

Environmental aspects and GHG credits impact on LCOE and key indicators for small installed PV plants in Albania.

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Abstract: A lot of techno-economic analyses have been conducted to seek the most cost-effective solution for electricity generation applied in the interval time of 25 years of project life. The actual benefits taken from small PV plants up to 2MW have been identified, as well as the effects of the most sensitive parameters, such as installation price, incentives and other credit options such as carbon credit rate or feed in tariff. The output carried out from the simulation performed in RETScreen Expert tool shows that PV system represents the best solution to provide free carbon and costless electricity to run the water pump for sprinkler irrigation in the agriculture sector in Albania. The environmental benefits have been also addressed, evaluating the CO₂ emissions saving achievable from the PV system operation and some financial aspects such as simple payback period (SPP), NPV, IRR. The annual electricity production from PV plant located in the village of Tërbuf, Divjaka Municipality with an installed capacity of 2MW results 3319MWh and would avoid 3253 tCO₂. The effects of ETS schemes on the LCOE from small PV plants are highlighted.

KEYWORDS: PV, RETSCREEN EXPERT, CO₂, SPP, CREDITS.

1. Introduction

Several trends are shaping an unfolding energy transition and giving an indication of its direction. **First**, the costs of renewable technologies have plummeted to the point that new fossil-based electricity is no longer an attractive option. **Second**, the progress in the power sector is spilling over to end uses, allowing a re-imagining of possibilities with the abundance of renewable options at hand. **Third**, a consensus has formed that an energy transition grounded in renewable sources of energy and efficient technologies is the only way to give us a fighting chance of limiting global warming by 2050 to 1.5°C [1]. The integration of distributed renewable energy can demonstrate various technical benefits to the energy sector but at the same time to the owners of the facilities. Benefits include the reduction of fossil fuel use and associated GHG emissions, the improvement of grid reliability and limitation of power outages, protection of critical loads, independence of foreign supply, and increased energy security coupled with a fixed energy cost which is immune to future tariffs and fossil fuel costs increases. The carbon intensity of PV power varies between technologies according to the materials and processes used and module efficiency.

In the other hand the depletion of fossil fuel and the negative effect on the environment as well as the potential techno-economic merits of "hybrid combinations" identified as a good solution moving towards reliable and more feasible energy systems based on renewables [2]. As the need for clean, sustainable energy increases, and renewable technologies get ever more advanced, more projects had been developed in greater sizes and complexities, including on-grid and off-grid solutions based on renewables.

Smart electrification with renewables focuses on the potential synergies between major increases in renewable power generation, electrification and digitalisation, and looks to create the conditions for the unprecedented co-ordination of their deployment and more efficient use across end-use sectors – power, transport, industry and buildings [3].

Growing shares of those jobs are off-grid, supporting productive use in farming, food processing and healthcare in previously remote, isolated, energy-poor communities. In parallel, rural areas benefit from the feedstock production that underpins bio-energy and which accounts for the bulk of about 3.6 million jobs in that segment. Renewables accounted for an estimated 11.5 million jobs worldwide in 2019. Using solar PV to power mini-grids is an excellent way to bring electricity access to people who do not live near power transmission lines, particularly in developing countries with excellent solar energy resources and reducing the negative effect on environmental. Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions [4].

1.1 Site location

The 2MW photovoltaic plant will be installed on the ground in Tërbuf. The property is located 14.8 km from the city of Divjaka, 73.6 km from the Albanian capital, Tirana.

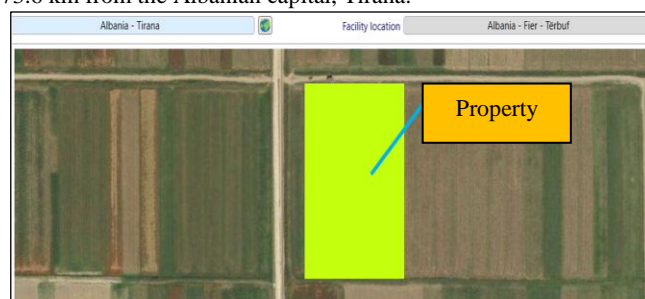


Figura 1: Location of the 2MW PV project. Village of Tërbuf, Divjakë Municipality, Albania.

