Solar Thermal Technology Roadmap

The Future for Solar Thermal Energy

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Namibia

Solar Thermal Technology Roadmap for Namibia

A Vision of Namibia’s Solar Thermal Energy Future

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“Vision for the large-scale roll-out of solar thermal technologies in Namibia”

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1 Preface

The mission of Solar Thermal Technology (STT) Roadmap 2030 is to provide a practical, independent and objective analysis of pathways to achieve a low-carbon economy in Namibia, in line with the universal energy access, energy security, environmental and economic goals of the Namibian Government. The STT Roadmap 2030 is an initiative of the Solar Thermal Training and Demonstration Initiative (SOLTRAIN) Project and has been developed by a consortium of experts funded by the SOLTRAIN Project.

1.1 The Solar Thermal Training and Demonstration Initiative: SOLTRAIN Project

The Austrian Development Agency (ADA) and AEE-INTEC (Institute for Sustainable Technologies from Austria) have the SOLTRAIN Project, in cooperation with Southern African educational institutions, renewable energy institutions and companies in South Africa, Mozambique, Namibia and Zimbabwe. The Project is funded by the ADA and the OPEC Fund for International Development (OFID). In Namibia, the SOLTRAIN Project is implemented by the Namibia Energy Institute (NEI) at the Namibia University of Science and Technology (previously known as Polytechnic of Namibia).

The project's aim is to build capacity in the field of solar thermal technologies, and promote the use of solar thermal systems by ensuring the quality, performance and lifetime of solar thermal systems. In addition, the project is indirectly aimed at creating new jobs in small and medium enterprises, and strengthening the local support mechanisms for solar thermal systems.

The main activities under SOLTRAIN include:

Development of a roadmap for solar thermal energy use - aimed at building capacity, establishing and strengthening sustainable institutional structures for increased uptake of solar thermal technologies and increasing awareness (informing all stakeholders on the different applications of solar thermal energy and the related impacts on security of energy supply, poverty alleviation, employment opportunities and the benefits to the environment).

Implementation of Centres of Competence - a sustainable institutional structure and focal points for solar thermal information, training, support for industry and policy makers, as well as for applied research. *Centres of Competence* will be implemented in institutions of higher learning in each country, which will offer comprehensive training programmes, ranging from practical hands-on training to courses that are to be offered at university level.

Development of Solar Thermal Technology Platforms (STTP) - these will be implemented at Centres of Competence in each partner country, and these will be cross-linked to a Southern African Solar Thermal Technology Platform to ensure effective information exchanges and cooperation between partner countries.

In order to ensure that the knowledge gained in training courses is applied, and to enhance public awareness, **40 - 50 solar thermal demonstration systems** of different sizes and applications will be installed at select social institutions as well as small and medium enterprises in each partner country.

Under the project, Namibia's Vocational Technical Centres (VTCs) have benefited by having solar thermal systems installed, and various instructors have since been up-skilled. The solar thermal technology roadmap for Namibia is another initiative under SOLTRAIN, which aims at creating favourable framework conditions to strengthen the technology platform to more optimally promote the application and implementation of solar thermal technologies in Namibia.

1.2 Purpose of the roadmap

The Namibia Solar Thermal Technology Roadmap (Nam-STTR) is a project of the Solar Thermal Technology Platform (Nam-STTP), which forms part of the SOLTRAIN 2 project. Nam-STTP supports the switching from fossil fuels to sustainable solar energy sources for applications such as water heating, (solar) cooling, the provision of process heat and low temperature steam.
Nam-STTP brings together all interested parties from academia, government, financiers, end-users and industry with the aims to:

- Share information on technical and financial aspects of solar thermal energy use;
- Identify knowledge gaps and opportunities;
- Mobilise institutions or individuals to do the required research; and
- Disseminate the results and keep records of the roll-out of solar thermal energy technologies and systems in the country.

The purpose of the Namibia Solar Thermal Technology Roadmap is to outline the path towards a national vision for solar thermal applications in the country, targeted at enhancing the quality of life of the Namibian people through the provision of a sustainable and quality-assured solar thermal technology value chain.

This vision document describes the goals and targets for solar thermal energy and provides an overview of the technological perspectives and needs of research and development to fully exploit the benefits of solar radiation as a major energy source in 2030. The document gives some ideas as to the sectors in which solar thermal energy will be used, to what extent, with which technology and in what types of applications.

In order to achieve the strategic goal this document presents the following issues:

- The concept of available technologies and present status;
- Identification of Strategic Focus Areas;
- Setting the targets and timelines; and
- Stakeholder roles.

To this end, the Solar Thermal Technology Platform has defined its mission, i.e*., to achieve a fully functional 0.5 m² (approximately 0.35 kW thermal equivalent) of flat plate solar thermal collector installed capacity per inhabitant in Namibia by 2030*. By achieving the said penetration of solar thermal technologies, some 1.5 million m² of collector area with a thermal output equivalence of approximately 525 MW would be available by 2030.

2 Introduction and Rationale

2.1 Context

About 54 % of all Namibian households rely on biomass (wood and charcoal) to cover their thermal energy requirements. In rural Namibia, some 82 % of all households use biomass, compared to about 20 % in urban areas. Biomass is predominantly used to provide thermal energy, in applications ranging from food preparation to water heating.

Most of the energy that is used in households and commercial buildings in Namibia is for the provision of thermal services such as cooking, heating and cooling. It is noted that a significant percentage of such thermal energy requirements could be met by using solar thermal energy, as most thermal energy uses are for applications at temperatures below 100°C. As a result, solar thermal applications have a considerable potential and could replace many of the more traditional fuels that are currently used for heating and cooling.

The use of fossil fuels cause greenhouse gas emissions, which are a leading driver of anthropogenic climate change. In addition, the import of fossil fuels places a permanent drain on national economies, and their price volatility renders them increasingly undesirable for heating and cooling applications. The excessive use of biomass resources also has negative environmental impacts, especially when using non-sustainable harvesting practices as are commonplace in many countries. On the other hand, an increase in the application and use of renewable energy and energy efficient technologies is expected to displace fossil fuel use, including in buildings and industrial processes. In particular, the deployment and increased application of solar thermal technologies will be essential to reduce the use of fossil fuels on the one hand, and enhance the sustainability of heating and cooling practices, on the other.

In order to utilise the full potential offered by contemporary solar thermal technologies, which are by now mature technologies, both research and development efforts need to be changed, as well as the way in which these technologies are implemented. Of note is that solar thermal applications are generally locality specific, and unlike electricity, heat is more difficult to transport over long distances.

Today, it is entirely possible to cover all heating and cooling requirements using contemporary solar thermal technologies in new buildings. Solar thermal technologies can often cover more than 50% of the heating and cooling requirements in existing building stock, which may increase up to 100% coverage depending on building- and technology-specific conditions.

Most industrial processes have not yet embraced existing solar thermal potentials, but increasing prices for electricity, biomass and/or fossil fuels are expected to introduce rapid changes as soon as solar thermal technologies can be shown to be financially viable alternatives. Here, solar heating and cooling, as well as solar cooking, drying and related thermal applications are the most likely candidates that will replace traditional technologies.

