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# Environmental Externalities from Electric Power Generation: The Case of RCREEE Member States

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**Abstract**

Most of the Arab countries energy systems are currently characterized at the same time by an increasing growth in electricity demand coupled with a high reliance on conventional fossil fuels in their electric power generation. This trend is expected to continue in the near and medium terms. Relying on conventional fossil fuels for electricity generation causes generally un-priced side-effects through their impacts on climate, human health, crops, structures and biodiversity, which are typically expressed as externalities. Unfortunately, externalities cost estimations are often based on quite diverse assumptions, making comparisons difficult. The main objective of this paper is to quantify for the first time the externalities of electric power generation in RCREEE Arab Member States. The paper summarizes recent literature in this area and addresses the question of environmental externalities of electric power generation, showing that estimates of external costs resulting from fossil fuels technologies if internalized into the price of the produced electricity, could lead to the result that some renewable energy projects are financially competitive with conventional power plants. Recognition of externalities costs and their "hidden" impact can actually serve to accelerate the process of transition towards more deployment of renewable energy projects in the Arab region.

***Keywords:*** *Externalities, electricity generation, fossil fuel, renewable energy*

## 1. Introduction

It has been well established now that generating electricity from most renewable resources is more expensive than conventional approaches, but on the other hand it reduces pollution externalities. Analyzing the tradeoff is much more challenging than acknowledged, because the value of electricity is extremely dependent on the time and location at which it is produced besides the generation technology and its input "fuel" type, quality and availability, which are not very controllable with some renewables, such as wind and solar. Hence, one of the most important public policy arguments for promoting electricity generation from solar, wind, and other renewable resources is the unpriced pollution externalities from burning fossil fuels.

Externalities are mainly considered as a form of market failure, its existence leads to a sub-optimal inefficient allocation of scarce resources [1]. It leads to a deviation from relying on the right-energy mix from technical, economic, social and environmental considerations, and thus a deviation from the first best world and from the Pareto efficient state[1].

The most basic definition of the external costs can be as follows « *Externalities are generally un-priced costs, usually of side-effects of production processes, which impose costs on third parties through their impacts on climate, human health, crops, structures and biodiversity* » (ASTE, 2009).

[1] The term is named after Vilfredo Pareto (1848–1923). In a Pareto efficient state, no one can be made better off without making at least one individual worse off.

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Usually, the most important kind of externalities to quantify are those that directly concern the impact of greenhouse gas emissions (GHG) on Climate change, human health, Agriculture (Crop yields) and on building materials [2]. Nevertheless and despite its massive importance, ascribing monetary values to external impacts on climate, health, biodiversity and other environmental qualities is acknowledged to be complex and typically argued as imprecise.

The scope of this paper will first of all start by defining the issue of externalities related to electric power generation. Secondly, it will focus on summarizing the most important methods and methodologies used to assess the externalities worldwide. Then, it will tackle the most accurate international estimates that have been elaborated within the most acknowledge methods. At the end, it will move to regional results trying to generalize and calibrate these results on RCREEE member States in order to be able to get some insight on the savings that could be achieved if we tried to internalize the environmental externalities.

## 2. Externalities and the need for monetization

The concept of external cost was initially introduced to draw attention to the environmental damage cost that has not been included in the producer's price in the seventies.

Formally, an externality or an external cost or benefit, is defined as an un-priced and uncompensated side effect of one agent's action that directly affects the welfare of another agent. Since these effects are not reflected in market prices, there exists a need to assist market processes by assigning them monetary values and then integrate them into private and public decision making.

Their monetization can be useful for so many reasons. *First,* it contributes in making investment decisions in ways that ensure that the full social cost of electricity from different sources is taken into account in planning future capacity. *Second,* it is used for estimating environmental taxes and subsidies [3], to be incorporated into national accounts and for raising awareness. And *finally,* it is also used for setting environmental policy priorities, such as, using externality valuations in cost-benefit analyses in order to determine where the best returns can be secured from new environmental policies.

