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Renewable Energies in Mwanza (Tanzania) - An Analysis of Potentials and Projects / Die Energiepotentialanalyse – das Beispiel Mwanza (Tanzania)

By/ von **Fabian Heymann**

with an address by Barbara Sponholz, an introduction by Roland Baumhauer and Konrad Schliephake, and additional texts by Christian Göpfert and Bernd Schmitt. With 25 Tab., 24 Fig. and data annex. (= Würzburger Geographische Manuskripte H. 83), 106 p. ,Würzburg , ISSN 0931-8623 .

Die Energiepotenzialanalyse ist eine nützliche Methode um eine Informationsgrundlage über verfügbare, erneuerbare Energiemengen zu schaffen. In Deutschland findet die Energiepotentialanalyse im Zuge der Energiewende bereits regelmäßige Anwendung in der kommunalen Energieplanung. Heymann übertrug die etablierte Methodik auf die Partnerstadt Würzburgs, Mwanza am Victoria-See in Tansania. Dabei benutzte er Daten aus der Volkszählung und der Fernerkundung (Landsat 8 und Google Earth). Zusätzlich geben Aufsätze von Baumhauer und Schliephake einen Einblick in die globale, afrikanische und regionale Energiesituation (Angebot und Nachfrage fossiler und alternativer Energien), C. Göpfert und B. Schmitt stellen gemeinsame Projekte der Verwaltungen in Mwanza und Würzburg insbes. zur Solarenergie vor.

Energy potential analysis is a useful method to provide fundamental information on renewable energy quantities available. In Germany, the energy potential analysis found frequently application within the "energy turnaround" in communal energy planning. The study transfers this methodology to the partner city of Würzburg, Mwanza City in Tanzania, on the shores of Lake Victoria, Mwanza City. Based on free available census data and Landsat 8 and Google Earth imagery it evaluates solar and biomass based energy potentials. Additional texts give an introduction into the Global, African and regional energy scene and picture solar energy projects currently elaborated in Mwanza in cooperation with the Würzburg Municipality Dept. of Environment

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…… Expl. WGM Heft 83 F. HEYMANN u.a. (2015): Renewable Energies in Mwanza (Tanzania) - An Analysis of Potentials and Projects / Die Energiepotentialanalyse – das Beispiel Mwanza (Tanzania**)** **à € 20,-** .....€

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Umschlag: W. Weber with pictures by B. Schmitt

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Grußwort

Die Julius-Maximilians-Universität Würzburg versteht sich als zukunftsorientierte und weltoffene Universität. So hat sie zahlreiche Universitäts- und Fakultätspartnerschaften weltweit aufzuweisen und freut sich über eine zunehmende Mobilität der Studierenden gerade auch aus dem Ausland nach Würzburg kommend. Von den zahlreichen Partnerschaften sind allein ca. 40 in afrikanischen Ländern angesiedelt, eine rege Forschungskooperation mit außeruniversitären Forschungs- und Lehrinstitutionen Afrikas ergänzt diese teils schon seit Jahrzehnten erfolgreich etablierte Zusammenarbeit. Die Hauptfelder der Kooperation zwischen Würzburg und Afrika liegen in den Bereichen Biodiversität und Klimaforschung, Chemie, Infektionsforschung und Entwicklung neuer Medikamente sowie diversen Sparten der Medizin, insbesondere der Tropenmedizin. Aber auch die reichhaltige Literatur, Geschichte und Kultur Afrikas sind Gegenstand gemeinsamer Forschungen. Mit dem seit 2006 etablierten „Afrikakreis“, seit 2009 „Forum Afrikazentrum“, stärkt die Universität Würzburg die wissenschaftliche Kooperation zu und mit Afrika.

Der vorliegende Band wird von der Stadt Würzburg im Rahmen der Partnerschaft mit Mwanza, der Geographischen Gesellschaft Würzburg e.V. und dem Institut für Unternehmenspolitik e.V. unterstützt und reiht sich in Afrika-bezogene Veröffentlichungen des Instituts für Geographie und Geologie ein (siehe Liste am Ende des Bandes). Er greift unser Interesse am afrikanischen Kontinent und seiner aktuellen Entwicklung auf und verdeutlicht mögliche künftige Forschungs- und Kooperationsfelder, zu denen die Universität Würzburg auch in Zukunft gerne beitragen wird.

