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# How to reduce financial costs using renewable energies in developing countries

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**Abstract**

A unique position is given to developing countries in achieving the socio-economic and environmental benefits of renewable resources as a means of adapting to energy demand in a sustainable way. Implementation of sustainable activities in developing countries have proven to be challenging, at least as much as in developed countries.The difficulty of attracting adequate and cost-effective investment is considered as one of the major barriers to implement renewable energy technologies in developing countries.This study examines the impact of investment costs on the prospects for renewable energy generation in developing countries. The present study presents a comprehensive analysis of developing countries, six renewable energy technologies and three fossil fuel-based power generationtechnologies. Accordingto the results, there are significant cost changes and a range under which renewables are deprived by current financial activities.The energy-economic model is used to illustrate how reducing financial costs improves the implementation of renewableresources. Also, according to the results of this study, climate policies reduce financial costs for renewable resources, which is an effective way to reduce greenhouse gas emissions.This study introduces new perspectives by using different scenarios to develop energy investment in developing countries and presents several conclusions for renewable energy policy makers and related projects developers and provides solutions for energy analysis and investment modeling.

**Keywords: financial costs, financial investment, energy-economic environment model, developing countries**

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## 1-Introduction

Demand for energy, which is one of the basic needs for socio-economic development, is growing significantly due to the rapidpopulation growthand the rate of increase in per capita income in the world and dedicates itself to a gradually larger share of global energy consumption. [1-4]. It is accepted to increase the implementation of renewable resources in the development of countries worldwide which helps achieve the SGD[1] goals set by the UN General Assembly[2] [5,9].Given that significant advances in the energy sector and the increase in renewable resources in developing countries will soon be available, as well as the cost reduction that has been achieved globally for renewable technologies in recent years, developing countries are in a position to do so. They are very suitable for achieving further development in energy production in order to use sustainable sources instead of alternative fossil fuels [10-13].Due to the ability to quickly access important advances in the energy sector and increase renewable resources in developing countries, as well as the cost reduction that has been achieved globally for renewable technologies in recent years, developing countries placed in a very good position to achieve further development in energy production in order to use sustainable resources instead of alternative fossil fuels [10-13].The implementation of renewable resources in developing countries is very limited [11], despite the many socio-economic and environmental benefits in the world [6,14]. One of the main reasons for this limitation is that the accepted and real risks in these countries have made it difficult to identify sustainable projects and attract sufficient investment [12,15]. Careful long-term planning and informed decision-making are required for the successful implementation of sustainable activities in economic development [16].Integrated Assessment Models (IAM)[3]refer to tools that can provide policymaking, as they make possibleto simulate long-term consequences of current efforts to achieve climate change mitigation and economic development goals in a hybrid structure. (See reference [17] for example). They can be used to guide medium-term decisions in an effort to achieve a variety of long-term goals[4] (e.g. [18-20]).IAM also makes it possible to assess the long-term costs of a low-carbon energy system generation and reducing the achievable cost of energy generation, but they focus on technology learning and the optimal use of natural conditions as the main drivers for cost recovery(e.g. [19,21,22]). Accessibility and investment cost play an important role in realizing the cost effectiveness of renewable resources compared to fossil fuel alternatives, especially in developing countries [23-26].Therefore, many efforts are made to reduce investment costs as a vital method in increasing the implementation of renewable energy [15,27]. Due to investment costs, the current activity of accepting generalized

[1]Sustainable Development Goals

[2]The United Nations General Assembly is one of the six principal organs of the United Nations, serving as the main deliberative, policy-making, and representative organ of the UN. Its powers, composition, functions, and procedures are set out in Chapter IV of the United Nations Charter.

[3]Integrated assessment models (IAM) aim to provide policy-relevant insights into global environmental change and sustainable development issues by providing a quantitative description of key processes in the human and earth systems and their interactions.

[4]Medium-term goal is close enough for you to project a specific targeted outcome, while also being distant enough to be meaningful for your longer-term vision.

