A GUIDELINE

For cost-efficient procurement of photovoltaic assets

CSIR

our future through science

Executive summary

This document aims to guide public entities on cost-efficient ways to procure photovoltaic (PV) assets. Traditionally, responses to the request for proposals for the engineering, procurement and construction (EPC) of a photovoltaic asset for a public entity are screened by using evaluation criteria based on the installed capacity in kW_p, quality criteria and other user-defined specifications, while the final decision is based on the total EPC price. This leads contractors to offer the minimum-required installed capacity at the minimum-required quality.

This guideline, however, takes a more holistic view and a levelised cost of electricity (LCOE) is used to screen proposals, evaluate and determine the price ranking. Bidding LCOE from different proposals is determined by evaluating all relevant influencing parameters, including projected installed size in kW_p, EPC price, operation and maintenance (O&M) fee and guaranteed performance ratio for an initial period. In applying this approach, contractors are issued with a financial model and they are required to provide key inputs. The model provided calculates the LCOE from each bid. This approach requires all contractors to optimise their design towards lowest LCOE. The goal is to provide the best value on a risk-adjusted, least-lifetime cost basis. The methodology was successfully implemented in the procurement of the CSIR's PV assets and described in more detail in this guideline. A competitive LCOE and a high-quality PV system were achieved.

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INTRODUCTION

A request for proposal (RFP) is a solicitation mechanism used by agencies to obtain products or services from potential service providers. This is achieved through competitive bidding. The procurement process, involves five generic steps:

- Developing an RFP
- Issuing the RFP
- Administering the RFP (e.g. respond to bidder question or concerns, receiving the bids and so forth)
- Evaluating bids based on predefined criteria
- Selecting the preferred bidder

Traditionally, when public entities buy an asset under an engineering, procurement and construction (EPC) contract, the screening of the responses to the RFPs is done in two stages:

In the first stage, all proposals that are technically unacceptable are excluded. In the second stage, the remaining proposals are then evaluated according to the financial offer (in most cases, this will be the EPC price). In the case of buying a PV asset, this approach of using the EPC price can be problematic because evaluating proposals on this basis will inevitably lead to the tenderers offering only the minimum-required installed capacity (in kW_p) at the minimum quality because any 'over-delivering' in terms of scope or quality will lead to an increase in EPC price, lowering the chance of being awarded the tender. This guideline proposes a methodology that can be applied by public entities in South Africa and elsewhere in the world, that permits the procurement of PV assets at the lowest possible lifetime costs measured in LCOE.

It also provides guidelines and recommendations for financial evaluation to be considered when making a decision to procure a PV asset for public entities.

What are the guidelines' objectives?

- To provide a financial tool to evaluate proposals that leads to the most cost-efficient procurement of PV assets
- To acquaint public authorities and officials with the use of the LCOE when procuring PV assets

Who should read this guide?

- Technical departments in public entities, officers in charge of preparing tender documents and appointing tenderers
- Delegated companies acting on behalf of local authorities

What this guide provides?

- A description of preferred procurement methodologies
- A description of the successful implementation of this methodology in procuring PV assets for the CSIR

OVERVIEW OF THE SOLAR MARKET IN SOUTH AFRICA

The South African government's plan for meeting its national electricity demand is outlined in the Integrated Resource Plan for electricity (IRP2010). The plan contains long-term electricity demand projections and provides details on how demand should be met using the most cost-optimal combination of generation technologies, demand-side management approaches and energy efficiency measures.

