ToR Closure Form

CRIDF Standard Activity | Activity 1806 | The Characterisation of Regional Virtual Water Transfers

Aspect	Detail
Project background	Trading and moving Virtual Water (VW), embedded in finished goods, within and between basins will become more important as the marginal cost water increases over time. The inter-linked nature of water, food and energy (the nexus) is also receiving increasing attention as a foundation for sustainable development. As such, future climate resilience and peaceful cooperation will depend on thinking beyond conventional (engineering-led) solutions to more nexus and virtual water based solutions. The purpose of the VW Project is to introduce the VW and Nexus concepts to SADC, specifically to influence and motivate strategic investments in water, irrigation and energy infrastructure.
Where does this fit with project plan?	Phases I & II of this Project (ToR 1805 and 1806), focused on an initial, broad analysis of Virtual Water data to scope the SADC VW picture, and then drilling down deeper into the data completing a detailed database of Virtual Water flows in, and financial value of, electricity and agricultural products in SADC. These databases would provide the evidence base required to support dialogues interactions with relevant stakeholders and countries with respect to introducing VW and Nexus concepts to national planning.
Aim of the Activity?	This Activity completed the development of detailed data on Virtual Water transfers into and out of the CRIDF countries and the DRC (for agricultural commodities and electricity), for all of the significant products and services in terms of ‘volume’ and economic value. The data was subjected to internal quality assurance checking.
Achieve objectives?	Objectives were fully met, with the exception of being unable to access the SAPP, IPP and Water Affairs (South Africa) data for the Electricity Database in D03. The Electricity database is therefore currently limited to VW in thermal power plants in South Africa. Efforts were made to engage the SAPP with regard to sourcing this outstanding data, and are ongoing in this regard. If required additional resources will be provided to the SAPP to assist the collation of the data under the follow up Activity.
Amendments, etc.	None
Recommendations	Develop a follow-on Terms of Reference to advise CRIDF on the most appropriate means to introduce VW and Nexus concepts into SADC and its other projects – using the data to provide an evidence base.
Deliverables Specific	This Activity consisted of 3 deliverables: • D01 & D02: Preliminary analysis of country-level data collected on time-

Comments	averaged Virtual Water Transfers • D03: Final Activity Report – This includes a comprehensive database on VW and values of agricultural products traded between SADC States, and with the rest of the world, as well as a database of VW imbedded in electrical outputs from thermal power stations in South Africa (some 75% of the total electrical output of the whole of SADC).

Deliverables D01 and D02: Report on the Preliminary Analysis of Data Collected on Virtual Water

The Characterisation of Regional Virtual Water Transfers [Phase 2]: Project 1806

Version 1

08 March 2014

Version #: 1 **Date: 08 March 2014** **Lead Author: Dr. David Phillips** **QA'd by: Gavin Quibell**

Disclaimer

The British Government's Department for International Development (DFID) financed this work as part of the United Kingdom's aid programme. However, the views and recommendations contained in this report are those of the consultant, and DFID is not responsible for, or bound by the recommendations made.

Contents

Executive Summary

The CRIDF Activity to which this report refers involves the development of a database of Virtual Water transfers within the continental countries of the Southern African Development Community (SADC) and with the rest of the world, embedded in agricultural products and in electricity supplies. The present report addresses the second phase of the work as covered by the Terms of Reference for CRIDF Activity 1806, and follows on from earlier work completed under CRIDF Activity 1805.

At the previous stage (under CRIDF Activity 1805), the project team reached a number of decisions on the preferred methodology for the work, these essentially aligning the ongoing studies to 'international best practice' in the Virtual Water arena. Several key sources of information are in use as a result of this.

The work relating to agricultural products has utilised certain of these key sources to assemble data revealing the Virtual Water transfers between all of the continental SADC countries and their respective trading partners, both inside and outside SADC. The data have been quality assured by comparisons of the assembled statistics with additional sources of information, including both international and national sources.

The work on Virtual Water trading within the regional electricity network has relied primarily on data provided by Eskom and by staff of the Southern African Power Pool (SAPP), augmented by published data on river flows and evaporative losses.

The Virtual Water database is presently in the final stages of construction, and will be completed by 15 March 2014, as required by the Terms of Reference for CRIDF Activity 1806.

Introduction

The Climate Resilient Infrastructure Development Facility (CRIDF) is an initiative of the Department for International Development (DfID) of the United Kingdom Government. CRIDF seeks to develop climate resilience in poor communities through the construction of infrastructure in the continental countries of the Southern African Development Community (SADC), thereby promoting the peaceful management of shared waters. However, CRIDF has recognised that in the longer term, peaceful cooperation in an increasingly water-stressed SADC also requires attention to larger strategic infrastructure investment and planning. This wider focus would also be inherently pro-poor, protecting access to water for community-based small scale infrastructure, but also supporting shared economic growth by planning water-related investments which recognise the potential for Virtual Water trading as a means of addressing regional water, food and energy security.

Virtual Water represents water that is 'embedded' in crops, livestock, and industrial items and services, having been used to produce these. The basic concept of Virtual Water was developed in the early 1990s[1], but has only recently been adopted by the international community as a component of the analysis of water security. The 'trade' between countries in Virtual Water can play a critical role in determining water security, especially in regions which display a range in water resource stress or water scarcity. The continental SADC countries exhibit just such a range in water resource availability, the southern portions of the African continent being much more water-stressed than the northern SADC States. Changes in international trading patterns can help to alleviate such stress, and can sometimes be mutually beneficial to partner countries – in certain instances, reducing the expenditure required to develop additional Blue Water resources.[2]

These factors underpin the basic rationale for the ongoing studies on Virtual Water, within the CRIDF programme. This report addresses the data assembled on Virtual Water transfers in agricultural products and in electrical supplies, and responds to the requirement in the Terms of Reference for CRIDF Activity 1806 for a report on the preliminary analysis of the collected data.

[1] See, for example, Allan, J.A. (1998) Virtual water: A strategic resource. Global solutions to regional deficits. *Groundwater*, **36** (4), 545-546; also Allan, J.A. (2011). *Virtual Water: Tackling the Threat to our Planet's Most Precious Resource.* London: I.B. Tauris.

[2] Blue Water is present in surface waters and aquifers, and is the classical focus of studies on the hydrosphere. However, Green Water (known sometimes as soil moisture) is also of great importance in the agricultural sector in particular, and Grey Water (reused flows, sometimes including other forms of water also) can also be of significance. Blue Water export represents a net 'loss' as this water could be viably used to support another economic sector, whereas Green and Grey Water use will not always represent a net 'loss'.

Virtual Water Transfers in Relation to Agricultural Trade

The initial work completed in Stage 1 Phase 1 of the Virtual Water studies pertaining to agricultural products (under CRIDF Activity 1805) focused primarily on South Africa, and on its relationship to the other continental SADC countries. The second phase of the work (under CRIDF Activity 1806) has extended this to the trading patterns of all of the continental countries within SADC, hence creating the database for agricultural products as a whole.

The primary databases employed were as follows:

- Chapagain and Hoekstra (2004) for bulk Virtual Water transfers[3];
- Mekonnen and Hoekstra (2011) for water footprints[4];
- statistics from the Water Footprint Network (http://www.waterfootprint.org);
- import and export data from Trade Map (http://www.trademap.org/), which rely on statistics from UN Comtrade (http://comtrade.un.org/); and
- national data for South Africa from the Department of Agriculture, Forestry and Fisheries (http://www.daff.gov.za/).

The first four sources cited above are those utilised by most or all researchers on Virtual Water internationally, and are widely recognised as offering state-of-the-art information that has been heavily quality-assured by the respective authors. The national statistics for South Africa are derived directly from the primary governmental source of such information. The trade-related data have been compared to information in the FAOSTAT database of the Food and Agricultural Organisation (http://faostat.fao.org/).

[3] Chapagain, A.K. and A.Y. Hoekstra (2004). *Water Footprints of Nations. Volume 1: Main Report. Volume 2: Appendices.* Value of Water Research Report Series No. 16, UNESCO-IHE Institute for Water Education, the Netherlands.

[4] Mekonnen, M.M. and A.Y. Hoekstra (2011). *National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption. Volumes 1 and 2.* Value of Water Research Report Series No. 50, UNESCO-IHE, Delft, the Netherlands. Base data include those from Mekonnen, M.M. and Hoekstra, A.Y. (2010) The green, blue and grey water footprint of farm animals and animal products, Value of Water Research Report Series No. 48, UNESCO-IHE, Delft, the Netherlands; and Mekonnen, M.M. and Hoekstra, A.Y. (2010) The green, blue and grey water footprint of crops and derived crop products, Value of Water Research Report Series No. 47, UNESCO-IHE, Delft, the Netherlands.

Virtual Water Transfers in Relation to Trade in Electricity

Data for the trade in electricity amongst the SADC countries were provided by Eskom and by the staff of the SAPP.[5] Further information of relevance (and to support the primary sources) was accessed from the US Energy Information Administration (http://www.eia.gov/countries/), which is an entity under the United States Department of Energy based in Washington D.C. Various published sources were employed to check general patterns of trade in electricity (which are subject to significant change over time).[6]

Data on the consumptive use of water in the generation of electricity and on the renewable water resources of specific countries were abstracted primarily from three sources:

- national statistics for South Africa, compiled by Eskom (see footnote [5] below);
- the report of Beilfuss (2012) for hydroelectric facilities[7]; and
- the FAOSTAT database of the Food and Agricultural Organisation.[8]

Cross-checks on these data were completed using published information for the consumptive use of water by electricity generating facilities elsewhere in the world.[9]

[5] Data from Eskom were provided by Dr. Dave Lucas (dave.lucas@eskom.co.za), and those from SAPP were provided by Dr. Lawrence Musaba (musaba@sapp.co.zw).

[6] The sources used included Economic Consulting Associates (2009): *The Potential of Regional Power sector Integration. South African Power Pool (SAPP) Transmission and Trading Case Study.* Economic Consulting Associates Limited, London, October 2009; and the *Southern Africa Regional Integration Strategy Paper 2011-2015* of the African Development Bank (2011).

[7] Beilfuss, R. (2012). *A Risky Climate for Southern African Hydro: Assessing Hydrological Risks and Consequences for Zambezi River Basin Dams.* International Rivers, September 2012.

[8] The FAOSTAT database is available at http://www.fao.org/statistics/en/

[9] Examples include Torcellini, P., N. Long and R. Judkoff (2003), *Consumptive Water Use for U.S. Power Production*. National Renewable Energy Laboratory, Colorado; and World Bank (2010), *The Zambezi River Basin: A Multi-Sector Investment Opportunities Analysis.* The World Bank, Washington D.C., June 2010.

Deliverable D03: Final Activity Report on Regional Virtual Water Transfers

The Characterisation of Regional Virtual Water Transfers [Phase 2]: Activity 1806

24th April 2014

Version 3

Version #: 3 **Date: 24 April 2014** **Lead Author: Dr. David Phillips** **QA'd by: Gavin Quibell**

Disclaimer

The British Government's Department for International Development (DFID) financed this work as part of the United Kingdom's aid programme. However, the views and recommendations contained in this report are those of the consultant, and DFID is not responsible for, or bound by the recommendations made.

Contents

List of Figures

List of Tables

Executive Summary

The CRIDF Activity to which this report refers involves the development of a database of Virtual Water transfers amongst the continental countries of the Southern African Development Community (SADC) and with the rest of the world, embedded in agricultural products and in electricity supplies. This Final Activity Report covers the second phase of the work as addressed by the Terms of Reference for CRIDF Activity 1806, and follows on from the earlier work completed under CRIDF Activity 1805, which focused on an initial broad analysis of Virtual Water transfers, addressing the products and services with the highest 'volume' and greatest economic importance. The former analysis determined the focus for this current Activity.

At the previous stage (under CRIDF Activity 1805), the project team reached a number of decisions on the preferred methodology for the work, these essentially aligning the ongoing studies to 'international best practice' in the Virtual Water arena. Several key sources of information are in use as a result of this. Quality assurance issues were addressed by an earlier report (deliverable D02) under this Activity dated 08 March 2014, and that information is shown again here in updated form including graphical analysis (deliverable D01), to ensure that the present report is fully comprehensive.