The increased use of solar water heaters (SWH) reduces the dependency on imported electricity, increases the security of local supplies and creates savings for end-users. Overall, these individual impacts create positive macro-economic benefits of tens of millions of Namibian dollars each year, which can then be channelled into other projects and initiatives.

2.2 Climatic Conditions

The effective use of solar thermal technologies depends on local climatic conditions. The following description of Namibia's climate is informed by the World Meteorological Organisation. Namibia's climate is predominantly semi-arid to arid. Large areas to the east and west of the country are covered by the Kalahari Desert and Namib Desert respectively.

The effectiveness of technologies relying on solar energy is determined by the type and intensity of solar radiation received and the number of sunshine hours per year. With an average of 300 days of sunshine annually Namibia is one of the sunniest countries in worldwide. One particular measure of relevance to most solar technologies is the level of insolation, i.e. the amount of direct normal irradiation, and global horizontal irradiation per square meter, as is shown in Figure 1.

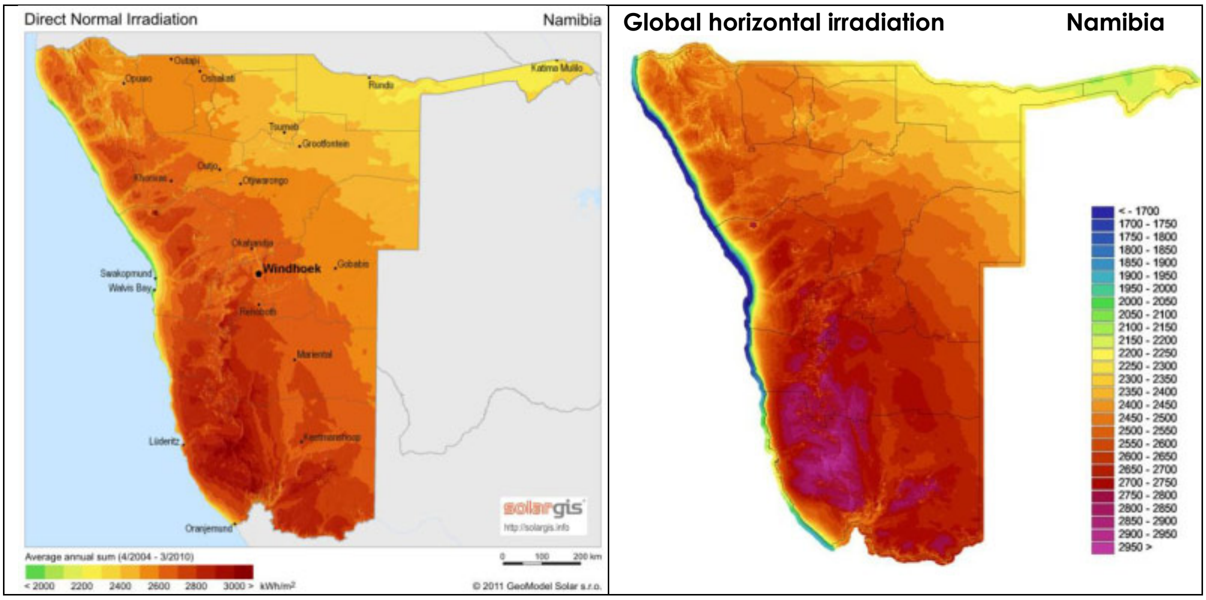


Figure 1: Annual Direct normal-, and Global horizontal solar radiation (Insolation)

The performance of solar systems also depends on other climatic conditions, such as the occurrence of wind and wind speeds, rainfall and humidity levels, as all these conditions have an indirect and/or direct impact on the ambient temperature.

On average, summer day-time temperatures are warm to hot, and generally range from about 20°C to just under 40°C, while average winter night temperatures range from about 7°C to about 17°C. Coastal areas exhibit the smallest temperature ranges as a result of moderation due to the cool south-westerly winds over the Benguela current in the Atlantic Ocean. Over much of the central areas of the country, which include the capital, Windhoek, conditions are fair due to the moderating effect of the high altitude.

The northern and north-eastern margins are affected by a sub-humid tropical climate. The main rainy season occurs during the southern hemisphere's summer season, i.e., between the months of October and April. However, winter rainfall is not an uncommon feature in the extreme southern parts of the country, where it accounts for over 50% of annual rainfall in some places. Average annual rainfall is highly variable in both time and space. The largest year-to-year differences are in the lower rainfall areas in the western and southern parts of the country, with a variability exceeding 100%. In the north and north eastern parts of the country, where annual rainfall is relatively higher than in the rest, the climatic variability amounts to some 20%. Mean annual rainfall varies from under 20 mm along the coast, to around 700 mm in the extreme north-eastern parts of the country.

The mean monthly rainfall in central Namibia varies between 0 mm in July and approximately 80 mm in March. Rainfall in Namibia is less than 50 mm in the south-west and in coastal areas, and increases to more than 700 mm in the north-eastern parts of the country. Humidity in the least humid months varies from less than 10% in the southeast to 80% on the coast and in the most humid months from 40% in the southeast to more than 90% on the coast.

The number of frost days per year varies from zero along the coast, to more than 30 days on the central eastern border. Hail is occasionally experienced in Namibia, with hailstones varying in size, but reliable records of the frequency of such events and associated hailstone sizes are not available.

2.3 Existing Legislation, and Institutional Setup

The success of the roadmap will depend on the supporting legislation, regulations and targets by key stakeholders, and especially the government.

The following extract from Namibia's 2015/16 national budget statement confirms the desire by Government to improve the quality of life of Namibian residents:

"Namibia has been able to make notable progress and register key achievements, which include:-
The expansion of the economy by a factor of 15 since 1990, from N$8.3 billion to N$126.6 billion by 2013, with the corresponding income per capita having increased more than 10 times, from N$5 500 to N$58 300, thus propelling Namibia into the league of upper middle-income economies by global comparison."

"The third priority for the 2015/16 national budget and MTEF is the achievement of prosperity and wealth creation through:-

- *empowering Namibians in a manner that creates sustainable and broad-based wealth creation,*
- *promoting affordable and sustainable access to finance and means of production, while maintaining responsible lending, developing facilities to support SME access to finance and mentorship programmes,*
- *increasing the share of local ownership and value share in the value chains across various industrial and service-oriented activities and*
- *encouraging wealth accumulation and prudent management, and expanding the provision of basic amenities to all Namibians."*

2.3.1 White Paper on Energy Policy (1998)

The White Paper on Energy Policy[i] was developed by the Energy Policy Committee of the Ministry of Mines and Energy, and was released in May 1998. It puts forward six specific national energy sector objectives, namely:

- Effective governance;
- Security of supply;
- Social upliftment;
- Investment and growth;
- Economic competitiveness and efficiency; and
- Sustainability.

The Policy recognises that the Namibian economy is energy intensive, partly as a result of the significant role played by the mining sector, a growing transport sector, and the inefficient use of energy in households, industry as well as in Government and commercial buildings. In order to reduce energy intensity and improve the economic efficiency, the Ministry of Mines and Energy has the responsibility to:

- Ensure that an appropriate level of national resources are invested in demand-side management activities;
- Ensure that economically viable energy efficient technologies and processes are implemented; and
- Address barriers or disincentives to energy efficiency.