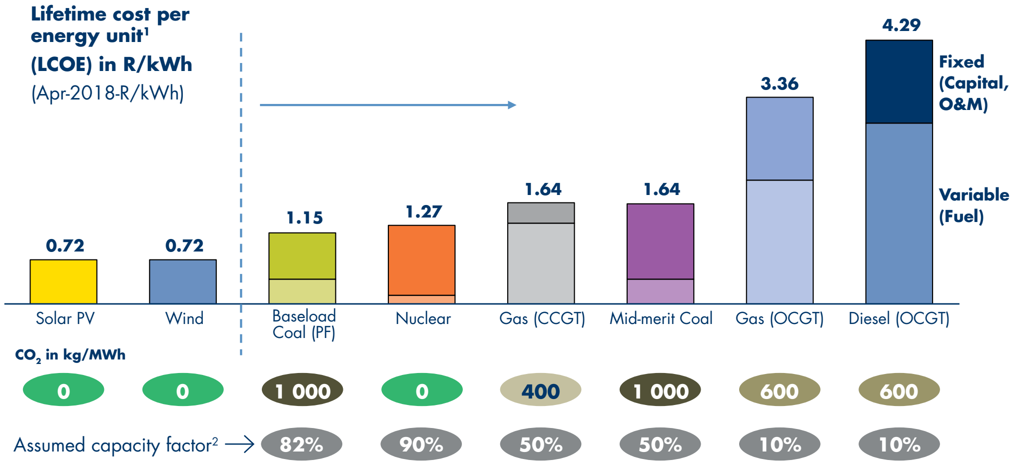
The Renewable Energy Independent Power Producers Procurement Programme (REIPPPP) is a South African renewable energy competitive bidding mechanism that implements the IRP2010 and commenced in 2011. A total of 8 122 MW was procured through the first four bidding rounds. In the annual reports of the United Nations Environment Programme (UNEP) and Pew Trust Report, South Africa emerged as the leading destination globally for renewable energy investment showing 96% growth over the past five years from 2008 to 2013, with total investment in the first bid window amounting to US $5.7 billion, up from virtually zero in 2010.

Figure 1 presents a cost comparison of alternative new-build options for the South African power system from a LCOE perspective. The cost of conventional new-build options is as per the Integrated Resource Plan (IRP) for South Africa with fuel updates. Typical full-load hours for each generator assumed are as follows:

- 90% for nuclear
- 82% for baseload coal
- 50% for mid-merit coal
- 50% for combined cycle gas turbines (CCGT)
- 10% for open cycle gas turbines (OCGT)

It is worth noting that changing load factor assumptions of conventional generation options drastically changes the fixed cost component for each kWh of energy they produce (lower full-load hours imply higher capital costs and fixed O&M costs per kWh). The average efficiency for CCGTs in this figure is assumed to be 55%, the average efficiency for OCGTs is assumed to be 35%. The cost of renewables is as per the bid window 4 for solar PV and wind and as per bid window 3 for Concentrated Solar Power (CSP).

Figure 1 also shows that wind and solar PV have reached 'new-build' parity. This is where the cost of electricity produced from wind and PV systems over the operational lifetime of the associated generation assets is equal to, or less than, the cost of all alternative new-build options. In bid REIPPPP Window 4, which closed in August 2014, the average tariffs bid for wind and solar were both 0.6 R/kWh.



[1] Lifetime cost per energy unit is only presented for brevity. The model inherently includes the specific cost structures of each technology i.e. capex, Fixed O&M, variable O&M, fuel costs etc.
[2] Changing full-load hours for new-build options drastically changes the fixed cost components per kWh (lower full-load hours → higher capital costs and fixed O&M costs per kWh);
Assumptions: Average efficiency for CCGT = 55%, OCGT = 35%; nuclear = 33%; IRP costs from Jan-2012 escalated to May-2016 with CPI; assumed EPC CAPEX inflated by 10% to convert EPC/LCOE into tariff; Sources: IRP 2013 Update; Doe IPP Office; April 2018 StatsSA for CPI; Eskom financial reports for coal/diesel fuel cost; EE Publishers for Medupi/Kusile; Rosatom for nuclear capex; CSIR analysis

Figure 1: Cost comparison of alternative new-build options for the South African power system

Results from the REIPPPP regarding the costs of alternative new-build options, as highlighted in Figure 1, show the competitiveness of wind and solar PV in the South African power system. This implies that PV may play an increasing role in the South African power system, especially under a conducive policy. This is the power-system view, comparing the cost of solar PV with the cost of alternative new-build options.