Address

The Julius-Maximilian-University today hosts approx. 28.000 students of all disciplines. Within its scope of a future-oriented institution with a global vision it has signed a broad range of cooperation agreements with universities and faculties abroad and it actively promotes the mobility of students from around the world. Cooperation with more than 40 universities and other research institution on the African continent has been sealed and filled with life, often since several decades. As the main fields of joint research the subjects of biodiversity, climate, chemistry and medical research should be mentioned. In addition, there are projects dedicated to literature, history, culture and languages of various African regions. In 2006, concerned staff members of Würzburg University founded an “African Circle”, which since 2009 acts as an interdisciplinary “Forum Africa Center”, promoting the exchange with African partners.

The present volume has been supported by the City of Würzburg in the framework of its cooperation agreement with Mwanza, by the Geographical Association Würzburg

and the Institute for Managerial Policy (Stuttgart). It comes as a timely addition to previous publications in the series edited by members of the Institute of Geography and Geology (see list at the end of this volume). Once again, it outlines the scope and the prospects of research cooperation, where the University of Würzburg is ready to contribute also in the future.

Prof. Dr. Barbara Sponholz –

Mitglied im Forum Afrikazentrum und Vize-Präsidentin der Julius-Maximilian-Universität / Member of Forum Africa Center and Vice President, Würzburg University

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Tanzania's Energy Challenge – Global Visions and Regional Realities

by Roland BAUMHAUER and Konrad SCHLIEPHAKE

Zusammenfassung - Tansanias energetische Herausforderungen im globalen und regionalen Kontext

Der folgende Einführungstext integriert die Arbeit von HEYMANN in den globalen und regionalen Kontext der Energiewirtschaft. In Tansania sind 73% der 50,8 Millionen Einwohner nicht an das Stromnetz angebunden. Traditionelle Biomasse ist die wichtigste Energie, sie deckt 88% des landesweiten Bedarfs von durchschnittlich nur 0.48 Tonnen Erdöläquivalent (TOE) pro Einwohnern und Jahr ab. Dies ist zu vergleichen mit Verbräuchen und Nordamerika (5.6 TOE) und dem Welt-Durchschnitt von 1.83 TOE. Unser Überblick über die weltweiten Produktions- und Verbrauchsräume verdeutlicht Afrikas sparsamen Umgang mit (fossiler) Energie, deren Produktion daher zu 1/3 exportiert werden kann.

Bei wachsender Bevölkerung, steigendem Lebensstandard und anhaltendem Druck auf die nachwachsenden Energiequellen (Holz) erweist sich heute die „Energielücke" als bedeutsames Hindernis für die Entwicklung Tansanias. Obwohl zahlreiche Studien dazu vorliegen, ist die Solarenergie /Photovoltaik bislang wenig ausführlich behandelt worden. HEYMANN verdeutlicht anhand seiner technischen Analyse für die Stadt Mwanza am Victoria-See, dass Sonnenenergie eine echte Alternative darstellen kann, die sich vor allem in die lokale Wirtschaft integrieren lässt. Seine Studie beinhaltet keine schnellen Patentlösungen. Sie zeigt aber, dass vorsichtige, technisch beherrschbare und mit der betroffenen Bevölkerung abgestimmte Energieprojekte wesentliche Bestandteile zur Schließung der „Energielücke" sind. Wie HEYMANN und die Autoren der übrigen in diesem Band veröffentlichten Beiträge versichern, stehen die Würzburger Geographen gemeinsam mit der Würzburger Stadtverwaltung bereit, um die Partnerstadt Mwanza dabei freundschaftlich zu unterstützen.