2. Materials and methods

Actually, there are several models available for conducting a set of analysis including environmental impact and benefits. RETScreen Expert is a clean-energy awareness, decision-support and capacity-building tool [5]. This model helps us as energy planners to determine the annual reduction in the emission of greenhouse gases stemming from using the proposed technology in place of the base case technology. The model uses a computerized system with integrated mathematical algorithms and top to bottom approach which has been developed to overcome the barriers to clean energy technology implementation at the preliminary feasibility stage. It provides a cost analysis, GHG emission reduction analysis, financial summary, sensitivity analysis, provides a low-cost preliminary assessment of RES projects with a small set of a detailed information. Methodology 2 as the more suitable to perform the emission analysis is chosen [5]

3. GHG summary in Albania and global trends

Albania is the largest producer and exporter of oil in the South-East Europe region, most oil extracted in Albania is exported as unrefined crude oil [6]. A further contributor to net energy imports is the country's rising demand for petroleum products, largely fuelling the transport sector. Greening the transport sector by taking up biofuels blending and introducing electric mobility could lower the country's energy imports and positively contribute to the national economy.

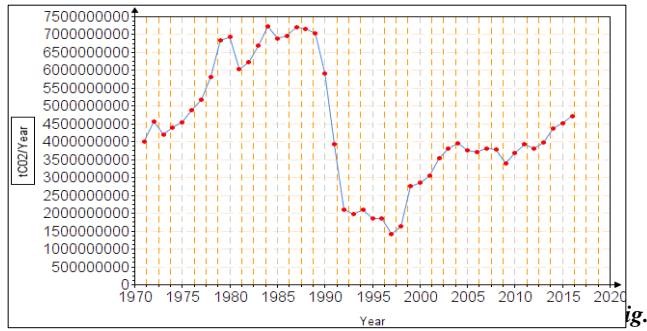


Fig. 2: Yearly variation of CO₂ in Albania [6].

In 2019, CO₂ emissions per capita for Albania was 1.93 tons of CO₂ per capita. Albania CO₂ emissions per capita fluctuated substantially in recent years, showing an increasing trend from 1970 up to 2019 period. By the end of 2019 the specific emission reached a value of 1.93 tons of CO₂ per capita.

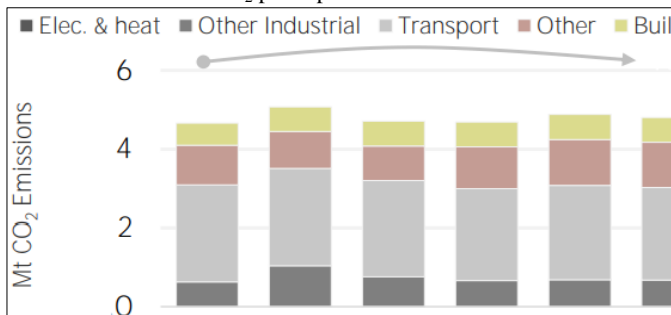


Fig. 3: Energy related CO₂ emission by sector in Albania [6].

Renewable energy sources, including solar, wind, hydro, biofuels and other future renewable sources are at the centre of the energy transition towards a less carbon-intensive and more sustainable energy system [7]. In the context of GHG emissions, Albanian's electricity sector is zero emitter in the region as the share of electricity from renewable sources in total electricity generation is almost 100%, while EU-27 countries together have a RES share of 32.3% and the border countries Greece (30.3%), North Macedonia (35.1%), Montenegro (59.2%) and Kosovo highly depended on lignite has only 5.1% [8]. Under the Planned Energy Scenario, annual emissions reach 36.5 GtCO₂ in 2050. To achieve the 1.5°C Scenario, emissions would have to drop to net zero in all sectors. Additional efforts in sectors such as power, heat and industry would be needed, with negative emissions delivering the necessary additional carbon reductions [1]. Aligned with the IPCC's special report on limiting global warming to no more than 1.5°C by 2050 [9], IRENA's 1.5°C Scenario starts with the goal of reducing global CO₂ emissions by following a steep and accelerated downward trajectory from now to 2030 and a continuous downward trajectory thereafter, reaching net zero by 2050. Because the energy sector is currently responsible for around 80% of anthropogenic CO₂ emissions, it has a central role to play in delivering the required decarbonisation. This is achievable but extremely challenging, requiring urgent action on multiple fronts. Fossil fuel use would have to decline by more than 75% by 2050 (Figure 4).