The work relating to agricultural products has utilised a number of key sources to assemble data revealing the Virtual Water transfers between all of the continental SADC countries and their respective trading partners, both inside and outside SADC. The data amassed extend to all agricultural products of significance in each country, at national and (where possible, at the current stage of the work) also provincial levels. Several separate but linked databases exist as a result, these including information at distinct geographical and product-related tiers. Information is provided on product tonnages; water footprints (Blue, Green and Grey Water); and product costs (and hence, 'water productivity'). The data for trade between the 12 SADC countries of relevance are shown in detail in the spreadsheets, whilst those involving the rest of the world are provided as summaries in most of the spreadsheets, although this is broken down into individual countries internationally in other data sources. This database and the reports outlined in the previous paragraph complete the requirements for this Activity.

The work to date on Virtual Water trading within the regional electricity network has relied primarily on data provided by Eskom and by staff of the Southern African Power Pool (SAPP), augmented by published data on river flows and evaporative losses. The key focus in relation to international trade within SADC in this regard involves the very great differences between the Virtual Water content of electricity supplies generated in the south of SADC mainly by thermoelectric stations, and electricity generated by hydropower facilities mainly in the north of SADC. It is anticipated that the next stage of work will give rise to a highly detailed dataset for consumptive water use by each of the specific electricity generating facilities (over 20MW) within the continental SADC countries, which can be utilised to contextualise all future international trade in electricity from a Virtual Water standpoint.

The Virtual Water data platform as originally conceptualised has thus been finalised, and represents an exceptionally useful and highly flexible tool for use in many distinct types of applications. It is believed that this database is one of the most comprehensive of its type developed on a regional basis, and is unique in this respect. The data are relevant to building regional Virtual Water concerns into infrastructure planning and trading patterns for electricity and agricultural products, and are acknowledged by CRIDF to be both politically and commercially sensitive, as a result.

During the construction of the data platform, several specific issues of interest were noted, and certain of these are covered here as examples of scenarios involving the use of the platform. Selected examples are laid out in the current report in graphical and text form, and these are intended to provide a partial input to the planned next stage of the work, which will involve a policy-level review of the opportunities to introduce interventions pertaining to Virtual Water to address poverty, climate resilience, and regional water stress. Other possible 'next steps' are also covered in the present report.

Introduction

The Climate Resilient Infrastructure Development Facility (CRIDF) is an initiative of the Department for International Development (DfID) of the United Kingdom Government. CRIDF seeks to develop climate resilience in poor communities through the construction of infrastructure in the continental countries of the Southern African Development Community (SADC), thereby promoting the peaceful management of shared waters. However, CRIDF has recognised that in the longer term, peaceful cooperation in the increasingly water-stressed SADC region also requires attention to larger strategic infrastructure investment and planning. This wider focus is inherently pro-poor, protecting access to water for community-based small-scale infrastructure, but also supporting shared economic growth by planning water-related investments which recognise the potential for Virtual Water trading as a means of addressing regional water, food and energy security.

Virtual Water represents water that is 'embedded' in crops, livestock, and industrial items and services, having been used to produce these. The basic concept of Virtual Water was developed in the early 1990s[10], but has only recently been adopted by the international community as a component of the analysis of water security. The transfers of Virtual Water in traded products can play a critical role in determining water security, especially in regions which display a range in water resource stress or water scarcity. The continental SADC countries exhibit just such a range in water resource availability, the southern portions of the African continent being much more water-stressed than the northern SADC States. Changes in international trading patterns can help to alleviate such stress, and can sometimes be mutually beneficial to partner countries – in certain instances, reducing the expenditure required to develop additional Blue Water resources.[11]

These factors underpin the basic rationale for the ongoing studies on Virtual Water, within the CRIDF programme. This report addresses the data assembled on Virtual Water transfers in agricultural products and in electrical supplies, and represents the Final Activity Report as cited in the Terms of Reference for CRIDF Activity 1806. A review is provided initially on the response of this work to the Terms of Reference for CRIDF Activity 1806. Information on Quality Assurance/Quality Control is summarised thereafter (this being an updated version of deliverable D02 for this Activity), and the data amassed on Virtual Water in agricultural products and in electrical supplies are addressed by subsequent sections. The last main section of the report lays out proposed next steps in the Virtual Water project, and Annex 1 shows a template for detailed data on water use in electricity generation.

[10] See, for example, Allan, J.A. (1998) Virtual water: A strategic resource. Global solutions to regional deficits. *Groundwater*, **36** (4), 545-546; also Allan, J.A. (2011). *Virtual Water: Tackling the Threat to our Planet's Most Precious Resource.* London: I.B. Tauris.

[11] Blue Water is present in surface waters and aquifers, and is the classical focus of studies on the hydrosphere. However, Green Water (known sometimes as soil moisture) is also of great importance in the agricultural sector in particular, and Grey Water (reused flows, sometimes including other forms of water) can also be of significance. Blue Water export represents a net 'loss' to potential downstream users, as this water could be employed to support another economic sector, whereas Green and Grey Water use will not always represent a net 'loss' to the system as a whole.

Response to the Terms of Reference

The Terms of Reference for CRIDF Activity 1806 note the following as the overall objective of the work:

> *"The Activity will complete the development of detailed data on Virtual Water transfers into and out of the CRIDF countries and the DRC (for agricultural commodities and electricity), for all of the significant items and services in terms of 'volume' and economic value. The data will be subjected to internal quality assurance checking, as an ongoing task."*

Three specific tasks are cited in the Terms of Reference and are noted to include:

"Development of Detailed Datasets

- *The completion of the development of detailed data on time-averaged Virtual Water transfers for the items and services of significant 'volume' and economic value, for each of the southern African countries. Water footprint data will be included, as will information on relevant economic values of products and services.*
- *This will require a detailed interrogation of national agriculture databases, information on blue, green and grey water used to produce key products, as well as information from the Southern African Power Pool on electricity trades, and generation capacity.*
- *Information on imports and exports of key products to and from other SADC countries, as well the rest of the world will have to be interrogated.*

Internal Quality Assurance Checking

- *The ongoing analysis of the data collected by comparison to published information, this to act as an internal quality assurance check.*
- *Initial scenarios for regional water, food and energy security, developed by the panel under ToR 1807, will be tested to assess the value of the database as a tool for the ongoing work.*

Final Activity Report

- *The drafting and completion of a Final Activity Report for the project as a whole, including recommendations for later stages of work."*

The work completed has responded to these requirements of the Terms of Reference, in full. The following section of this report lays out the data sources used, and the Quality Assurance/Quality Control procedures, updated from deliverable D02. Subsequent sections summarise the data amassed relating to Virtual Water in the agricultural and electricity arenas, and the final section addresses proposed 'next steps' in the work. This report also includes the graphical depiction of Virtual Water flows for specified scenarios (deliverable D01), and constitutes the Final Activity Report (deliverable D03). Together with the data platform itself (held by CRIDF), this report therefore completes the deliverables required in the Terms of Reference.

It is noted that work under CRIDF Activity 1807 (cited in the Terms of Reference for Activity 1806 as noted above) has not yet commenced, but the database is ready for use in that regard. It is currently anticipated that CRIDF Activity 1807 will commence during May 2014.

Data Sources; Quality Assurance/Quality Control

Data Relating to Agricultural Products

The initial work completed in Stage 1 Phase 1 of the Virtual Water studies pertaining to agricultural products (under CRIDF Activity 1805) focused primarily on South Africa, and on its trading relationship to the other continental SADC countries. This allowed the team to assess the availability of data and their overall quality/reliability, and to highlight some of the key products with respect to Virtual Water transfers in the SADC region. The second phase of the work (under the present CRIDF Activity 1806) has extended this to the trading patterns of all of the continental countries within SADC, hence creating the database for agricultural products as a whole. The database developed under the present Terms of Reference therefore collates the data in far greater detail, providing a basis for building regional water and food security scenarios. The data will be utilised as the basis for developing scenarios for potential Positive-Sum Outcomes through changes to the patterns of Virtual Water transfer, which can be tested with stakeholders in the following phase of the work.

Most of the resources available to the study team precluded the collation of primary data from specific agricultural sectors, or the data available from SADC States which are not available on the internet. The primary databases employed were therefore mainly of a global nature, and include:

- Chapagain and Hoekstra (2004) for bulk Virtual Water transfers[12];
- Mekonnen and Hoekstra (2011) for water footprints[13];
- statistics from the Water Footprint Network (http://www.waterfootprint.org);
- import and export data from Trade Map (http://www.trademap.org/), which rely on statistics from UN Comtrade (http://comtrade.un.org/); and
- national and regional data for South Africa from the Department of Agriculture, Forestry and Fisheries (http://www.daff.gov.za/), supplemented in particular scenarios by other national/ regional data.

The first four sources cited above are those utilised by most or all researchers on Virtual Water internationally, and are widely recognised as offering state-of-the-art information that has been heavily quality-assured by the respective authors. However, the Trade Map and UN Comtrade data include some inconsistencies which have been noted by the project team. These involve occasional mis-matches between the export statistics for a specific product involving a particular country of

[12] Chapagain, A.K. and A.Y. Hoekstra (2004). *Water Footprints of Nations. Volume 1: Main Report. Volume 2: Appendices.* Value of Water Research Report Series No. 16, UNESCO-IHE Institute for Water Education, the Netherlands.

[13] Mekonnen, M.M. and A.Y. Hoekstra (2011). *National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption. Volumes 1 and 2.* Value of Water Research Report Series No. 50, UNESCO-IHE, Delft, the Netherlands. Base data include those from Mekonnen, M.M. and Hoekstra, A.Y. (2010) The green, blue and grey water footprint of farm animals and animal products, Value of Water Research Report Series No. 48, UNESCO-IHE, Delft, the Netherlands; and Mekonnen, M.M. and Hoekstra, A.Y. (2010) The green, blue and grey water footprint of crops and derived crop products, Value of Water Research Report Series No. 47, UNESCO-IHE, Delft, the Netherlands.

destination and time period, and the mirror-image import statistics of the country of importation for the same product and time period. In order to complete a comprehensive Quality Assurance check in line with best practice, the following advice from UN Comtrade has been followed:

> *UN Comtrade disclaimer: http://comtrade.un.org/db/help/uReadMeFirst.aspx. (Point 5) "Imports reported by one country do not coincide with exports reported by its trading partner".*

In such circumstances, UN Comtrade recommends the use of data for imports when evaluating trade patterns, as such data are independently verified through the Customs protocol of a receiving country. The Virtual Water trade database for agricultural products has therefore been constructed in this way to ensure that the most accurate and verifiable data sets have been used.[14]

The national statistics for South Africa were derived directly from the primary governmental source of such information, and this is also the case for other specific State-centric data used in the examples quoted in the present report. Trade-related data for various countries have been compared in general terms to information in the FAOSTAT database of the Food and Agricultural Organisation (http://faostat.fao.org/), and this acted as a further quality assurance check.

Sector-Specific Studies

The data used to compile the agriculturally-related database for the 12 continental SADC States are of a country-specific nature and are hence broad in scope. While the specific treatment of these data adds considerable value and creates a data platform to support the development of regional water and food scenarios, scope remains for more detailed analyses within specific sectors. For example, an analysis of Blue and Green Water use in the sugar and beer industry in different regions, and the transfer of this through trading in semi-processed and final products, would yield additional information. Similarly, the Virtual Water footprints (and potentially also those for carbon) of food transported around SADC to support the tourism industry would yield additional insights. It is recommended that CRIDF considers these and other scenarios in further studies.

Data Relating to Trade in Electricity

At the present stage of the work, data for the trade in electricity amongst the SADC countries were provided primarily by Eskom and by the staff of the SAPP offices in Harare, Zimbabwe.[15] Further information of relevance (and to support the primary sources) was accessed from on-line sources of the US Energy Information Administration (http://www.eia.gov/countries/), which is an entity under the United States Department of Energy based in Washington D.C. Various published sources were

[14] See http://unstats.un.org/unsd/trade/methodology%20IMTS.htm

[15] Data from Eskom were provided by Dr. Dave Lucas (dave.lucas@eskom.co.za), and those from SAPP were provided by Dr. Lawrence Musaba (musaba@sapp.co.zw).

employed to check the general patterns of trade in electricity (which are subject to a degree of change over time).[16]

Data reported here on the consumptive use of water in the generation of electricity and on the renewable water resources of specific countries were abstracted primarily from three sources:

- national statistics for South Africa, compiled by Eskom (see footnote [6] above);
- the report of Beilfuss (2012) for hydroelectric facilities[17]; and
- the FAOSTAT database of the Food and Agricultural Organisation.[18]

Cross-checks on these data were completed using published information for the consumptive use of water by electricity generating facilities elsewhere in the world.[19]

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[16] The sources used included Economic Consulting Associates (2009): *The Potential of Regional Power sector Integration. South African Power Pool (SAPP) Transmission and Trading Case Study.* Economic Consulting Associates Limited, London, October 2009; and the *Southern Africa Regional Integration Strategy Paper 2011-2015* of the African Development Bank (2011).

