POLYTECHNIC UNIVERSITY OF TIRANA
FACULTY OF ENGINEERING MATHEMATICS AND ENGINEERING PHYSICS
DEPARTMENT OF ENGINEERING PHYSICS

Regional Variation LCOE of Photovoltaic Systems in Albania Using Satellite Solar Data

Authors: Driada Mitrushi, Pëllumb Berberi, Irma Bërdufi, Valbona Muda, Daniela Topçiu, Urim Buzra, Eduart Serdari

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Photovoltaic Projects and LCOE calculation

- There are many technological, economic and local parameters and assumption to be made that underlie an accurate LCOE calculation of a photovoltaic project
- Performing such an analysis or utilizing the results we must consider the influence of these parameters and assumptions to achieve realistic evaluation results.
- Accuracy calculation of LCOE (Levelized Cost of Energy) depends firstly of the data for solar radiation and temperature. Then by technological and financial parameters.
- The most important is the initial capital investments that is affecting the cost, this investments is depending from the market of photovoltaic's nowadays.

Climatic conditions in Albania

- Albania is a small country with coastlines on the Adriatic and Ionian seas, with an area of 28.000 m^2 and a population of 2.893 million as for 2015.
- The retail market of electricity is dominated by the Distribution Operator of Electrical Energy (DOEE),which supplies electricity to all categories of customers under regulated prices.
- Albania has favorable conditions to develop solar energy, due to its geographical position and climate. Yearly average of long term daily horizontal insulation on different regions of Albania range from 3.96 kWh/m^2d to 4.49 kWh/m^2d.
- Due to some structural changes on meteorological stations net in Albania during last twenty years, access to valid ground data is very difficult.
- In this situation, use of Satellite solar data remains the only source of data. Accuracy of this data, compared with ground data for Albania, is estimated to be 10-20%. (From another research work)

Information for SolarGIS Database

- In this study we had chosen to use the **Solar GIS dataset**. The SolarGIS database is a high resolution database.
- SolarGIS is high-resolution climate database operated by GeoModel Solar.
- Solar radiation data are calculated from the satellite and atmospheric data: Meteosat PRIME satellite (© EUMETSAT, Germany) 1994 - 2010, 15-minute or 30-minute values for Europe, Africa and Middle East.
- The data analysis is made using simple algorithms that process satellite imagery and atmospheric and geographical inputs. Uncertainty of SolarGIS Global Horizontal Irradiance GHI and Direct Normal Irradiance DNI yearly summaries for 80% of observations is within the range of ±4% and ±8% (±5% and ±10% for 90% of observations).
- In complex geographies and extreme cases, uncertainty of GHI and DNI yearly summaries can be as high as ±8% and ±15%, respectively.

PvPlanner software tool

PvPlanner is a tool for calculate PV electricity potential with accuracy. It is the best choice for site prospection.
It is also the ideal tool for comparing energy yield from various PV technology options (e.g. crystalline versus amorphous silicon modules) and benefits from different mounting systems.
Simulations methods used in PvPlanner are scientifically validated.
In PvPlanner, photovoltaic power production is simulated using numerical models developed or implemented by GeoModel using aggregated data based on 15-minute time series of solar radiation and air temperature data as inputs. Data and model quality is checked according to recommendation of IEA SHC Task 36 and EU FP6 project MESoRstandards

Methodology

- Solar and renewable energy systems "fix" energy cost in time: Once installed, it will provide years of energy "Levelized cost of energy LCOE" is the average cost of renewable energy, it is the price at which energy must be sold to all the lifetime of the technology.
- Definition for levelized cost of electricity is the total cost of the PV system (the net present value) divided by total energy produced in the lifetime:

$$LCOE = \frac{Lifecycle\ \ costs}{Lifetime\ \ Energy\ \ production} \qquad LCOE = \frac{Annual\ \ capital\ \ costs}{Annual\ \ production\ \ kWh}$$

- For the PV system we will use it as an economic measure to compare different technologies in locations with different climatic conditions. It gave to an investor the cost of electricity per unit of the project:

$$LCOE = \frac{INVEST + \sum_{i=1}^{N} \frac{O\ \&\ M\ costs}{(1+r)^i}}{\sum_{i=1}^{N} \frac{E_i * (1-d)^i}{(1+r)^i}}$$

Methodology

Assumptions associated with costs

There are included in the assumptions all the requirements of the installations of the PV system:

1. Solar PV System Installation Requirements
2. Selection of a location in the specific area.
3. Determine the energy requirement and estimate the size of the system
4. Select a PV module type and mounting method.
5. Select inverter to match PV array:
5. Ensure solar access: location to be mounted had to get maximum exposure to sunlight; and is better to choose a location that is not shaded, for eliminating in maximum the shading effect.

