ENERGY SECTOR MAP: INTERLINKAGES BETWEEN THE OTHER SUPPLY & DISPOSAL SECTORS

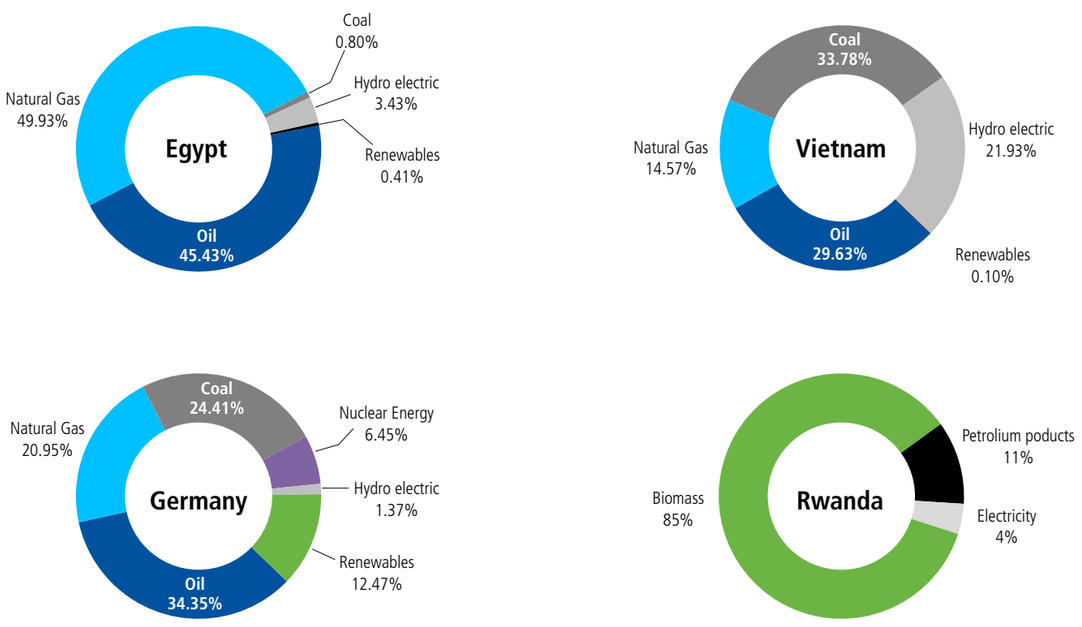
1. Primary Energy

In Egypt primary energy consumption was 86.2 Mtoe (3,609 PJ) in 2015. Thereby, about 96% was fossil fuel. Especially natural gas and oil are the main sources as depicted in figure 1. In Vietnam primary energy consumption was 65.9 Mtoe (2,759 PJ) in 2015. Hydroelectric had a share of 22%, the rest is based on fossil fuel, while coal held the highest share with 34%.

With 320.6 Mtoe (13,423 PJ) in 2015, Germany is the biggest consumer of PE. Coal, oil and gas are the main sources in Germany, nuclear power will disappear within the next decade due to political decisions. A detailed proportional distribution is depicted in figure 1. Due to the lack of data on Rwanda by [1], two other sources are used to draw a comparison. According to [2] and [3], PE consumption in Rwanda is with 85% based on biomass, which is part of renewables compared to the other three diagrams. The difficulty of this illustration is, that there is no further classification of petroleum products and electricity. Thus, the real primary source is indistinguishable. However, for a preliminary comparison to the other three countries it is sufficient.

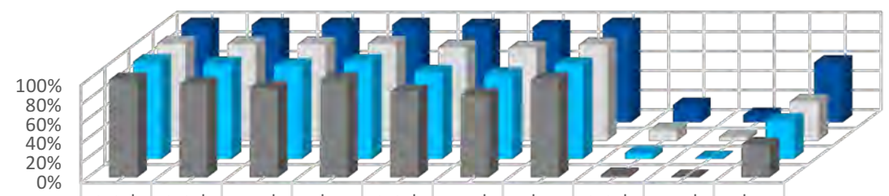
The three main parts to consume energy are mobility, heat and electricity. For the latter it is either necessary to have a grid connection or to have an own off-grid system including power plant. However, it is not natural to have access to electricity as the following chapter shows.