Fossil fuels primary supply (EJ)

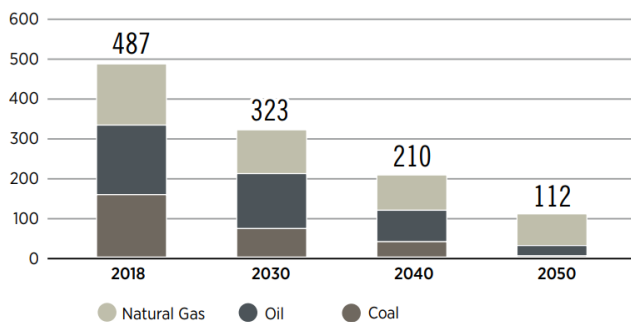


Fig. 4: Primary fuel supply (EJ) road map [Source IRENA].

Fossil fuels would still have roles to play, mainly in power and to an extent in industry, providing 19% of the primary energy supply in 2050. Oil and coal would drop the fastest, while natural gas would peak around 2025 and decline thereafter. The global production of oil in 2050 is expected to be 85% lower than today. Most of it would be used in industry for petrochemicals (non-energy uses, close to 40%), and in aviation and shipping. Coal production would decline even more drastically, from around 5 750 million tonnes in 2018 (160 exajoules [EJ]) to 240 million tonnes per year (7 EJ) in 2050. In the power sector, coal generation would be cut in half by 2030, in half again by 2040 and phased out by 2050. The remaining coal demand would be largely restricted to industry, mostly for steel production (coupled with carbon capture and storage) and to a certain extent in chemicals production. Natural gas would be the largest remaining source of fossil fuel in 2050, making up 70% of total fossil fuel supply and 13% of total primary energy supply (down from 26% in 2018). In 2050, natural gas would primarily be used in industrial processes, blue hydrogen production (coupled with carbon capture and storage) [10] and power plants.

4. Emission reduction analysis in RETScreen Expert model

The model performs a GHG emission reduction analysis depending on whether the clean energy system under consideration generates electricity or provides other energy requirements.

The only difference lies in transmission and distribution losses, which are incurred only by electricity generating systems. The reduction Δ_{GHG} is calculated as follows in equation 1:

$$\Delta_{GHG} = (e_{base} - e_{prop}) E_{prop} (1 - \lambda_{prop})(1 - e_{cr}) \quad (1)$$

where e_{base} is the base case GHG emission factor, e_{prop} is the proposed case GHG emission factor, E_{prop} is the proposed case annual electricity produced, λ_{prop} is the fraction of electricity lost in transmission and distribution for the proposed case, and e_{cr} the GHG emission reduction credit transaction fee. For both the base case and proposed case system, the transmission and distribution losses are deemed to be negligible for on-site generation, such as off-grid and water-pumping PV applications.

5. GHG emission factor – base case electricity system

For the base case electricity generation system is strictly required the calculation of the GHG emission factors, defined as the mass of greenhouse gas emitted per unit of energy produced. For a single fuel type, the following formula in equation (2) is used to calculate the base case electricity system GHG emission factor, e_{base} :

$$e_{base} = \left(e_{CO_2} GWP_{CO_2} + e_{CH_4} GWP_{CH_4} + e_{N_2O} GWP_{N_2O} \right) \frac{1}{\eta(1-\lambda)} \quad (2)$$