1. Introduction

Energy is life – life is energy. Since approximately more than one million years man uses renewable energy, probably starting in Africa. Two centuries ago he gradually switched to fossil energy and this is what probably makes mankind feel as the "master of the world". With the discovery of large oil reserves in many parts of the World, supplemented by natural gas fields, the decades from the 1950ies to the 1980ies were characterized by a firm belief in continuous economic growth based on a cheap and abundant energy supply. This growth notably took place in the already industrialized countries, to the (relative) detriment of those parts of the globe which they labelled the "Third World Countries". We know today that the reserves are limited and that, probably, the moment of "peak oil" (equilibrium between oil consumption and additional annual production from newly explored fields) has already passed. However, all forecasts point to a continuously rising demand of between 1.2 % p.a. (average between 2011 and 2035, "New policies Scenario" with forced reduction of consumption) and 1.5 % p.a. (Current policies with no

intervention, both figures from World Energy Outlook 2013, p. 572-573). This would imply a doubling of demand in 45 years and should be compared with our calculations in Fig. 1. Industrialized nations which express their visions about energy through publications, for example of the International Energy Agency in Paris, feel that the continuing consumption of (fossil) energy resources is their inherited right and that energy supply should develop accordingly. Fortunately, their thirst seems to be satisfied, and with a stagnating population their additional demand is calculated with + 0.1 to +0.4 % p.a. for the United States of America resp. 0% for the European Union. But other energy-hungry big nations do appear on the market and ask for a fair share. For China a demand growth is calculated with 1.6 % to 2.2. % annually and the biggest state of the world has become the major oil importer. India does not like to lag behind with a supposed growth rate of 3.0 % to 3.3 % p.a. of additional energy consumption (figures in this paragraph from World Energy…2013, p. 592 ff.).

In general, most of the industrialized states highly subsidize the search for alternative energies, and some of its phenomena seem like playful experiments The overall picture painted by global studies comes down to a different reality in many countries of Africa (see the survey World energy…Africa 2014). The limited purchase power of the local population does not permit a stable supply of fossil or "modern" energy, and the technical infrastructure is unreliable and somewhat erratic. Under the triple pressure of population growth, deterioration of climate (see BAUMHAUER 2011) and volatile supply with hydrocarbons the search for alternatives is a must. The paper by HEYMANN in this volume therefore presents more than a typical case study. It comes in the tradition of previous research published in our series (see SCHLIEPHAKE 2008 and list of publications at KLEIN 2008) and is focusing on Mwanza, the partner city of Wuerzburg. This area not only suffers from the three elements of pressure mentioned above, but is also situated far away from the oceans and the axes of world market supply with fossil energy. In addition, the paper demonstrates the will and the capability of our geographic science to analyze and promote projects directly related to the improvement of the living standard – the best way to stabilize population in its home area.

The recent Africa Energy Outlook (2014, p. 155) points out that "Sub-Saharan Africa's energy sector can be improved to unlock a better life for its citizens". It "describes one of the most poorly understood parts of the global energy system…… and shows how investment in the sub-Saharan energy sector can stimulate rapid economic and social development across the region".

Any observer comparing this and other surveys with the geographical realities becomes aware that energy research on the various levels encounters shortcomings from data collection and interpretation, not only in developing countries. In addition, the homologation of data from different backgrounds and concerning different types of energy production and consumption is not an easy task. Even slight differences in conversion factors within volume (barrel, cubic meter, cubic foot…), weight (ton) and caloric value (BTU, Joule…), which may appear from one producer to the other, imply changes of the overall results, as it is the case with several of our tables. However, we try to create an overall picture as near as possible to the geographical realities.

2. World-wide fossil reserves and resources

This introductory text does not pretend to give a survey on all spatial aspects of the world wide energy situation (see the monography by BRÜCHER 2009 and the survey by SCHLIEPHAKE 2005). Some global data are sufficient to present the dramatic issue of a

growing consumption contrasting with limited reserves and resources and thus proving the necessity to develop alternatives.
The interaction of sedimentology and tectonics in the history of the earth has unequally distributed and limited fossil energy and notably hydrocarbons on the globe. Researchers distinguish (according to Energiestudie…2014) between

- Reserves, i.e. known and explored fields of oil, gas and coal with their stocks, which can be exploited under present economic and technical conditions;
- Resources, i.e. potential deposits, which are known to exist, but still have to be evaluated concerning the contents and the price of extraction and marketing, generally only competitive under the conditions of price increase.

