected households consume 450 kWh/month or more. Such end-users may eventually invest in grid-connected or off-grid systems should the price of grid-supplied electricity escalate further and/or in case the reliability of grid supplies deteriorates in future.

As the costs of autonomous electricity supplies decrease, grid defection will increase, unless distributor prices remain competitive. Should a sizeable number of end-users decide to switch to using their own grid-independent supplies, the business models of most contemporary electricity distributing entities would be challenged.
Also, as solar PV panels and energy storage prices continue to decline, the viability of small-scale off-grid systems will improve further, which places the business models of most Namibian electricity distribution entities under considerable pressure.

At the time of writing, Namibia's National Electrification Policy is being developed. The Policy recognises the pivotal role of small-scale off-grid electricity supply systems in enhancing access to electricity in the country. The Policy also defines a multi-tiered electricity service framework, and pronounces Tier 3 to be the minimum service level for an off-grid end-user to be recognised as having access to electricity.

8.2 Medium-scale Energy Supply System with Storage

This section presents an example of a medium-scale stand-alone power supply system including energy storage technologies.

Many of Namibia's unelectrified areas are far away from the grid, characterised by low population densities and/or highly dispersed settlements. Here it is often neither technically nor economically justifiable to provide access to electricity by way of a conventional grid connection. Credible alternatives delivering grid-equivalent electricity include contemporary mini-grid power supply systems, i.e. electricity supply systems that are not connected to the main electricity grid while feeding one or several grid-code compliant local electricity distribution networks to provide electrical energy to multiple end-users.

Mini-grids are often powered by hybrid generation systems using two or more electricity generating technologies, e.g. a diesel-powered generator and a solar PV generator, or a combination of wind and solar systems. Electrification using mini-grids is particularly effective in areas having clustered household settlement patterns and some commercial and institutional presence, thereby offering an attractive alternative to diesel-/petrol-powered generators, solar home systems or an extension of the grid.

Namibian examples of mini-grid supply systems include those at Tsumkwe (from end-2011) and Gam (from the fourth quarter of 2014), as has been referred to in section 6.4. The Tsumkwe mini-grid is powered by a solar PV-diesel hybrid power plant coupled to a storage facility with a capacity of 1.05 MWh. The system provides electricity to a few hundred households as well as a handful of business and institutional end-users. Today, a similar system consisting of a solar PV generator of 1 MWp and lithium battery energy storage system of 1 MWh only costs about N$ 33 million and has a life expectancy of 20 years, implying a LCOE of approx. N$ 2.3/kWh.

8.3 IPP-scale Storage

This section showcases the multiple uses of IPP-scale energy storage technologies. Energy storage of IPP scale can offer commercial opportunities provided that the regulatory framework conditions are in place and result in viable business cases. While the scope of this overview paper does not allow for the detailed coverage of all relevant opportunities, it is still instructive to reflect on those aspects that may be developed into commercial undertakings if IPPs.

IPP-scale storage is useful and a potentially viable if one or several of the following challenges exist:
- Extending IPP supplies to beyond the operating hours dictated by intermittent resources
- Increasing intermittent renewable supplies to levels close to the grid’s absorption capacity
- Providing supplies in peak demand periods, or to avert or at least delay load shedding, or as emergency supplies in periods where other grid supplies are temporarily unavailable
- Delaying investments in grid infrastructure and grid-related upgrades
- Providing ancillary services to the network operator.

Namibia’s high-voltage connections to SAPP readily enables the trade of energy, which does however rely on such exchanges not exceeding the maximum capacity of the grid or its stability. As yet, Namibia has no automatic generation control, implying that essential grid-related stability controls such as power balancing, frequency control or providing reserve capacities are undertaken through the Southern African Power Pool (SAPP) and in particular, by ESKOM in South Africa.