where e_{CO_2} , e_{CH_4} , and e_{N_2O} are respectively the CO₂, CH₄ and emission factors for the fuel/source considered, GWP_{CO_2} , GWP_{CH_4} , and GWP_{N_2O} are the global warming potentials for CO₂, CH₄ and N₂O, η is the fuel conversion efficiency and λ is the fraction of electricity lost in transmission and distribution. The GHG emission factor will vary according to the type and quality of the fuel, and the type and size of the power plant. In cases for which there are a number of fuel types or sources, the GHG emission factor e_{base} for the electricity mix is calculated as the weighted sum of emission factors calculated for each individual fuel source given in equation (3):

$$e_{base} = \sum_{i=1}^n f_i e_{base,i} \quad (3)$$

where n is the number of fuels/sources in the mix, f_i is the fraction of end-use electricity coming from fuel/source i , and $e_{base,i}$ is the emission factor for fuel i , calculated through a formula similar to equation (2):

$$e_{base,i} = (e_{CO_2,i}GWP_{CO_2} + e_{CH_4,i}GWP_{CH_4} + e_{N_2O,i}GWP_{N_2O}) \frac{1}{\eta,i} \frac{1}{1-\lambda,i} \quad (4)$$

where $e_{CO_2,i}$, $e_{CH_4,i}$ and $e_{N_2O,i}$ are respectively the CO2, CH4 and N2O emission factors for fuel/source i, η,i is the fuel conversion efficiency for fuel i, and λ,i is fraction of electricity lost in transmission and distribution for fuel i.

The GHG emission factor for the electricity mix will apply from year 1 up to the year of change in baseline, as specified by the user, unless no changes are specified; in this case, the emission factor will apply throughout the life of the project. When a change in the baseline emission factor is specified, the new factor for the year that the change in baseline takes place, and the years that follow will be determined by (e*):

$$e_{base}^* = e_{base} r_{change} \quad (5)$$

where r_{change} is the percentage change in the base case (baseline) GHG emission factor for the year that the change in baseline takes place, and the years that follow.

6. GHG emission factor – proposed case electricity system

The calculation of the proposed case electricity system GHG emission factor, e_{prop} , is similar to that of the base case GHG emission factor, with the exception that for off-grid systems the fraction of electricity lost in transmission and distribution is set to zero. e_{prop} is therefore calculated through equation (2) with $\lambda=0$, in the case of a single fuel/source, or through equations (3) and (4) with all $\lambda_i=0$, in the case of a mix of fuel/sources.

7. Simulation of the PV system in RETScreen Expert

Emission factors will vary for different types and qualities of fuels, and for different types and sizes of power plants.. The electricity mix factors thus account for a weighted average of the fuel conversion efficiencies and T&D losses of the different fuel types. For fuel type selected, diesel 2, 100% single fuel mix, units are given in (kg/GJ) as it is shown in table 2. The other financial parameters are transferred directly once the energy PV model is created such as inflation rate 3%, discount rate 8%, fuel escalation rate 2% and project life 25 years.

Table 2: Emission factors for the chosen fuel type taken in the study (Diesel 2)

Fuel Type (Base case)	Fuel Mix	CO ₂ emission factor (kg/GJ)	CH ₄ emission factor (kg/GJ)	N ₂ O emission factor (kg/GJ)	Electricity Generation efficiency (%)	T&D losses (%)	GHG emission factor (tCO ₂ /MWh)
Fuel Mix (%)	100	70	0.002	0.0006	35	7	0.777
Electric Mix (%)	100	215	0.0063	0.0018	7	7	0.777

In this study the plant efficiency of 35% and 7% T&D losses are considered. The default factors provided are those which are representative of large power plants that feed a central electricity grid such as CO₂ gas emission factor 70 kg/GJ, CH₄ emission factor 0.002 kg/GJ and N₂O level 0.0006 kg/GJ. The model calculates the GHG emission factor for the chosen fuel type considered Diesel#2. Values are calculated based on the individual emission factors, the electricity generation efficiency and the T&D losses. The weighted GHG emission factor for the total electricity mix is calculated 0.777 tCO₂/MWh as it is given in table 2.

Table 3: Calculation of fuel consumption and GHG emission (the base case system).