Results

- In the TABLE 1, are given Horizontal irradiation, inclined global irradiation, and results of calculations of electricity produced by four technologies for each kWp installed capacity, crystalline silicon **c-Si**, amorphous silicon **a-Si**, copper - indium - selenium **CIS** and cadmium telluride **CdTe**.

Location	Daily sum of GHI (kWh/m^2 d)	Global in-plane irradiation (kWh/m^2 d)	Optimum Inclination to horizon (degree)	Daily electricity production coefficient [kWh/kWp]			
				c-Si	a-Si	CIS	CdTe
Vlora	4.48	5.11	32	4.01	4.16	4.21	4.07
Fier	4.49	5.15	33	4.10	4.20	4.15	4.27
Kuçova	4.40	5.06	33	4.02	4.12	4.08	4.20
Korça	4.26	4.85	32	3.92	3.95	3.97	4.06
Kukës	3.96	4.45	31	3.58	3.60	3.63	3.71
Himara	4.39	4.99	31	3.95	4.07	4.39	4.13
Borsh	4.32	4.94	32	3.93	4.05	3.99	4.11
Dhermi	4.39	4.99	31	3.95	4.07	4.01	4.13
Gjirokaster	4.26	4.80	31	3.84	3.91	3.89	4.00
Durrës	4.43	5.11	33	4.06	4.15	4.13	4.23
Tirana	4.29	4.95	33	3.93	4.02	3.99	4.09
Shkodra	4.21	4.90	34	3.82	4.04	3.89	4.01
Elbasan	4.28	4.92	33	3.92	4.00	3.97	4.07
Saranda	4.54	5.17	32	3.96	4.26	4.05	4.21

Results

Daily electricity production for the PV system are calculated for the four types of technologies and have a good accuracy for for small and medium-size PV systems. The accuracy of the method for calculations is important for solar power estimations.

- System performance, represented by conversion efficiency and system degradation, is also a significant contributor to the uncertainty in LCOE.
- Countless decisions associated with solar energy technologies are based on financial calculations, ranging from investors to regulators to technologists, yet the established method of comparing costs between electricity-generating technologies—LCOE—is being misused in virtually all cases in the context of photovoltaics.

In the Figure 1a, 1b, is shown the difference between the levelized costs of energy calculation. In the Kukes we can see the highest value and in Fier the lower value for each technology of photovoltaics.

And in the Figure 2, we can see that the CIS technology gave the highest values of the LCOE, and the Cd-Te is gave the lower value for LCOE.