Figure 1: Primary Energy Consumption by fuel Egypt, Vietnam and Germany in 2015 and Rwanda in 2012 (Own representation based on data from [1-3])



2. Access to electricity

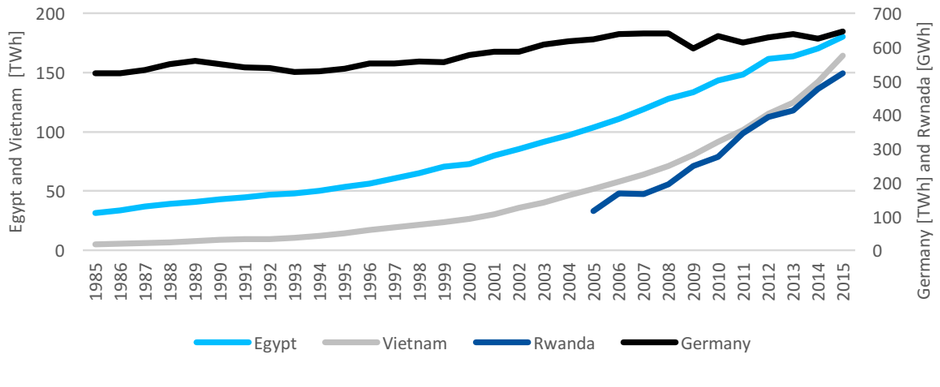
In Germany nearly 100% of the population have access to electricity, therefore just the three other countries are depicted in figure 2. Within these countries, Egypt has the highest rate, Rwanda the lowest. Due to a higher level of electrification, marginal costs are increasing. Therefore, electrification in Rwanda will catch up to Vietnam, while Vietnam has high investment costs to connect everyone in rural areas.



	total	total	rural	urban	total	rural	urban	total	rural	urban
	Germany	Egypt			Vietnam			Rwanda		
1990	100%	95.50%	91.90%	100.00%	87.94%	84.47%	100.00%	2.30%	0.50%	33.73%
2000	100%	97.70%	95.90%	100.00%	89.10%	86.60%	96.86%	6.20%	0.90%	39.38%
2010	100%	99.60%	99.30%	99.99%	96.00%	94.90%	98.52%	10.80%	4.00%	40.15%
2012	100%	100.00%	100.00%	100.00%	99.00%	97.65%	100.00%	18.00%	7.70%	61.50%

3. Electricity generation

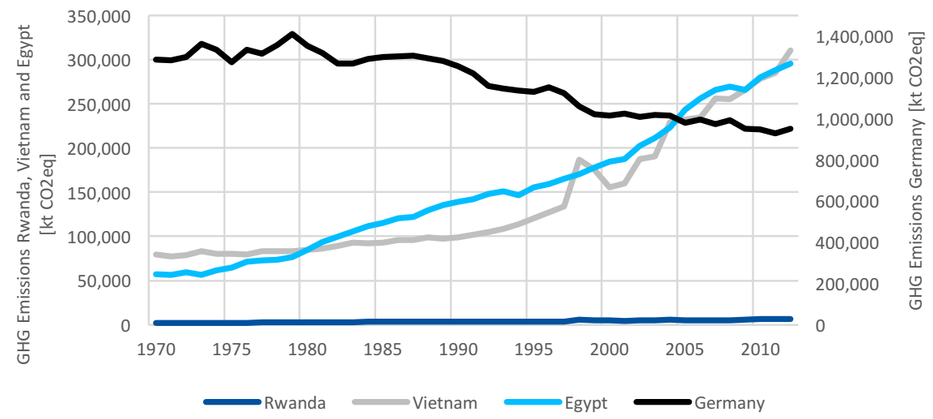
Besides access to electricity, the electricity network, the installed capacity and the power generation are important in the energy sector. According to the statistical yearbooks of Rwanda, the electricity generation increased from 116 GWh in 2005 to 524 GWh in 2015 [5, 6]. For further historical development there is no data available. Nevertheless, Rwanda's electricity generation is way beyond the other three countries. In Vietnam, there was an increase from 5 TWh in 1985 to 165 TWh in 2015. In Egypt there is a similar trend in the same period from 31 to 181 TWh, while Germany's production increased from 523 to 647 TWh. With 181.1 TWh electricity generation of renewable energies, the value is higher than Rwandans overall generation. By analyzing the last decade according to the annual growth rate, it was 35% in Rwanda, 7.4% in Egypt, 21.6% in Vietnam and 0.4% in Germany. Figure 3 visualizes the annual electricity generation in all four countries.