Fuel consumption	GHG emission factor	GHG emission
MWh	tCO ₂ /MWh	tCO ₂
3,319	0.777	2,578
3,319	0.777	2,578

In the table 3 the GHG emission for the base case system by multiplying the fuel consumption by the GHG emission factor. The model also calculates the GHG emission for the base case system by multiplying the annual system losses by the global warming potential. The model calculates the gross annual reduction in GHG emissions estimated to occur if the proposed case is implemented. The calculation is based on emissions of both the base case and the proposed case systems on an annual basis.

The annual GHG base case results 2578 tCO₂ and the proposed 180 tCO₂. The proposed GHG emission is calculated by multiplying the annual fuel consumption, GHG emission factor and the accepted T&D losses (7%). The gross annual GHG reduction results 2397 tCO₂.

8. GHG reduction credit

In this case study the optional GHG reduction credit, per equivalent ton of CO₂ (tCO₂) is considered. It is used in conjunction with the net GHG reduction to calculate the annual GHG reduction revenue. Prices for GHG reduction credits, per equivalent ton of CO₂ (tCO₂), vary widely depending on how the credit is generated and how it will be delivered. Other factors which have an impact on price may include voluntary or mandatory emissions reduction; private or public purchase of credits; credits traded within, for example, the European Union Greenhouse Gas Emission Trading Scheme (EU ETS), other national, transnational, or regional schemes; type of technology used to generate the emissions reductions; and others. As of May 2014, prices including rates for carbon taxes varied between \$1 to \$168 per ton of CO₂ [11].

The model escalates the GHG reduction credit rate yearly according to the GHG reduction credit escalation rate starting from year 1 and throughout the GHG reduction credit duration as it is given in the table 4.

Table 4: Carbon credit revenue calculation.

	€/tCO ₂	14
Net GHG reduction	tCO ₂ /yr	2349
Net GHG reduction-25yrs	tCO ₂	58729
GHG reduction credit rate	€/tCO ₂	14
GHG reduction revenue	€	32889
GHG reduction credit duration	yrs	15
Net GHG reduction-15yrs	tCO ₂	35238
GHG reduction credit escalation rate	%	2

Carbon credit instruments often coexist with other heterogeneous policies that may directly or indirectly contribute to reducing GHG emissions by addressing areas such energy or infrastructure. In our study they have to be planned to interact and complement other strategic priorities at local and national levels. The GHG reduction credit duration is accepted to be applied all into the whole lifetime of the proposed PV system with a reduction credit escalation rate of 2%. The credit transaction fee is accepted 2%. In the graph in figure 3 the results of the simulations of the PV system compared to that of the base case (diesel#2 powered) is given. The proposed system, PV offers the lowest possible scenario for the mitigation of GHG emissions resulting to 180 tCO₂ compared to baseline scenario 2578tCO₂.

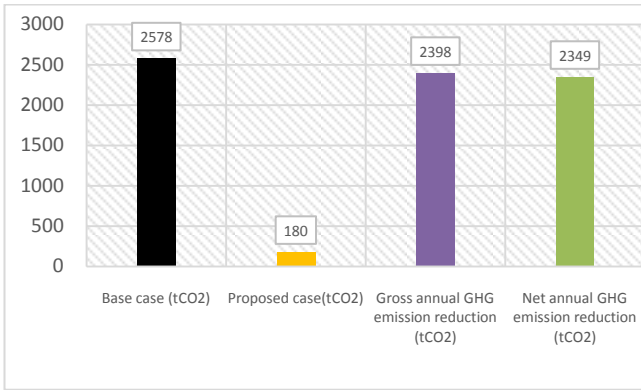


Figure 5: Results of the simulation of the baseline scenario and proposed PV system.

Assuming that the annual electricity produced (3319MWh/year) by the photovoltaic plant (PV) with a capacity of 2MW located in the village of Tërbuf, Divjaka Municipality would be produced through the use of fuel Diesel#2.