[17] Beilfuss, R. (2012). *A Risky Climate for Southern African Hydro: Assessing Hydrological Risks and Consequences for Zambezi River Basin Dams.* International Rivers, September 2012.

[18] The FAOSTAT database is available at http://www.fao.org/statistics/en/

[19] Examples include Torcellini, P., N. Long and R. Judkoff (2003), *Consumptive Water Use for U.S. Power Production*. National Renewable Energy Laboratory, Colorado; and World Bank (2010), *The Zambezi River Basin: A Multi-Sector Investment Opportunities Analysis.* The World Bank, Washington D.C., June 2010.

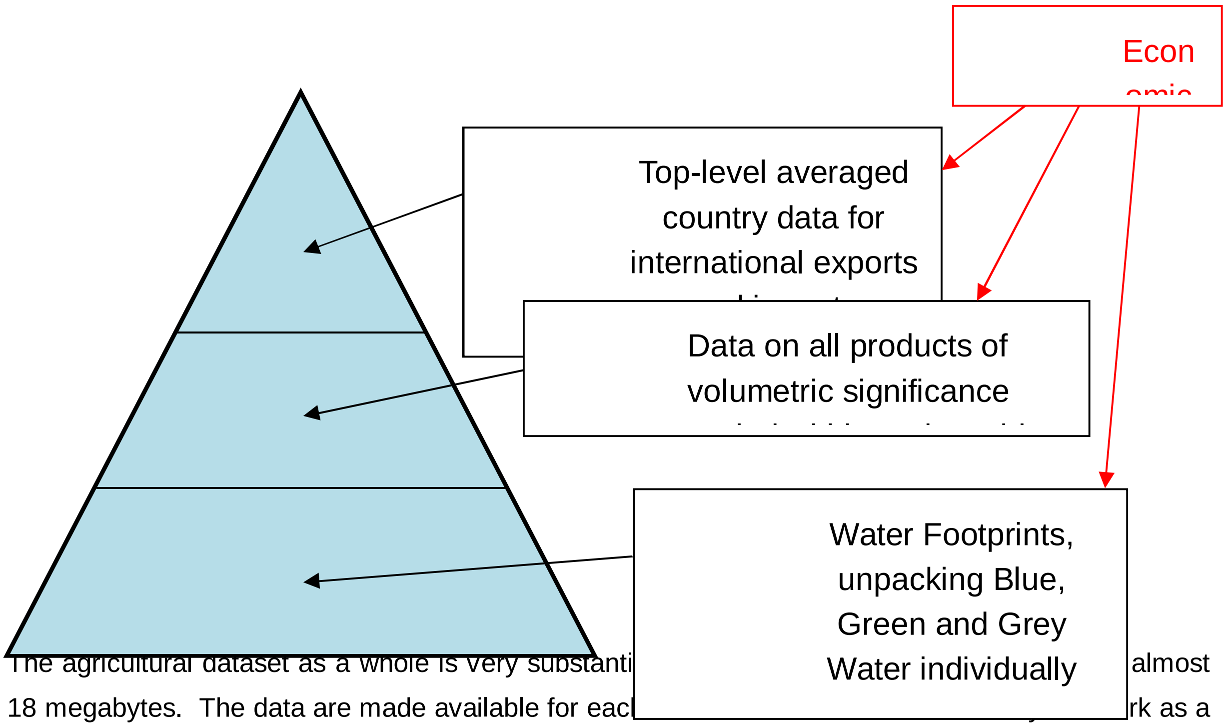
Virtual Water Transfers in Agricultural Products

Development and Structure of the Database

The work completed under the initial phase of the present project (through CRIDF Activity 1805) assembled data on the agricultural products traded by South Africa with the other 11 continental SADC countries, and with the rest of the world. The second phase of the effort addressed by CRIDF Activity 1806 has extended this to trade between all of the continental SADC countries, and with the rest of the world.

As was the case previously, the data that have been made available are at several distinct tiers of detail (Figure 1). Thus, the top-level data involve gross and net estimates of all traded agricultural products (crops and livestock) at the national level, with external parties. The next tier of detail provides information on all individual traded items, as either single products or small groups of products according to the citations in the available trade data (as 4-digit categories of the Harmonised System[20]). The lower tier of detail superimposes water footprints onto each product and country source, with Blue, Green and Grey Water all being identified in full. While this averages the information across countries, it provides a useful starting point for more detailed analysis.

Figure :1 A diagram of the types of data available for the trade in agricultural products amongst the continental SADC countries.



The agricultural dataset as a whole is very substanti… almost 18 megabytes. The data are made available for eac… rk as a

[20] The Harmonised System – also known as the Harmonised Commodity Description and Coding System – was introduced in 1988 and is used by most countries in the world to characterise trade. It is run and maintained by the World Customs Organisation based in Brussels, which has over 170 members.

whole, as well as individually. This assists users of the database to access information relating to their own specific interest. The units employed have been chosen to create sufficient precision, while avoiding the use of decimal points (i.e. a rounding up/down method has been utilised). This rounding up/down technique occasionally results in minor differences between information synthesised from the data platform, and that published by Mekonnen and Hoekstra (see footnote [4] above), but such distinctions are not of any significance.

Examples of the Use of the Database

Many examples could be provided here of the use of the data platform relating to agricultural products, but in the interests of simplicity and brevity, the present report is restricted to only a few of these. Figures 2 and 3 show averaged country data for imports and exports of agricultural products during the year 2012 by the individual SADC countries, and the respective values of those traded products (as thousands of US dollars).

Generic information from the data platform on the water footprints of traded agricultural products is shown in Figure 4. It is notable that agricultural products imported into SADC from the rest of the world tend to have a higher Grey Water content than those derived from and traded internally within SADC. The water footprint of SADC-based exports and imports in agricultural products is generically similar, however, with only a minor Grey Water component. In overall terms, the continental SADC countries import more Virtual Water than they export.

Figure 2: Imports of agricultural products by the continental SADC countries, and their total values.

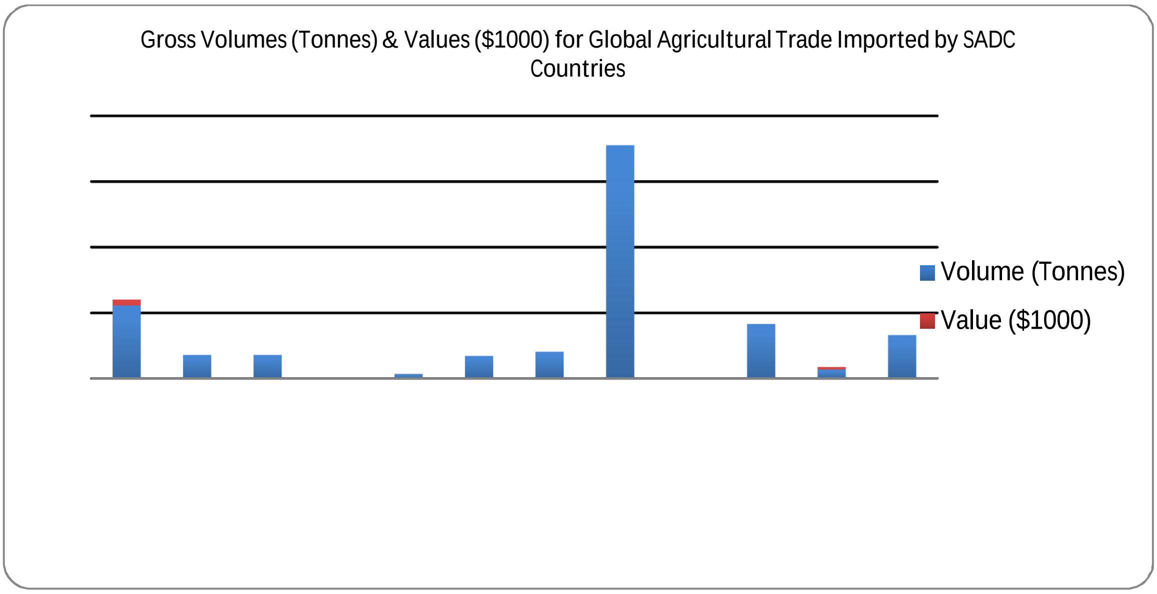


Figure 3: Exports of agricultural products by the continental SADC countries, and their total values.

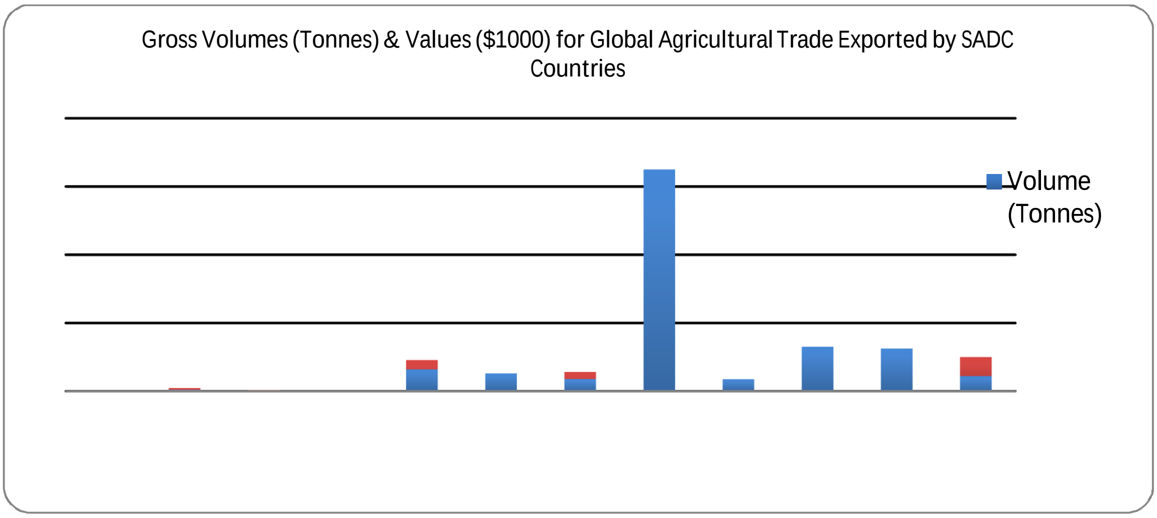
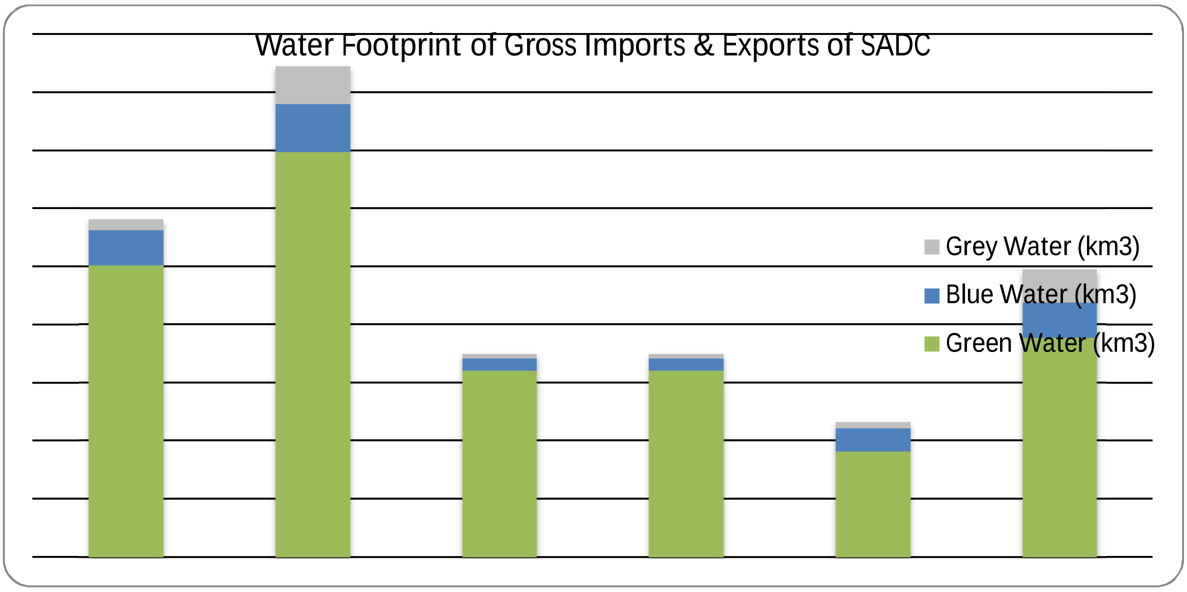


Figure 4: The water footprint of gross imports and exports of agricultural products by the 12 continental SADC countries. RoW: Rest of the World.