The data in Fig. 1 give a useful insight into the (fossil) energy scene and the (hypothetical) lifespan, calculated from a division of reserves resp. resources by current annual production.

Fig. 1- World-Wide Energy Reserves, Resources, Consumption and Lifespan at Current Consumption Rate, in million tons oil equivalent (TOE)/year, 2013

Origin of Energy	Reserves Mill. Tons	Consumption Mill. Tons	Lifespan of Reserves (years)	Resources Mill. Tons	Lifespan of Reserves (years)
Oil	216842	4189	52	431970	103
Nat. Gas	179219	3046	59	759196	249
Coal (incl.Lignite)	485591	3808	128	11649909	3060
Uranium	14328	500	29	235620	471
Total fossil energy	895980	11453	77	13089785	1134
Renewable energies incl. Hydro		1142			

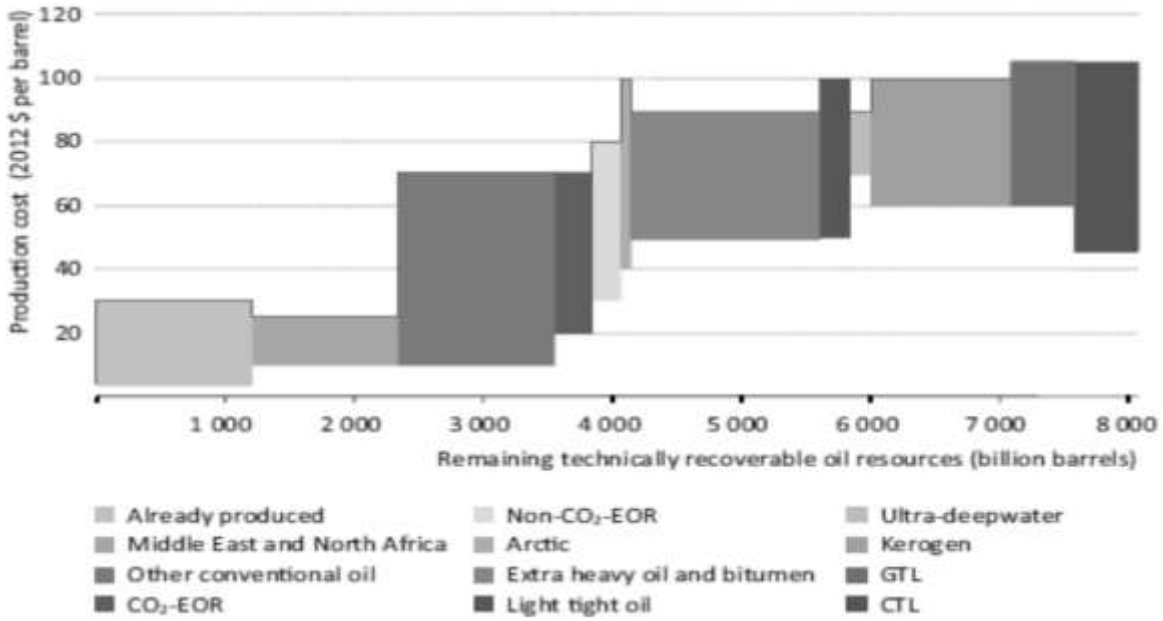
After data from Energiestudie ….Bundesanstalt für Geowissenschaft und Rohstoffe (2014) calculated by K. Schliephake. 1 Exajoule= 23.8 mill. TOE. Key World Energy… (2014) gives slightly higher figures for 2012 see here Fig.3.