The demand for power changes constantly as end-users switch appliances on or off. This changing demand must constantly be met by dispatching power plant, while ensuring that the least-cost options are used first. The order in which power plant are dispatched also depend on the conditions contained in the power purchase agreement (PPA) that exists between suppliers and the off-taker. For example, supplies from Ruacana are inexpensive, but the ability to supply depends on the water levels in the Kunene River. There is some limited water storage available which allows for some flexibility in its dispatch. Power plants with take-or-pay clauses in their PPAs with NamPower are dispatched first. Additional supplies are then secured by way of imports from the SAPP region. If additional supplies are required, the Anixas heavy-fuel oil plant at Walvis Bay and the coal-fired Van Eck power station in the northern part of Windhoek are dispatched.

The use of storage by an IPP is only viable if it is fully integrated into the grid infrastructure. As indicated above, IPP-scale storage can provide several services, all of which have their own distinct value proposition and viability considerations. For example, a solar PV IPP can extend its supplies to beyond the operating hours that are dictated by the sun. In this way, an IPP may benefit from higher in-feed tariffs, for example when it can supply in peak demand periods.

The architecture and elements that characterise the Namibian power grid places limits on the degree by which supplies can be provided by intermittent sources. Both the ECB and NamPower have commissioned studies to investigate what such uptake limits may be, indicating that intermittent sources contributing up to 50% of the current electricity mix should not destabilise the current system. This implies that, as the percentage of power supplied by intermittent renewables increases, the management of the grid will require tools to ensure its operability. Storage is one such tool and the adoption and use of storage by IPPs enhances the grid's resilience and allow for the introduction of additional intermittent capacities. As shown in Figure 1, the installed nameplate capacity of the solar PV and wind plant (at the time of writing) amounted to 126.5 MW, thereby accounting for 24% of the country's total installed generating capacity (excluding Namibia's installed generating capacity, excl. embedded, off-grid and behind-the-meter plant).

In other areas, the existing grid network may be constrained. Here, the introduction of a storage facility may delay investments in grid upgrades, which can be monetised by way of a PPA. The viability of such storage facilities is location-dependant, i.e. locations in network-constrained areas offer advantages over others where there are little or no such constraints.
The following example of an IPP-scale storage facility is introduced to provide a high-level illustration of the costs and benefits associated with such a facility. It is assumed that the IPP under consideration is located close to an existing substation and feeds electrical energy into the transmission system via the substation. It is further assumed that network studies have indicated that the local network is constrained and that an extension of operating hours would secure favourable in-feed prices.

A fully grid-integrated lithium energy storage facility of 75 MWh costs some N$ 400 million, has a total project life of about 8 000 charge-and-discharge cycles which is equivalent to an operational life of some 20 years and offers a levelised cost of storage (LCOS) of about N$ 2/kWh, excluding the cost of the energy supply . Such a large-scale storage facility would extend the window during which the IPP can supply the network. Most importantly, this would enable supplies during the evening peak demand period, thereby reducing the requirement for imports, which delays investments in grid upgrades and reduces the use of expensive power supply options such as Anixas and Van Eck.

An IPP could also benefit by taking advantage of supply capacity it may have that go beyond the capacity indicated in the PPA and using such extra capacity to charge up the storage facility during off-peak periods while discharging it in peak demand periods. In addition, such a plant could provide ancillary services to the grid operator, for example providing emergency power in response to address local intermittency by solar plant outputs, respond to short-term power fluctuations or provide short-term supplies for power balancing purposes, all of which saves on the operation of expensive thermal plant such as Anixas or Van Eck that have electricity costs exceeding N$ 4/kWh.

9 Local Value Addition to Advance Energy Storage Technologies

This section reflects on the opportunities to use local resources to advance the application of energy storage technologies in Namibia. Namibia has many known mineral deposits, including those required for the production of contemporary electricity storage technologies, such as lithium, cobalt, copper, tin, nickel, tantalum, graphite as well as a variety of rare earths minerals. The development of storage technologies for batteries in domestic, commercial and industrial applications as well as those in electric vehicles is driving the global demand for the so-called battery minerals.