Two main methods are commonly referenced to estimate the externalities [4]. First, the evaluation of externalities in theory using *economic models* which are based on the simple idea of individual preferences, and thus the tool for analyzing welfare changes is therefore **"The utility theory"**. These kinds of economic models and despite their simplicity are not used widely in real world. Second, the more realistic evaluation of externalities using avoidance or abatement cost approaches that will be described in details in the upcoming parts.

## 3. Realistic approaches used to estimate energy sectors externalities

In practice there are two basic methodological approaches used for the valuation of external costs in the energy sector: The abatement and the damage cost approach.

The abatement cost approach uses the costs of controlling damage or the costs of meeting legislated regulations as a value of the damage avoided.

The damage cost approach on the other hand is aimed at measuring the net economic damage arising from negative externalities by focusing on explicitly expressed preferences. It can be divided into two main categories [5]:

- *Top-down approach:* Make use of highly aggregated data to estimate the external costs of particular pollutants, most probably carried out at the national or the regional level, using estimates of usual quantities of pollutants and estimates of total damage caused by the pollutants.

- *Bottom-up approach:* Damages from a single source are typically traced, quantified and monetized through damage functions. It makes use of technology specific data, combined with dispersion models, information from receptors and dose-response functions to calculate impacts from specific externalities.

The use of methods have shifted over time, in the beginning, the abatement cost approach was the dominating method, however with time, the use of damage cost approach started to increase more specifically since 1991, researchers moved from the top down to the bottom up approach which is considered as the dominating approach nowadays.

Abatement and top-down damage cost directly give a monetary estimate of the damage associated with the impact from an externality. The third approach, bottom-up damage cost, however, needs to translate the identified and quantified impacts into monetary terms. Generally speaking, when market prices can be used as a basis for valuation, most impacts from externalities are not reflected in existing prices. Consequently, any attempt to monetize an externality using bottom-up damage needs to rely on impact valuation methods, these methods can be sub-divided into direct and indirect methods. The ground rule for monetary valuation of damages is to account for all costs; market and non-market with different methods are well elaborated by SUNDQVIST et al [6].

## 4. Key assessment inputs assumptions

The main focus in the next sections will be on the externalities of conventional power plants treated as avoided costs resulting when replacing conventional power stations by renewables. Nevertheless, the issue of externalities is subject to many uncertainties and needs a huge time and research to execute it in reality. That's why the analysis will rely on the key assessment inputs from the internationally most acknowledged projects such as the ExternE [7] and the NEEDS [8] projects where their results were not only used on the European scale but also on different countries.

ExternE project represents the most important work in the energy externalities field which lasted for almost 10 years. Originally, the ExternE is an acronym of the method used for the calculation of External costs of Energy. Research on the ExternE has been launched by the European Commission since 1991. The project has involved more than 100 scientists and researchers from all over Europe and the United States. The most important achievements of the ExternE project were the development of two dedicated software to the estimation of energy related externalities: *The EcoSenseWeb and the RiskPoll.* [9]

NEEDS is a research project funded within the European Commission. Its ambition extended beyond the purely scientific field, as it intended to provide direct usable inputs to the formulation and evaluation of energy policies in the framework of sustainability, taking into account of the economic, environmental and social dimensions of energy policies. NEEDS has made a significant progress in the valuation of biodiversity based on the valuation of the PDF (Potentially disappearing fraction), in increasing the robustness of what concerns the climate change, and in generating new knowledge and data for human mortality.