Results

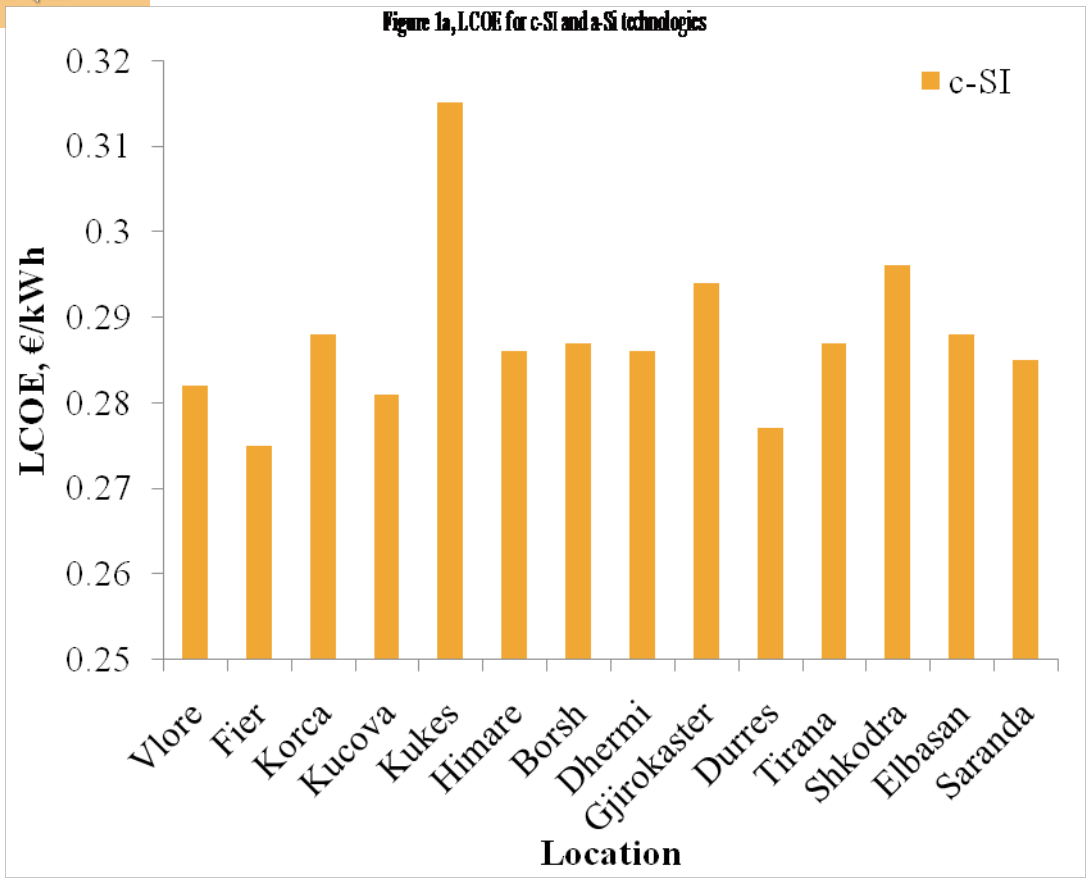


Figure 1a, LCOE for c-SI and a-Si technologies
c-SI
LCOE, €/kWh
0.32
0.31
0.3
0.29
0.28
0.27
0.26
0.25
Vlore
Fier
Korca
Kucova
Kukes
Himare
Borsh
Dhermi
Gjirokaster
Durres
Tirana
Shkodra
Elbasan
Saranda
Location

