Meridian's Renewable Energy Levelised Cost Tool

This tool is aimed at informing the debate around renewable energy generation costs in South Africa. There are very few publicly accessible models that shed light on how various financial and technical components influence generation costs. Meridian Economics has responded to this gap by developing an interactive levelised cost calculation tool for wind and solar technologies in a South African context.

Background and context for the development of the tool

Globally, an energy transition is underway. Many countries are witnessing a rapid decline in the cost of renewable energy generation technologies, specifically solar PV and wind, due to technological advancements and the development of economies of scale in these industries. Though there are clear global trends in renewable energy cost declines, it is important to recognise that different regional renewable energy resource endowments and financial contexts provide nuances to this picture. Tax incentives, feed-in tariffs and the cost of capital may vary quite significantly across regions, which makes direct technology cost comparisons more complicated.

Use of the tool

Meridian Economics developed this tool to enhance our understanding of renewable energy generation costs in South Africa, and to share this with others in the field. Importantly, we wanted to incorporate country-relevant technical resource and financial parameters. In conducting this research and developing the levelised cost model, we had the opportunity to learn about some key considerations for project development in South Africa and how different input parameters influence levelised cost calculations. We plan to incrementally develop the tool as our understanding grows and incorporate cost comparisons with conventional technologies in addition to wind and solar. The levelised cost of electricity (LCOE) is an indicative tool for energy generation costs and should be interpreted as such. If assumptions remain consistent, it is useful for comparing the cost of energy generation across different technologies[1]. We hope this tool provides some useful food for thought to and would welcome any feedback.

Methodology

- Development of levelised cost model for wind and solar PV technologies in Excel, initial model input parameters based on extensive review of international and national literature (including IRENA, Lazard, National Renewable Energy Laboratory, Fraunhofer ISE, GreenCape, CSIR, and others).
- Interrogation of model input parameters through consultation with South African industry experts and project developers.
- Reflective range defined for input parameters based on collated industry and literature information (Table 1).

[1] However, this metric does not reflect the fact that generation technologies differ in the value that they deliver to a power system based on factors such as the time of day they are able to generate, whether they are dispatchable and the degree to which they can provide other ancillary services.

- "Best estimate" input parameter values derived by Meridian Economics from reflective range for illustrative LCOE calculations (Table 1).
- Sensitivity analysis performed on LCOE calculations.
- Application of technology learning rates and associated uncertainty explored.

Important to note

This work was done before the rise of COVID-19. Displaying overnight capital costs in Rands assumes a relatively stable currency and exchange rate of ~R14.50 to the US dollar[2] and ~R15.50 to the Euro.

[2] Many capital costs in the literature are displayed in these currencies and some local experts use USD values in cost models instead of Rands due to exchange rate fluctuations

Tool application: baseline LCOE calculation for South African projects

This section presents a baseline calculation of the LCOE for South African solar and wind projects using best estimate values derived from industry consultations and an extensive literature review. Best estimate values are used as inputs into the Meridian LCOE tool, and the levelised cost of wind and solar PV projects is calculated to be 66 and 64 ZAR (2020) cents/kWh, respectively. Importantly, these represent costs for projects that will have their first operational years in 2021 (solar PV) and 2022 (wind), for example, projects that may be associated with the next round of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP)[3].

Table 1. Input parameter ranges and best estimate values derived by Meridian.