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hypotheses in Integrated Assessment Models (IAMs)[5]can lead to misguided simplifications and consequently uninformed and unjustified conclusions. Integrated evaluation models of compatible designs are implemented with the goal that the energy system may in the future be subject to a wide range of similar hypotheses and conditions related to climate change mitigation[6].They often focus on technical possibilities, while considering possible costs technically and ignoring many real-life considerations. This study has been carried out aimedto compensate these shortcomings by upgrading and improving integrated evaluation models with respect to financial issues. There is an important barrier to the renewable energy commercialization in developing countries due to the difficulty of attracting sufficient investment, so this study examines the importance of financial investment in creating the levels of investment needed to support sustainable development goals and compares the impact of financial conditions on the energy generationcost among six renewable technologies and three fossil fuel technologies in 46 developing countries.According to the results, there is a significant change in cost and the results show the extent to which renewables are deprived by current financial activities, but refers to a potentially significant potential for improvement iffinancial investment costs are reduced.These findings become scenarios for the long-term integration of the energy system in the future, and an energy-economic-environment technology model called TIAM-ECN analyzes the implications of different investment methods for renewable energy emissions. This study concludes that reducing investment costs leads to much greater implementation of renewable resources and in fact reduces the total costs of the energy system.For example, solar PV accounts for 10 to 15 percent of total energy production by 2050 due to de-taking investment programs. Furthermore, according to the results of this study, changes in investment costs lead to an increase in the impact of technology learning. Therefore, some important components in achieving the potential of renewable energy in developing countries are investment de-risking and support for sustainable policies.If integrated assessment models are used in developing countries to design energy and climate policies and select renewable technologies, then they should be complemented by investment modeling.First, after the research topic was reviewed, the steps considered in the analysis are discussed. Then, the impact of investment on energy generation costs is analyzed. Then, the main mechanisms behind investment cost scenarios are described, focusing on country risks, technology fees, and investment de-risking criteria. Finally, prospects are proposed for energy supply in developing countries for future, both based on cessation of energy generationby technology and the annual energy system cost-relatedrequirements.These findings become scenarios for the long-term integration of the energy system in the future, and an energy-economic-environment technology model called TIAM-ECN analyzes the implications of different investment methods for renewable energy emissions.

## 2- Impact of investment on the energy generationcost

The long time allocated to the project leads to an increase in investment costs, which includes a significant share of the cost of energy system generation and thus describes the nature of

[5]Integrated assessment modelling or integrated modelling is a term used for a type of scientific modelling that tries to link main features of society and economy with the biosphere and atmosphere into one modelling framework.
[6]Climate change mitigation means avoiding and reducing emissions of heat-trapping greenhouse gases into the atmosphere to prevent the planet from warming to more extreme temperatures.

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investment in the energy sector [29]. Investment costs are a function of the capital needs of investors and the returns required of these investors. The investment required for a project typically involves a combination of debt and capital. Debt often forms the largest share and is usually created by banks, while capital forms the rest and is often provided by private sector investors or companies.Capital is typically characterized by higher returns than debt. The weighted average cost of capital (WACC)[7]is a measure of the average financial cost of a project. The high investment cost of renewable energy projects makes them sensitive to changes in the required rate of return (RRR)[8][6,28,30]. Levelized cost of electricity (LOCE)[9] is calculated for six renewable technologies and three fossil fuel technologies commonly used in developing countries to show the effect that investment costs on energy generation costs.A set of LCOE input values has been selected for each technology based on project level estimates by international organizations and national institutions in developing countries due to cross-comparisons (Supplementary Table 1). The LCOE is broken down into debts, capital, fuel and operations and maintenance (O&M) and capital depreciation costs.

As shown in Figure 1, the upcoming investments show that most renewable energy technologies lead to a rapid increase in debt and capital and accounting costs for most of the total energy system production costs in line with the increase in average capital costs. Fossil fuel options, especially those that burn natural gas and diesel, increase their energy generation costs by increasing fuel prices. Given that the fuel is purchased and used on a short-term scale, there are no investment-related costs; As a result, the energy generation cost using fossil fuels is much less sensitive to changes in the WACC than renewable fuels.In Figure 1, the vertical lines show the WACC, so that renewable technology has less LCOE than the selected alternative fossil fuels. As these lines show, renewable technologies such as wind and solar energy may be comparable in low-cost amounts of average capital compared to natural gas and diesel-based energy generation, but are much more sensitive even than diesel generators in high-cost WACC. There are significant differences between different renewable technologies.While wind energy achieves 13% cost competitiveness with natural gas at WACC, solar PV energy requires WACC of 6%. Concentrated solar power (CSP) is preferred over diesel only when the WACC decreasesless than 9%. The price of geothermal poweris relatively and has better performance than gas and diesel fuel under different values ofWACC.Lowelectromotive force achieves cost competitiveness with coal and natural gas at 2% and 21% of the WACC, respectively. High electromotive force achieves cost competitiveness even with coal at the WACC of 22%. LOE input factors-basedsensitivity analysis confirms that renewable energy technologies are more sensitive to changes in average capital costs and fossil fuel technologies are more sensitive to changes in fuel costs.

[7]The weighted average cost of capital (WACC) is a calculation of a firm's cost of capital in which each category of capital is proportionately weighted. All sources of capital, including common stock, preferred stock, bonds, and any other long-term debt, are included in a WACC calculation.

[8]The required rate of return (RRR) is the minimum return an investor will accept for an investment as compensation for a given level of risk.