In order to address these challenges, the Policy mandates the Ministry of Mines and Energy to coordinate initiatives, and where possible, assist in funding studies to determine the nature of energy end-use patterns in all sectors. Challenges in the dissemination of information and education, as they pertain to energy efficiency, are highlighted as a barrier, to be addressed through a national awareness campaign. In addition, energy efficiency in commercial and residential buildings was identified as being an area of application for energy efficiency measures, and it is stated that "Government will promote the use of energy efficient appliances and renewable energy technologies and practices enhancing energy efficiency and conservation".

The Policy envisages the Ministry of Mines and Energy to lead the development of an energy efficiency appliance labelling system, and associated information dissemination. In addition, the Ministry is to encourage local authorities to set minimum energy efficiency requirements in new building construction, and encourage the adoption of measures aimed at saving energy used in water heating, in particular through the use of solar water heaters in buildings. In the industrial and commercial sectors, the Ministry is to take the lead in conducting showcase energy audits in the industrial and mining sectors, create incentives for energy efficient devices, and coordinate energy efficiency training for industry.

2.3.2 Codes of Practice for Namibian Solar Energy Technologies (2006)

Codes of Practice for select solar technologies were compiled under the Ministry of Mines and Energy's Namibian Renewable Energy Programme, and includes Solar Home Systems (SHS), Solar Photovoltaic Water Pumping Systems (PVP), and Solar Water Heaters (SWH). These were considered important to ensure minimum quality levels and provide assurance in regard to the reliability of solar technologies applied in Government-supported programmes, including the Solar Revolving Fund, which offers loan facilities for SHS, PVP and SWHs.

The Codes provide practical guidance, especially to solar technicians, and address activities at and around installation sites, including safety, site assessment criteria, installation procedure and commissioning, maintenance and hand-over procedures to end-users. The Codes' main purpose is to minimise the number of poor quality products entering the market, and promote good workmanship by setting minimum requirements for SHS, PVP and SWH. As such, the Codes are a necessary pre-requisite for the successful implementation of Namibia's solar roadmap.

2.3.3 Cabinet Directive on Solar Water Heaters – 2007

In 2007, Cabinet approved the implementation of the following directive on water heating in Government buildings:

- All new governmental and parastatal buildings' hot water requirements should be met through the installation of Solar Water Heating only;
- In the existing governmental and parastatal buildings, any replacement of the existing Water Heating System to be done through Solar Water Heating only;
- In the existing governmental and parastatal buildings without any Water Heating Systems, any new installation for the provision of hot water should be through Solar Water Heating only;
- In case where the above clause(s) cannot be implemented, approval must be obtained from the Ministry of Works, Transport and Communication in consultation with the Ministry of Mines and Energy.

Government may consider extending the Cabinet directive to all public projects, including to the National Mass Housing Initiative, which aims to add 185 000 houses to Namibia's building stock between 2012 and 2030.

2.3.4 Namibia's Fourth Development Plan – (NDP-4), 2012

The Government of Namibia is committed to building the economy, and improving the quality of life of all of its citizens. The launching of the fourth National Development Plan (NDP-4)[ii] expresses the Government's key short- and medium-term development objectives. The Plan recognises energy as a cross cutting input into all sectors of development. For rapid economic development, the provision of affordable and sustainable energy is recognised as a key developmental pre-requisite. In addition, NDP-4 recognises the need for promotion of demand side management strategies, especially for commerce and industry as well as domestic end users. In this regard, the continuous promotion and development of renewable energy and energy efficient technologies is to be given special attention and consideration, and can positively influence the national energy mix, and is a clear indication Government's commitment to support the sector. Therefore, an increased penetration of solar water heaters supports the Government's initiative in this field, and explicit solar thermal targets are therefore a necessity in realising the national development ambitions.

2.3.5 The Namibia Energy Institute: NEI

In 2006, Namibia's Renewable Energy and Energy Efficiency Institute (REEEI) was established to undertake research and promote renewable energies and energy efficiency practices. In May 2014, REEEI was officially transformed to become the Namibia Energy Institute (NEI).

NEI is a national institute of the Government of the Republic of Namibia, hosted by the Namibia University of Science and Technology (NUST), i.e., the erstwhile Polytechnic of Namibia.

NEI has the mandate to undertake research, development and capacity building in the field of energy, including on different energy technologies and energy efficiency. NEI's mission is to contribute to Namibia's industrialisation by linking energy research, technology, policy and education to the needs of industry, in support of national socio-economic development imperatives, initiatives and programmes. This will be achieved through targeted interventions by the four centres of the NEI, i.e., the Centre for Renewable Energy and Energy Efficiency (CREEE), Centre for Electricity Supply (CES), Centre for Petroleum (Oil and Gas) (CPOG), and Centre for Nuclear Sciences (CNS).

2.3.6 Namibian Standards Institution (NSI)

The Namibian Standards Institution (NSI) and the Ministry of Mines and Energy defined minimum quality levels for renewable energy technologies and associated services, as outlined in the Code of Practice and Register of Products for Namibian Solar Energy Technologies. Such quality levels pertain to installation workmanship, system performance and after sales service.

In order to enforce and monitor the quality of such products and services, the National Technical Committee on Renewable Energy (NTCRE) was formed, and is the first technical committee of the NSI whose membership includes MME, Namibia Energy Institute (NEI), NSI, Renewable Energy Industry Association of Namibia, NamPower, Namibia Training Authority and the Electricity Control Board. Its mandate is to develop, adopt and improve the use of quality standards in renewable energy industry.

2.4 Current and Planned Programmes

The demand-side-management (DSM) study which was commissioned by the Namibian Electricity Control Board (ECB) in 2006 recognised widespread use of solar water heaters (SWHs) as an effective demand side management measure. It estimated that SWHs could reduce electrical capacity requirements by up to 54 MW in a decade. At the time, a steering committee was established by the ECB to oversee the implementation of DSM initiatives, and included stakeholders from the mining industry, the National Housing Enterprise, NamPower, Regional Electricity Distribution companies and Municipalities, as well as the MME, National Planning Commission and the Ministry of Works.

In 2014, and in response to the viability of many DSM initiatives, NamPower embarked on a demand side management campaign, amongst others by incentivising the replacement of 20 000 domestic electric water heaters by SWHs over a 5-year period. In this way, peak electricity demand due to electric water heaters would be reduced, which contributes to the security of electricity supplies by reducing electricity requirements in peak demand periods.

In another initiative, the Government has started Mass Housing Development, which is envisaged to see the construction of 185 000 domestic dwellings between 2012 and 2030. As yet, the implications that such an ambitious building program will have on the country's electricity supply and distribution industries have not been ascertained. It is however obvious that the addition of 185 000 domestic dwellings within a period of less than two decades will bring about substantial increases in the demand for electrical energy, which have not been factored into medium- to long-term demand projections, and cannot be served from existing generating capacities. Such developments therefore imply that significant investments are required, both in electrical generation and distribution capacities. However, recognising that a significant part of domestic energy

use is for water heating, the Mass Housing Project could substantially benefit from the increased use of solar technologies.
In 2001, the Ministry of Mines and Energy created the Solar Revolving Fund (SRF), to provide loans, of up to N$35 000, for select solar technologies at subsidised interest rates. In its present form, the SRF also funds the acquisition of SWHs.
Since 2013, the Environmental Investment Fund (EIF) of Namibia offers loans of up to N$100 000 to individuals for the installation of renewable energy systems, including solar water heaters.
In 2011, Namibia had a population of 2.2 million people, with an estimated growth of about 1.57% per annum [iii,iv,v], implying a population of approximately 3 million people by 2030.