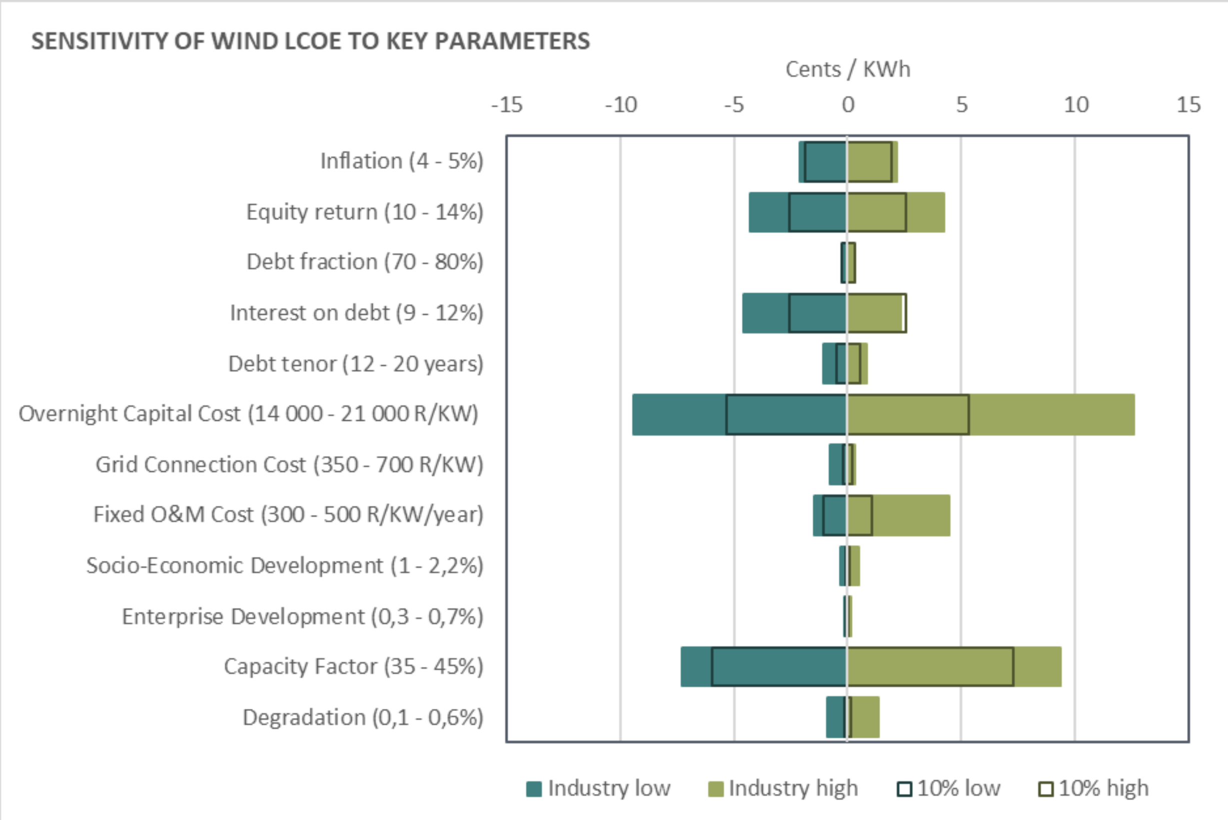
Input Parameter	Reflective Range (Based on Industry and Literature Review)			Best Estimate Values
South African Financial Assumptions				
Inflation (%)	4	-	5	4.5
Equity return (%)	10	-	14	12
Debt fraction (%)	70	-	80	75
Interest on debt (%)	9	-	12	11
Debt Tenor (yrs)	12	-	20	15
Wind Technology Assumptions				
Overnight Capital Cost (R/kW)	14 000 (970 USD)	-	21 000 (1450 USD)	17 000 (1200 USD)
Grid Connection Cost (R/kW)	350	-	700	600
Fixed Operations and Maintenance Cost (R/kW/yr)	300	-	500	350
Socio-Economic Development (% revenue)	1	-	2.20	1.50
Enterprise Development (% revenue)	0.30	-	0.70	0.50
Capacity Factor (%)	35	-	45	40
Annual Degradation (%)	0.10	-	0.60	0.30
Solar PV Technological Assumptions				
Overnight Capital Cost (R/kW)	9 000 (620 USD)	-	13 000 (900 USD)	11 000 (760 USD)
Grid Connection Cost (R/kW)	300	-	550	450
Fixed Operations and Maintenance Cost (R/kW/yr)	150	-	250	180
Socio-Economic Development (% revenue)	1	-	2.20	1.50
Enterprise Development (% revenue)	0.30	-	0.70	0.50
Capacity Factor (%)	22	-	26	24
Annual Degradation (%)	0.30	-	0.60	0.50
Levelised Cost of Energy (Baseline LCOE Calculation)[4]				
			Wind (2020 ZAR cents/kWh)	**66**
			Solar PV (2020 ZAR cents/kWh)	**64**