These examples of generic data that can be derived in a relatively simple manner from the data platform are interesting in their own right. However, the data on individual products and the water footprint of these provide an additional and highly significant information resource, extending to all traded products individually (in the normal categories cited by sources of trade data); their water footprints; and their financial values. Examples of the latter type of data are shown in Figures 5 and 6, relating to maize (which is an important vector for Virtual Water transfers in the continental SADC countries, being a staple dietary item).

Figure 5: The import and export of maize within SADC, in terms of tonnages and respective values. Data for trade with the rest of the world are not shown.

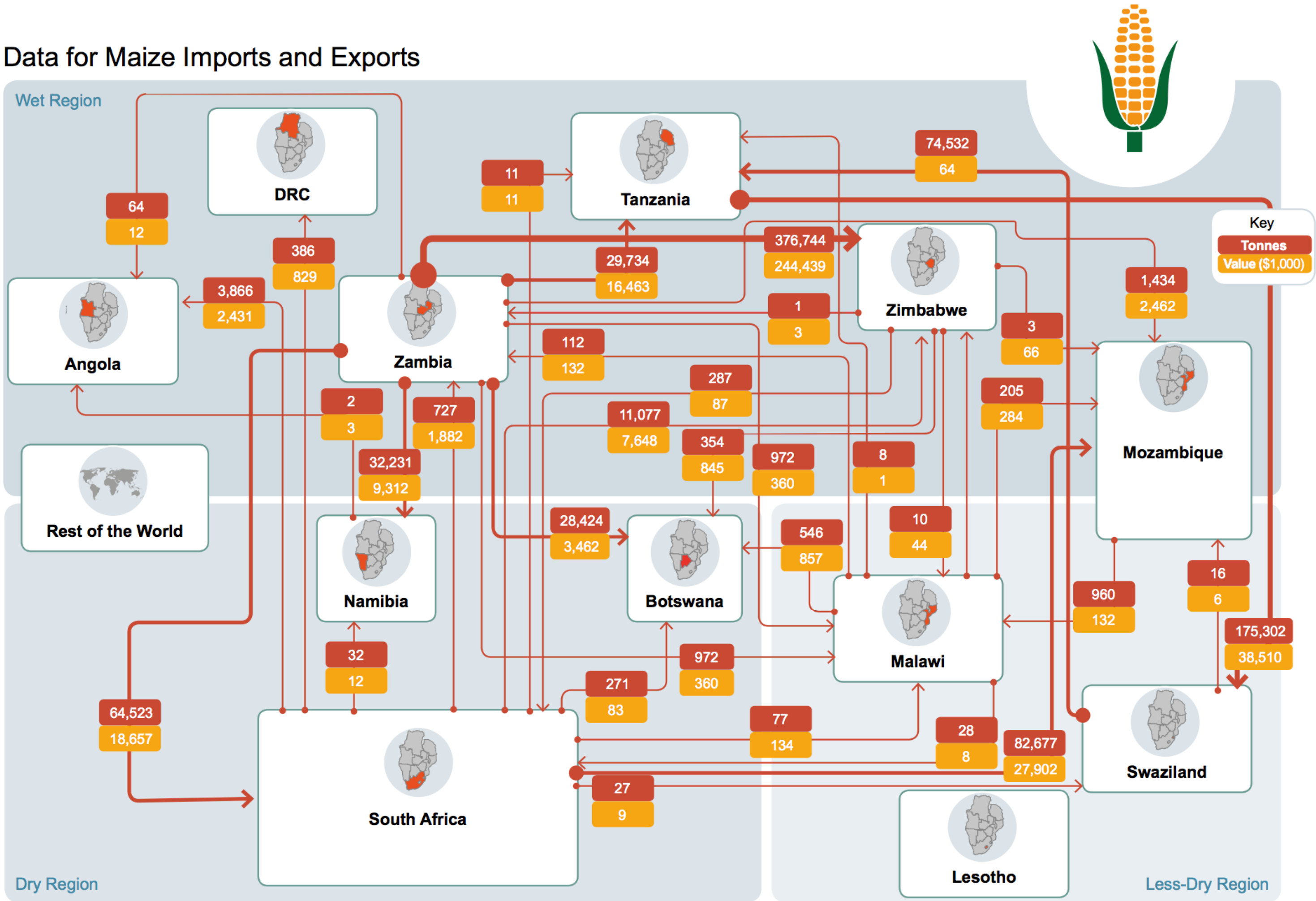
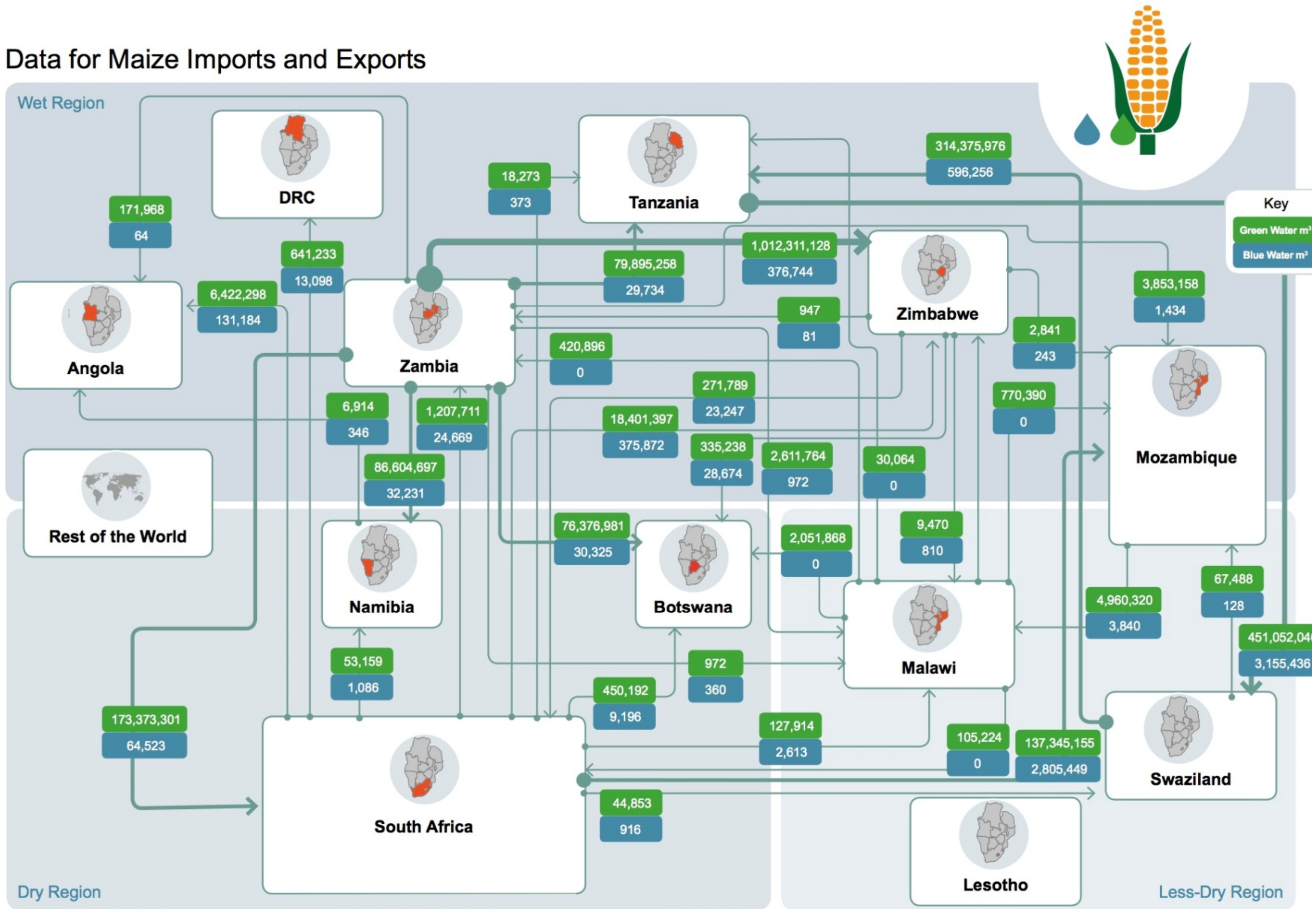


Figure 6: The import and export of Green Water and Blue Water in maize traded within SADC. Data for trade with the rest of the world are not shown.



These examples show that the data platform is of exceptional utility, and is capable of providing information at many levels of detail and specificity. It is important to note that the tool that has been created by the current work is not simply a cut-down version of the dataset published by Mekonnen and Hoekstra (see footnote [4] above), but has been designed specifically for use in southern Africa to assist SADC in moving towards regional water and food security and a vision of water as a regional public good. The data platform as described here is believed to be the first of its type in the world.

As noted in a previous section of this report, the work completed to date has responded in full to the requirements of the Terms of Reference for CRIDF Activity 1806. However, in the course of the construction of the data platform, the team addressing the Activity noted that certain types of data could be added to the data platform as originally conceptualised. These include the following:

- Data on the national production and consumption of agricultural products (as opposed to internationally traded products), which would be of interest when parties wish to interrogate the efficiency of the sector in particular countries and provinces. The production data can be associated with areas farmed, yields, and economic values.
- Detailed data on the specific trade patterns of the SADC nations with individual countries in the ‘Rest of the World’ category, on a product-by-product basis or more generic platform, as may be desired.
- Specific data (above those which can be derived from the current database) on ‘water productivity’ in US dollars/m^3 of water, which is an indicator that is commonly cited in the international literature and offers a broad indication of economic returns from the agricultural sector. It is important to note that Green Water volumes interfere in this indicator, and the project team has proposed using ‘Virtual Water productivity’ as a more useful parameter (see also below).

In terms of high levels of detail, a few products do not have assigned water footprints, as no data were available internationally in this regard. Further work could also be completed to superimpose more detailed estimates of animal size on the data platform, to better assess the Virtual Water component of livestock products. However, given that this type of additional work is likely to require substantial resources, it will only be pursued on an as-needed basis. This may be addressed in analyses of other CRIDF Projects, or to support the development of more specific scenarios necessary to reinforce the uptake of Virtual Water concepts into regional water policies. The data platform in its current form is considered to be more than adequate to act as the basis for the envisaged future work.

The data platform relating to Virtual Water in agricultural products has been uploaded in its entirety to the CRIDF-based Google-Drive, and is therefore available for ongoing work.

Virtual Water Transfers in Traded Electricity

The second phase effort to construct the data platform in response to the Terms of Reference for CRIDF Activity 1806 has included the development of additional information on Virtual Water in electricity traded amongst the southern African States. The key feature in this regard involves the distinction between a predominant reliance of the northern countries on hydropower for the generation of electricity (see Table 1), while South Africa presently utilises coal-fired thermoelectric generation for the great majority of its electrical supplies, as shown in Table 2.

Table :1 Examples of major existing hydropower facilities in the northern countries of SADC.