[9]The levelized cost of energy (LCOE), or levelized cost of electricity, is a measure of the average net present cost of electricity generation for a generating plant over its lifetime.

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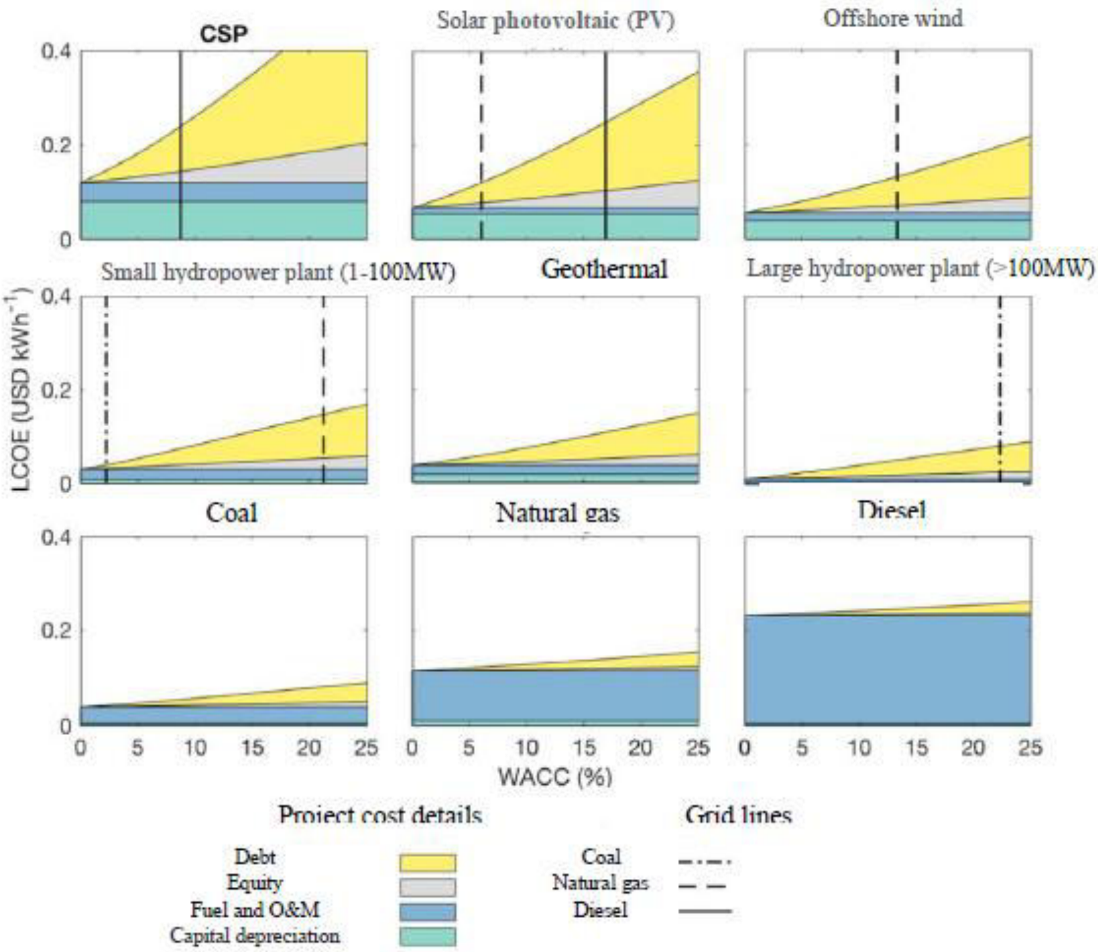


**Figure 1: The impact of investment cost on energy generation cost**

LCOE is plotted versus WACC along with grid equality lines in the values of the cost of capital, so that the cost of renewables and fossil fuels is equal (fuel subsidy, grid connection, greenhouse gas emissions and the costs of environmental damage are not considered). Input tables and calculations are provided in Supplementary Section 1A.The LCOE calculations shown in Figure 1 are converted into the WACC by analyzing the energy system generation cost under the country-specific estimates (Supplementary Table 3). The weighted average cost of capital (WACC) varies between 8 to 32% among a sample including 46 developing countries.Figure 2 shows the findings in summary, as shown, the energy generation cost from concentrated solar power (CSP) is more than 5 times higher than coal and almost three times higher than natural gas. Solar PV is three times more expensive than coal and nearly twice as expensive as natural gas. Diesel generators generate energy at a higher cost than solar PV in 34 countriesexcluding long distances; they do so at a higher level than concentrated solar power only in two countries.Off shore wind farms cost twice as much to produce electricity as gas and coal powered stationsbut it's less than gas in 15 countries, and the proportion of diesel fuel is lower in all countries. Small power plants and geothermal power plants generate energy at a lower cost than diesel generators to generate natural gas-based energy. Implementation of small power plants, geothermal and wind energy is limited to areas having sufficient renewable resources.As shown in Figure 2, renewable sources (especially solar and wind energy) show greater dispersion in LCOE than in their fossil fuels. Here, more

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dispersion means more costs under a wider range of the values of WACC, but it shows an opportunity to reduce costs by reducing investment costs.