Under the condition of current consumption level, oil and gas reserves will last for not more than another 52 resp. 59 years. Explored coal reserves give more hope for the next 128 years, but the mining is costly and emissions of Green House Gases (GHG) pose a definite danger to the future of our planet (see BAUMHAUER 2006). Alternative energies today cover just 10% of the world's consumption, although there are doubts whether their production and consumption estimates in Third World countries correspond to the realities. (See here Ch. 4.).

Serious analysts avoid giving too much importance to the potential of fossil energy resources as listed in Fig. 1. Their real amount and value are uncertain, and their production costs may be double or triple the current price levels, according to Fig. 2.

The world has become accustomed to cheap energy. But as we look at the limitation of its affordable reserves, we must intensify the search for sustainable alternatives in all parts of the globe.

Fig. 2 – World Wide Supply Costs of Liquid Hydrocarbons (US-$ per Barrel, 2012)



EOR= Enhanced Oil Recovery; GTL/CTL= Gas/Coal to Liquids. Source: World Energy Outlook,, Fig. 3.17, (2013), p. 454.

3. Uneven Distribution of Reserves

Historically, industrial development and the rise in public and personal welfare and wealth were based on the availability of cheap (fossil) energy. We can point to Great Britain in the 19th century and, in recent decades, to the Persian Gulf (see, for instance, SCHLIEPHAKE 2007). In the last 60 years, the situation has changed. Actual or former Third World countries provide cheap and, up to today, abundant fossil energy to the world market with priority to industrialized states with highest purchase power. But, in many cases it is the buyers and consumers which profit most, not the producers. HUMPHREYS, SACHS and STIGLITZ (2007) even spoke of the “resource curse” put on the latter.
A quantitative survey referring to continents resp. major economic entities and including all forms of energy (fossil and renewable incl. hydro energy) is presented in Fig. 3. This is the data base for Figures 4. and 5.

Fig. 3 helps to identify not only the major consumers, but also the important importers of energy. OECD Europe and OECD Asia each import more than half of their consumption, supplied by the Middle East, Russia and neighbors as well as Africa. The graph in Fig. 4 makes better visible the sources and the destinations of international energy flows.

Fig. 3 - The World Energy Scene by Regions –Production, Consumption and Trade in mill. Tons of Oil Equivalents (TOE), 2011

Region (Population in Mill.)	**Oil** **p**ro-duction	**Gas** pro-duction	**Coal** pro-duction	**Nuclear Power** Prod.	**Alter-native** Energies Prod.	**Total** recor-ded Prod.	Total utilized Prod.*	Total Energy con-sumption	Energy Trade §
North America (477)	784	773	550	241	211	2559	2424	2663	-239
Europe OECD (563)	173	249	165	236	209	1032	977	1778	-801
Asia OECD (205)	30	53	215	67	41	406	385	863	-478
Latin America (460)	365	151	57	6	177	756	716	586	+130
Eurasia (337)	681	794	286	77	45	1883	1785	1159	+626
Rest of Asia (3664)	385	377	2251	44	695	3752	3554	4324	-770
Middle East (209)	1391	467	1	0	3	1862	1764	640	+1124
Africa (1045)	498	180	139	4	347	1168	1106	698	+408
Total (6960)	4307	3044	3664	675	1728	13418	12711	12711	0

- Recorded production x0, 947.
  § (-) = Import; (+) = Export. 1barrel/day = 49.3 tons/year; 1 ton of coal = 0, 67 TOE.Calculated by K. Schliephake after data from World Energy Outlook 2013.

The “Rest of Asia” contains non-OECD-states like China, India and Vietnam, which, today, are the consumers of 1/3 of the energy produced and consumed in 2011. But they also host, with their 3.66 bn. Inhabitants, 53% of the world’s population. 18% of their energy consumption (fossil and renewable) is imported. This is a fair rate in comparison to OECD-Europe (without Russia and other Eastern European countries) with 37.5% imports and OECD-Asia & Oceania (Australia, New Zealand, Japan, and S. Korea) with more than 55%. Together with the Asian Middle East (notably OPEC-members) the African continent emerges as the major supplier of the world market. It exports 37% of all energy produced within its shores, a ratio which is only outmatched by the Middle East with 64%.