While most of the local deposits of are not yet (or no longer) being mined, many continue to be prepared for development. These include AfriTin's revived tin mine near Uis, Gecko's Okanjande graphite project south of Otjiwarongo, Desert Lion Energy's Rubikon and Helikon lithium projects near Karibib, Namibia Rare Earths' Lofdal project near Khorixas, the Gecko Opuwo Cobalt project near Opuwo, Deep South Resources' Haib copper-molybdenum porphyry deposit in the southern Karas Region and North River Resources' Namib Lead and Zinc mine east of Swakopmund.

Namibia's mining sector is a key contributor to the country's economy. It provides direct employment to some 16 000 people and plays a marked role the country's ongoing development. However, mining does mostly not include further mineral processing to enhance local value addition. This is because such efforts necessitate additional expertise, capital and focus that the local mining fraternity – in most instances – does not consider to be part of their business undertakings.

Manufacturing necessitates specialised capacities as well as capital and markets that are optimally aligned with prevailing local economic framework conditions if it is to flourish. Namibia and many other developing nations do not fulfil these pre-requisites, implying that most developments in the field of energy storage technologies continue to take place in industrialised countries where framework conditions, incentives and large market actors (such as those in the automobile industry) drive innovation and production processes.

Namibia's skills, access to capital and existing manufacturing capabilities are unlikely to attract any of the major actors that are advancing storage projects for now. Mineral exploration and mining activities, on the other hand, have a solid track record and the country is recognised as being amongst Africa's premier mining destinations. Market conditions offer considerable additional scope for advancement, benefitting from rich mineral endowments. Therefore, while opportunities for value addition should be pursued further, Namibia's key attraction of relevance to energy storage technologies is likely to remain being a reliable destination and supplier of minerals and associated concentrates.

10 Conclusions

This section provides some take-away messages of relevance to energy storage technologies in Namibia:

1. Namibia's renewable energy resource endowments, specifically its solar and wind resources, can offer significant benefits when combined with contemporary energy storage technologies.

2. The appetite shown by commercial, industrial and domestic end-users in adopting solar PV is indicative of what is likely to lie ahead in terms of the uptake and use of energy storage technologies in future.

3. Increasingly cost-effective energy storage technologies will further incentivise the uptake of intermittent renewable energy technologies, especially solar PV and wind. This is likely to lead to further off-grid electrification as well as the adoption and use of medium- and large-scale storage applications for commercial and industrial applications, provided that relevant legal and regulatory provisions enable innovative business applications of storage technologies.

4. It is imperative that Namibia is adequately prepared to deal with the arrival of cost-competitive energy storage technologies. Legal, regulatory and statutory provisions are currently being strengthened to pave the way for the large-scale introduction of energy storage technologies; other issues to enhance the value of energy storage technologies in Namibia are listed in Annexure 2 below.

5. The ongoing decline of energy storage and renewable energy technology costs has a profound impact on non-renewable energy generation assets, including conventional fossil-fuelled plant. Today, numerous applications relying on modern energy storage technologies enable the viable supply of electricity in settings that could previously only be served by fossil-fuelled power supplies.

6. Energy storage technologies are expected to have a profound impact on the business models of all electricity utilities as increasingly cost-effective storage will incentivise grid defection and reduce the electricity demand as end-users displace conventional grid electricity supplies using their own supplies.

7. Despite such looming challenges, efforts of most local electricity utilities centre around continuing to do what has always been done. This creates a multitude of opportunities for suppliers and installers of renewable energy and storage technologies, while inviting the development and implementation of innovative business models involving on- and off-grid supplies.

8. While energy storage technologies are being procured and used in Namibia, the total market for such technologies and associated systems remains small. The current economy-wide challenges necessitate solutions that enable end-users to reduce recurring costs immediately, including for electricity supply.

9. The renewable energy business fraternity has been negatively affected by Namibia's current economic downturn, including the impacts associated with the coronavirus pandemic. Currently, some forty local companies offer energy storage systems in Namibia. Four of these are considered to have the capacity to implement systems that are larger than the most common domestic behind-the-meter applications.