Individual retail electricity customers (residential, commercial, industrial and public entities) will take a slightly different view. They compare the lifetime energy costs of rooftop PV systems with their retail electricity tariffs. Once the LCOE are below retail tariffs, so called 'retail grid parity' is achieved, which will generally occur earlier than new-build parity, assuming there is no subsidisation to keep retail tariffs artificially low. The LCOE of rooftop PV in South Africa is in the order of 0.7-0.8 R/kWh compared to residential electricity tariffs (without VAT) reaching 1.1 – 1.4 R/kWh. This creates a huge incentive for residential customers to install PV systems on their roofs to supplement or partially offset their grid supply.

It is also expected that this will create a huge incentive for public entities that are also electricity customers (e.g. schools, hospitals, government buildings and so forth) to install PV systems to complement their grid supply. This gives them the opportunity to lead by example and will not cost them anything on a net basis. When decisions are being made to procure PV assets, these entities should ensure that they buy them at the lowest possible lifetime cost. The screening of the request for proposals for the EPC of a photovoltaic asset for a public entity is usually done using evaluation criteria based on installed capacity in kW, quality criteria and user defined specifications. While this is an important factor, it leads contractors to offer the exact required capacity at the minimum quality. However, in this guide, we propose LCOE to screen and evaluate proposals and to determine the price ranking.

OVERVIEW OF THE PROPOSED PROCUREMENT PROCESS

Although the focal point of this PV procurement guide is to introduce LCOE as a selection criterion, it is equally important to ensure a sound overall process from start to finish. To reduce the opportunity for error, a linear process can be adopted. The flowchart below tries to be as prescriptive as possible, giving a step-by-step easy to follow methodology:

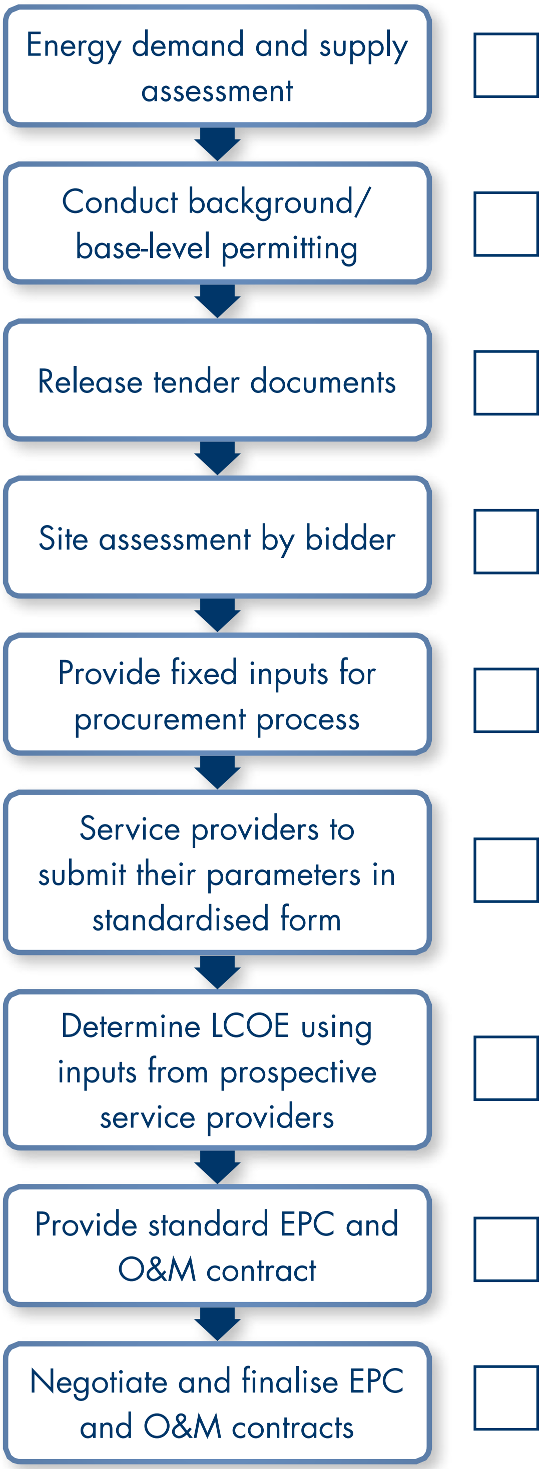


Figure 2: Suggested flowchart for execution of procurement

SOLAR PV PROCUREMENT METHODOLOGY FOR PUBLIC ENTITIES

The following methodology and steps are proposed as a guide when procuring PV assets. This approach is applicable for either ground-mounted or rooftop installations.

1. Energy demand assessment

When procuring any asset or service, a needs assessment should be conducted to determine the merits of embarking upon the procurement exercise. In the case of a solar PV generation unit, this means quantifying the demand for energy from the building or campus hosting the solar PV asset.

Ideally, the energy demand profile would be quantified in terms of key metrics over a period over one year. This would be as follows:

- kWh demand for each hour
- Peak demand per day
- Total demand per day
- Minimum or baseload demand

All these amounts may be determined with reliable time series data showing hourly demand trends. Figure 3 shows a typical demand load profile for a commercial business or building where office hours exhibit higher energy use while a low or base-level demand remains overnight.

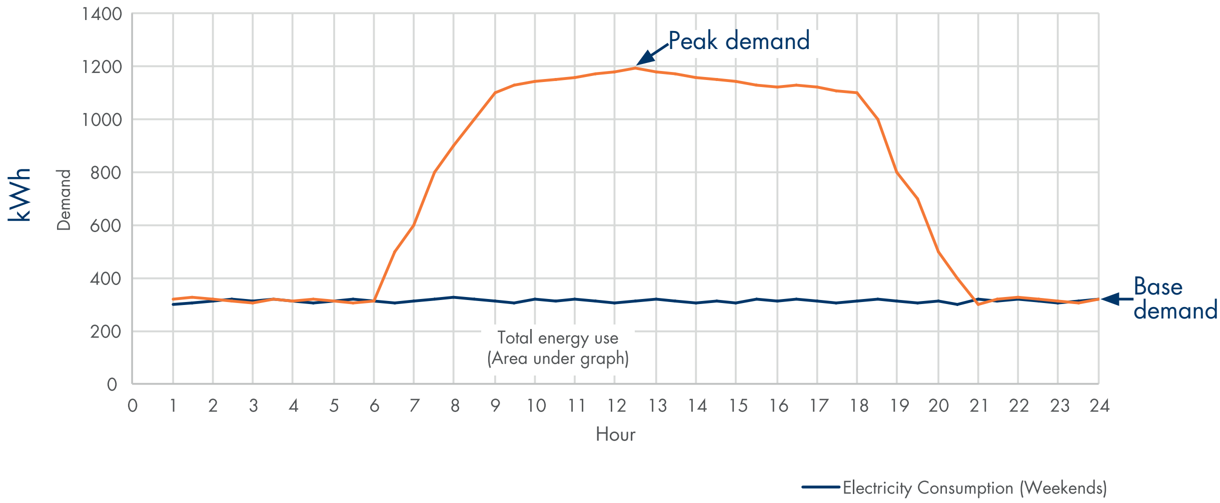


Figure 3: Typical daily demand load profile for commercial building or campus

This basic level investigation already provides valuable information for any entity looking to procure a solar PV asset for covering part of their on-site demand. The solar PV assets can be sized such that the following parameters are optimised:

Self-consumption ratio: This refers to the proportion of energy from the solar PV unit that is used directly in the host building (rooftop PV) or on the host campus (ground-mounted PV).

Self-sufficiency degree: This refers to the proportion of energy from the solar PV unit against the total energy demand in the host building or on the host campus.