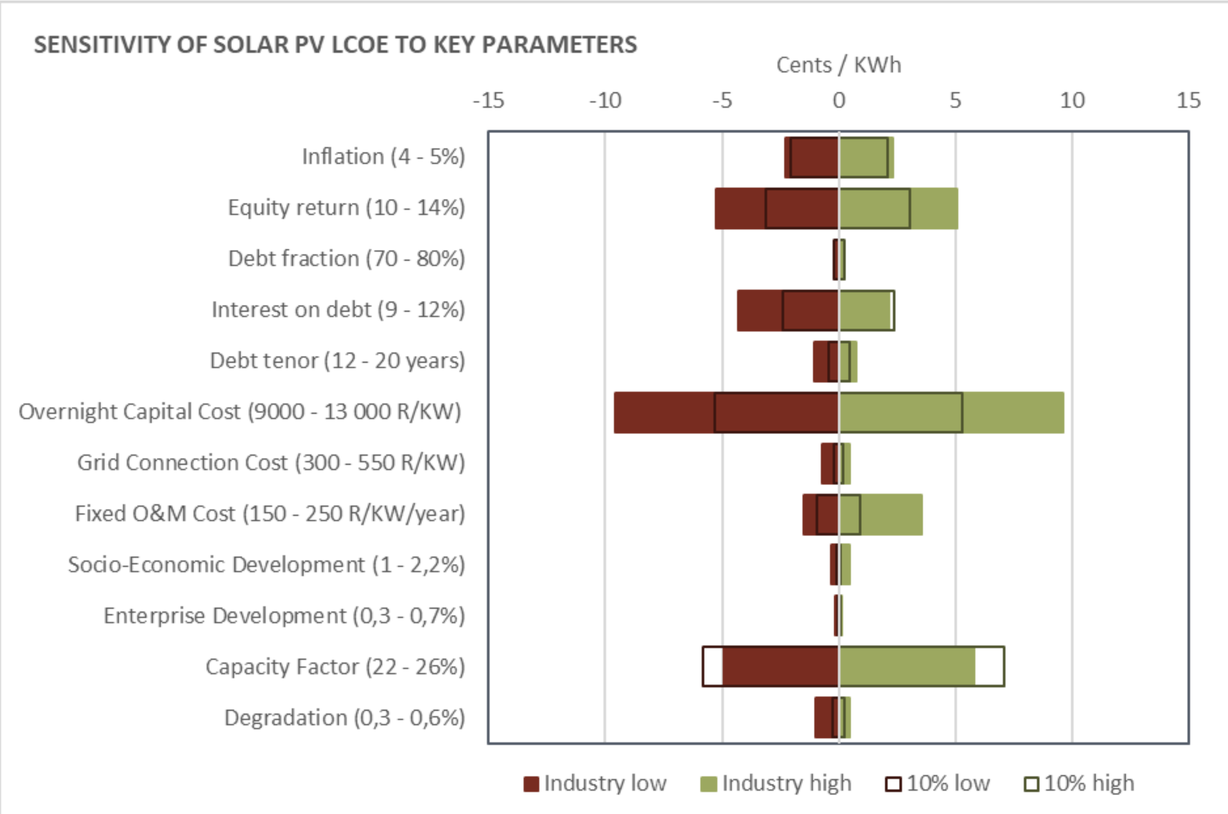
[3] The REIPPPP was launched in 2010 as part of a set of interventions to enhance South Africa's electrical power generation capacity. It is comprised of a competitive tender process, structured into rolling bid-windows and aimed at attracting sustained market interest and reduced prices for renewable energy projects (Eberhard and Naude, 2017).

[4] First operational years: 2022 for wind projects; 2021 for solar PV projects

Sensitivity analysis

A sensitivity analysis was performed to understand the influence of individual variables on the calculated baseline LCOE values for solar PV and wind. Overnight capital cost, capacity factor, interest rate on debt and equity return have the most significant influence on cost.





Technology learning rates

To inform an understanding of what costs may look like into the future, the Meridian LCOE tool applies a learning rate assumption to the cost of wind and solar technologies to 2040. The learning rate assumption is drawn from the National Renewable Energy Laboratory's (NREL) Annual Technology Baseline 2019 – a key data source in renewable energy cost projections. The figure below presents the application of NREL's learning assumption to the 'best estimate' values for overnight capital cost (OCC), fixed operations and maintenance cost (FOM) and capacity factor[5] (CF) used for our baseline calculations. This results in a reduction of the expected LCOE of wind and solar projects over time.