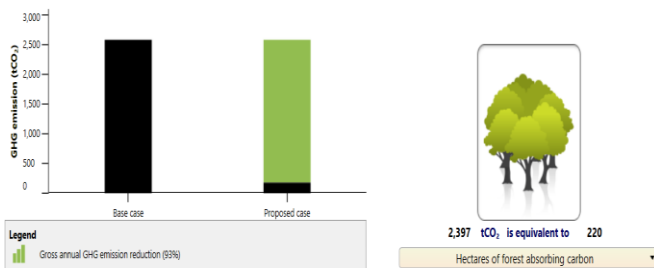


Figure 6: Results of the simulation of the baseline scenario and proposed PV system.

As it is clearly shown in figure 6 the proposed PV system can avoid 2349 tCO₂/year equivalent to 220 hectares of forest absorbing carbon.

The model calculates the equity payback, which represents the length of time that it takes for the owner of a facility to recoup its own initial investment (equity) out of the project cash flows generated. The equity payback considers project cash flows from its inception as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback. The model uses the year number and the cumulative after-tax cash flows in order to calculate this value.

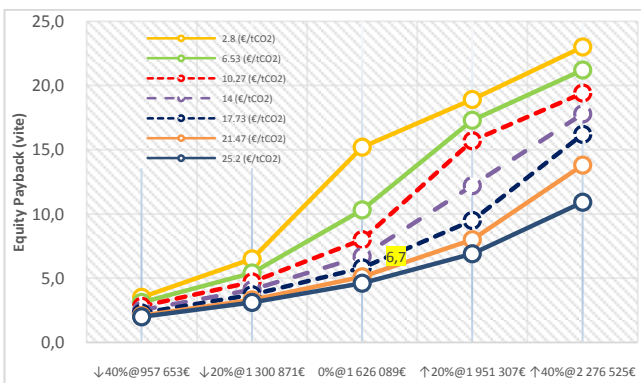


Figure 7: Graphical presentation of sensitivity analysis (± 40%) for investment repayment period (years) as a function of total installation cost (€) and carbon credits (± 80%) (€/tCO₂).

The graph in figure 7 shows the graphical representation of the sensitivity analysis (±40%) for the investment repayment period (years) as a function of the total cost of installation (€) and the selling price of carbon credits (€/tCO₂) in the range (±80%). In our analysis the selling price of carbon is accepted €14/tCO₂ and the fixed price of electricity €65/MWh.

If the selling price of carbon is 14-25 (€/tCO₂) and the fixed price of electricity €65/MWh then the self-repayment period is reduced to 3.3 years for the assumed selling price of electricity €65/MWh.

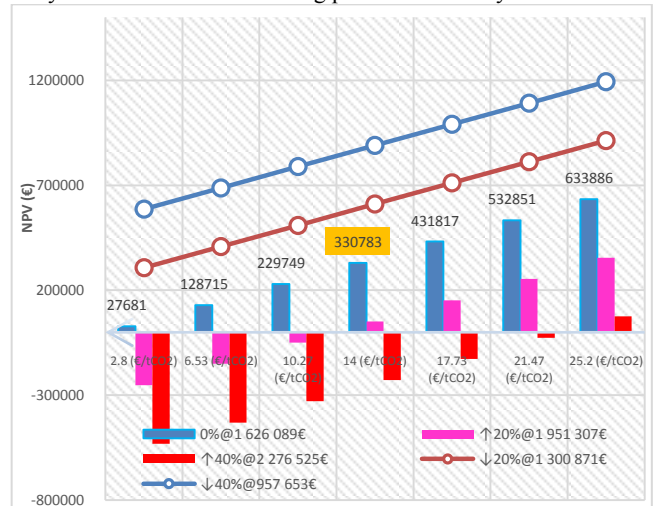


Figure 8: Variation of NPV in function of total investment cost (€) for discount rate 8%, interest rate 5.5% fixed price of electricity 65 €/MWh @ ± 40% of sensitivity analysis and sale price of carbon credits (€/tCO₂) @ ± 80%.

The graph in Figure 8 clearly shows the effect of the economic performance of the photovoltaic system under the application of carbon credit trading schemes.