2.5 Why solar thermal systems in Namibia?

As of 2014/15, Namibia imported up to 65% of its electricity demand. Electricity imports are expensive: for example, the cost of electricity imports in 2014 is estimated to have amounted to about N$ 2.4 billion, and electricity imports until 2018/19 are estimated to cost an additional N$10 billion. Such costs have a marked impact on the electricity tariffs of local end-users, which are expected to increase by more than 10 % each year.
While most of the electricity that is locally generated originates at the Ruacana hydro-electric power station, more than 90 % of the electricity that is imported is from coal-fired power stations. This implies that Namibia's grid emissions factor, i.e., the quantity of greenhouse gases created in supplying the nation with electrical energy, is relatively low, as greenhouse gases that originate in neighbouring countries are not included in local greenhouse gas emissions, even though the electricity is consumed locally. This implies that each kWh of electrical energy that is displaced by solar thermal energy technologies saves the emissions of approximately 0.5 kg of carbon dioxide equivalent.
Solar thermal technologies can reduce the use of electrical energy. For example, solar waters heaters (SWH) reduce the total electricity requirement needed to heat water, and may also reduce the electricity demand in peak demand times, when electrical energy is most valuable. This is of benefit to Namibia's balance of payments, and can add value irrespective of whether the country is a net energy importer, as is the case in 2015, or once Namibia becomes a net electricity exporter. The Table below shows the amount of electricity that can be saved, because the energy required is provided directly by the sun.
A typical family of six can have their hot water requirements fulfilled by a solar water heater of about 2m² of collector area.

Table 1: Daily energy production (kW_{th}.h) of five solar thermal systems
(The evacuated tube systems used below both have 20 tubes)

Technology	**Flat plate**	**Flat plate**	**Evacuated**
Configuration	Thermo-syphon	Indirect active	Indirect active
Overall size (m²)	1.98	1.87	2.85
Absorber size (m²)	1.98	1.72	2.85
Maximum efficiency	0.74	0.61	0.57
Estimated cost (Jan 2016) (US$)	$4,000	$4,600	$6,000
Energy production (kW.h/day): – Insolation 6.5 kW.h/m²/day (Most parts of Namibia receive above 2400 kWh annually)	8.8	7.1	9.9

Source: RENEWABLES GLOBAL STATUS REPORT 2009 Update. Deutsche Gesellschaft für Technische Zusammenarbeit. ren21.net

In the domestic sector alone, the replacement of an electric water heater (EWH) with a solar water heater can save more than a quarter of the total electricity required per year. Realizing that there are more than 100 000 EWH installed in Namibia's residential building stock implies that considerable opportunities exist for the large-scale introduction and use of SWH in this sector. In addition, neither the commercial, industrial nor institutional sectors have invested significantly in solar thermal applications; this therefore offers additional long-term investment opportunities for such technologies.

Solar thermal installations amounting to more than 22 000 m² in total were estimated to be in operation nationally at the end of 2012[v], including:

- Solar water heaters using flat plate collectors: 20 700 m²; and
- Solar water heaters using evacuated tube collectors: 1 300 m².

This implies that installations have to increase by 25% annually to reach the target as expressed in the solar thermal vision, i.e. 1.5 million m² of collector area by 2030. It is noted that 2012 saw the installation of an estimated 5 400 m² of flat plate collectors in the year, while evacuated tube collectors of some 860 m² were installed[v]. No reliable information is available for installations of unglazed, pumped and cooling systems. Evidently, adding a little over 6 200 m² per year would result in one tenth of the total installed solar thermal capacity envisaged in the roadmap.

It is noted that no reliable statistics are available for:

- Unglazed tubular solar water heaters as are often used for residential swimming pools;
- Industrial / commercial installations using solar heating and cooling;
- Solar space heating applications in buildings; and
- The number and features of solar thermal technologies and passive design elements using solar thermal features as may be found in current building stock.

The payback period is shorter in countries with a large amount of insolation, such as Namibia. In terms of energy, some 60% of the materials of a SWH system goes into the tank, with some 30% towards the collector[vi] (thermosyphon flat plate in this case) (Tsiligiridis et al.). In Italy,[vii] some 11 GJ of electricity are used in producing the equipment, with about 35% of the energy going towards the manufacturing of the tank, and another 35% towards the collector and the main energy-related impact being emissions. The energy used in manufacturing is recovered within the first two to three years of use of the SWH system through heat captured by the equipment according to this southern European study.

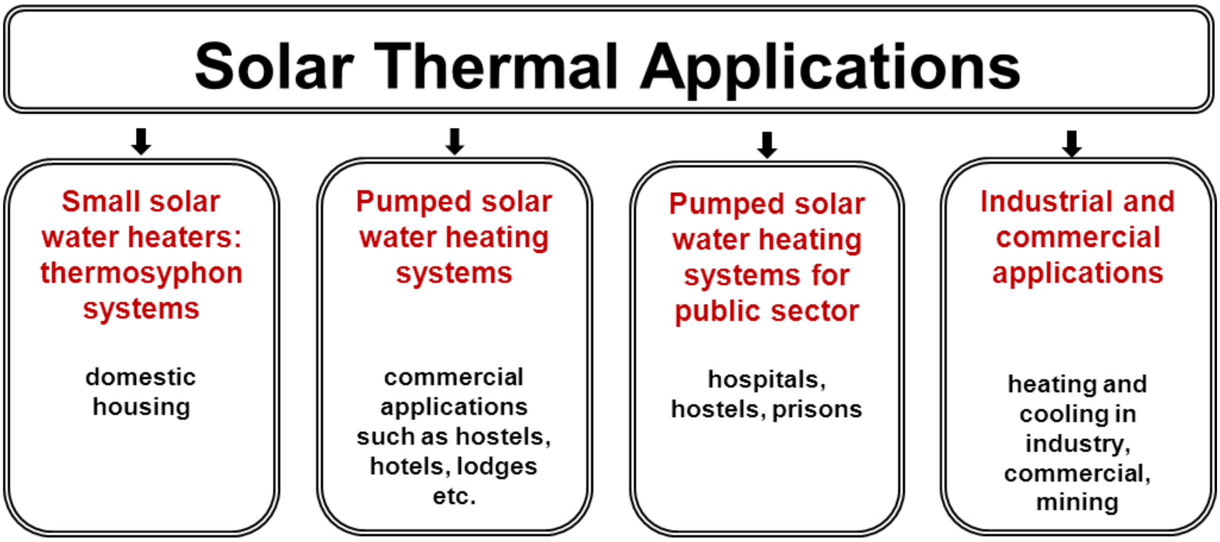
The production of a test SWH system in Italy[vii] produced about 700 kg of CO2, with all the components of manufacture, use and disposal contributing small parts towards this. Maintenance was identified as an emissions-costly activity when the heat transfer fluid (glycol-based) was periodically replaced. However, the emissions cost was recovered within about two years of use of the equipment through the emissions saved by solar water heating.