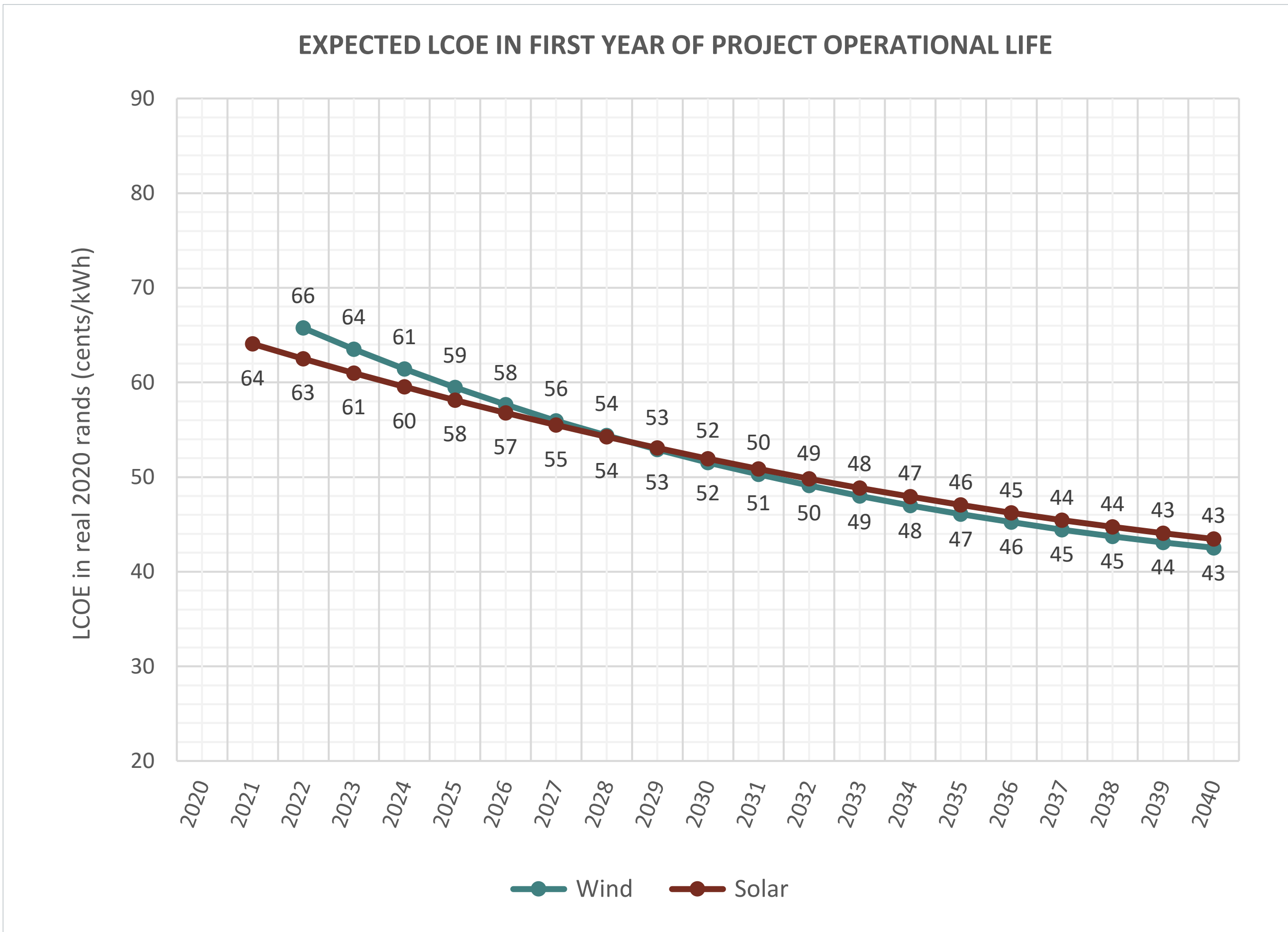


Figure 1. *Example of baseline LCOE for wind and solar projects projected over time based on inputs from Table 1 into the Meridian LCOE tool and an application of NREL learning assumptions (Meridian Economics, 2020; NREL, 2019)*

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[5] For this example, we applied 50% of NREL's assumed learning on the wind project capacity factor. In this way, the tool is adaptable to meet more- or less aggressive learning assumptions relative to the NREL learning rate. Applying only 50% of the assumed learning on the capacity factor may seem conservative, but the reason for doing so was to refrain from overstating technological learning as per the NREL assumption (based on wind turbines in the United States) without further analysis of its relevance for future South African wind project locations and turbine configurations. The energy produced by wind turbines is subject to location-specific dynamics and points to the need for more research on country-specific estimates on potential capacity factor advances linked to local wind resource conditions.

Testing for uncertainty in levelised cost projections

LCOE projections include assumptions around numerous variables with their own ranges and uncertainties, which may play out differently over time. Hence, a single projection line does not accurately reflect the possible range of LCOE values.

In order to quantify this uncertainty, we performed a stochastic analysis to determine 80% and 95% confidence intervals for expected LCOE values for wind and solar to 2040. This entailed running thousands of combinations of forecasts to reflect the range for each variable found in the literature and interactions with industry (Table 1). For purposes of this stochastic analysis, forecast variable values were selected at random from the entire range of values without assigning higher or lower probability to any part of the variable range (i.e. based on a uniform distribution between maximum and minimum values).

Our best estimate values (Table 1) were derived based on a convergence of literature values and industry estimates which were not necessarily positioned in the centre of the range. For example, the range on interest on debt is 9% to 12% and our 'best estimate' is 11%, based on a judgement of where literature values and industry estimates converged most strongly. Overnight capital cost, debt tenor and fixed operations and maintenance costs are other examples of variables where best estimates are drawn from above or below the centre of the range. This explains why, as seen in the next section, our best estimate LCOE trajectories from Figure 1 do not lie symmetrically within the bounds of the confidence interval. Rather, they are a representation of one possible cost pathway for each technology which starts with a specific set of input assumptions that are not positioned in the centre of each variable range.