Worst case scenario, increase of installation cost by 40% (red columns give negative NPV in all cases), while pink scenario with increase of installation cost by 20% brings benefit only with credit values carbon (€/tCO₂) in the interval of [14 → +∞[.

Baseline scenario, for discount rate 8%, interest rate 5.5% fixed price of electricity 65 €/MWh and sensitivity analysis of installation cost @ ±40% and sale price of carbon credits (€/tCO₂) @ ± 80% (blue columns) show in all cases of lending positive values of NPV. NPV in the baseline scenario reaches the value of € 330780 and doubles when the selling price of carbon credits increases (€/tCO₂).

9. Conclusion

The effects of carbon credits for the photovoltaic project with an installed capacity of 2MW, located in the village of Tërbuf, Divjaka Municipality were considered at the level of €14/tonCO₂. The analysis and the results of the study according to the scenario of application of carbon credits showed that it has a positive effect on the main indicators of the system by reducing the repayment period to 3.3 years from 6.7 years.

Emission trading systems are suitable to accelerate the transition of clean energy in the energy sector. Currently, the energy sector around the world is moving towards a decarbonised system, due to falling costs of low carbon technology and low risks from competition, but this is not happening at a satisfactory pace to meet the objectives of "The Paris Agreement." The electricity sector is very convenient to be regulated under an emissions trading system. First, it is a large emitting sector with proven technologies, with low GHG levels that are available in the market.

Second, the availability of data on electricity generation is moderately strong across all jurisdictions, which is needed to set allocation standards. Furthermore, some jurisdictions already have experience in implementing energy sector mitigation activities with carbon price support, for example through lending mechanisms such as the Clean Development Mechanism.

The energy sector is involved in almost all emissions trading operating systems worldwide, as well as in the jurisdictions that are developing or considering the development of an emissions trading system. It is recommended that in our country to regulate by law, especially in the RES sector, the application of carbon credit schemes at least at the level of 14-25 (€/tCO₂).

References

- [1] IRENA. (2021). World energy transitions outlook: 1.5 degrees pathway. In Irena. <https://irena.org/publications/2021/March/World-Energy-Transitions-Outlook>
- [2] Malka, L., Gjeta, A., Konomi, I., Alcani, M., Bebi, E., & Kaci, S. (2020). Off-grid hybrid PV configuration' s role to supply internet access points antenna in remote areas. Case study: " Ostren i vogël - Trebisht " villages, Bulqiza district, Albania. 226(5), 218–226 <https://stumejournals.com/journals/i4/2020/5/218>
- [3] Renewable, I., & Agency, E. (n.d.). ELECTRIFICATION Driving the transformation. <https://www.irena.org/publications/2022/Feb/Smart-Electrification-with-Renewables>
- [4] Malka, Lorenc et al. 2020. "An Approach to the Large-Scale Integration of Wind Energy In." 10(5): 327–43 <https://www.econjournals.com/index.php/ijeep/article/view/9917/5291>
- [5] RETScreen. Financial and risk analysis, 2004. Retrieved: July 20, 2015 from http://www.retscreen.net/ang/financial_and_risk_analysis_with_retscreen.php
- [6] IRENA (2021), Renewables Readiness Assessment: Albania, International Renewable Energy Agency, Abu Dhabi
- [7] IEA. (2020), Renewable Power. Paris: IEA. Available from: <https://www.iea.org/reports/renewable-power>
- [8] Malka, L., Konomi, I., Bartocci, P., & Rrapaj, E. (2021). An Integrated Approach toward a sustainable transport sector using EnergyPLAN model: case of Albania. 147(4), 141–147. <https://stumejournals.com/journals/innovations/2021/4/141.full.pdf>
- [9] IPCC (2018), Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Intergovernmental Panel on Climate Change, Geneva
- [10] ICEF (2018), "Direct Air Capture of Carbon Dioxide–ICEF Roadmap 2018", ICEF – Innovation for Cool Earth Forum, Tokyo, December, www.icef-forum.org/pdf/2018/roadmap/ICEF2018_DAC_Roadmap_20181210.pdf.
- [11] World Bank. 2014. State and Trends of Carbon Pricing 2014. Washington, DC: World Bank