The energy and emissions cost of a SWH system forms a small part of the life cycle cost and can be recovered fairly rapidly during use of the equipment. Their environmental impacts can be reduced further by sustainable materials sourcing, using non-mains circulation, by reusing existing hot water stores.

3 The Solar Thermal Technology Roadmap

Namibia's solar thermal industry offers the following solar thermal technologies:

- Thermo-syphon systems for domestic houses (2 – 4 m² per system);
- Thermo-syphon systems for commercial operations, including tourist establishments and lodges (2 – 4 m² per system);
- Solar combi-systems (pumped systems) which combines hot water preparation and space heating for domestic houses (10 – 20 m² per system)
- Pumped systems for multi-family houses, hotels, hospitals etc. (20 – 100 m² per system);
- Cooling and air-conditioning of larger offices, hotels etc. (50 – 500 m² per system);
- Industrial applications, including the desalination of sea water (50 – 500m² per system); and
- Solar cooking systems.



3.1 Vision

The Namibia solar thermal technology roadmap aims to achieve the installation of 1.5 million m² of solar thermal collectors by 2030, which translates to about 0.5 m² per inhabitant.

In order to achieve the envisaged target of 0.5 m² of solar thermal collector area per person living in Namibia in 2030, the sector-specific targets as summarised in Table 2 would have to be achieved.

Table 2: Sector-specific solar thermal targets until 2030

Sector	**Description of thermal energy requirements (units)**	**Estimation of solar thermal collector area to satisfy requirements (m²)**	**Estimated total energy produced ($kW_{th}h$)**	**Estimated cost of equipment (US$2000/m²)**
Mass housing project	SWHs for additional 185 000 domestic houses	400 000	642 400 000	800 000 000
Private one-family housing stock	replacement of most domestic electric water heaters by SWHs	600 000	963 600 000	1200 000 000
Private multi-family housing stock	20 000	100 000	160 600 000	200 000 000
Private commercial establishments, incl. lodges	1 000	20 000	32 120 000	20 000 000
Hotels, hospitals, student homes	180 hotels, 343 hospitals and clinics, etc.	60 000	96 360 000	120 000 000
Solar air-conditioning and cooling	Office buildings	20 000	32 120 000	40 000 000
Systems for industrial and mining applications	Low temperature applications, < 200°C	200 000	321 200 000	400 000 000
Domestic and commercial	Solar cooking at 1m² per family	100 000	160 600 000	20 000 000
TOTAL		**1 500 000**	**4 818 000 000**	**4 240 000 000**

Calculation of the total energy is based on 2m² passive flat plate thermo-syphon systems (see Table 1), which gives the lower limit, at 8.8 kW_{th}.h per day.

The vision is based on the assumption that the accessibility to clean water, especially piped water, will be wide spread. The ambitious target of 0.5m² per inhabitant will be based also on cumulative installation and total population. The figure may not necessarily mean that each inhabitant will be having the target capacity, but increased use on large scale especially industrial and public facilities will play a significant role on the figure. In this regard, the figure of 0.5m² will be translated into energy use per person in relation to 0.5m² of collector area. The effort to ensure that most Namibians especially households have access to clean water is considered to be a concerted responsibility of government. The power provided through solar thermal technologies of this nature avoids the generation of electricity by an equivalent 550 MW generator operating continuously.

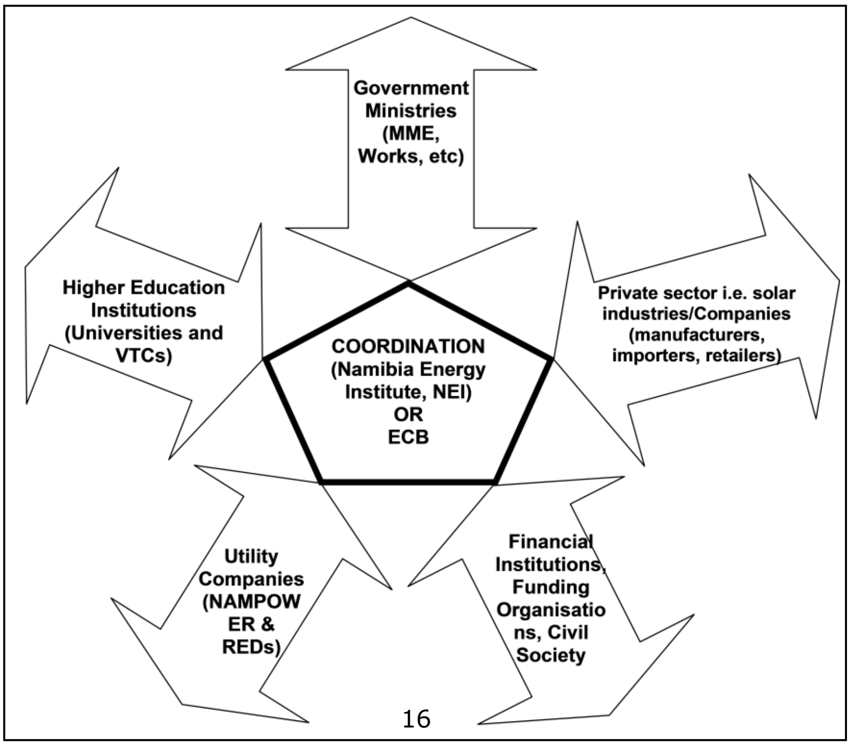
The estimated cost of US$4.24 billion would ensure at least 15 years of operation without having to pay ever-changing fuel prices, since all the technologies are directly solar driven. If implementation is started at the beginning of 2017, there are 13 years till 2030. This implies an average installation of 115 385 m² of collector area per year, at an average cost of US$326.2 million. Namibia’s total non-interest Government expenditure for 2015/16 was budgeted at N$63.23 billion, equivalent to about US$4.44 billion. Implementation of the roadmap as envisaged here means that more than 7 % of the annual budget of the country would have to be allocated towards solar thermal technology provision. This is an optimistic figure, and Government alone may not be in a position to fully finance this venture, therefore private and other donor participation is encouraged.

3.2 Stakeholder Roles on Implementation of the Roadmap

Successful implementation of the roadmap necessitates the close collaboration of various stakeholders, including the following:

Government ministries and related entities: these are responsible for the development of policies, as well as further support in executing the existing Cabinet directive. In addition, Government is to provide a significant proportion of the funding required for additional research and development activities, as well as the funding required for promotions, awareness raising, and deployment of demonstration systems. Provided that funding partners join in, Government may also become active in public-private partnerships and as a co-financier.

Namibia Energy Institute: national focal point and coordinator of the activities under the roadmap. It is to disseminate information amongst relevant stakeholders, and collaborate with tertiary institutions to provide relevant information. The NEI is should furthermore develop a database on solar thermal technologies and projects taking place in the country, and in this way be a one stop centre for information on solar thermal systems and linking stakeholders active or interested in this field.



Private sector: commerce, industry as well as manufacturers and private developers interested in the application of solar thermal energy technologies are likely to play a significant role in developing and implementing cost-effective end-use systems, including by way of research and development activities, product promotion and the establishment of demonstration systems.