The disequilibrium between producing and consuming regions is yet more impressive if we turn to a per capita analysis based on the same data and regional definitions and presented in Fig. 5.

Fig. 4 . World Energy Consumption and Balance by Regions in Million TOE (2011)

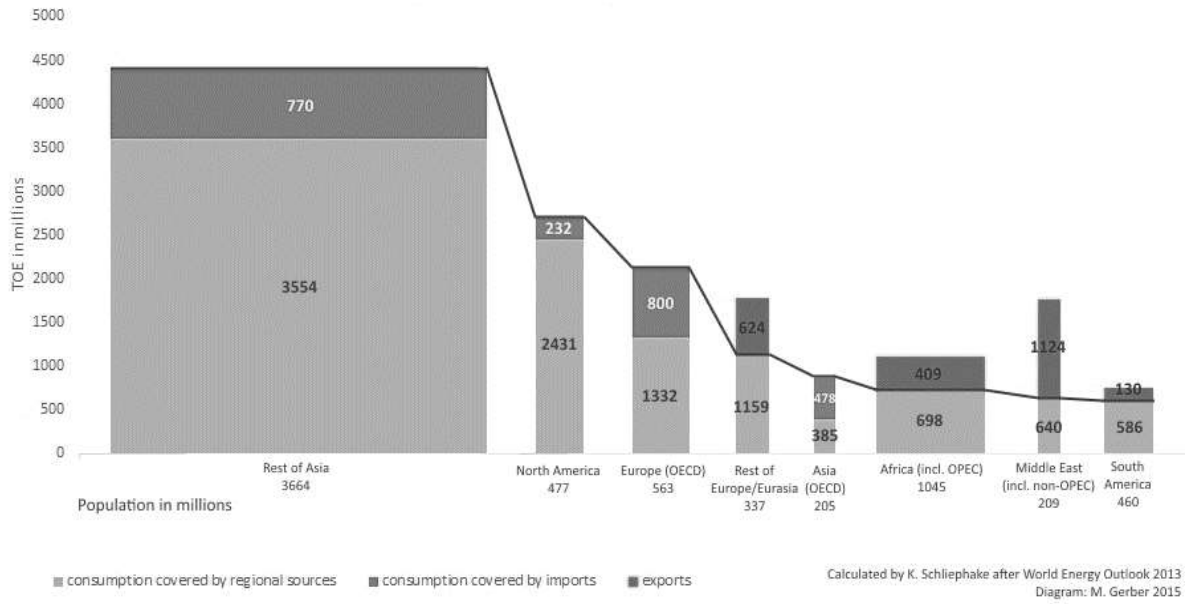
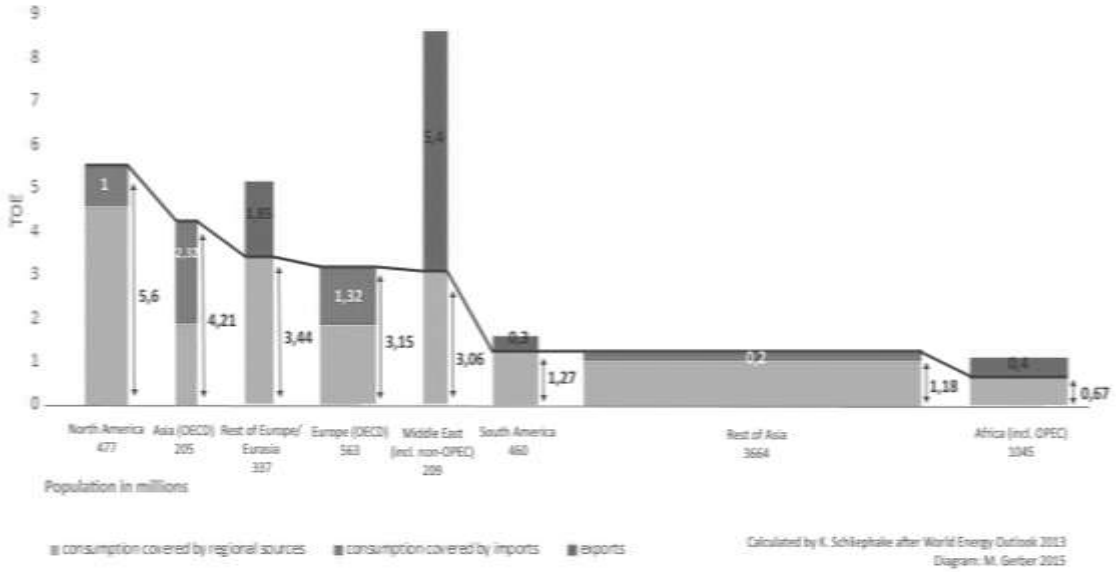