ExternE and NEEDS are considered as the most famous and important international projects that have been realized in the field of estimating externalities in the energy sector. Their results have been aggregated and used worldwide in different studies all over the European Union as well as some neighboring countries. As a summary of the ExternE series of projects, the following table represents the average externalities of power generation technology based on different fuels for some European countries [10].

| Country | Coal | Oil | Gas | Nuclear | Bio | Hydro | PV | Wind |
|---|---|---|---|---|---|---|---|---|
| AUT | | | 1-3 | | 2-3 | 0.1 | | |
| BE | 4-15 | | 1-2 | 0.5 | | | | |
| DE | 3-6 | 5-8 | 1-2 | 0.2 | 3 | | 0.6 | 0.05 |
| DK | 4-7 | | 2-3 | | 1 | | | 0.1 |
| ES | 5-8 | | 1-2 | | 3.5 | | | 0.2 |
| FI | 2-4 | | | | 1 | | | |
| FR | 7-10 | 8-11 | 2-4 | 0.3 | 1 | 1 | | |
| GR | 5-8 | 3-5 | 1 | | 0.08 | 1 | | 0.25 |
| IE | 6-8 | | | | | | | |
| IT | | 3-6 | 2-3 | | | 0.3 | | |
| NL | 3-4 | | 1-2 | 0.7 | 0.5 | | | |
| NO | | | 1-2 | | 0.2 | 0.2 | | 0.025 |
| PT | 4-7 | | 1-2 | | 1-2 | 0.03 | | |
| SE | 2-4 | | | | 0.3 | 0-0.07 | | |
| UK | 4-7 | 3-5 | 1-2 | 0.25 | 1 | | | 0.15 |

**Table 1: External costs for electricity production in some European Union countries (US c/kWh)**

What we can get from this table is that the highest amount of externalities in the European Union comes usually from the Coal and oil followed by Gas and comes at last from the renewable energy sources such as wind and PV. The highest amount of externalities in these countries is registered mainly in France.

Table 2 along with figure 1, shows the range of externalities estimation from previous studies. It should be noted that the results can vary from country to country according to different factors, for instance; the use of different technologies that could imply different emission factors, or according to the characteristics of the specific sites under consideration that could differ in the population density, income or transport distances, or even according to the differences in scope (Only a fraction of externalities could be included in some analysis, and/or the entire fuel cycle rather than including only the generation stage).

| US c/kWh | Coal | Oil | Gas | Nuclear | Hydro | Wind | Solar | Bio mass |
|---|---|---|---|---|---|---|---|---|
| Min | 3 | 4 | 0.49 | 0.2 | 0.03 | 0.001 | 0.25 | 0.08 |
| Max | 9.5 | 9 | 3 | 1.5 | 1 | 0.25 | 0.6 | 3.5 |
| Mean | 5.4 | 5.9 | 1.7 | 0.6 | 0.4 | 0.1 | 0.5 | 1.3 |

**Table 2: Range of external cost estimates (US c/kWh)**

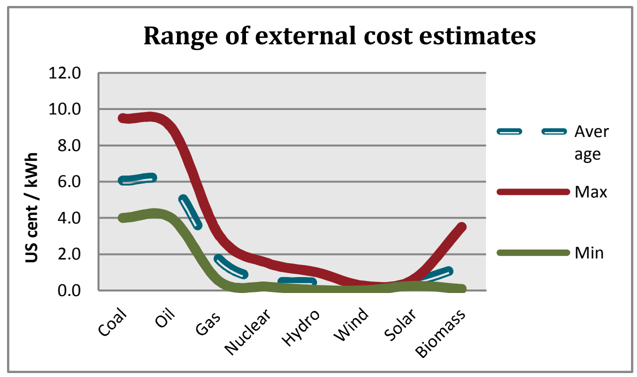


**Fig. 1: Range of external cost estimates (US c/kWh)**

## 5. Estimating the externalities in RCREEE Member States

Due to the data unavailability and the lack of reliable information, the international average of external costs estimated from various studies and resulting from different kind of fuels, summarized in table 2, were used to estimate the externalities in the region taking into consideration the electricity generation per type of fuel for each country.

Another key challenge was to gather data on the electricity generation in RCREEE Member States according to the fuel type used; these data were calculated based on Arab Union of Electricity (AUE) 2011 statistics [11] providing generation mix and different fuel consumptions. The calculation results are presented in figure 2, showing the dominance of natural gas in Egypt, Algeria, Tunisia & Bahrain, and the dominance of oil in Lebanon, Palestine, Jordan, Morocco and Libya. Sudan has the largest part of Renewable energy in its current state because of hydropower.