Utilities: Namibia's electricity utilities, such as NamPower and the Regional Electricity Distribution companies are expected to integrate solar thermal technologies into their demand side management programmes.

Research/Academic and Vocational Institutions: the key responsibility of all tertiary institutions is to ensure that adequately qualified persons enter the labour market. To this end, such institutions are expected to integrate solar thermal technologies into their curricula, offer post-graduate programmes in the solar thermal field, and engage in applied research.

Financial Institutions: It will be the responsibilities of the industrial sector and research institutions to demonstrate the financial viability of solar system in order to attract financial institutions to support the programme. Also the strong government support in form of policy and rebates will contribute significantly in attracting financial institutions. The institutions should have attractive financial support to encourage more users to apply for loans.

The following sections present a discussion for each of the solar thermal applications shown above, and elaborate stakeholder roles on how these could each be implemented.

3.2.1 Thermo-syphon systems for single family houses and lodges (2 – 4 m² per system)

SWHs use collector panels to capture the sun's radiation and heat water. A solar collector coupled with a storage system reduces the requirement for additional electric heating of domestic hot water. A particular class of SWHs commonly used in small- to medium scale applications are thermos-siphon systems, which require neither pumps nor controllers. The solar collector can be of the flat plate or evacuated tube type. The transfer of heat from the collector into the hot water storage system can be either direct or indirect, and circulation is by way of the principle of thermo-syphoning. In Namibia, hot water storage systems with direct circulation are not recommended, due to the water quality which may corrode the system.

About 50% of electricity demand is in the domestic sector, for cooking, lighting and water heating. This indicates that most households water traditionally heated by electric resistance elements in Namibia. The energy to heat water typically contributes significantly to the households' monthly electricity bills. Domestic solar water heating may give potential to save more than 30% of electricity demand. Namibia is among the few countries in the world blessed with abundant sunshine, and switching to a solar water heater can typically save more than 60% of the electricity spend for hot water over a year. This way SWHs can contribute towards Namibia's energy saving programmes.

As adopted in some countries (e.g. South Africa) for Namibia to achieve the target of the vision it will be wise for the utilities to introduce rebates, based on the potential electricity saving that generally amounts to about realistic cost. The cost may be the capital cost of the installation of the solar geyser or the cost of operating the electric geyser.

According to the study "Revision of National Building Codes to Incorporate Renewable Energy Technologies and Energy Efficiency Principles" by NEI it was revealed that existing building codes in Namibia are old (date from 1970). Therefore, it was recommended to have a review and an update of the overall building and regulations to include energy efficiency and renewable energy in buildings. This will ensure alignment with international and regional standards. With proper standard building codes and regulations the line ministry will be guided on how to develop bylaws that encourage municipalities to enforce the installation of solar water heaters in buildings (especially new and renovated buildings).

As the Government of Namibia considering extending the cabinet directive to all public projects or government projects such National Mass Housing projects, the roadmap will be significantly supported. The cost for solar water heaters can be added to a home loan and where applicable to encourage commercial banks in the country to support SWH short-term loans. Using example of South Africa, the insurance industry also called upon to join the programme to support and encourage the switch from conventional water heating to solar water heating, and support the SWH industry. The industrial intervention must also be supported by policy and government effort to create the competitive environment for solar water heaters against conventional water heating e.g. electrical geysers.

Strong government support, coupled with the financial benefits from installation of solar water heaters, anticipated to be an incentive to attract entrepreneurs to join the market which will significantly growing the supply side. The achievement of this also should be linked to public awareness campaign to sensitise households the benefits of solar water heating.

Table 3: Industry and Government Roles in supporting Thermo-syphon systems

Awareness and Marketing	
Industry Role	Design appropriate and affordable technologies, and promote the thermo-syphoning in all households especially low income communities
Government Role	Promote the thermo-syphoning in all households especially low income communities
Institutional issues	
Industry Role	Developing manufacturing facilities for the technologies especially collector components
Government Role	• Put in place for the roll-out of systems aiming at achieving the 0.5m² per person as per the vision target • Enforce local manufacturing and enforce appropriate fiscal means • Enforce the Namibia Building Regulations on all buildings and extend the cabinet directive on solar water heaters to all buildings • Local governments e.g. municipalities to enforce laws on solar water heaters
Workforce development	
Industry Role	Ensure competent qualified personnel and oversight from qualified installers
Government Role	Support training and certification of installers, especially support training in institutions e.g. VTCs and Universities
Research and development	
Industry Role	Develop low cost SWH systems focusing more on localised and promoting local resources and materials. Also to work with research and academic institutions in this strategy
Government Role	Support the development of low cost SWH systems that can be locally manufactured and support research programmes in institutions

3.2.2 Combined Solar Thermal and Heat Pump Systems (combi-systems)

A **solar thermal combi-system** provides a combination of thermal services, which may include water and space heating from a common array of solar thermal collectors. Such systems may also be backed up by an auxiliary non-solar source of energy, such as biomass, coal, gas, oil or electricity. Solar combi-systems may range in size from those installed in individual properties to those serving several end-users in a block heating scheme. As such, solar combi-systems are solar heating systems for combined domestic hot water preparation and space heating. Often, the installed collector area of combi-systems is larger than that of single purpose solar thermal technologies such as SWH.

The demand for solar heating systems for combined domestic hot water preparation and space heating is rapidly growing, and the combination of solar thermal systems with heat pumps is topical. Solar thermal systems providing such services in single family domestic settings have capacities in the range of between 10 – 20 m² per system.

Table 4: Industry and Government Roles in supporting the Solar combi- systems

Awareness and Marketing	
Industry Role	Design appropriate and affordable systems, and promote the solar-combi-systems
Government Role	Promote the solar combi-systems especially households, and in public and commercial buildings
Institutional issues	
Industry Role	Developing manufacturing facilities for the components and complete systems
Government Role	• Put in place for the roll out of at systems aiming at achieving the 0.5m² per person as per the vision target • Enforce local manufacturing and enforce appropriate fiscal policies promoting local manufacturing of systems and components with emphasis to job creation. • Enforce the Namibia Building Regulations on all buildings and extend the cabinet directive on solar water heaters to all buildings • Local governments e.g. municipalities to enforce laws on solar water heaters
Workforce development	
Industry Role	Ensure competent qualified personnel and oversight from qualified installers
Government Role	Support training and certification of installers, especially support training in institutions e.g. VTCs and Universities
Research and development	
Industry Role	Develop low cost SWH systems focusing more on localised and promoting local resources and materials. Also to work with research and academic institutions in this strategy
Government Role	Support the development of low cost SWH systems that can be locally manufactured and support research programmes in institutions

The key design challenge is how to integrate the different requirements of the heating source and the heating loads into single, cost-effective, durable and reliable heating systems while achieving the most benefit from each installed square meter of collector. The complexity of solar combi-systems has led to the development of a large number of different system designs. These designs do not necessarily reflect local climate or practice. For example, several systems on the market can be used in a variety of geographical locations. Therefore a collaborative work to analyse and optimize combi-systems is necessary if these systems are to reach a more wide spread market.