After optimising for these parameters, the procuring entity is able to determine the extent of their procurement programme and answer more strategic questions, which include 1) Whether satisfying energy demand will require a combination of technologies? 2) The extent of energy autonomy desired? and 3) The timelines for achieving these desired goals?

2. Conduct base-level assessment and permitting

Solar resource assessment

In the case of rooftop PV and ground-mounted PV, it is advisable to quantify the solar resource for the PV host site because this parameter materially affects the final LCOE achieved by a bidding service provider. To ensure that offers from competing bidders are objectively comparable, a third party may perform the resource assessment. An estimate of the Global Horizontal Irradiance (GHI) must be provided for the LCOE calculator utilized in this document. An overly-optimistic value for GHI in a given area will lead to an overly-optimistic, i.e. lower, LCOE value.

Rooftop PV:

i) Plans and technical drawings

Prior to embarking on a request for proposal (RFP), the owner of the building that will host the PV facility should be notified and architectural plans should be acquired to assess the available area for the placement of solar PV assets.

Technical drawing should include a single-line diagram depicting wiring for the building to clearly identify electrical tie-in point for the PV facility. This may influence the positioning of any inverters. The existing grid connection and network should be assessed, and there should be an investigation on whether or not the grid connection network and the main distribution board needs to be replaced.

ii) Structural assessment of rooftop

In addition to building plans, a professional structural engineer should provide an assessment on the maximum loading to be placed on the rooftop. This will be an important design input for the bidding service provider.

Ground-mounted PV:

iii) Environmental permitting

Major alterations to the natural environment are subject to environmental regulations. If the construction activities trigger the need for an Environmental Impact Assessment, this work should be completed prior to releasing the RFP since this permitting can be time consuming and requires interactions with government authorities who, despite being able to give indicative timelines, may not be able to give certainty on permitting timelines.

iv) Aerial plan drawings

The spatial configuration of solar arrays can be optimised with surveyor drawings of the host land parcel. Such drawings provide the buildable area for the PV asset and are a major factor in sizing the project.

v) Geotechnical study

It is recommended that the procurer performs a basic geotechnical assessment of the land that will host the project so that adverse land conditions are identified at an early stage giving indication of any upward pressure on the pricing of the installation due to extra work required for foundations.

vi) Land-use permitting (if applicable)

Depending on the size of the project, a ground-mounted solar PV facility may mean that the land that will host the asset might have to be rezoned . The procurer of the PV assets should approach a qualified town planner to receive a view on the need for a land-use change permit.

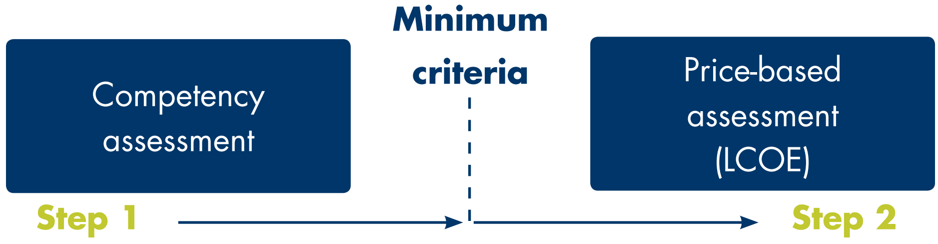
3. Release of tender document

The tender documents are the first point of reference for prospective suppliers of energy services or assets. As a result, a clear indication must be given on all criteria and expectations on any bid that will be deemed compliant. Each procuring entity will have specific compliance criteria that speak to their organisational policies and the purpose of the RFP.