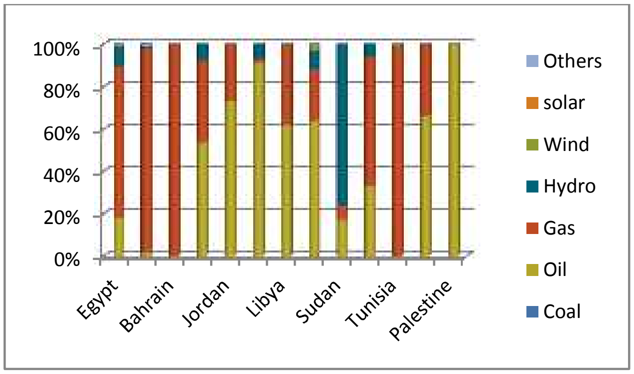


**Fig. 2: Electricity generation mix in RCREEE member states by type of fuel in 2011**

After gathering the essential data about the electricity production in each country, the second step was the calibration of these data together with the reference average values of externalities estimates. Key results are shown in table 3 below.

| Country | Coal | Oil | Gas | Hydro | Wind | solar | Total |
|---|---|---|---|---|---|---|---|
| **Egypt** | 0 | 1523 | 1785 | 56 | 2 | 1 | **3366** |
| **Algeria** | 0 | 39 | 795 | 2 | 0 | 0 | **835** |
| **Bahrain** | 0 | 0 | 233 | 0 | 0 | 0 | **233** |
| **Iraq** | 0 | 1696 | 350 | 18 | 0 | 0 | **2063** |
| **Jordan** | 0 | 625 | 66 | 0 | 0 | 0 | **691** |
| **Lebanon** | 0 | 604 | 3 | 3 | 0 | 0 | **611** |
| **Libya** | 0 | 1176 | 210 | 0 | 0 | 0 | **1386** |
| **Morocco** | 2 | 904 | 99 | 9 | 1 | 0 | **1014** |
| **Sudan** | 0 | 85 | 9 | 28 | 0 | 0 | **122** |
| **Syria** | 0 | 961 | 499 | 13 | 0 | 0 | **1472** |
| **Tunisia** | 0 | 1 | 253 | 0 | 0 | 0 | **254** |
| **Yemen** | 0 | 200 | 29 | 0 | 0 | 0 | **229** |
| **Palestine** | 0 | 37 | 0 | 0 | 0 | 0 | **37** |
| **Total** | **1.6** | **7851** | **4330** | **129** | **2.5** | **1.1** | **12315** |

**Table 3: Externalities for the total generated electricity in RCREEE member states (Million US$)**

The first point to highlight in these findings is the dominance of oil externalities in RCREEE member States; it represents almost 64% of the total estimated externalities while it only represents 32% of the total current generated electricity mix. Also, it is important to note that Egypt has the highest amount of externalities within the member states (more than 3.3 billion US$) followed by Iraq (2 billion) then Syria, Libya and Morocco of more than one billion US$ each. The dominance of hydro in Sudan and natural gas in Tunisia coupled with the relatively lower generation capacity clearly justify the low externalities in Sudan, Palestine, Tunisia and Yemen.

The overall externalities for the electricity generation sector for RCREEE member states were also compared to each country's GDP and population. It is found that externalities might constitute in some countries 2 to 3% of its GDP. And in total, the externalities represent almost 1.5% of the total GDP of RCREEE countries.