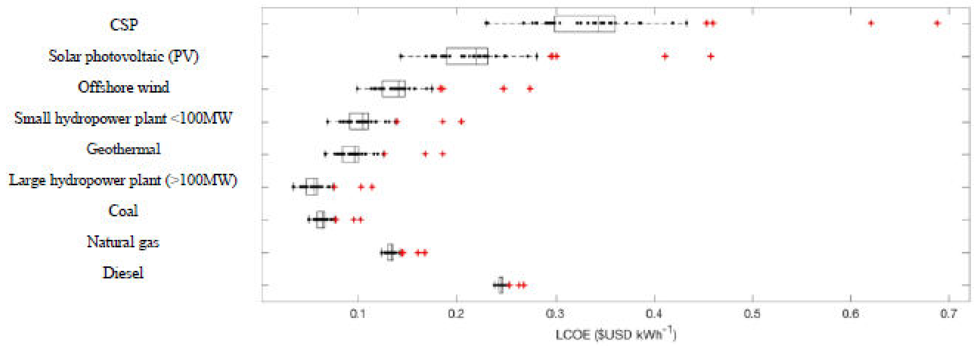


**Figure 2: The levelized cost of energy (LCOE) for renewable technologies and fossil fuels in developing countries**

Black dots indicate different countries. Each point is calculated by the estimated WACC for the power sector in the country. Boxes show lower and higher values of the fifth and sixth percentages. Red + symbols represent statistical items.

### 3- Mechanisms in investment cost scenarios

In order to change the financial situation of these countries, the forecasts are studied and the effects on the implementation of (renewable) energy technologies are evaluated. To do so, a model is introduced that makes it possible to develop technology and the WACC for the country for future (Figure 4). This model is based on an idea aimed to provide an estimate of the effects of actual and perceived risks on the WACC. This model includes three main components: country risk, technology fee, and investment de-risking. Then, these three scenarios are created to examine the effects that changes in these components include the WACC.There is a strong link between the realization of energy projects and the risks specific to a country. The perceived and real risks of investment in developing countries are more than in developed countries. As a result, investors seek higher rates of return to accept these risks. Risks are often related to considerations of political and financial sustainability as well as regulatory and institutional conditions [33].According to the results of several studies, there are relationship between political, financial and economic risk or the internal relationship between economic development and political stability [34]). Weak democratic institutions, relevant risks, and consequently high interest rates often characterize countries with high growth and low incomes. In this regard, figure 3 shows the estimated WACC versus per capita GDP for 130 countries.As shown in Figure 3, there is a correlation between the WACC and the average GDP per capita (PPP), which is shown by the solid dashed line. In general, developing countries (solid circles) are characterized by low per capita GDP and high average capital expenditures. According to the figure, the economies of developing countries have grown significantly over the past decade, and GDP per capita is shown to increase 3 to 16 times by 2050 by country.Country-specific risks are reduceddue to this fact the economy and financial markets are based on the maturity of the

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continent.Underdeveloped and developing countries are likely to move towards a better country risk rating published by international credit rating agencies, which will lead to more foreign investment with lower interest rates. The relationship between the average cost of capital and GDP per capita is used to observe these conditions, shown by the dashed line in Figure 3 (see Supplementary Equation 3), which is almost the first step to the effect of economic development on investment cost. .