3.2.3 Pumped systems for multi-family houses, hotels, hospitals etc. (20 – 100 m²)

Pumped solar water heaters are usually designed as an indirect system, utilising a heat exchanger to transfer heat from the collector to the water in the storage tank. Such indirect systems use a heat transfer fluid which is usually a water-antifreeze mixture. Once the heat-transfer fluid is heated in the solar collectors, it is pumped to a storage tank, where a heat-exchanger transfers the heat from the fluid to the stored water. The design of such SWH is relevant in those areas of Namibia that experience episodes of winter freezing.

Table 5: Industry and Government Roles in supporting Pumped Systems for Multifamily houses, hotels, hospitals

Awareness and Marketing	
Industry Role	Design appropriate and affordable technologies, and promote the solar water heating with pumped systems in all households especially in multifamily systems, in hotels, lodges and other public places like hospitals
Government Role	Promote the use of systems in all government facilities e.g. recreation centres and hospitals, and encourage the use these systems in high income households.
Institutional issues	
Industry Role	Developing manufacturing facilities for the technologies e.g. collectors, pumps and other components
Government Role	• Put in place for the roll out of at systems aiming at achieving the 0.5m² per person as per the vision target • Enforce local manufacturing and enforce appropriate fiscal policies promoting local manufacturing of systems and components with emphasis to job creation. • Enforce the Namibia Building Regulations on all buildings and extend the cabinet directive on solar water heaters to all buildings • Local governments e.g. municipalities to enforce laws
Workforce development	
Industry Role	Ensure competent qualified personnel and oversight from qualified installers
Government Role	Support training and certification of installers, especially support training in institutions e.g. VTCs and Universities
Research and development	
Industry Role	Develop low cost SWH systems focusing more on localised and promoting local resources and materials. Also to work with research and academic institutions in this strategy
Institutions	Examples: NEI and academic institutions
Government Role	Support the development of low cost SWH systems that can be locally manufactured and support research programmes in institutions

There are no statistics available for this sector and installations for the purpose of this roadmap as a baseline the installation can be estimated.

3.2.4 Cooling and air-conditioning of Hotels and larger offices (50 – 500m² per system)

There is a considerable demand for cooling and air conditioning services during Namibian summers. Conventional air conditioning systems are typically powered by electricity, which contributes to an increase in the country’s peak electricity demand.

In a study undertaken under the Namibia Energy Efficiency Programme in Buildings Project (NEEP), it was shown that cooling and refrigeration require a significant portion of the total electrical load in hotels, supermarkets and office buildings. In many of the cases investigated, air conditioning was found to be the single largest energy consuming technology, especially for hotels and offices, while it was refrigeration for supermarkets.

An alternative to conventionally powered air conditioners is the use of, so-called, solar air conditioners, which are cooling systems using solar thermal power. The distinct advantage of cooling based on solar energy is the high coincidence of solar irradiation and the demand for air conditioning, i.e. air conditioning is most necessary during the day when sunlight is abundantly available. This coincidence reduces the need for energy storage, as the cooling produced from solar energy is almost immediately used.

Despite solar air conditioners having reached first levels of technical maturity, both technical and non-technical barriers remain. The main technical barriers include specific design requirements as well as their energy management systems. Most contemporary system designs remain complex, necessitating considerable control and maintenance. In addition, initial investment costs for solar air conditioners are significantly higher than the more conventional solutions. Also, both awareness and know-how of suppliers and installers remains limited, and most have not received training in solar thermal cooling systems.

The solar air conditioning and space heating technology can be used by the residential, commercial and industrial sectors in Namibia. There are no statistics available for the application and use of these technologies in the country.

Table 6: Industry and Government Roles in supporting the Cooling and air-conditioning of Hotels and Large Office Buildings

Awareness and Marketing	
Industry Role	• Solar Air cooling technology can be considered as an optional solution to reduce peak electricity consumption, particularly in summer when high cooling loads create high peak demands. • Demonstration systems can be used to show the public about the technology and their specific requirements, potentials and limits.
Government Role	Increase public awareness about solar cooling giving the benefits to both users and utilities. Solar air cooling helps shave costly peak loads in the electricity grid, reduce conventional energy consumption, and avoid GHG emissions from vapour compression cooling machines.
Institutional issues	
Industry Role	Developing manufacturing facilities for the technologies especially collector components
Government Role	• policy makers in the field of energy policy to provide means and supporting measures for an accelerated market deployment • The government should help solar cooling enter the market with financial support and attractive fiscal means • Building regulations prescribing minimum energy efficiencies should cover not only heating, but also cooling.
Workforce development	
Industry Role	• Ensure competent qualified personnel and oversight from qualified installers • Developing guidelines and planning tools as well as offering training courses
Government Role	Support training and certification of installers, especially support training in

	institutions e.g. VTCs and Universities
Research and development (R&D)	
Industry Role	• Both, public and private R&D efforts are needed to support solar air cooling at the system level. • Develop low cost solar air cooling systems focusing more on localised and promoting local resources and materials. Also to work with research and academic institutions in this strategy • Research and development should focus on pre-engineered systems for the smaller capacity range, which minimize planning efforts and the risk of installation errors. • To develop a sustainable market there is a need to focus on quality procedures for design, commissioning, monitoring and maintaining solar cooling systems
Government Role	• Support the development of low cost solar air cooling systems that can be locally manufactured and support research programmes in institutions • Demonstration installations are an opportunity for all involved professionals to learn about the technology and their specific requirements and potentials and limits.

To make solar air conditioning technologies more attractive in Namibia, market conditions will have to be improved. In addition, applications that are particularly suited for an initial roll-out of such applications have to be targeted, including:

- In cases of a high demand for heating and cooling;
- Where high electrical loads and constraints in the electricity distribution favour the use of technologies that have no or only a small additional impact on the network; and
- Where the cost of electricity as a result of the use of conventional air conditioning systems is high.

Evidently, there are market opportunities for solar air conditioning systems which could be enhanced, and should therefore form part of the roadmap. In particular, applications in:

- Commercial operations, e.g. shopping centres, hotels and lodges;
- Hospitals, hostels and prisons;
- Industry, such as the food production and processing industry; and
- Domestic residences.

Presently, no statistics are available on the application and use of solar air conditioning systems in Namibia.

3.2.5 Industrial applications including sea water desalination (50 - 500m² per system)

Heat requirements in industry range across the entire spectrum from high to medium temperatures and depend on individual end-use needs, as shown in Table 7. Despite a growing demand for thermal energy in industry, reliable end-use figures are unavailable.

Important sectors in industry which may benefit from solar thermal systems include the food processing, dairy and beverages industries, as well as the textile, meat processing and chemical industries. As a result, the roadmap must include solar thermal systems as may be used in industry.