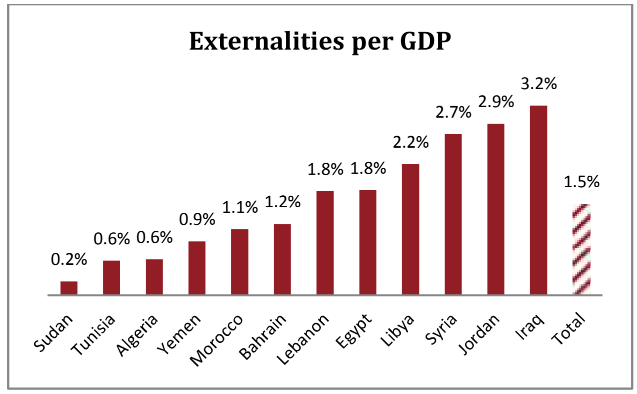


**Fig. 3: Externalities per GDP in RCREEE Member States**

As for the externalities per capita, the graph below shows that in RCREEE countries each citizen bears an extra cost of 76 US$ per year without realizing, paid either directly by him or by the state budget according to the type of impact or damage. It can be noticed also from this table that Sudan has the minimum share of externalities per capita due gain to its high reliance on hydro and low accessibility of energy, on the other hand, Libya and Bahrain have holds the highest records reaching in 2011 almost 215 US$/capita, this is mainly due to the fact that they are known to be oil rich countries with low population. As for Lebanon, it mainly depends on oil, however, the recent discovery of gas reserves would definitely improve the externalities if utilized for power generation.

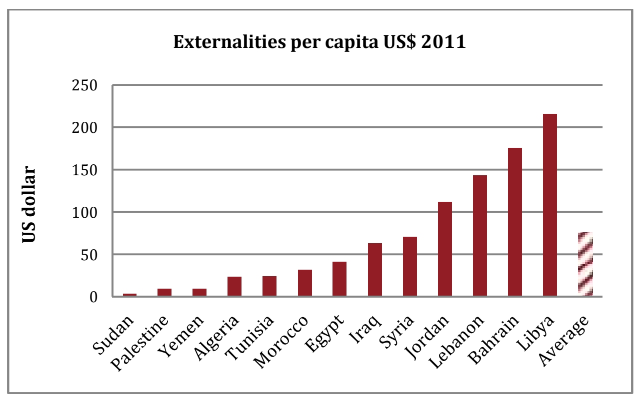


**Fig. 4: Externalities per Capita (2011)**

If the externalities costs for each kWh generated from fossil fuels technologies were simply added to the current average price of electricity in each of RCREEE member countries it can be easily demonstrated that some renewable energy projects are financially competitive with conventional power plants. In Iraq, Libya, Lebanon, and Yemen externalities/kWh are even higher than the average price of electricity per kWh. This may be the result of heavy subsidies in these countries.