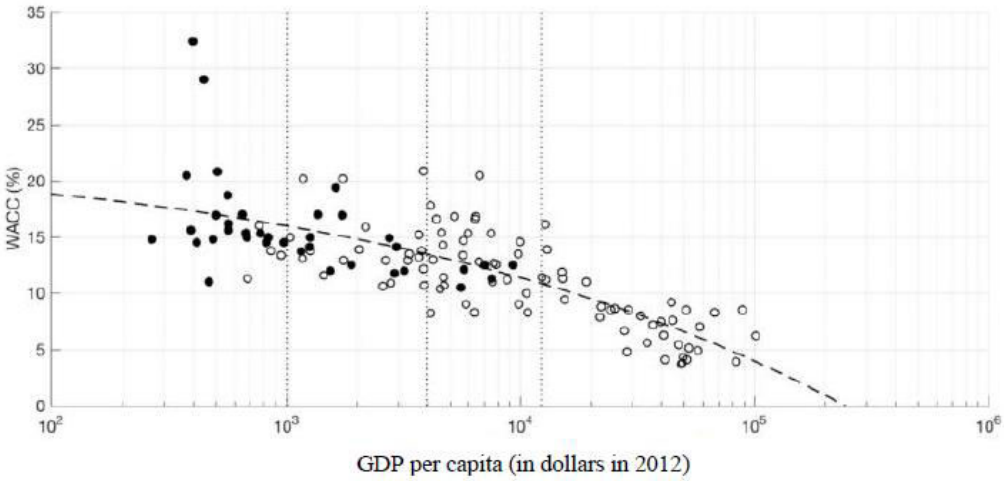


**Figure 3: Weighted average cost of investment versus GDP per capita. Each circle represents a country. Each solid circle represents a developing country. The dashed line shows a proportional trend and the general lines show the boundaries of income classification by the United Nations. (Bottom, middle down, middle up and up).**

### 1-3- Technology fee

Sustainable risks may arise from technology-specific considerations over the availability of skilled workers, construction materials and infrastructure, or technical knowledge in emerging markets [31,32]. These multiple types of risk come together to form what is referred to in this study as the Technology Fee. Given that there is a significant relationship between the improved technology implementation and technical and financial skills, the investment-related risks associated in this technology increase. The internal capacity of a technology is used as a constraint to estimate the technology fee and its design for the future.

### 3-2-Financial de-risking

In this study, "financial de-risking" refers to any form of external financial support that leads to reduce the investment risks, whether by financial institutions or in the form of national or international policy. Financial de-risking reduces the perceived risks and the required rate of return and thus investment costs. At the international level, bilateral and multilateral development of the bank plays an important role in supporting development in developing countries which provides this through financing and technical.These Development Finance Institutions (DFIs) usually majority owned by national governments, which guarantees their high credibility and enables them to invest large volumes in the international market. Thus, they can finance or finance debt and capital at lower interest rates than domestic capital providers. Grants for access to energy have become a larger part of the overall activity of financial institutions.The continued involvement of development financial institutions plays a vital role in the dissemination of renewable energy technologies in the development of countries [27]. Creating climate budgets, especially to support climate change projects, is

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considered as another source of international financial support for low-carbon energy. In particular, the UNFCC-related green climate fund (GCF) is expected to be worth $ 100 billion a year by 2020. It plays an important role in providing the levels of investment required to implement renewable energy technologies in the development of countries in terms of global efforts to reach the Paris Agreement climate target of well below 2 degrees C [31].The GCF explicitly states that one of its main objectives is to assess the needs of least developed countries. By the end of 2017, the GCF had approved climate change mitigation projects worth a total of $ 1.1 billion. At the national level, financial de-risking includes supportive policies such as food tariffs, subsidies or low-carbon promotion tools such as carbon pricing. These efforts increase investor confidence and reduce perceived risks and attract more investment for sectors or technologies [33,34].According to an international analysis, financial de-risking is examined by estimating a portion of the total investment needs for renewable energy in a given country, so that Development Finance Institutions (DFIs) and the GCF can provide an annual basis. Expected Rate of Return is based on the United Nations income classification (market rate, concession or combination) for a country and the subsequent WACC is recalculated.Three scenarios are developed to illustrate the effects of risk and financial de-risking based on the WACC, indicating different possible paths for its evolution in developing countries. The starting point is a reference assumption that includes the WACC at 15%, which is time-constant and uniform across technologies and countries: These scenarios are called Uniforms. The other three scenarios examine the effects of different levels of economic development and financial de-risking, taking into account the time dependence and the WACC values of technology-specific capital and countries called Diverse, Concessional, and De-risked.The main hypotheses in each of these three scenarios and the WACC plans at the level collected for all developing countries are shown in the figure 4. More details about the hypotheses used in the scenarios are provided in Tables 3 and 4 in the supplementary section. As shown in Figure 4, the Diverse, Concessional, and De-risked scenarios between today and 2050 show an overall reduction in the values of WACC of 4, 2, and 5%, respectively. According to the Diverse scenario, it is assumed that there is no financial de-risking now and in the future. Therefore, the other two scenarios have greater starting point of the values of WACC.In the Concessional scenario, financial risk aversion remains constant against the US dollar between 2015 and 2050. The growing investment needs of the renewable energy sector in developing countries mean that the impact of the percentage on financial risk aversion is declining. The component of financial risk mitigation in the De-risked scenario has evolved over time due to the interaction between a uniform increase in the share of risk mitigation and the overall investment needs.In the Concessional scenario, financial de-risking remains constant against the US dollar between 2015 and 2050. The renewable energy sector-related growing investment needs in developing countries mean that the impact of the percentage point on financial de-risking is declining. The component of financial de-risking in the De-risked scenario has evolved over time due to the interaction between a uniform increase in the share of de-risking and the overall investment needs.