Country	Hydropower Site	Installed Capacity (MW)	Date of Construction	Comments
DRC	Inga I and II	351 and 1,424	1972 and 1982	Major refurbishment needed
DRC	Inga III	4,800	2015 on?	Being developed currently
Lesotho	Lesotho Highlands Water	110	1998	Phase II being considered at present
Mozambique	Cahora Bassa	2,075	1974	Operation delayed until 1997 (Figure 7)
Namibia	Ruacana	330	1978	Fourth turbine added in mid-2012
Zambia/Zimbabwe	Kariba	1,470	1959	Two separate power stations exist
Zambia	Kafue Gorge	990	1973	The Itezhi-Tezhi Dam regulates flows

The most recent data from Eskom reveal a consumptive use of water of 1.37 litres/kWh in the generation of South African electricity, as a nation-wide average. This is competitive by comparison to performance elsewhere, e.g. Torcellini *et al.* (2003) reported an average consumptive use of water of 1.4-1.9 litres/kWh for thermoelectric power generation by a large range of such facilities in the USA.[21] In total for South Africa, this implies a consumptive use of water of approximately 317 MCM/year[22] in total for electricity generation in South Africa (which accounts for just over 80% of the electricity generated in SADC as a whole in recent years, and about 42% of the generation in the continent of Africa).

[21] See Torcellini, P., N. Long and R. Judkoff (2003). *Consumptive Water Use for U.S. Power Generation.* Technical Report, National Renewable Energy Laboratory, Golden, Colorado.
[22] MCM = Million cubic metres.

Figure 7: Cahora Bassa Dam in Mozambique.

Table 2: The generation of electricity by South Africa for the year 2012/2013. [After data from Eskom].

Source	GWh (net)	Percentage of Total
Coal-fired stations	232,749	90.5
Nuclear power station	11,954	4.6
Purchase from IPPs[23]	3,516	1.4
Pumped storage stations	3,006	1.2
Wheeling (transmission)	2,948	1.1
Gas turbine stations	1,904	0.7
Hydroelectric stations	1,077	0.4
Wind energy	1	<0.1
Totals	**257,155**	**100**

[23] IPPs: Independent Power Producers

The consumptive use of water in the generation of electricity using hydropower differs considerably between distinct facilities.[24] Run-of-the-river systems which do not involve large impoundments have low consumptive use, while facilities including large dams and reservoirs exhibit a much higher consumptive use of water. This is due to a number of factors, including in particular the surface area of any impoundment; the rate of evaporative loss from the reservoir; and the efficiency of the turbines. In the USA, Torcellini *et al.* (2003) cited a range for hydropower plants from close to zero consumptive use for run-of-the-river systems to more than 208 litres/kWh, and this immediately reveals the great distinction between thermoelectric stations and hydropower facilities relying on dams and large impoundments.[25] The consumptive use of water by hydropower facilities in Africa can be much higher than that of similar plants in the USA, due to the extreme rate of evaporative loss in many locations in Africa (although these also vary considerably from site to site).

Data from Beilfuss (2012) were used to determine the consumptive uses of water at the three major hydropower sites in the Zambezi River basin.[26] These revealed the lowest use at Itezhi-Tezhi/Kafue Gorge (64 litres/kWh); intermediate values at Cahora Bassa (296 litres/kWh); and by far the highest consumptive use of water at Kariba (1,040 litres/kWh). The particularly high losses at Kariba reflect the relatively shallow reservoir with a large surface area, and this is also demonstrated by data for electricity generation per reservoir surface area (0.3 MW/km^2 at Kariba, as opposed to 1.4 MW/km^2 for Cahora Bassa). The total evaporative losses at the hydropower facilities in the Zambezi River basin equate to a consumptive use of about 11% of the mean annual flow of the system as a whole, and this creates major changes not only to the total water flow in the basin but also to the seasonal pattern of flows.

It is important to note that the international trade of electrical power in southern Africa varies substantially over time. This reflects short-term changes in the capabilities of utilities to generate power, coupled to fluctuations in power demand. Some such variations are challenging to predict, e.g. unexpected problems at generating stations can reduce the electrical power available, and can also have knock-on effects elsewhere, sometimes with major consequences involving wide-scale loadshedding. This is a particular problem in circumstances where the reserve margin is low, as has been noted throughout almost all of SADC since late 2007 – in large part because of the difficulties experienced in South Africa over recent years (reflecting the high proportion of SADC electricity that is generated in South Africa; see above).

[24] See, for example, *Energy Demands on Water Resources. Report to Congress on the Interdependency of Energy and Water.* US Department of Energy, December 2006.

[25] It is notable that some of the water sources used to support thermoelectric power generation also involve impoundments, in some instances to increase assurance of supply. However, these are generally much smaller than those employed to generate hydropower, with minor evaporative losses – and they are also usually multi-use facilities, being employed in support of agricultural irrigation in particular. It is also arguable that the evaporation off the large hydropower-related impoundments such as Kariba and Cahora Bassa might not all be allocated to hydropower generation in isolation (where multiple use occurs), but in those cases the hydropower generation was the primary *raison d'etre* for the construction of the dams. The analysis provided here is thus considered to be generically robust, and in any event the very large distinction between consumptive water use in the two forms of electricity generation would persist, even where additional (minor) factors are taken into account.

[26] See footnote [8] above for this reference.

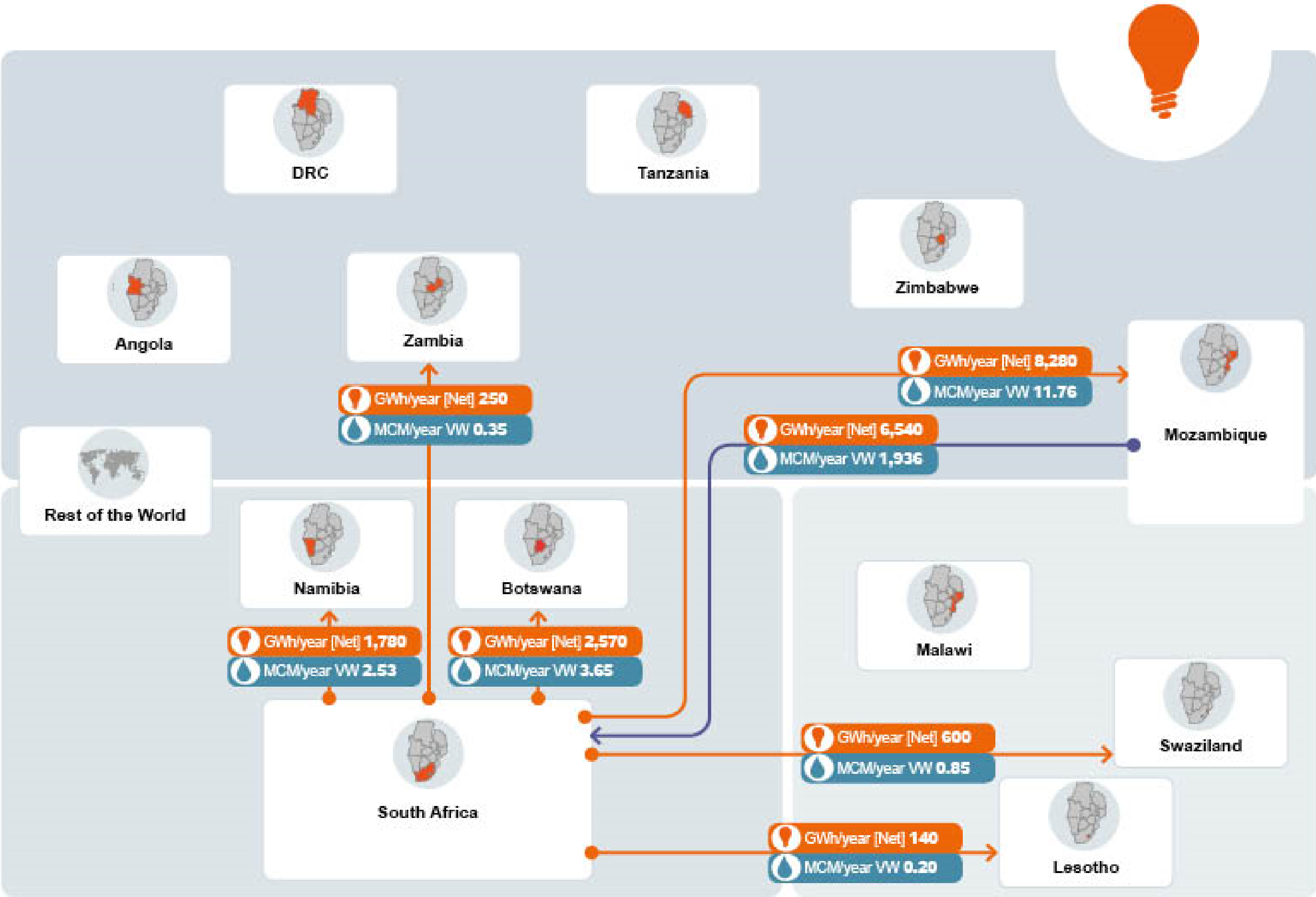
These time-related variations in the international trade in electricity in southern Africa imply that any analysis of Virtual Water transfers in electrical supplies that are traded between the various countries should be considered as a general ***pattern***, rather than in terms of absolute values which are in fact of relevance only to one particular time period. This is not especially problematic, however, as the key issue relating to Virtual Water transfers in the region involves the massive difference in the consumptive use of water by facilities involving thermoelectric technology (largely in the south), *versus* hydropower plants (primarily in the north).

Table 3 and Figure 8 show an example of Virtual Water transfers in electricity traded internationally within southern Africa for the year 2012-2013, data on the trading pattern being derived from Eskom and from the SAPP offices in Harare. Exports from South Africa to other countries occur in general through the SAPP network, and Eskom does not assign a specific source to any such trading, all electricity generated in-country being considered as a ‘common pool’. In this circumstance, the national estimate of consumptive use of water in South Africa for the generation of electricity is utilised to calculate the volumes of Virtual Water transferred in each trade. Relatively small volumes of Virtual Water are involved, as South Africa exhibits a low consumptive use of water in its overall electricity generation portfolio (and most of the power generated is in any event used nationally, rather than being traded). The total transfer of Virtual Water in electricity traded externally by South Africa in 2012-2013 was 19.34 MCM, as compared to 317 MCM of water used consumptively for all of the power generation in-country (6.1% traded; the remainder used nationally).

Table 3: The transfers of Virtual Water in internationally traded electricity in the year 2012/2013. [After data from Eskom and SAPP]. VW: Virtual Water.

From	*To*	*GWh/year [Net]*	*Litres/kWh*	*MCM/year VW*	*Comments*
South Africa	Mozambique	8,280	1.42	11.76	No specific source identified; generic consumptive use figure employed.
	Botswana	2,570	1.42	3.65	
	Namibia	1,780	1.42	2.53	
	Swaziland	600	1.42	0.85	
	Zambia	250	1.42	0.35	
	Lesotho	140	1.42	0.20	
Mozambique	South Africa	6,540	296	1,936	From Cahora Bassa

Figure 8: The trade in electricity in 2012-2013 amongst the SADC countries. [After data from Eskom and SAPP].



The cross-trade in electricity between South Africa and Mozambique involves a considerable differential in Virtual Water transfers. As shown in Table 3 and Figure 8, the 8,280 GWh traded from South Africa to Mozambique in 2012-2013 involved a transfer of 11.76 MCM of Virtual Water, whilst the 6,540 GWh of electricity derived from Cahora Bassa and traded to South Africa in the same time period implied a Virtual Water transfer of 1,936 MCM. This distinction reflects the very great differences in the consumptive use of water by the two power generation systems.[27]

The total volume of water utilised in generating electricity in South Africa is not insignificant, at 317 MCM/year in total in the latest year (2.54% of the total annual renewable water resource nationally, making Eskom the single largest user of water in the country). However, this is altogether dwarfed by the water volumes used in the large hydropower schemes in the northern SADC countries. As noted by Beilfuss (2012; see footnote [8] above), the three biggest hydropower facilities in the Zambezi River basin have altogether altered the total mean annual flow of the river system, and have very significantly changed the seasonal flow patterns. Thus, the evaporative losses at Kariba amount to 16% of inflows at that point, on average; those at Itezhi-Tezhi/Kafue Gorge account for 3% of inflows; and the evaporative loss at Cahora Bassa equates to 6% of inflows at that point in the system. In overall terms, some 11% of the flow of the Zambezi River system is lost by evaporation at the various hydropower facilities along its length – amounting to more than 12 km^3 of water annually, as an average. This represents by far the single largest use of water in the Zambezi River system, and rivals the Blue Water component of the Virtual Water volumes traded in the agricultural sector (see the previous section of this report).