In addition, we examine the impact of varying the learning rate on overnight capital cost (OCC), capacity factor (CF) and fixed operations and maintenance costs (FOM) for each technology. This assumes that there is uncertainty around the speed at which technology learning occurs. As a baseline, we performed a stochastic analysis without any variation in the technology learning rate. Then, a stochastic analysis was performed which included a range on the % application of the NREL learning rate. This implies that technology learning could happen slower or faster than the NREL learning assumptions as represented by the cost pathways in Figure 1.

Results: Uncertainty Analysis

1. No range on learning

Figure 2.1 and 2.2 indicate the likely ranges within which LCOE values for solar and wind projects will be situated in their first operational year up to 2040, *without* varying the application of NREL learning rate assumptions to overnight capital cost, fixed operations and maintenance costs and capacity factor as in Figure 1. Estimated LCOE values from Figure 1 are plotted as an example of one cost pathway.

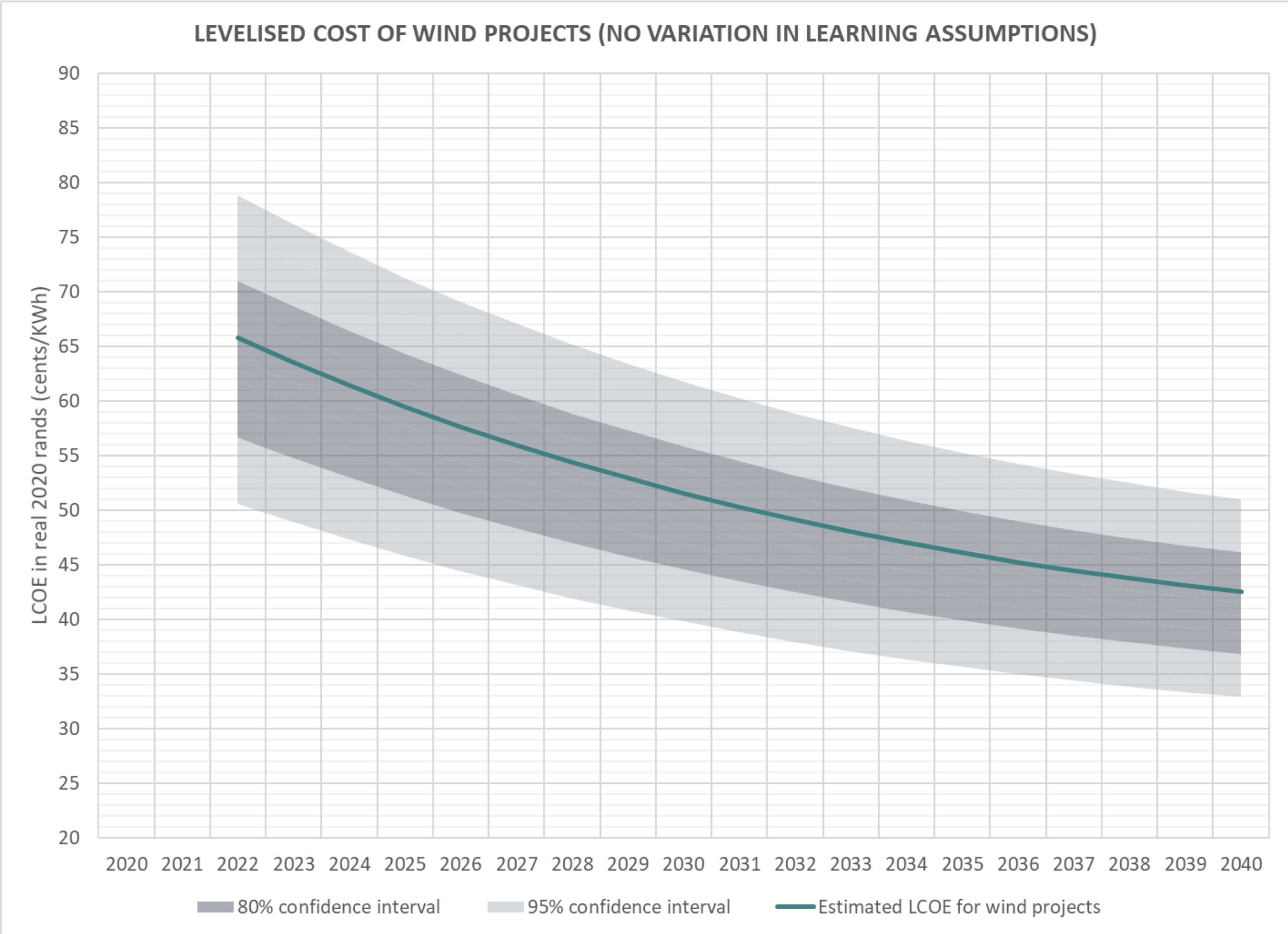

Figure 2.1. *Wind LCOE confidence interval range with no variation in learning for projects in their first operational year, expected LCOE plotted from Figure 1.*