Fig. 5 – Per Capita Energy Consumption and Balance (Export-Import) by Regions in TOE (2011)



In comparison to a world average of 1.83 TOE per year , Northern Americans (USA and Canada) definitely take the lead with a per capita consumption of 5.6. Tons of oil equivalent (TOE) or 15 kilograms per day. They are not too much to blame, as only 9% of this comes from outside the area. Asian and European OECD –countries follow with

4.2 TOE (of which 55% imports) resp. 3.15 TOE (42 % imports). Africa's gift to the energy-hungry world may be seen in the fact that, within its per capita production of only 1.06 TOE, it saves enough to provide 37% of its energy for export outside the continent. In fact, its inhabitants show, with an average of 0.67 TOE or 1.8 kilograms per day, by far the lowest rate of individual consumption in the whole world.

4. The Case of Africa and Tanzania

A look at Africa as an entity veils the local realities. Recent research by the International Energy Agency (IEA, see Africa Energy…2014) gives a good insight into the regional realities. However, it does not deal in detail with Tanzania, except for an overview of off-shore natural gas fields their possible marketing (inland and LNG exports, see p.155). As can be seen from Fig. 7, we find states with sufficient fossil energy resources and corresponding capability of providing them to local and international markets. They are situated notably in Northern (Libya, Algeria; Oil and Gas), Western (Nigeria, Gabon; Oil) and South Africa (Coal). Similarly, Central Africa includes oil exporters like Gabon and Congo. In contrast, Eastern African states belong to the only group of net importers, with notably Ethiopia as major consumer. Tanzania, in this report, is counted among the Southern African group, which is dominated by coal-rich South Africa and oil exporters like Angola, and therefore, acts again, as an entity, as an energy exporter.

Fig. 7 – The African Energy Scene by Regions –Production, Consumption (Primary Energy Demand) and Trade in mill. Tons of Oil Equivalents (TOE), 2012

Region (Population in mill.*)	**Oil** Pro-duction	**Gas** Pro-duction	**Coal** Pro-duction	**Alter-native Energies** Prod.	**Total** Recorded Prod.	Total Energie Consumption	Energy Trade §
North Africa (180)	163	138	0	5	306	170	+136
West Africa (352)	128	39	0	149	316	197	+119
Central Africa (126)	49	7	0	30	86	37	+49
East Africa (261)	10	1	0	98	109	112	-3
Southern Africa (232)	94	6	125	81	296	223	+73
Africa Total (1151)	444	191	125	364	113	739	+374

§ (-) = Import; (+) = Export; *= 2015 figures. 1barrel oil/day = 49.3 tons/year; 1 ton of coal = 0, 67 TOE; 1 bn cu.m= 0, 9 mill. TOE. Calculated by K. Schliephake with data from Africa Energy Outlook (2014), notably p. 78, 99,188, 190,198,206,210,214 &230.

Fig. 8 – Tanzania. Energy Balance 2010/12, in mill. Tons oil equivalent (TOE)

Energy Source	Production	Import	Total consumption	Share of total consumption
Oil	0	1.72	1.72	7.5%
Nat. Gas	0.58	0	0.58	2.5%
Coal	0.07	0	0.07	0.3%
Hydropower	0.28	0	0.28	1.2%
Other renewables	20.51	0	20.51	88.5%
Total	21.44	1.72	23,2	100%

Calculated by K. Schliephake with data from Key World…2014 and Materials and Energy...2015, see also MSIYANI 2013.