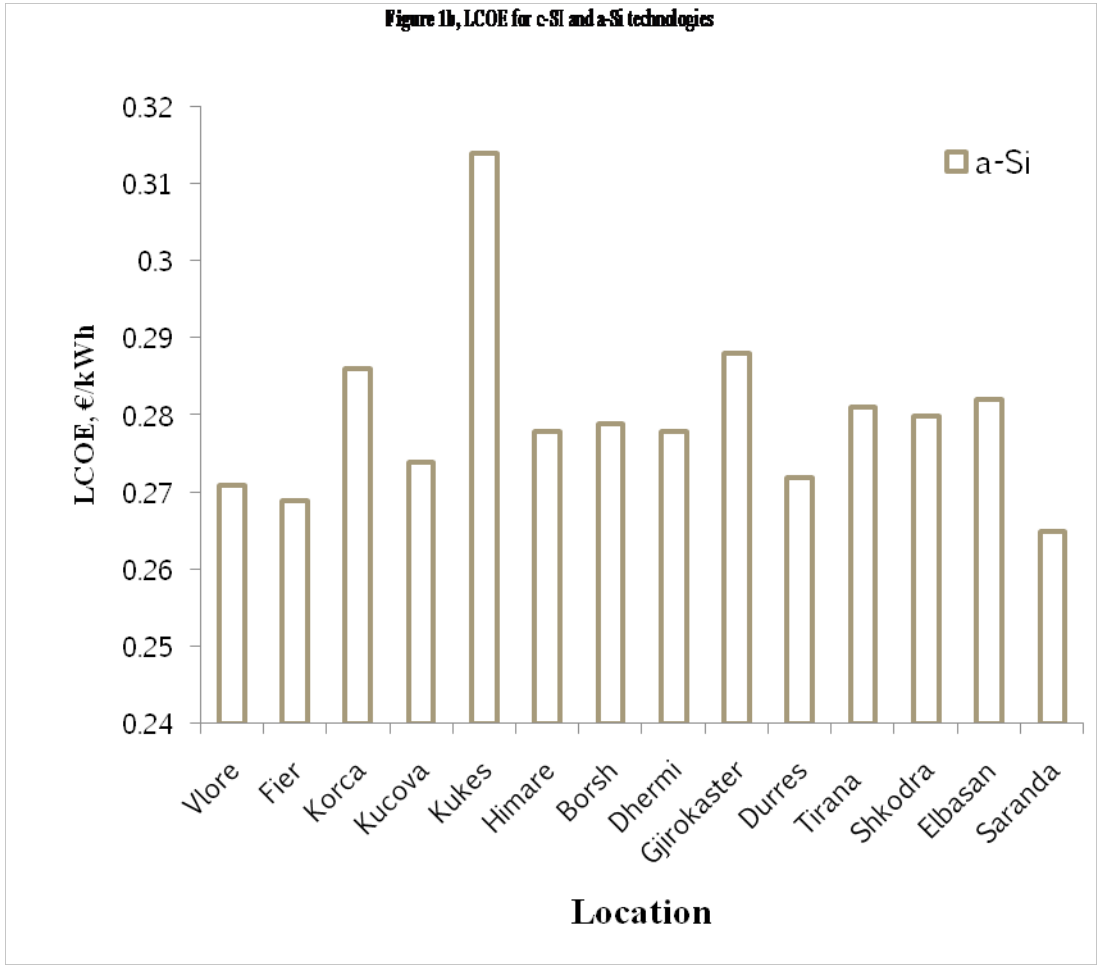


Figure 1b, LCOE for c-SI and a-Si technologies
a-Si
LCOE, €/kWh
0.32
0.31
0.3
0.29
0.28
0.27
0.26
0.25
0.24
Vlore
Fier
Korca
Kucova
Kukes
Himare
Borsh
Dhermi
Gjirokaster
Durres
Tirana
Shkodra
Elbasan
Saranda
Location