10. Strengthening local capacities in research and development, as well as innovative vocational and business training relating to energy storage technologies will remain essential, and could inform the activities of the Renewable Energy Industry Association of Namibia in future.

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Annexure 1: Terms of Reference

This Report was guided by Terms of Reference specifying the following tasks and minimum output requirements:

1. A brief introduction to Namibia's intermittent renewable energy resources and contemporary energy storage technologies, and how these can potentially contribute to the country's electricity supplies (approx. one A4 page);
2. a summary of the main opportunities and challenges for an improved integration of wind and solar energy sources into the national resource mix, and the role of contemporary energy storage technologies to enhance Namibia's electricity supply (approx. one A4 page);
3. a non-technical overview of the commercial opportunities to utilise cost-effective energy storage technologies as part of both on- and off-grid electricity supplies in Namibia (approx. two A4 pages);
4. two energy storage examples, e.g. one for a 1MW stand-alone power supply and one for an IPP-scale application, to showcase the application and use of energy storage technologies in Namibia (approx. one A4 page of context, and one A4 page per example);
5. main conclusions on the application and use of energy storage technologies in Namibia, and brief reflections on the use of local resources (including mineral resources such as lithium) to advance energy storage technologies in Namibia (approx. one A4 page); and
6. an addendum that identifies the topics that are likely to require further investigations, and/or legal, regulatory or other aspects to enhance the value of energy storage technologies in Namibia (approx. one A4 page).

Annexure 2: Issues Requiring Further Attention

This annexure provides a high-level summary of topics requiring further strengthening to enhance the value of energy storage technologies in Namibia. Energy storage technologies will profoundly influence the further uptake of intermittent renewable energy technologies. This necessitates that the arrival and use of such technologies is actively prepared for. Amongst others, the following aspects require further attention:

- **National Integrated Resource Plan (NIRP):** the NIRP is the Government's 20-year generation plan. The version of 2016 does not include the use of storage technologies. In 2020, the NIRP is fully reviewed and would pave the way for the use of storage provided that these form part of the update.
- **Legal framework:** since 2018, a draft Electricity Bill is in circulation, which contains provisions for the licensing of energy storage technologies. However, in 2020, the Bill has not yet been passed, which is necessary to develop the regulatory provisions required for the orderly uptake and use of storage.
- **Regulatory treatment of storage and associated services:** in 2020, Namibia's regulatory framework for the electricity sector does not specifically address the multiple uses of energy storage technologies. However, the Electricity Control Board is currently supported by consultants to develop the national regulations for energy storage. This is of critical importance as such regulations will further support the country's drive towards the uptake of renewable energy sources and energy self-sufficiency.
- **Provisions for tariffs:** grid-integrated energy storage technologies can provide several services, including but not limited to receiving and injecting electrical energy. Such services will only be considered if there is a solid basis on which such services are provided. In 2020, tariffs for the services provided by energy storage technologies

is unavailable. This implies that business models that include storage services cannot as yet be remunerated. It is, however, expected that the ECB will develop the tariff regime required for the transparent treatment of energy storage technologies in due course. This is to include tariffs for ancillary services, i.e. those operations required to maintain the stability of the grid, e.g. frequency control, operating reserves and the provision of spinning reserves.