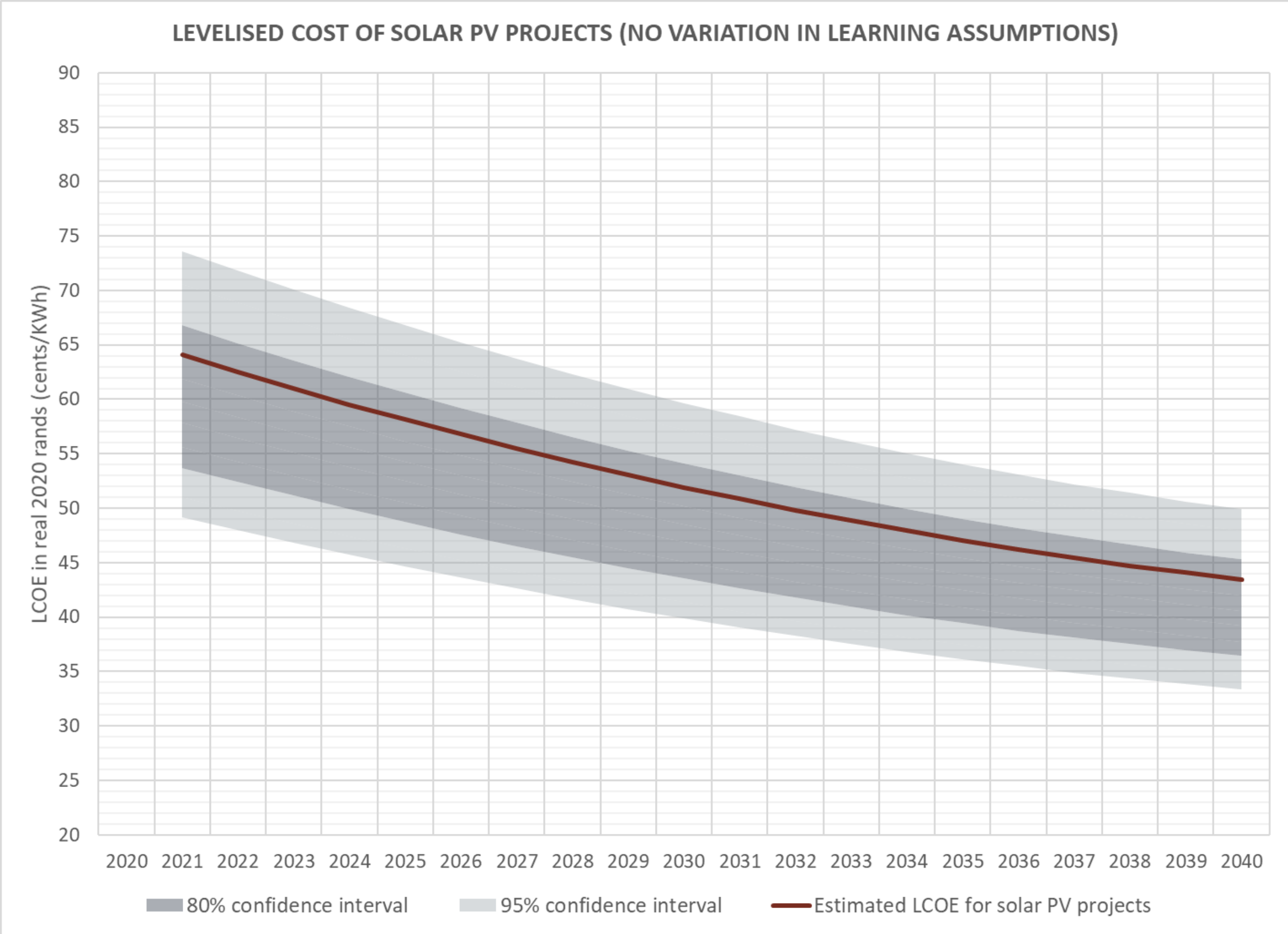

Figure 2.2. *Solar PV LCOE confidence interval range with no variation in learning for projects in their first operational year, expected LCOE plotted from Figure 1.*

Results: Uncertainty Analysis

2. With variation applied to learning rate

Figure 3.1 and 3.2 present the likely ranges within which LCOE values for solar PV and wind projects will fall *with variation* in the application of NREL learning assumptions. In recent years, experts have been surprised by the rapid pace of renewable energy cost declines over time relative to expected learning rates, suggesting that large uncertainties exist around LCOE projections (Wiser et al, 2016).

In our analysis, we vary the application from 50%-200% (half of the expected learning, to double the expected learning) on solar and wind overnight capital costs and fixed operations and maintenance costs to illustrate the possibility that realised cost declines may occur slower or faster relative to NREL assumptions. We varied the application of the learning rate from 50%-100% (half of the expected learning, to full expected learning) on capacity factors for both technologies, not wanting to overstate technological advances due to complexities associated with variable resource locations and associated energy production.