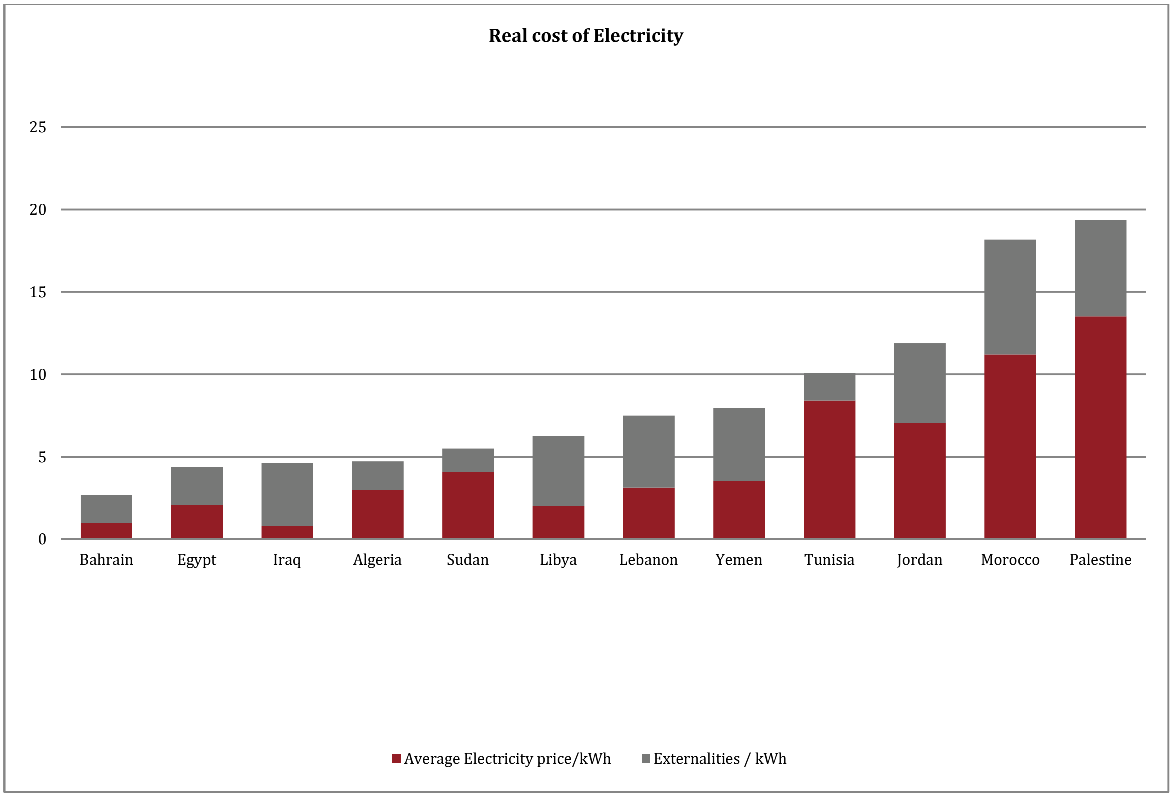


**Fig. 5: Real cost of electricity (2011)**

Recognizing the importance of renewable energy targets announced recently by most of RCREEE countries, the average externality reductions per kWh if these targets are realized were calculated for the year 2020, as shown in the following table. Due to lack of data, it was assumed that the remaining conventional mix oil and distribution will be maintained in 2020. It is clear that substantial savings could be realized especially for countries with high RE targets, for e.g. Egypt can save about 720 million US$ and Morocco 685 million US$. If this savings are combined with other positive impacts of energy security, fuel savings, improved environment, jobs creation, etc. it will confirm clearly the rightness of moving towards more reliance on renewable energies.

**Table 4: Externalities savings due to renewable energy 2020 targets in RCREEE member states (Million US$)**

| | Externalities ($ cent/ kWh) | | Savings | Savings %/kWh | Million $ | 2020 |
|---|---|---|---|---|---|---|
| Country | 2011 | 2020 | US cent / kWh | 2020 | Total savings | R.E target |
| Egypt | 2.3 | 2.0 | 0.2 | 10.6% | 723 | 20.0% |
| Jordan | 4.7 | 4.3 | 0.4 | 9.2% | 134 | 10.0% |
| Morocco | 4.2 | 2.9 | 1.3 | 31.5% | 658 | 42.0% |
| Palestine | 5.9 | 5.3 | 0.6 | 9.5% | 45 | 10.0% |
| Algeria | 1.7 | 1.5 | 0.2 | 10.8% | 172 | 15.0% |
| Libya | 4.3 | 4.0 | 0.3 | 6.5% | 247 | 7.0% |
| Tunisia | 1.7 | 1.4 | 0.2 | 13.8% | 58 | 18.0% |
| Yemen | 4.4 | 3.8 | 0.6 | 14.6% | 68 | 15.0% |

## 6. Conclusion

The analysis presented in this paper shows that electricity generation externalities can be estimated on average 12 billion US$ in the RCREEE countries, where the highest amount are observed in Egypt and the lowest in Palestine. Oil externalities represents about 64% from the total externalities, while it only represents 32% from the current mix, which represents the importance of switching towards renewable energy, more reliance on natural gas and adopting energy efficiency measures. Increasing Renewable Energy targets is definitely helping countries to increase their savings per kWh, which may reach 2 billion dollars taking into consideration only the 2020 announced targets.

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