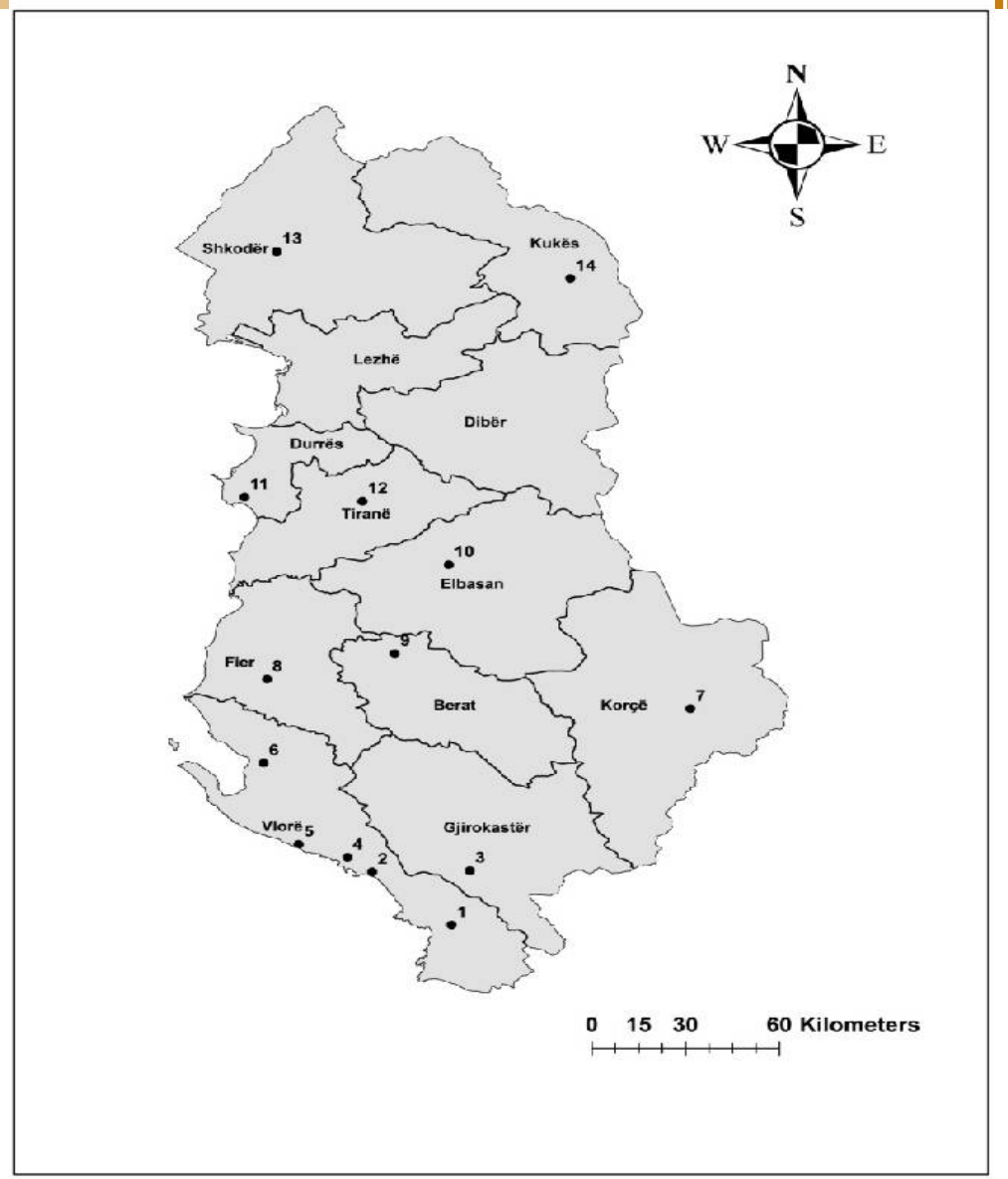
Results

TABLE 2, Levelized price of electricity in €/kWh

Region	Levelized Cost of ElectricityLCOE €/kWh			
Modules	c-SI	a-Si	IS	CdTe
Vlore	0.282	0.271	0.286	0.254
Fier	0.275	0.269	0.280	0.250
Korca	0.288	0.286	0.293	0.263
Kucova	0.281	0.274	0.285	0.255
Kukes	0.315	0.314	0.320	0.288
Himare	0.286	0.278	0.290	0.259
Borsh	0.287	0.279	0.291	0.260
Dhermi	0.286	0.278	0.291	0.259
Gjirokaster	0.294	0.288	0.290	0.268
Durres	0.277	0.272	0.282	0.253
Tirana	0.287	0.281	0.292	0.261
Shkodra	0.296	0.280	0.299	0.266
Elbasan	0.288	0.282	0.293	0.262
Saranda	0.285	0.265	0.287	0.254
Regional mean	0.288	0.280	0.291	0.261
Regional standard deviation	0.0097	0.0118	0.0096	0.0093