- **Business models:** once the regulatory provisions for energy storage technologies are established, new business models involving such equipment can be devised with greater clarity and confidence. It is expected that energy storage technologies will affect the business models of most current electricity utilities and it is therefore impetrative that utilities address how they intend to continue to operate in the face of rapidly declining solar PV and storage costs.
- **Behind-the-meter developments:** declining solar PV and energy storage costs will have a profound impact on the uptake and use of behind-the-meter investments. In this context, behind-the-meter refers to the end-user's side, where various types of energy storage technologies are expected to make an entry. This may, in time, lead end-users to defect from the grid, causing a downward spiral of decreasing revenues and increasing operational pressure on distribution utilities.
- **Mobile energy storage:** energy storage technologies as used in hybrid or fully electric vehicles are expected to become more plentiful, thereby changing the supply, design and operation of today's grid infrastructure. Developments such as the creation of smart grid infrastructure will change the way in which end-users benefit and interact with the electricity grid.
- **Off-grid electrification:** this refers to the provision of electricity by means of a supply system or distribution network that is not connected to the grid, irrespective of the proximity of the grid. Cost-competitive energy storage technologies will enable end-users to benefit from off-grid technologies, including in areas that are well-served by way of existing grid infrastructure.
- **Rural electrification:** cost-effective energy storage technologies will enable the electrification of rural areas in ways that remain unattainable using the grid. This creates multiple opportunities for development, including for schooling, health, communication, food security and many others.

References

The topics covered in this text are informed by data and information from the Namibian Ministry of Mines and Energy, Electricity Control Board, NamPower, Namibia Statistics Agency and the author's extensive energy- and electricity-related database:

- Ministry of Mines and Energy: www.mme.gov.na
- Electricity Control Board: www.ecb.org.na
- NamPower: www.nampower.com.na
- Namibia Statistics Agency: www.nsa.org.na

A selection of books and public reports compiled by the author relating to Namibia's electricity industry include the following:

1. State of the Namibian Electricity Sector – 2019, 2019
https://voconsulting.net/wp-content/uploads/2020/03/SNES_2019.pdf

2. Energy Storage Systems and their Applications in Namibia's Electricity Sector, 2018
https://voconsulting.net/wp-content/uploads/2020/03/Energy-Storage-Systems.pdf

3. Economic impacts of the deployment of Renewable Energy Technologies in Namibia, 2018
https://voconsulting.net/wp-content/uploads/2020/03/Econ-Impacts-Ren-Energy-Namibia.pdf

4. Smart Grids and their Potentials in Namibia's Electricity Sector, 2018
https://voconsulting.net/wp-content/uploads/2020/03/Smart-Grids-and-their-Potentials.pdf

5. REEE-Powering Namibia - Energising National Development, 2015
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6. Namibia's Energy Future: A Case for Renewables, 2012
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7. Hybrid Electricity Systems Powering Mini-grids – A Southern African Perspective, 2007
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Dr Detlof von Oertzen is an independent technical and management consultant, holding a PhD in high-energy nuclear physics and an MBA (Advanced) with a focus on finance. He is the director and principal consultant of VO Consulting which is a specialist consulting firm active in the energy, environment and radiation sectors. In his consulting career which spans over some 30 years, Detlof has worked in numerous multi-disciplinary teams and as a member of international expert and specialist groups. His clients include various international entities, including the United Nations Development Programme, United Nations Framework Convention on Climate Change and the World Bank Group to name a few.

About the EAN:

The Economic Association of Namibia (EAN) is a Namibian Think Tank conducting research and providing public policy advisory services. The Association also organizes public discussion forums on topical issues in order to inform the broader public and stimulate public debates on current issues. Moreover, the EAN has established an online document repository accessible through its website that provides access to relevant socio-economic research reports and official documents.

About the REIAoN:

REIAoN's core purpose is to facilitate Renewable Energy potential into a sustainable reality. REIAoN believes that Namibia's potential leaves enough room for various solutions, players and innovation. This can be leveraged through proactive quality engagement around the sector and REIAoN hopes to play its part in facilitating relevant platforms.

About the Hanns Seidel Foundation (HSF):

Present in more than 60 countries world-wide, the Hanns Seidel Foundation Namibia (HSF) is a German non-profit organisation, largely funded by the German Federal Ministry for Economic Cooperation and Development. Together with its Namibian partners, the Foundation promotes democracy and good governance, the rule of law and anticorruption, sustainable economic and social development, environmental sustainability, as well as climate adaptation and mitigation.

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