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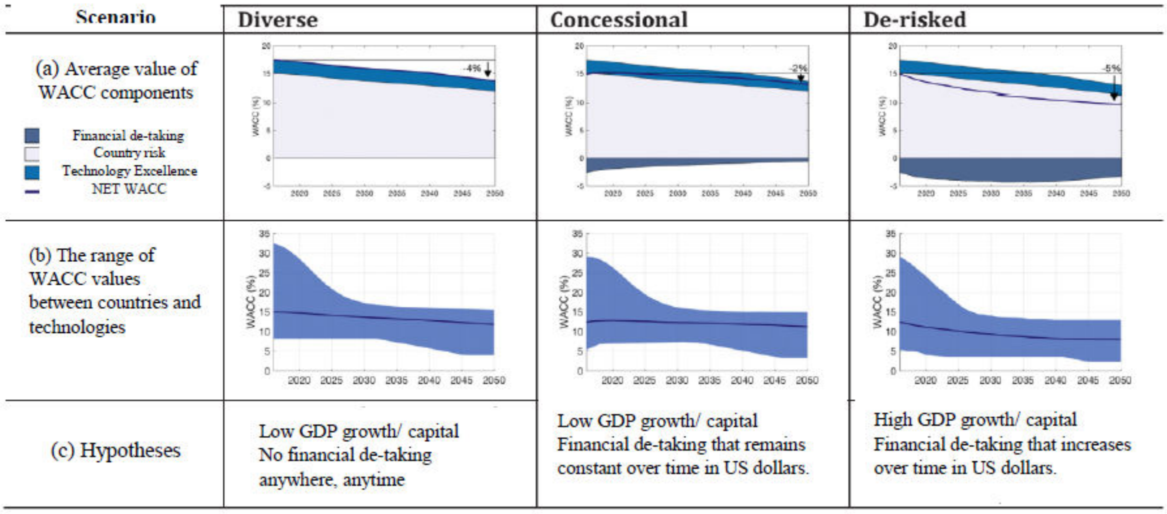


**Figure 4: A summary of three weighted average cost of capital (WACC) scenarios.**
**Line a: WACC values relative to technologies and developing countries**
**The area under the z-axis represents the WACC valuehas decreased due to financial de-risking.**
**;Line b: Distribution of WACC values between countries and technologies in developing countries**
**The dark blue line represents the average between countries and technologies.**
**Line c: Hypotheses in question regarding economic development and financialde-risking.**

## 4. Forecasts for the energy system in developing countries

These four scenarios achieve a set of technology and country-specific WACC schemes. This study uses the technology-rich TIAM-ECN model to examine the impact of financial conditions on energy system development in developing countries under four WACC scenarios. The Energy-Environment Model (TIAM-ECN) is the TIMES Integrated Assessment Model that operates at ECN-TNO and is a certified version of the TIMES Integrated Assessment Model (TIAM-WORLD) approved under the Energy Technology Systems Analysis Program (ETSAP) by International Energy Agency (IEA). (See Supplementary Note 3 for more details on IAM, which is based on the general principle of minimizing the cost of the entire energy system).Recently, the energy-economic environment model has been updated, revised and developed to better reflect the advances in the energy system in developing countries [35].The energy system generation designed in four scenarios is shown in Figure 5, which is divided into several technology groups. By 2020, there is no significant difference in the composition of energy supply between the scenarios: there is a significant increase in the share of gas as an alternative to oil for energy generation in all scenarios compared to 2010. In 2030, natural gas (and coal) will play a bigger role, but the other three scenarios show the average cost of capital for less energy generation from gas, as well as a relative increase in coal compared to the uniform scenario. This is due to the relative reduction in the WACC due to the presence of coal relative to natural gas in energy generation.This replacement will continue after 2030. The other three scenarios ofWACChave a relatively higher overall level of energy supply than the Uniform scenariowith the beginning of 2040, in which solar PV and wind will generate several shares. This trend continues in a declining manner, so that solar PV (alternative to natural gas) accounts for 10 to 15% of the total energy supply in the alternative scenario of the WACC. This rapid growth follows a steady decline in PV costs which is created due to technology

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learning at a higher rate than others.The overall dissemination is shown in Figure 6, which decreased slightly between scenarios. The greater share of coal in the energy mix, where lower average capital cost scenarios are observed, it compensates reduced dissemination as a result of natural gas replaced by renewable sources. Solar PV plays an important role in the other three scenarios of WACC, while its presence in the Uniform scenario remains limited, it can be concluded that a favorable financial situation is necessary to fully demonstrate the potential impact of reducing renewable technology costs on system composition. Also, according to plans for 2050, reducing the WACC will lead to increase the overall level of energy generation. This suggests that favorable financial conditions are not only necessary for the implementation of low carbon technologies, but are also useful for increasing the energy supply of the energy system.It should be noted that recent studies have achieved a greater share of renewable energy generation in 2050 than the items presented in this study, which is shown in Figure 5. This is the result of imposing a precise climate policy on these studies, based on which this study achieves a financial role in stimulating the deployment of renewable energy. The failure of energy generation is shown in supplementary Figure 7, which is calculated by the model of the energy-economic environment under a precise climate policy.