By applying variation to the learning rate, a range of cost pathways is established whereby technological learning and associated cost decreases could deviate from NREL learning assumptions. As seen in Figure 3.1 and 3.2, by including variability in the learning rate, the uncertainty range widens in later years.

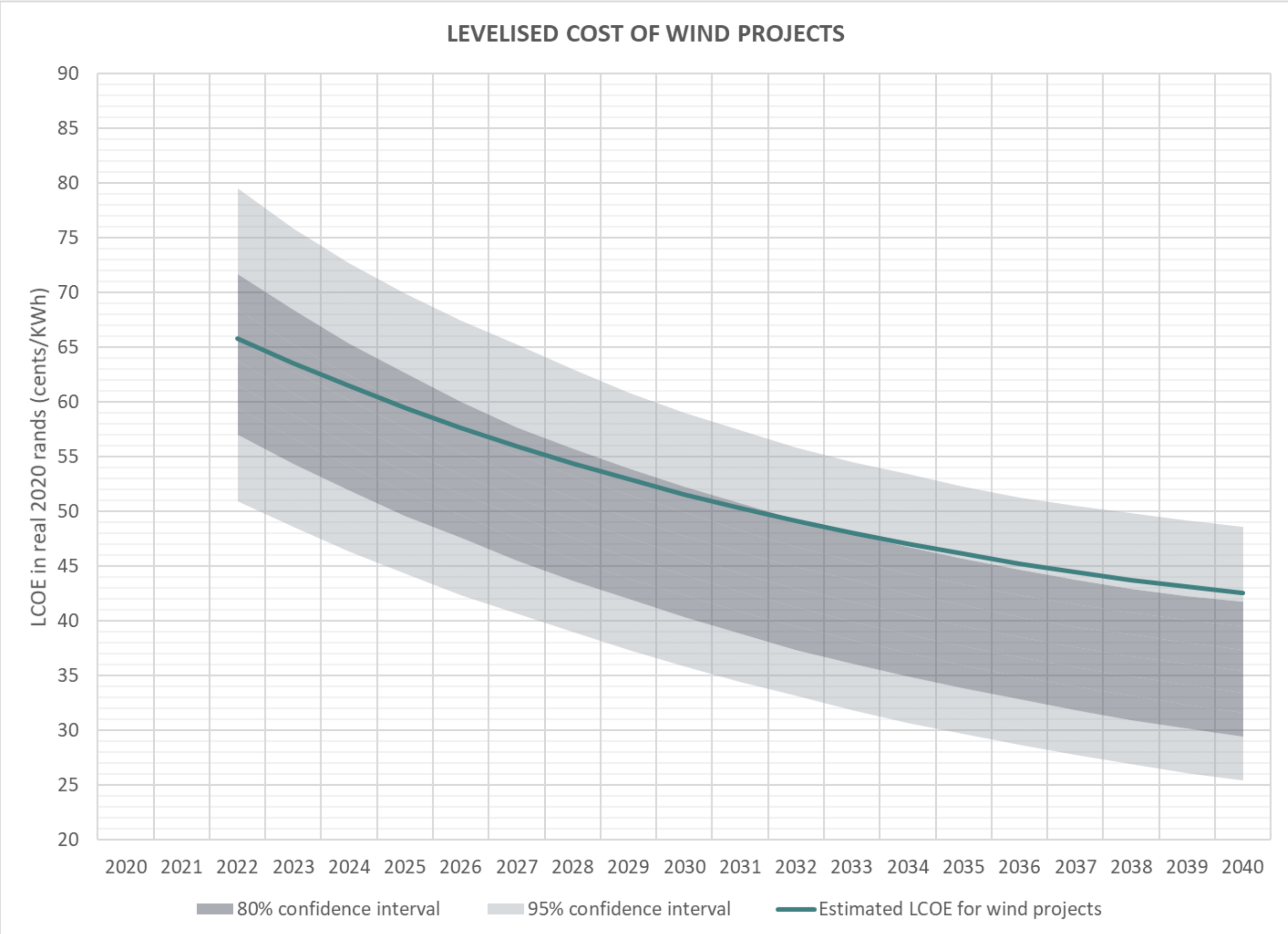

Figure 3.1. *Wind LCOE confidence interval range with variation in learning for projects in their first operational year, expected LCOE plotted from Figure 1.*