During the course of the completion of work under Activity 1806, a decision was made to develop a detailed dataset for water consumption and electricity generation relating to all of the facilities individually, within the 12 continental SADC countries of relevance. This had not been envisaged at the outset of Activity 1806, in large part because of the treatment by Eskom of the system as a ‘single pool’ with a generic consumptive use, as described previously. However, the very great differences in the site-specific consumptive use of water at each of the generating facilities were considered sufficient to merit the development of more detailed information. Such data are generally not available within the public domain, being held by the various utility companies charged with maintaining dams/reservoirs and generating electrical power (by various means) throughout SADC. To create the detailed dataset, the project team developed a template to include all data of relevance, populated in the first instance by the electricity generating facilities of interest and of scale greater than 20MW. That template is shown at Annex 1 to the current report, and is being employed to amass the additional data, with the assistance of various parties in the region. The completed dataset will be included in later reports on the Virtual Water project as a whole, and will be of utility in three fashions:

[27] Such distinctions need to be considered against the background of the annually renewable water resources in each country, as a whole. Thus, the degree of constraint on the water supplies is of importance in determining preferred regional patterns of electricity generation in the future. It is intended that these types of details will be addressed in future work by the project team.

- the various public sector entities and the utilities of relevance would be able to consider their use of Blue Water for the electricity generating sector in greater detail;
- proposals for any particular international trade in electricity could be characterised rapidly and simply in terms of the accompanied Virtual Water transfer; and
- the planning of preferred future electricity generating patterns could take account of implications for Blue Water use.

Representatives of the SAPP have stated that electricity demand in southern Africa is increasing by more than 5% annually (faster than the GDP growth in most of the countries), and this implies a doubling in the total demand for electricity every 14 years, amongst the continental SADC countries as a whole. Major challenges exist in terms of satisfying the increasing demand:

- Large numbers of new generating facilities will be required. Some of these are already in construction (e.g. Inga III) or are planned (e.g. Batoka Gorge, Mphanda Nkuwa), with hydropower facilities again dominating in the northern SADC countries.
- South Africa is continuing to consider its preferred energy mix, with possible increases in nuclear energy but the certainty of new coal-fired stations also being involved (the Kusile thermoelectric station having been selected to follow the finalisation of the Medupi facility), and the potential use of shale gas (although the latter remains highly controversial).[28]
- Major new transmission systems are required, both to satisfy existing demand and to create a robust network for international trade in electricity. This is a particular focus of the SAPP.

For South Africa, the future is especially challenging due to tightening restrictions on water availability; the inexorable increase in demand for electricity nationally; and the current deep reliance of some of the neighbouring countries on exports of electricity from South Africa. The high assurance of supply that is required for electricity generation implies that this end use of Blue Water exerts particularly severe effects on other types of water utilisation or allocation in times of drought. Inter-sectoral competition for water already exists in many of South Africa's basins (and in some of the neighbouring countries also), and the high and increasing domestic/municipal demand for water is especially notable on a country-wide basis in South Africa. In addition, the atmospheric emissions from power generating facilities in South Africa are very considerable, and concerns exist over greenhouse gases and effects on climate change. The possibility of the development of shale gas resources in the Karoo – estimated by the US Energy Information Administration to amount to up to 485 trillion cubic feet – remains controversial, in large part due to concerns over the environmental impacts of hydraulic fracturing ('fracking'). These factors are responsible for the positive attitude of South Africa in past years to the possible construction of the Grand Inga hydropower development in the DRC (see below).

[28] See *Report on Investigation of Hydraulic Fracturing in the Karoo Basin of South Africa*. Department of Mineral Resources, Republic of South Africa, July 2012.

Other countries in southern Africa exhibit varying responses to the energy sector, and the satisfaction of their own national demand (see Table 4). For example, Namibia has long been reliant on imports from South Africa, but it is predicted that this will change in the future as major new supplies of electricity are developed within Namibia (a coal-fired power station near Walvis Bay; the Kudu gas reserve in Namibian waters offshore; and the Baynes hydropower site on the Kunene River). Botswana depends heavily on its national coal resources, and also on imports of electricity from South Africa. Tanzania, having suffered loadshedding due to low water levels serving its hydropower plants (which produce almost 40% of the country's electricity needs) is focusing on expanding thermal energy production – and the newly discovered gas supplies in the Rovuma basin offshore offer considerable future potential in this regard. Nonetheless, there are still opportunities to develop hydropower in the wetter regions of the country – some of which are being explored through CRIDF.

Other SADC countries have limited hydrocarbon reserves and continue to rely heavily on hydropower, with major facilities planned or under development at sites such as Batoka Gorge (Zambia/Zimbabwe), Lower Kafue Gorge (Zambia), Mphanda Nkuwa (Mozambique) and Inga III (the DRC). Extensions to existing hydropower stations are also envisaged, substantially increasing the present electricity generation portfolio of SADC as a whole.

The Grand Inga development in the DRC would fundamentally alter the pattern of electricity production in Africa, given its massive potential (variously estimated as 39,000 to 42,000 MW). Several types of scheme have been considered, including run-of-the-river facilities and impoundments of various forms. Although the latter would be likely to imply a higher consumptive use of water, the Congo River flow is so massive (and the percentage use of water in the DRC is so small at the present time) that Virtual Water transfers should not raise problems in that instance.

A second recent factor that could substantially change the future pattern of electricity production in southern Africa involves the very large gas reserves discovered in the offshore Rovuma Basin in northern Mozambique/south-eastern Tanzania, referred to briefly in the text above. Recent estimates suggest that this will exceed 100 trillion cubic feet, and the world class resource offers very significant opportunities for electricity production (with relatively low consumptive water use and atmospheric emissions). No decisions have been made as yet as to the preferred use of the gas – although the export of liquefied natural gas to the Far East appears to be almost certain for a significant proportion of the resource.

It is also possible that South Africa will proceed with the exploitation of shale gas in the Karoo. However, this option involves the use of hydraulic fracturing ('fracking'), which remains highly controversial and relatively water intensive. No analysis of the possible use of water in fracking procedures has been made during the current work, although this could be addressed at a later stage to provide important new information of relevance to eventual policy considerations.

It is anticipated that these types of 'mega-projects' will be amongst the issues to be discussed under the forthcoming CRIDF Activity 1807, which will address policy-level considerations connected to Virtual Water transfers in southern Africa.

Table 4: Brief overview of the energy resources and electricity supplies in each of the continental SADC countries. (Page 1 of 2).

Country	Energy Resources	Electricity Supplies
Angola	Very considerable oil and gas resources (global #18 in reserves) in ongoing development, these entirely dominating the national economy. Primary energy use still dominated by biomass, followed by oil, hydropower and natural gas.	Approximately 70% of internal generation from hydropower (Cuanza, Catumbela, Cunene Rivers). Gas-fired production likely to increase. Only 30% coverage of the population currently. Not yet fully integrated into the SAPP, but a connection to Namibia is being established currently.
Botswana	No oil or gas reserves. Moderate coal resource, essentially all utilized within the country.	Significant importer of electricity, mostly from South Africa.
DRC	Significant oil reserves, with more likely to be discovered. A minor oil exporter currently. Some coal, and significant hydropower at Inga in particular. The development of Grand Inga could completely alter the African balance of power generation.	Only a moderate net exporter of electricity, mostly from the Inga projects. New Power Purchase Agreement with South Africa relating to Inga III. Massive future potential as an exporter of hydropower from Grand Inga.
Lesotho	No oil, gas or coal reserves; reliant on national biomass and imported fossil fuels.	Minor generation through hydropower, including the Lesotho Highlands Water Project. Minor net importer of electricity, from South Africa.
Malawi	Very minor oil production at present. No gas currently exploited, but attempts are ongoing to develop oil and gas under Lake Malawi/Nyasa (involving a dispute with Tanzania).	Essentially all electrical power generated in-country mostly through hydropower – with significant new hydropower plans, and no significant imports or exports.
Mozambique	No significant oil reserves. Natural gas exploited from the onshore Pande and Temane fields mainly (80%) used by South Africa, *via* the Sasol pipeline. Massive natural gas reserves found recently in the Rovuma basin offshore in the north. Significant coal reserves.	Poor internal access to electricity (25% of population). National grid backbone to be constructed. Cahora Bassa and other hydropower sources of key importance, but coal and gas also used increasingly for generation. Significant exporter of electricity, likely to increase considerably over time. Imports energy from the RSA to support an aluminium smelter.

Table 4: Brief overview of the energy resources and electricity supplies in each of the continental SADC countries. (Page 2 of 2).

Country	Energy Resources	Electricity Supplies
Namibia	No oil or gas reserves exploited currently, but Kudu gas field offshore (shared with South Africa) under early development. Ruacana hydropower facility operating in the north, and hydropower at Baynes on the Cunene River is planned (shared with Angola). Coal imported to supply ageing Van Eck facility in Windhoek. Plans for 500MW coal-fired facility at Walvis Bay.	Significant importer of electricity, mainly from South Africa and historically also from Zimbabwe (Hwange thermal station). New agreement with Aggreko for importation from Mozambique (Ressano Garcia), sourced from natural gas.
South Africa	By far the most dominant country in southern Africa in terms of energy development to date. Small internal reserves of oil and gas, but some imports from Mozambique, and Kudu/shale gas in the Karoo may change this in the future. Heavily reliant on coal currently (global #9 in coal reserves) but poor quality leads to very high *per capita* greenhouse gas emissions. Major synthetic fuels sector. Minor hydropower, mostly already constructed.	Strong coverage of the population, being enhanced over time. By far the largest electricity generator in southern Africa, about 90% from coal (minor nuclear, hydropower and gas). Plans to increase nuclear generation to diversify the energy mix remain under review. Recent exports have decreased as domestic demand has increased and growth of generation capacity slowed.
Swaziland	No oil or gas reserves, but moderate coal resources. Biomass dominates the energy use in-country.	Minor net importer of electricity, mostly from South Africa.
Tanzania	No proven oil reserves, but significant gas, some of this shared with Malawi (under dispute) and also with Mozambique in the Rovuma Basin. Likely to export natural gas in the future. Moderate coal reserves, supplemented by importation. Heavy reliance on biomass for fuel.	Low population coverage (15%). Most electricity from hydropower (60%), with the remainder from fossil fuels. Essentially self-sufficient for electricity. Recent link to the SAPP; Tanzania represents a link between the SAPP and the Eastern Africa Power Pool.
Zambia	Minor oil production, and no gas. Significant hydropower, Kariba being dominant. New hydropower being planned.	Net minor exporter of electricity from hydropower sources. This may change given the rapid growth in national demand.
Zimbabwe	Minor oil reserves and no gas, but moderate coal resources. Thermal power plants are present, with some hydropower. Marked reliance on biomass in rural areas.	Net importer of electricity, mainly from South Africa. Previous Power Purchase Agreement for export to Namibia has apparently lapsed.

The current modelling of possible future climate change in the Zambezi River basin implies the potential for very considerable problems, with mean annual river flows predicted to decrease by 16% in the upper section; 24-34% in the middle reaches; and 13-14% in the lower Zambezi.[29] While most scientists now acknowledge that the precise changes to hydrological parameters that would accompany climate change are deeply challenging to predict, any such alterations in flow patterns would be little short of catastrophic in relation to hydropower generation in the system.

Various alternatives are being considered in this regard, including the operation of hydropower plants as effective run-of-the-river facilities (at full reservoir levels), coordinated hydropower management (as opposed to unilateral management), and other possibilities. Such considerations bring the importance of regional planning into the forefront of the debate. The rationale for the creation of the SAPP is instructive in this regard.[30] Prior to the SAPP being established, the early development of transmission systems between Botswana, Zambia and Zimbabwe was intended to reduce the reliance of the 'Frontline States' on imports of electricity from South Africa during apartheid. The dismantling of apartheid in the early 1990s brought new opportunities, and in response to the 1991-92 drought which imposed severe limitations on hydropower production in the Zambezi River basin, South Africa was able to fill the gap through the existing transmission network.