Tanzania itself belongs to those African countries which are less well equipped with fossil energy resources, according to recent reports by the US Energy Intelligence Agency (Tanzania…2015) and Materials and Energy…2015. From these sources, we have established, in Fig. 8, its energy balance.

Only 71% of the urban (15,7 mill. persons) and 7% of the rural population (35.1 mill., according to World Bank for 2014) have access to electricity, and biomass such as wood, charcoal, manure and crop residuals cover the needs of the remaining citizens.

With a per capita consumption of 0.48 TOE annually, of which not more than 7.5% are imported, Tanzania ranks among the countries with the lowest demand, although this is currently increasing by 6.7% p.a. (average between 2000 and 2012, including population growth. The “energy gap” - in comparison to neighbors and other parts of the world- has double negative effects: A lack of affordable and reliable energy supply hampers industrial (and social) development, and the respective states lack a more or less stable income from energy exports. Therefore they have fewer possibilities to establish a productive infrastructure and to stabilize the living standard of the population (see Africa Energy …2014)

What solutions can be proposed? Local fossil resources offer few prospects. Some off-shore natural gas fields in the Mnazi Bay have been identified, and they should supply, from 2015 on, the mainland/Dar es Salaam with probably 0.8 bn cu feet/ day. This is an equivalent of 7.6 mill tons/ year, of which a share can liquefied and exported as LNG to abroad (see African Energy…2014, with map; and Tanzania…2105), the rest being available notably for electricity generation.

The expansion of alternative and sustainable energy supply is certainly the best solution. The study by HEYMANN in this volume points to this issue, but there is no real lack of learned studies. Tanzania Renewable Energy Association (TAREA) has published an impressive “Strategy 2011 to 2014”, and this is supplemented by initiatives like Tanzania Domestic Biogas Programme (Dutch SNV ca. 2011, see presentation 2012 and SNV homepage). With Norwegian support, a National Electrification Program was presented in

2014, but with virtually no mention of photovoltaic potential. In a larger scope, the Electricity Supply Industry Strategy (2014) proposed by the Ministry of Energy and Minerals gives projections up to the year 2025 when electrical power generation capacity should attain nearly 10.8 mills. MW (2013: 1.6 MW). According to this strategy, solar (photovoltaic) energy will play a minor role with a share of less than 1% - not impressive for the nation as a whole, but an important relief for rural areas far away from the coast.

5. Summary

This introduction puts the study of HEYMANN into a global and regional context of energy supply and demand. Tanzania is poorly equipped with fossil reserves, and 73% of its population is not linked to the national electricity grid. Therefore, traditional biomass forms the most important source of energy, but climate change and population pressure more and more limits its availability. The “energy gap”, i.e. the lack of access to modern energy threatens the social and economic development of Tanzania. Although numerous studies to counter it have been presented, there is a certain lack of action, as most of the projects need an enormous technical and capital input. In contrast, energy from the sun, captured by photovoltaic installations, is a viable alternative especially for areas far away from the coast and from the international trade routes of oil and gas.

Geographers all over the world have traditionally been aware of the interdependence between nature, mankind and technical equipment. During the 2014 Conference on “Energy Geography in International Perspective” at Bonn University among others two papers were presented specifically focusing on renewable energies in Tanzania (see HOFFMANN 2014 and SCHWARZ 2014). Our research efforts do not present a quick solution to an age-old problem. But a cautious approach which integrates the major stakeholders on the regional and local level seems to be promising. As a result of our case study, we feel that it is most rewarding to provide the people with a technology easy to install and to manage. Together with the Municipality of Würzburg (see GÖPFERT and SCHMITT in this volume) , geographers pledge to give their support to the partner city of Mwanza.

6. **Literature** (in addition to the study of HEYMANN, see also the compilation by SCHLIEPHAKE in this volume) - Thanks go to Prof. Dr. Ralf KLEIN (Würzburg) for pointing to recent geographical energy research in Germany

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