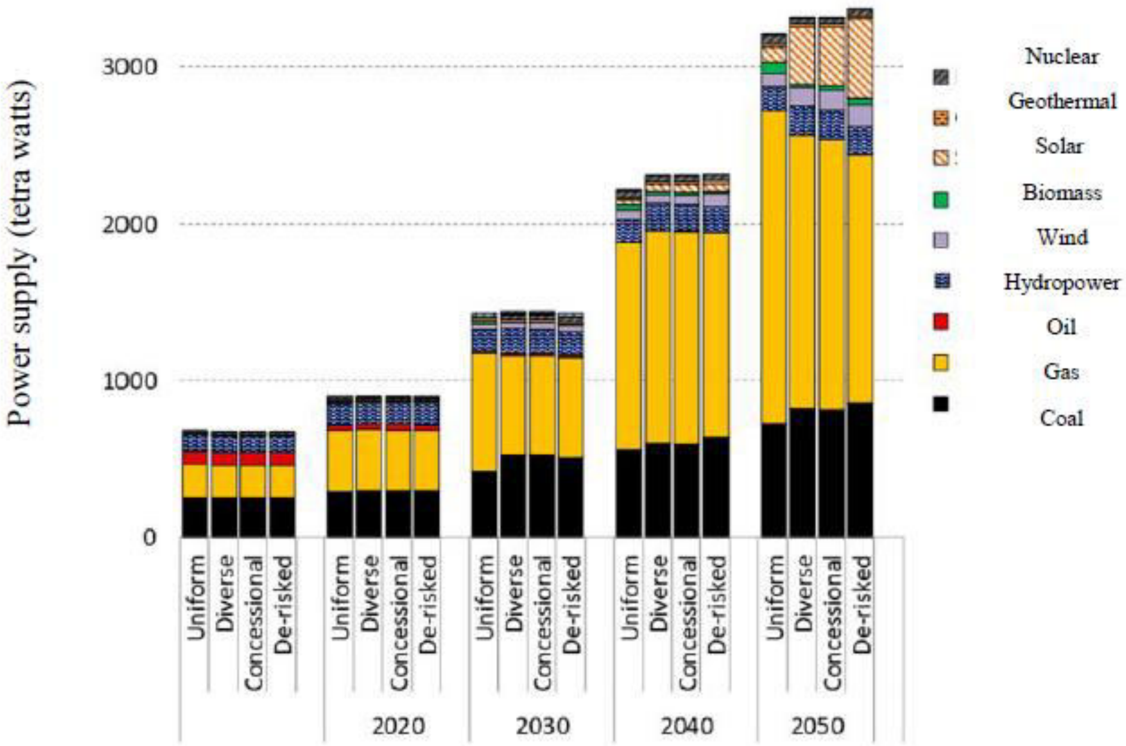


**Figure 5: Energy system generation plans in developing countries by 2050**

According to the figure, each bar represents the cessation of energy generation in a given scenario and the simulation year. Assuming the absence of a global climate policy, only the effects of financial de-risking measures are shown.

Further developments in the annual cost of the designed system (excluding interregional trade-related costs) in four scenarios compared to Uniform are shown in Figure 6. The cost

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mix changes based on the average cost of capital over time. The investment costs in the three alternative scenarios of the WACC is somewhat lower than the uniform scenario until 2015, which is the result of reducedWACC and similar energy generation capacity.However, an increase in the cost variable have more weight than these reductions in investment costs in 2014, leading to a net increase in annual energy system costs. In 2040, the increase in variable operating costs is mainly due to the greater use of coal and natural gas in energy generation (Figure 5), which imposes higher fuel costs. In 2050, the increase in investment costs will be modified by implementing renewable energy technologies with massive investment, most of which are related to PV.However, the large share of solar PV in the energy supply mix (alternative to natural gas) leads to significant savings in variable fuel costs and consequently net energy system profit of between $ 8 billion and $ 13 billion per year. The benefits of more renewable sources are presented in the De-risked scenario, which shows the greatest energy generation capacity with a significant reduction in the total cost of the system.