South Africa possessed two goals through this and the later period: initially to act as the power-house of southern Africa; and later to be in a position to import relatively cheap hydropower from the northern SADC countries. Neither of these goals has been realised in full, primarily due to the rapid growth in electricity demand in South Africa, which has meant that about 95% of electricity production is used domestically with little available for export. The bilateral trade in electricity that pre-dated the establishment of the SAPP therefore continues to represent the great majority of the electricity trade in the region, the initial short-term electricity market (STEM) and the more recent day-ahead market (DAM) created under the SAPP representing only very small proportions of the electricity traded internationally.

In the present context, the southern countries within SADC face a complex challenge – the need to meet sovereign demands, while also receiving benefits from regional cooperation in electricity trading (and the water-related benefits that may accompany this). Thus:

- The demand for electricity is growing rapidly in all of the countries involved, at a generally faster rate than the growth in Gross Domestic Product, and commonly at a faster pace than the electricity generation/transmission infrastructure can be delivered.

[29] World Bank (2010). *The Zambezi River Basin: A Multi-Sector Investment Opportunities Analysis.* The World Bank, Washington D.C., June 2010.

[30] Economic Consulting Associates (2009): *The Potential of Regional Power sector Integration. South African Power Pool (SAPP) Transmission and Trading Case Study.* Economic Consulting Associates Limited, London, October 2009.

- There is little scope for further hydropower generation in the southern countries, with the exception of the 600 MW Baynes facility to be shared by Namibia and Angola on the Kunene River, and the expansion of hydropower production through the Lesotho Highlands scheme.[31]
- A continued reliance on coal-fired power stations in SADC as a whole will exacerbate the emissions of greenhouse gases, which are already high on a *per capita* basis in South Africa in particular.
- Concerns raised by the Fukushima event of 2011 and by previous incidents in the nuclear power industry have cast doubt on plans for enhanced nuclear power generation in South Africa.
- Only minor scope exists for the expansion of renewable electricity generation, e.g. from wind and solar sources, and the lead times for these systems may be longer than is typical in more developed economies.

The southern countries in SADC – which experience much greater water stress than those further north – therefore need to finalise strategic decisions on their preferred approach to electricity generation in the future. The fundamental components of this decision relate to a choice between additional thermoelectric facilities which will maintain national supplies in South Africa at least, *versus* the importation of the relatively cheaper mix of hydropower and thermally-derived electricity from the northern SADC countries (the latter, accompanied by a concomitant reduction in national energy security for the southern States). The preferred degree of regional integration represents a significant issue in this regard, and some commentators have placed this goal to the forefront of the debate.[32]

Despite this, the water-related implications of regional integration in energy production have received little attention in SADC, to date. However, the connections within the water, food and energy Nexus are coming into greater focus in the international arena.[33] The data reported here on the distinctions in consumptive water use between thermoelectric and hydropower facilities in southern Africa augment this debate, and support the CRIDF focus on the Nexus (as opposed to simply addressing water availability in isolation).

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[31] The second phase of the Lesotho Highlands Water Project was officially commenced in late March 2014. This is reported to involve a total cost of R15.5 billion, and will involve the construction of the Polihali Dam and the Kopong pumped storage supplying a further 1,200MW of hydroelectric power to Lesotho.

[32] For example, see the *Southern Africa Regional Integration Strategy Paper 2011-2015* of the African Development Bank (2011).

[33] See, for example, *Thirsty Energy*: Water Paper 78923, June 2013, the World Bank, Washington D.C.; also the report on shale gas as cited in footnote [19] above.

Proposed Next Steps for the Virtual Water Project

Inputs for CRIDF Activity 1807

The work covered here under CRIDF Activity 1806 will be followed up in the initial instance by policy-level considerations of potential interventions involving Virtual Water trading. This is the primary focus of CRIDF Activity 1807, Terms of Reference for which have already been drafted (and are not therefore attached to this report). CRIDF Activity 1807 is intended to outline the most appropriate means to introduce the concepts of Virtual Water transfers and the water, food, energy and carbon Nexus into regional policies, specifically in the pursuit of the peaceful management of shared watercourses for the benefit of the poor. That process will be facilitated by the development of specific examples or scenarios to provide data on the accompanying Virtual Water transfers.

While the full form and extent of these scenarios will be developed during CRIDF Activity 1807, the following examples have been generated as part of the current work to demonstrate some of the capabilities of the data platform, and to initiate discussions under Activity 1807. These examples are not intended in any manner to represent a key focus of the input under Activity 1807, but are provided to assist in guiding the general thinking and conceptualisation of the work. Specialists contributing to the next phase of work may generate their own scenarios, which they may believe to be necessary for them to develop their recommendations.

The key issue in relation to Virtual Water transfers in electricity involves the massive distinction between the Virtual Water content of electrical supplies derived from thermoelectric facilities, and those from hydropower stations relying on large impoundments. Example 1 (shown in Text Box 1) has therefore been based around this, and raises questions as to the preferred mix of regional electrical supplies in the future.

Many different examples could be generated from the agriculturally-related database, as created in the present work. To assist future conceptualisation, this Activity analysed the Virtual Water transfers associated with three distinct types of primary crops:

- Virtual Water transfers relating to a water-thirsty and relatively cheap crop, with sugar being taken as an example.
- Virtual Water transfers pertaining to a staple food crop, maize being selected in this instance.
- Virtual Water transfers of relevance to a high-value crop that requires little Blue Water, groundnuts being preferred as an example.

Information for each of these three types of agricultural products is summarised in Text Box 2. As noted therein, the Blue Water productivity is generally quite low for sugar, averaging US\$2.78/m^3. Higher Blue Water productivity is noted for groundnuts (mean of US\$4.41/m^3), with very much higher values for maize (averaging US\$177/m^3).

Text Box 1: An example concerning Virtual Water transfers in electrical supplies in southern Africa.

South Africa faces specific problems in relation to electricity generation in the future:

- The national demand for electricity continues to grow rapidly, with no reduction forecast.
- Demand for electricity exports to neighbouring countries is still strong, and their own capacity to generate sufficient electricity for their needs remains poor (although this might change within the next ten years in some countries, e.g. in Namibia).
- The capacity for additional hydroelectric supplies within the RSA is minor.
- Other renewable sources (wind, solar) are very unlikely to contribute significantly to RSA demand, especially peak demand, in the shorter term.
- Concerns exist in relation to the development of further nuclear energy.
- A continued reliance by South Africa on coal-fired facilities will increase atmospheric emissions yet further, which is not preferred. Carbon capture technologies are not yet sufficiently developed to reduce effects on climate change.
- There are concerns regarding the availability of sufficiently high grade coal, and the reliance on open cast mining which affects the suitability of coal in wet weather.
- The South African Government is currently exploring shale gas and fracking, but this will occur in one of the drier regions of the country, and remains highly controversial.
- Fresh water demand will also rise if electricity generation within South Africa is to increase in the future. The water demand of Eskom is already significant, at 331 MCM/year.

In such a scenario, a case can be made for a regional approach to electricity generation and use, with South Africa importing some of its electricity from countries to the north, most of whom rely heavily on hydropower (and have very significant water resources). The development of Grand Inga in the DRC is one obvious option.

An alternative possibility (which is not mutually exclusive) would involve an agreement with Mozambique for electricity supplies from natural gas reserves, to be developed off northern Mozambique/southern Tanzania. However, this will increase South Africa's reliance on external electricity, and hence requires a shift in thinking from sovereign to regional security. This can, however, reduce the demand for water in South Africa.

What strategy appears most appropriate for South Africa, and is this an issue that should be addressed in the near future in strategic terms, including a recognition of Virtual Water transfers in the scenario?

Should South Africa seek bilateral talks on future electricity generation and use, with the

Text Box 2: An example concerning Virtual Water transfers in agricultural products traded internationally in southern Africa.

‘Water productivity’ is considered by many commentators to be an important measure of the efficiency of agricultural activities. Generally measured as the financial return per volume of water used (US$/m^3), water productivity values as reported to date in the literature refer to a basis of Blue Water only. Where crops are grown with a heavy reliance on Green Water (and only limited Blue Water use), this increases the apparent water productivity.

The data platform was used to derive the standard water productivity values (based on Blue Water alone) and also for a new parameter, which could be termed the ‘Virtual Water productivity’. The latter values are based on all forms of water used to grow a primary crop: Blue, Green and Grey Water, in combination.

Three distinct types of crops were selected to create this example, and the resulting data are summarised as follows:

- Average (Blue) water productivity values were US$2.78/m^3 for sugar; US$4.41/m^3 for groundnuts; and US$177/m^3 for maize.
- Mean values for the Virtual Water productivity were US$0.38/m^3 for groundnuts; US$0.69/m^3 for sugar; and US$1.28/m^3 for maize.

The water productivity data show the influence of the Blue Water/Green Water mix used for each crop, in a very clear fashion. Virtual Water productivity figures provide a much more coherent base to compare the financial output from each crop, but effectively value each form of water equally.

The data for these three crops traded in various fashions between the SADC countries show great differences from place to place (trade to trade) in both water productivity and Virtual Water productivity – the averages cited above masking very large variations. Such information is not usually used by farmers or by governmental authorities in reaching decisions on preferred crops to be produced in specific locations.

Should public or private entities incorporate considerations of Virtual Water (or at least, the distinct types of water) into their planning in terms of which crop to grow, where?

Are governmental bodies the most appropriate to lead in any such an intervention, or would private sector farming interests be better engaged?

These figures reflect the reliance on Blue Water (and often, irrigation) for the crops involved. It is noted that while the data on water productivity are to some extent dependent on exactly where the crop is grown, average data have been used here.

When analysed on the basis of the full Virtual Water footprint, productivities average only US$0.38/m^3 for groundnuts, but somewhat higher for sugar (US$0.69/m^3) and considerably greater for maize (US$1.28/m^3). The most striking facet of the data relates to the very large differences between the water productivities calculated for specific sources/destinations of traded crops. These reflect a combination of the efficiency of crop production, and the prices assigned to traded crops. It is clear from the relatively simple analysis completed to date that further focus on the patterns of crop production would materially affect both agricultural efficiency and economic returns, with potentially large effects on poverty in certain rural areas.

The third and final example provided here involves the production of sugar on a regional basis in both South Africa and Zimbabwe. In South Africa, sugar is grown primarily in KwaZulu Natal and Mpumalanga Provinces. Very considerable differences exist between these two locations in terms of the extent of irrigation of the crop, this being far greater in KwaZulu Natal (at 90% of the total area devoted to sugar) than in Mpumalanga (only 14% of the total area used for sugar production being irrigated). As expected, crop yields are lowest for the non-irrigated product (56 tonnes/hectare as an average in KwaZulu Natal), but rise considerably when irrigation is made available (89 tonnes/hectare in Mpumalanga). In Zimbabwe, the primary distinction relating to sugar production involves the average yields attained by subsistence farmers on small-holdings (34 tonnes/hectare) and those achieved by commercial operations (76 tonnes/hectare). Text Box 3 includes some initial analysis in this regard.

Further Development of the Data Platform

The work reviewed in the present report has completed the data platform for Virtual Water transfers in agricultural products and electricity traded in southern Africa, as this was originally conceptualised and as covered by the Terms of Reference for CRIDF Activity 1806. However, during the course of the creation of the data platform, several options were noted to exist in terms of its extension to more detailed concerns. These are as follows:

- The addition of specific items cited in the section above concerning Virtual Water in agricultural products (national production/consumption patterns; trade with entities outside SADC; specific animal sizes/weights).
- The addition of a dataset on the present and estimated future national demand for electricity. It is believed that the SAPP office in Harare could assist in this regard, and that such a dataset would be of utility in decisions on preferred locations for interventions in the electricity generation sector (taking Virtual Water transfers into account).
- The completion of the detailed dataset shown in template form in Annex 1 to this report.

Text Box 3: The production of sugar in southern Africa.

Yields for the production of sugar in South Africa and Zimbabwe are shown below:

Location	*Type of Production*	*Yield*
KwaZulu Natal (RSA)	Dry land (not irrigated)	56.0
	Irrigated	70.7
Mpumalanga (RSA)	Dry land (not irrigated)	63.6
	Irrigated	89.5
Zimbabwe	Subsistence (small-holdings)	34.0
Zimbabwe	Commercial	76.0

As would be anticipated, the yields increase perceptibly when irrigation is made available (in South Africa), although the uplift in yield provided by irrigation is not particularly great (26% in KwaZulu Natal, and 41% in Mpumalanga). In Zimbabwe, the key determinant of yields of sugar involves the distinction between those attained by subsistence farmers on small-holdings, and the much higher yields achieved by commercial operations.