4. Country specific GHG emissions

For the assessment of the greenhouse gas (GHG) emissions, country specific data is essential. Next to the overall emissions per country, the emissions per capita are especially suitable for the comparison. The total GHG emissions are 950 million t (CO2 eq) in Germany, 295 million t in Egypt, 311 million t in Vietnam and 7 million t in Rwanda in 2012. Thereby, Vietnam and Egypt show an increase over the last years, while Germany show a decrease and Rwanda is about constant. (Figure 4)

Figure 4: Total GHG Emissions in kt Carbon Dioxide equivalent Emissions per Country (Own representation based on data from [4])

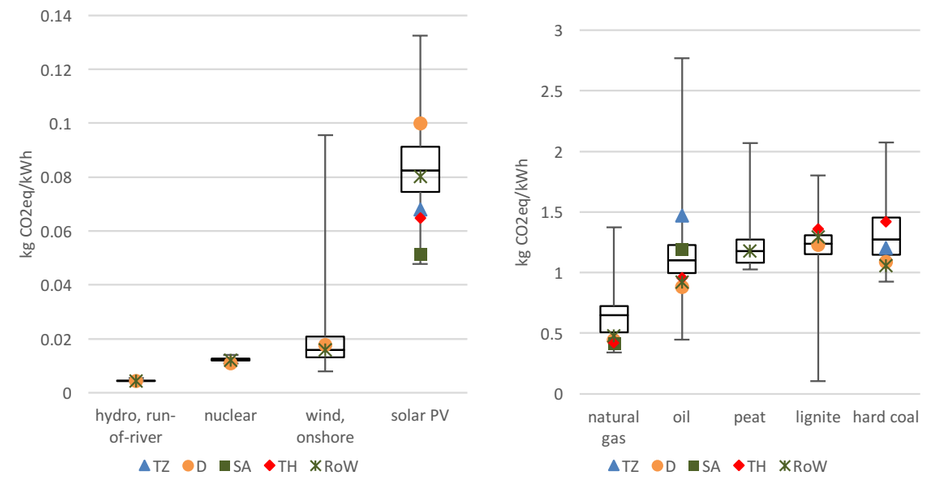


5. Life-cycle GHG emissions of electricity generation

The global energy system is the single largest contributor to climate change, and reducing energy consumption and GHG emissions from energy is of paramount global importance to avoid catastrophic climate change [9]. Latest since the Paris Agreement, countries all over the world are willing to contribute to GHG emission mitigation. Changing the power plant portfolio is a crucial factor concerning the mitigation potential.

There are several studies on life-cycle GHG emissions of electricity generation. E.g. Wagner et al. 2007 [7] and WNA 2011 [8] give a literature review and an analysis of about 100 studies. Due to differences of the methodology for calculating the emissions it is more expedient to mention a range, without determine a universal value. Due to lack of information on the studies itself, an own analysis of life-cycle GHG emissions of electricity generation was done. For this purpose about 1,000 data sets of the life-cycle inventory (LCI) database ecoinvent 3.3 respectively the life cycle assessment (LCA) software GABI have been evaluated. For comparable assessment methodologies the functional unit is set as global warming potential for 100 years (GWP100). Meaning, that the weighting was not on technical quantities but environmental. IPCC AR5 GWP100, excluding biogenic carbon, allocation, cut-off by classification with the unit kg (CO2 eq) / kWh was used. The main findings are depicted in figure 5. Furthermore, there is a lack of country-specific data on Egypt, Rwanda and Vietnam. Therefore, neighboring countries with related climatic and technical conditions serve as orientation. Tanzania (TZ), Saudi Arabia (SA) and Thailand (TH) appear to be expedient. If still no data is available, the category "Rest of the World" (RoW) seems appropriate. Germany (D) is used as reference.

Figure 5: Life-cycle GHG emissions of electricity generation by technologies (Own representation and calculation based on data from [10])



By analyzing the life-cycle GHG emissions of electricity generation by technologies it seems appropriate to have a subdivision in renewables plus nuclear and conventional energy sources as depicted in figure 5. With 0.004 kg (CO2 eq) / kWh hydro would be the best source of power, if no pumped storage is included. Renewable energies like wind and solar power highly depend on climatic conditions. For wind power it is impossible to make a general statement. Wind conditions have reginal and local differences and must be analyzed in detail. Due to a high solar irradiation, life-cycle GHG emissions of solar PV are at the lower end of the whisker in Saudi Arabia, about the same in Tanzania and Thailand, and worse in Germany.

Natural gas is the best conventional energy source regarding the GHG emissions. However, differences occur concerning the efficiency and therefore the specific emissions of the power plant. Nevertheless, even the best plants using this source have about 100 times the emissions of hydro and 10 times the emissions of solar PV. Due to the fact, that a lot of the power plants using lignite are commissioned recently, the median of hard coal is higher than the one of lignite. However, the calorific value of hard coal is higher than the one of lignite and therefore GHG emissions could be lower after all.

Sources:

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Authors: Jannik Vetter-Gindele, Ludger Eltrop (IER)

Further Information: Jannik Vetter-Gindele, Institute of Energy Economics and Rational Energy Use (IER), University of Stuttgart, Hessbruehlstrasse 49a, 70565 Stuttgart, Germany, jv@ier.uni-stuttgart.de

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