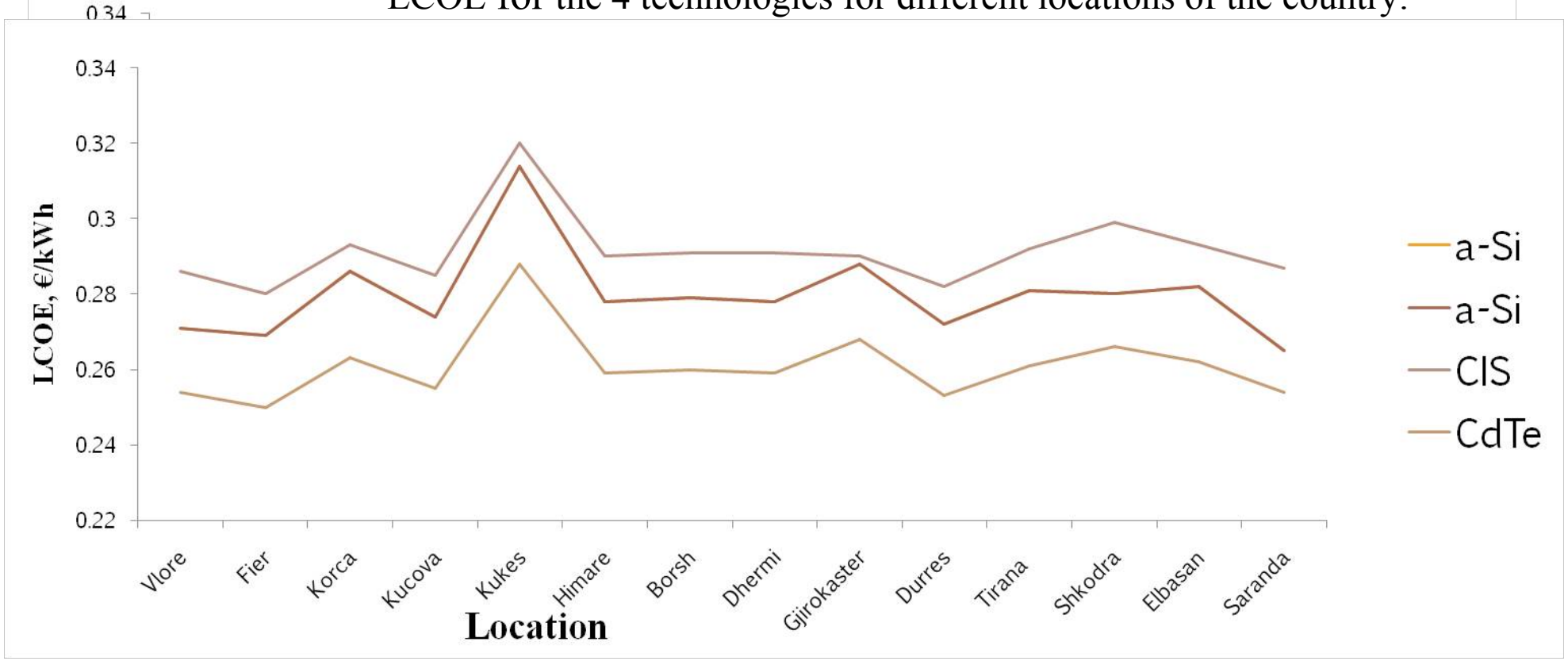

TROPOJE
MALESIA E MADHE
SHKODËR
Shkodër
PUKË
Puke
HAS
Krumë
Kukës
KUKËS
LEZHË
Lezhë
MIRDITË
DIBËR
Peshkopi
KURBIN
Laç
Buttel
KRUJË
Kruje
DURRËS
Durrës
Shijak
TIRANË
(Tirana)
LIBRAZHD
Kavajë
TIRANE
Librazhd
KAVAJË
PEGIN
Elbasan
Cërrik
ELBASAN
LUSHNJË
Lushnjë
POGRADEC
Pogradec
KUÇOVË
GRAMSH
Kuçovë
FIER
Fier
Patos
Berat
KORÇË
Maliq
Korçë
DEVOLL
BERAT
MALLAKASTËR
SKRAPAR
Vlorë
TEPELENË
VLORË
PËRMET
KOLONJË
GJIROKASTËR
Gjirokastër
DELVINË
Delvinë
Sarandë
SARANDË

Results


N
W
E
S
Shkodër 13
Kukës 14
Lezhë
Dibër
Durrës
11
12
Tiranë
10
Elbasan
9
Fier 8
Berat
Korçë 7
6
Vlorë 5
4
2
Gjirokastër
3
1
0 15 30 60 Kilometers

Results

LCOE for the 4 technologies for different locations of the country.



Conclusion

- In our study we have compared LCOE of four photovoltaic technologies in different regions of Albania.
- What it is important, results of calculations show that even distances between regions are relatively small, differences in LCOE are notable.
- The mean LCOE for all regions for different technologies varies between 0.288 €/kWh for c-Si modules, 0.280 €/kWh for a-Si, 0.291 €/kWh % for CIS and 0.261 €/kWh for CdTe.
- For the same technology but different regions LCOE varies up to 14.5 %, it is from 0.315 €/kWh in Kukes region to 0.275 €/kWh in Fier region. This is mainly to cloud coverage.

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Thank you for your attention