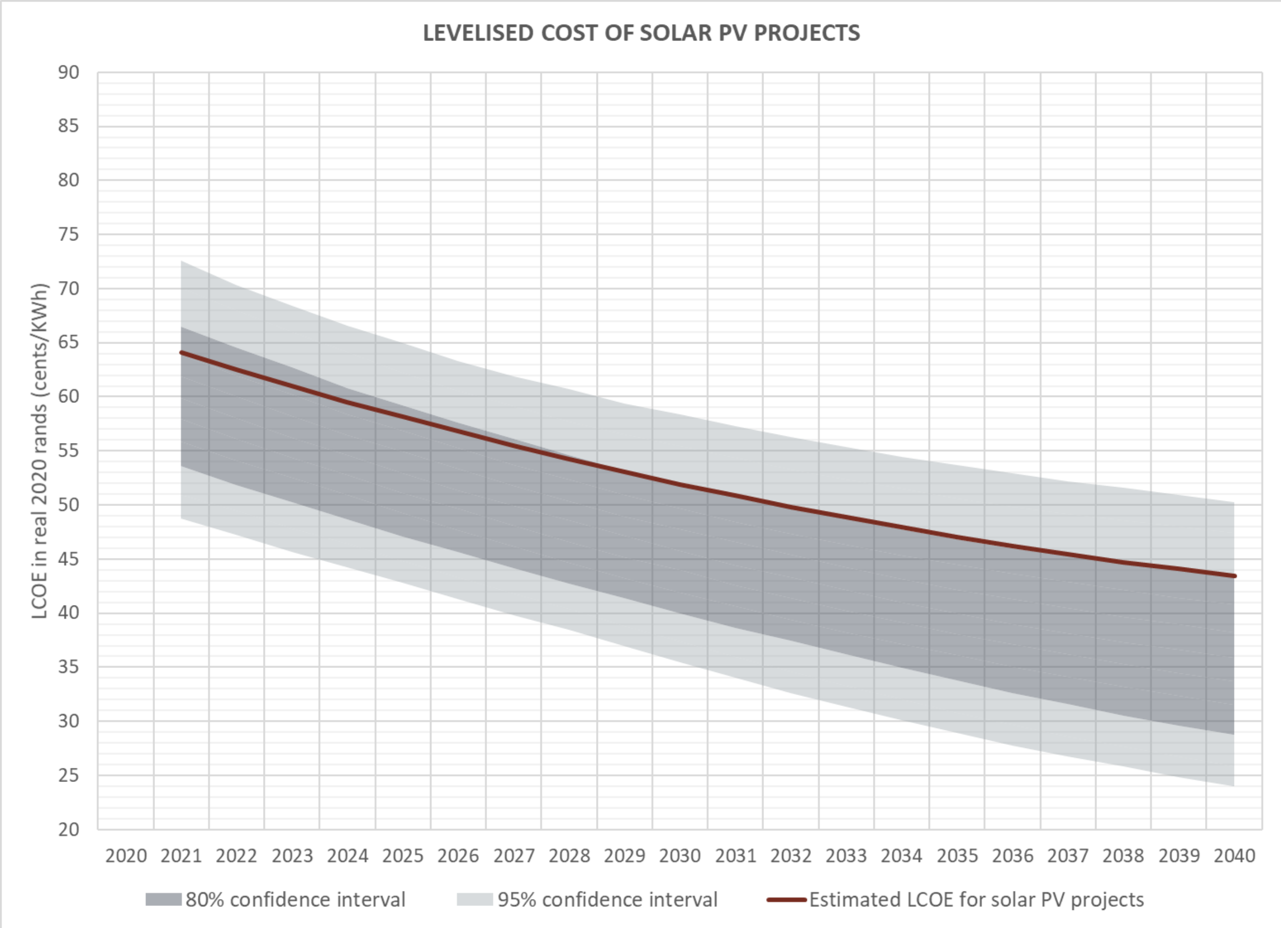

Figure 3.2. *Solar LCOE confidence interval range with variation in learning for projects in their first operational year, expected LCOE plotted from Figure 1.*

Conclusion

Overall, this analysis demonstrates incredibly promising cost outcomes for wind and solar PV projects over the next 10 to 20 years. Our best estimate LCOE values were modelled using a specific set of input parameters and the Meridian LCOE tool. The results demonstrate a cost pathway where the costs of solar PV and wind technologies both reduce by more than 30% by 2040. Importantly, this analysis also demonstrates the near-term uncertainty around renewable energy costs that may be realised in the next bidding round of the REIPPPP. It further demonstrates the range of uncertainty around modelled cost pathways over time, which is important to bear in mind when interpreting LCOE projections.

This analysis was based on a select sample of industry estimates and literature sources and could be improved through further engagements with industry and analyses of realised projects in the next South African REIPPPP bidding round. We hope that these engagements can be facilitated through the interactive Meridian tool, which we will incrementally develop and refine whilst incorporating further relevant inputs and suggestions.

Find the tool on our website and contribute your expertise: https://meridianeconomics.co.za/

This research consulted a range of literature sources:

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