What level of Government intervention may be countenanced, to attempt to improve crop yields in such scenarios?

Is the irrigation of sugar (which has low water productivity in general) a rational use of Blue Water supplies in the water-stressed areas of southern Africa? Should Blue Water be allocated to higher-value crops in such water-stressed areas, and how might this be achieved?

What forms of intervention may be promoted to increase subsistence-level yields of crops? Should subsistence farmers be encouraged to grow crops with higher water productivities,

- The updating of data on Virtual Water in electricity traded in the most recent period, when such information becomes available for 2013-2014. This could be augmented by prospective information relating to any known future trading patterns (e.g. from Inga III in the DRC to South Africa, and from Ressano Garcia in Mozambique to Namibia).

Developing Scenarios/Mainstreaming Virtual Water into CRIDF Activities

There is merit in developing further specific scenarios (or 'stories') pertaining to Virtual Water transfers within southern Africa. At least some of these may be based upon ongoing CRIDF Activities, and the CRIDF staff are considering which Activities would be most appropriate to interrogate, in this regard. Other scenarios are likely to arise from CRIDF Activity 1807 and may address potential Positive-Sum Outcomes, where trading patterns could be modified to the mutual benefit of two or more parties within southern Africa.

Mainstreaming Virtual Water into SADC Activities

It is believed that the data platform created by the work to date under CRIDF Activities 1805 and 1806 will be of very considerable interest to certain other parties. These include the SADC offices in Gaborone; many of the River Basin Organisations (or similar bodies with distinct nomenclature) within southern Africa; private sector bodies engaged in commercial agriculture; Eskom and other electrical utilities; and the SAPP offices in Harare. The forthcoming Activities under the Virtual Water Project should consider the preferred roll-out of the data platform and selected information derived from the platform.

Annex 1 The Template for Electricity Generation

Electricity Database, Continental SADC Countries: Country-Level Data (Page 1 of 2)

Country	*Water Consumption, MCM/year (% of ARWR)*	*Electricity Sent Out, GWh/year*	*Water Consumption, Litres/kWh*	*Comments*
Angola				
Botswana				
DRC				
Lesotho				
Malawi				
Mozambique				
Namibia				
South Africa	317,052,040	231,129,000	1.37	Latest Eskom data
Swaziland				
Tanzania				
Zambia				
Zimbabwe				
Total, 12 countries				

NOTES:

1. Column 2: Data should be cited as million cubic metres/year (MCM/year). The ARWR is the annual renewable water resource, as cited by AQUASTAT. The data shown for the RSA are derived from Eskom, and the water consumption is a national average. Other countries should provide their own data, also as national summaries.

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Electricity Database, Continental SADC Countries: Facility-Level Data, Angola (Page 1 of 2)

Facility	*Water Consumption, MCM/year*	*Electricity Sent Out, GWh/year*	*Water Consumption, Litres/kWh*	*Comments*
Hydroelectric Stations:				
Biopo Dam				
Cambambe Dam				
Capanda Dam				
Lomaum Dam				
Matala Dam				
Viana station				
Total, all facilities				

NOTES:

[1] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered.

[2] Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

Electricity Database, Continental SADC Countries: Facility-Level Data, Botswana (Page 1 of 1)

Facility	*Water Consumption, MCM/year*	*Electricity Sent Out, GWh/year*	*Water Consumption, Litres/kWh*	*Comments*
Coal-Fired Stations:				
Morupule				Under expansion
Mmamabula				Not yet constructed: Jindal S&P
Total, all facilities				

NOTES:

[1] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered.

[2] Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

Electricity Database, Continental SADC Countries: Facility-Level Data, DRC (Page 1 of 2)

Facility	*Water Consumption, MCM/year*	*Electricity Sent Out, GWh/year*	*Water Consumption, Litres/kWh*	*Comments*
Hydroelectric Stations:				
Grand Inga				Being considered
Inga I+II				
Inga III				Under construction
Katende				Under construction
Koni				
Kwadingusha				
Nseke				
Nzilo				
Ruzizi I+II+III				
Zongo				
Zongo II				Under construction
Total, all facilities				

NOTES:

[1] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered.

[2] Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

Electricity Database, Continental SADC Countries: Facility-Level Data, Lesotho (Page 1 of 1)

Facility	*Water Consumption, MCM/year*	*Electricity Sent Out, GWh/year*	*Water Consumption, Litres/kWh*	*Comments*
Hydroelectric Stations:				
'Muela				
Total, all facilities				

NOTES:

[1] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered.

[2] Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

Electricity Database, Continental SADC Countries: Facility-Level Data, Malawi (Page 1 of 2)

Facility	Water Consumption, MCM/year	Electricity Sent Out, GWh/year	Water Consumption, Litres/kWh	Comments
Hydroelectric Stations:				
Kapichira				RoR; fed by Kamuzu Barrage
Nkula Falls A+B				RoR; fed by Kamuzu Barrage
Tedzani I, II + III				RoR; fed by Kamuzu Barrage
Total, all facilities				

NOTES:

[1] RoR: Run-of-river facility.

[2] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered. Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

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Electricity Database, Continental SADC Countries: Facility-Level Data, Mozambique (Page 1 of 2)

Facility	Water Consumption, MCM/year	Electricity Sent Out, GWh/year	Water Consumption, Litres/kWh	Comments
Coal-fired stations:				
Benga				Under construction
Jindal S&P				Under construction
Moatize				Under construction
Gas-fired stations:				
Aggreko				Under construction
CTM				Under construction
Gigawatt				Under construction
Kuvaninga				Under construction
Ressano Garcia				Under construction
Sasol-EDM				
Temane				Under construction
Hydroelectric Stations:				
Alto Malema				Under construction
Boroma				Under construction
Cahora Bassa				
Chicamba				Under construction
Lupata				Under construction

Lurio				Under construction
Massingir				Under construction
Mavuzi				Under construction
Mphanda Nkuwa				Under construction
Total, all facilities				

NOTES:

[1] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered.

[2] Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

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Electricity Database, Continental SADC Countries: Facility-Level Data, Namibia (Page 1 of 2)

Facility	*Water Consumption, MCM/year*	*Electricity Sent Out, GWh/year*	*Water Consumption, Litres/kWh*	*Comments*
Coal-fired Stations:				
Erongo/Arandis				Planned
Van Eck				
HFO-fired Stations:				
Anixas				
Paratus				
Gas-fired Stations:				
Kudu				Being constructed
Hydroelectric Stations:				
Ruacana Falls Dam				Recently expanded
Baynes				Planned
Total, all facilities				

NOTES:

[1] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered.

[2] Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

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Electricity Database, Continental SADC Countries: Facility-Level Data, South Africa (Page 1 of 3)

Facility	*Water Consumption, MCM/year*	*Electricity Sent Out, GWh/year*	*Water Consumption, Litres/kWh*	*Comments*
Coal-Fired Stations:				
Arnot	24,031	10,841	2.22	
Bloemfontein				IPP; data awaited
Camden	20,147	8,727	2.31	
Duvha	39,469	17,925	2.20	
Grootvlei	12,568	7,346	1.71	
Hendrina	22,871	8,862	2.58	
Kelvin				IPP; data awaited
Kendal	3,936	27,012	0.15	
Komati	12,617	5,059	2.49	
Kriel	34,411	14,443	2.38	
Kusile				Under construction
Lethabo	42,862	23,093	1.86	
Majuba	25,756	23,801	1.08	
Matimba	3,013	25,895	0.12	
Matla	37,535	18,376	2.04	
Medupi				Under construction
Pretoria West				IPP; data awaited
Rooiwal				IPP; data awaited
Tutuka	37,351	18,104	2.06	
Gas Turbine Stations:				
Acacia		56		No significant water use
Ankerlig		2,358		No significant

				water use
Gourikwa		1,133		No significant water use
Port Rex		73		No significant water use
Hydroelectric Stations:				
Drakensberg PS		1,973		Data awaited from DWR
Gariep Dam		457		Data awaited from DWR
Ingula PS				Under construction
Palmiet PS		908		Data awaited from DWR
Steenbras Dam				No data available
Vanderkloof Dam		580		Data awaited from DWR
Nuclear Station:				
Koeberg	485	14,106	0.034	
Total, all facilities	**317,052,040**	**231,129,000**		

NOTES:

[1] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered.

[2] Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

Electricity Database, Continental SADC Countries: Facility-Level Data, Swaziland (Page 1 of 1)

Facility	*Water Consumption, MCM/year*	*Electricity Sent Out, GWh/year*	*Water Consumption, Litres/kWh*	*Comments*
Hydroelectric Stations:				
Edwaleni				Luphohlo Dam supply
Ezulwini				Luphohlo Dam supply
Maguga				
Total, all facilities				

NOTES:

[1] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered.

[2] Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

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Electricity Database, Continental SADC Countries: Facility-Level Data, Tanzania (Page 1 of 2)

Facility	*Water Consumption, MCM/year*	*Electricity Sent Out, GWh/year*	*Water Consumption, Litres/kWh*	*Comments*
Coal-fired Stations:				
Kiwira				Planned
Mchuchuma				Planned
Ngaka				Planned
HFO-fired Station:				
Mwanza				Under construction
Gas-fired Stations:				
IPTL				
Kilwa (Somanga)				Under construction
Kinyerezi I+II+III				Under construction/Planned
Mnazi Bay				Planned
Songas				
Tegeta				
Ubungo I+II				
Hydroelectric Stations:				
Hale				RoR
Kidatu				
Kihansi				RoR
Mtera				
Pangani				RoR
Ruhudji				Under construction
Rumakali				Planned
Total, all facilities				

NOTES:

[1] RoR: Run of river.

[2] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered. Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

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Electricity Database, Continental SADC Countries: Facility-Level Data, Zambia (Page 1 of 2)

Facility	Water Consumption, MCM/year	Electricity Sent Out, GWh/year	Water Consumption, Litres/kWh	Comments
Coal-fired Stations:				
Maamba Collieries				Under construction
Hydroelectric Stations:				
Batoka Gorge				Planned; shared with Zimbabwe
Ithezi-Thezi				Under construction
Lower Kafue Gorge				Planned
Kafue Gorge				Ithezi-Thezi Dam upstream
Kariba North Bank				Planned
Kariba				Zimbabwean facility exists also
Mulungushi				
Victoria Falls				
Total, all facilities				

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NOTES:

[1] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered.

[2] Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

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Electricity Database, Continental SADC Countries: Facility-Level Data, Zimbabwe (Page 1 of 2)

Facility	Water Consumption, MCM/year	Electricity Sent Out, GWh/year	Water Consumption, Litres/kWh	Comments
Coal-fired Stations:				
Bulawayo				
Gokwe North				Planned
Harare				
Hwange				
Munyati				
Hydroelectric Stations:				
Batoka Gorge				Planned; shared with Zambia
Kariba				750MW; Zambian facility also
Total, all facilities				

NOTES:

[1] Only those facilities of significant scale are included in the database. Wind, solar and biomass facilities are not covered.

[2] Diesel generators are not covered.

[3] Column 2: Calculations for hydroelectric stations should cite the components of consumptive water use individually, these expected to be dominated by evaporation rates where large reservoirs are present. Evaporation from reservoirs should be calculated as being consumptive use for hydropower even where the reservoirs are of a multi-use type, but notes may be added to address the latter if this is deemed to be necessary.

[4] Column 3: This should be an average of recent years, for electricity sent out annually (in GWh).

[5] Column 4: This is calculated as consumptive water use divided by electricity sent out, for each facility.

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Electricity Database, Continental SADC Countries: Specific International Trade Data (Page 1 of 1)

From-To [Period]	*Water Consumption at Source, MCM/year*	*Electricity in Trade, GWh/year*	*Water Consumption, Litres/kWh*	*Virtual Water Transfer, MCM/year*
Total, all trade				

NOTES:

[1] All international trade of significant scale since the beginning of 2012 should be added to the above Table, showing the period of any agreement in parentheses in the first column.