Table 7: Industrial sectors and processes with the greatest potential for solar thermal uses

Industrial sector	Process	Temperature level, °C
Food and beverages	Drying Washing Pasteurising Boiling Sterilising Heat treatment	30 - 90 40 - 80 80 - 110 95 - 105 140 - 150 40 - 60
Textile industry	Washing Bleaching Dyeing	40 - 80 60 - 100 100 - 160
Chemical industry	Boiling Distilling Various chemical processes	95 - 100 110 - 300 120 - 180
All sectors	Pre-heating of boiler feed water Heating of production halls	30 - 100 30 - 80

Table 8: Industry and Government Roles in supporting the Industrial Applications

Awareness and Marketing	
Industry Role	• Design appropriate and affordable technologies, and promote the solar water heating with pumped systems in all households especially in multifamily systems, in hotels, lodges and other public places like hospitals • Broad awareness raising campaigns targeted at suitable decision industries • Requirement for all industries to keep statistics on the energy demand (especially thermal energy) and use in industries
Government Role	• Promote the use of thermal energy for industrial use as a part of demand side management. • Broad awareness raising campaigns targeted at suitable decision makers and industries
Institutional issues	
Industry Role	• Specific training courses for professionals and inclusion of special solar thermal technologies into standard education for technical people e.g. engineers etc. • Developing manufacturing facilities for the technologies especially collector components

Government Role	• Put in place for the roll out of at systems aiming at achieving the 0.5m² per person as per the vision target • Enforce local manufacturing and enforce appropriate fiscal means • Develop and enforce standards, planning guidelines and simple design tools • Local governments e.g. municipalities to enforce laws on solar water heaters
Workforce development	
Industry Role	Ensure competent qualified personnel and oversight from qualified installers
Government Role	Support training and certification of installers, especially support training in institutions e.g. VTCs and Universities
Research and development	
Industry Role	• Develop cheap and sustainable solar thermal systems for industrial applications focusing more on localised and promoting local resources and materials. Also to work with research and academic institutions in this strategy • Development of concepts which lead to pre-engineered solutions • Development of design guidelines and proven operation, servicing maintenance concepts
Government Role	• Support the development programmes promoting use of solar thermal to substitute conventional means in industries • Large number of demonstration projects, which are essential to achieve a high standardization and proven guidelines

3.2.6 Unglazed Swimming Pool Solar Water Heaters

Solar-powered swimming pool heating systems are mature and can be considered an established technology. Such unglazed solar collectors provide low-temperature water heating services, typically in the range between 20°C to 35°C, and are characterised by low capital and maintenance costs and are simple to install.

While data on the application and use of such solar technologies is unavailable, a market for unglazed swimming pool heating systems has established itself and is unlikely to require any support by Government.

3.2.7 Other Solar Thermal Technologies

Solar thermal desalination and water treatment

Namibia is a dry country, and potable water sources are scarce. The roadmap, therefore, includes considerations on how the country's abundant solar energy resource can be used to provide clean drinking water.

Of note are Namibia's favourable meteorological conditions for solar thermal applications, in general, and the application of solar thermal desalination systems in particular. In view of the country's vulnerability to climate change, water is a most precious commodity which implies that solar water desalination and treatment would increase the country's resilience to the effects of a changing climate and provide additional opportunities for the preparation of drinking water in areas experiencing scarcity.

Solar cooking

Solar cooking is already practiced in Namibia. As a result, the roadmap recognises solar cookers as another technology that can make a contribution towards the attainment of the national solar vision. To this end, the promotion of solar cooking and dissemination of solar cooking technologies will be given special consideration.

More than half the population of Namibia relies on wood, charcoal or other biomass for daily cooking, leading to respiratory diseases, economic hardship, environmental degradation, and carbon emissions. Solar cooking offers a practical, affordable, and sustainable alternative. The Döbra Solar Development Project website[viii] indicates that 150 parabolic solar cookers of mirror diameter 1.4 m were sold since 2009. This translates to 150 x 6.16m² = 924 m² by 2015. Other companies, such as Amusha Consultancy Services [ix] have sold in excess of 1000 x 0.5 m² = 500 m² aperture area of box solar cookers.

Solar dryers

Solar drying is another solar thermal technology to be included in the roadmap. In addition, other and less mature solar thermal applications are available, including solar thermal refrigerators, steam sterilisers and driers. These technologies have definite niche appeal but may require additional development before they can be mainstreamed.

3.3 Cost Reduction Perspective

Capital cost requirements of typical domestic hot water systems used in Namibia have decreased in the past years. While further cost decreases are considered likely in the coming years, they are expected to depend on the size and pace of the development of the local market as well as on further technology developments, for example as a result of R&D.

3.4 Support Requirements

By 2030, solar thermal technologies could potentially have become a sizeable economic sector. In order to facilitate such a development, a consistent and stable support environment is necessary. Such support activities are multi-faceted, and include, amongst others, support for R&D, support for demonstration systems, project-specific support as well as awareness and training.

3.5 Market Development and Support

Technological development needs market development. Therefore, market deployment measures are necessary, as long as initial investment in solar thermal energy is more expensive than the same for heat from fossil fuels. Currently, most of the subsidy schemes provide grants, like in Germany or Austria, or tax reduction for the installation of a solar thermal system, like in France. In Spain, solar thermal systems have to be installed due to a solar ordinance. The most important aspect of a successful subsidy scheme is that it works continuously over a longer period. If there are grants, the budget has to grow every year in order to cover the expected growth of the market and therefore the growing numbers of applications. In this regard it is the responsibility of the government to ensure that there are incentives and rebates. The alternative is to provide a tax reduction for solar thermal systems which is not limited. With reference to practice done in other countries as mentioned herein, Namibia has to plan a marketing strategy to increase the installation of renewable energy systems to contribute to the countries energy balance. The development of a marketing plan involves all stakeholders and the role to be played by each stakeholder should be clearly spelt out.

Government's role: Government should play a significant role in the handling of all fiscal aspects in the initial development of the sector. The government will be advised to create an environment that is conducive, and makes solar thermal technologies competitive in the market. It is advisable to develop policies supporting the promotion of the technologies. In other words, the government is expected to play a significant role on the policy, incentives, promotion and training. For solar thermal technologies to compete favourably with other low-cost options, the upfront costs should be addressed both at policy level and introducing attractive financing strategies. The government may therefore work with, and/ or encourage, financial institutions to come up with attractive financing programmes and loans. The promotion of any programme supporting solar thermal technologies should focus on the long-term benefit to individual consumers, and to the nation at large. A general public campaign to sensitise prospective consumers or users, and promotion of solar thermal technologies must be spearheaded by the government. The availability of professionals to support the sector is vital for the success of the vision. The government working hand in hand with industry and other institutions should ensure that there is adequately trained and equipped manpower to support the sector.

Industry support in manufacturing and business, promotion and training: industry is encouraged to propose appropriate, affordable and tailor-made solutions that are appropriate to the local market and conditions. Innovation should be central for coming up with solutions appropriate to the local market and needs. To ensure long-term sustainability, the industries should work with the research institutions (e.g. NEI, and academic institutions) to develop solutions, and disseminate the technologies. The industries should work hand in hand with government and research institutions to develop good workable business plans and promotion strategies for various solar thermal technologies. Training is essential of all stakeholders. The industries should support academic and research institutions to produce personnel with relevant skills and competencies.

3.6 Research Agenda

In order to achieve the goals set out in this vision document, a strong increase of Research and Development (R&D) activities in the solar thermal sector in the country is needed. R&D as an input into innovation is vital for the success of the solar thermal technology roadmap. This will allow the creation of an innovative atmosphere in the solar thermal field, in public institutions as well as in industry. The vision considers a strategic research agenda to ensure long-term sustainability of the sector. For this to be managed properly, the government should consider supporting and budgeting for research and demonstration programs.

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