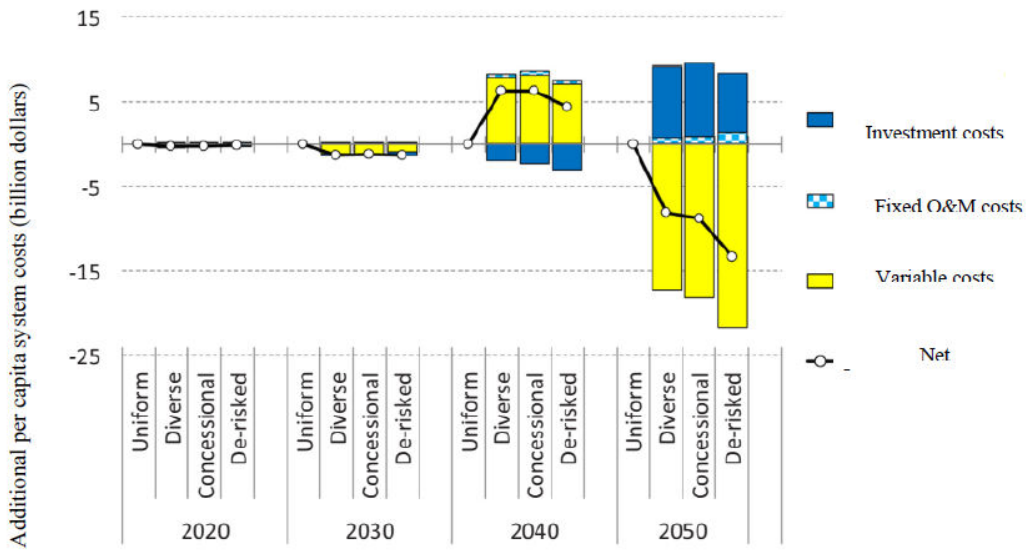


**Figure 6: Additional per capita costs of the energy system compared to the uniform scenario. Total costs are divided into investment costs, O&M costs and variable costs (The second item includes fuel costs). Net costs are indicated by the white circles.**

## 5- Conclusions

This study was carried out aimed to examine the impact of investment conditions on the cost of energy generation for different technologies and countries and evaluate the long-term implications that different investment mechanisms may have for the development of the energy system in developing countries. This studyconsists of three steps:

1) Calculating and comparing the cost of energy generation with different technologies under the current financial systems, 2) Investigating the impact of economic development and obvious de-taking activities on financial costs and forming three plans to develop investment costs by next year and 3) Evaluating the effects findings under two stages in scenarios for the implementation of renewable energy determined by an IAM, it was consistent with the results of previous work [24,28], renewable energy technologies are more sensitive to increased investment costs than other fossil fuel-based technologies.For example, energy production from solar PV is more

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expensive than technologies based on coal, natural gas and in some cases diesel under current investment conditions. This study analyzes the potential for significant cost reductions if investment costs are reduced. This supports the discussion of capital de-risking as a promising way to reduce the cost of renewable energy generation and thus increase the implementation of renewable resources.This study has analyzed the energy generation system in developing countries, according to the results of the analysis, many changes have been observed to develop renewable resources between different scenarios of WACC. The uniform scenario has reduced the penetration of renewable sources, especially solar PV, compared to the other three scenarios. In the first case, the WACC is assumed to be constant over time and is uniform across countries and technologies because they are common to all common IAMs.The latter makes possible the temporal evolution and geographical variation of the WACC. According to the other three scenarios used in this study, solar PV could account for 10 to 15% of total energy generation by 2050 due to financial de-risking programs. It can be concluded that good financial conditions are crucial to take full advantage of the reduced PV cost of technology learning.According to the reduced dissemination observed in the WACC scenarios combined with a greater share of renewables, less financial costs are not enough to achieve lower disseminations. Climate policies must be motivated to replace high-carbon energy generation, especially coal, in order to effectively reduce disseminations. However, according to the results of this study, by applying climate policies, reducing financial costs is considered as an effective way to reduce dissemination among developing countries.According to the results, the initial implementation of renewable resources in the long run is compensated by fuel cost savings, which finally, it has more weight than the annual investment costs. Given that the greatest savings are achieved in the De-risked scenario, it can be concluded that financial de-risking methods are essential in achieving maximum benefits from a renewable energy system.According to the results of this study, lower financial costs lead to the implementation of more renewable energy technologies and increase the level of energy generation. This database can be completed by surveys conducted by experts on the technical-economic perspective of various technologies of renewable sources by developing estimates for the future value of financial parameters.Second, the results of this study show that, activities can be done to create broader investment cost models that can release various risk components and their share in the WACC. Third, the effectiveness of de-risking mechanisms between countries and regions can be achieved in a more efficient and better way. Fourth, the bottom-up and top-down models of energy-economic environments conducted by the IAM to examine climate change policy should take into account the perspectives derived from financial analysis. It is necessary to implement this research program to developrecommendations for the development of banks and GCF to provide financial support for development with less carbon in an effective and efficient way.

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