Notwithstanding the individual circumstances and rules for each procurer, it is advisable to have core sections of the tender documents adequately structured to ensure clear responses to the RFP and consistency in the structure of competing bids. These core sections are given below:

- Background and context:
  - Purpose and structure of the RFP
  - Timelines for the procurement process
  - Functional specification for solar PV asset
  - Governing procurement policies applicable to the RFP
- Definitions and interpretation:
  - The rights of the procurer
  - Public Q&A session (if applicable)
  - General bid rules
  - Non-eligible persons
  - Minimum requirement for compliance (on each section of the bid response)
  - Contacts for clarification
  - Technical evaluation and selection criteria

Within the public sector, the procurement process is typically a two-step mechanism:



The screening of prospective bidders is done via criteria for assessing competency level as follows:

1. Organogram of the project team (EPC and O&M team)
2. Professional profiles of all members of the project team
3. Track record of installing and commissioning PV modules
4. Track record of installing and commissioning inverters
5. Track record of installing and commissioning mounting structure
6. Track record of managing subcontractors
7. Review of technical design

Information must clearly show experience of successfully delivering projects on a similar scale and complexity. The procurer must set minimum requirements on competency level before allowing the prospective bidder to participate in a second evaluation round, which will assess price.

4. Site assessment by bidder

The site assessment is paid for by the prospective bidder and is encouraged by the procurer as a tool for their own benefit to assess the ease of implementing the project and quality of the host site. The results from the site assessments produced by each of the bidders may be compared to ensure that bidders are working from the same view and assumptions regarding the host site. For this reason, the procurer may also prescribe the site assessment as a mandatory part of the bid response.

This guideline recommends site assessment as an integral part of the RFP response. Key elements of the site assessment report applicable to rooftop and ground-mounted PV units are as follows:

Shading and soiling assessment

Shading and soiling are critical factors that determine the output of solar installations. The amount of sunlight reaching the solar generator directly impacts the energy yield of the PV asset. The energy yield (together with the cost of financing, capital and O&M expenditure) ranks among the top factors impacting the LCOE.

Existing electrical service and grid connection

Inverters typically need breakers for over-current protection. Existing electrical service to the host site may not be large enough or have enough bays for a new breaker. It is vital to determine these limitations before starting to design or install a solar system. Electrical service will rarely mean an installation cannot be done, but it might make it more expensive. An appropriate grid connection point should be identified and key parameters, such as a feed-in voltage level, should be confirmed. The position of the connection point will impact the location of key components of the installation while the voltage level will influence the rating and selection of inverters. As a result, grid connection is one of the most important design considerations.

Age and condition of roof (only applicable to rooftop PV)

Regardless of how much power an installation is able to produce, if the roof is in poor state, the outcome is not representative until the cost of restoring the roof is included in the capital cost either by the procurer or by the bidder. Once solar panels are installed, re-working a roof with panels can be costly. It is advisable that the procurer or bidder ensures to check the age of the roof and, if there are any questions, obtains the information from the warranting contractor. If the roof is in really bad condition, the owner of the building will want to rectify it before panels are installed.

Obstacles (only applicable to rooftop PV)

If there are too many hindrances on the roof, panels may not fit and it could be prohibitively difficult to work on that roof. Some examples of obstacles are chimneys, stink pipes, complicated architecture and sky lights. This may not be the biggest deterrence in the solar site assessment, but it's important to keep in mind when determining where to place the solar arrays.

Space for conduit run

Power needs to run from the panel to the tie-in point or existing electrical service. If the building owner is strictly against an outside run on the building and if the entire inside is finished space, it may be difficult to get the power to its destination. This is rarely a factor that will stop the project, but something that must be discussed upfront and is typically only an issue in the rooftop PV case.

5. Client to provide fixed inputs for procurement process

In this next phase of the process, the procurer is required to provide fixed inputs that create an equal basis as the prospective bidder calculates the LCOE that they may offer. The list also includes extra contractual prescriptions required by the procurer. The procurer will provide a template, perhaps in MS Excel format as depicted below, to the bidder to ensure a standardised input format. The numbers given are for illustrative purposes only.

Inputs to be provided by procures (these inputs will be explained directly below)

Minimum installed DC capacity	500	kWp DC
Lifetime	25	yrs
Duration of O&M contract	3	yrs
Penalty factor for PR underperformance	1.5	
OPEX after end of tendered O&M contract	400	R / kWp / yr
Replacements in year 11 as percentage of initial CAPEX	15%	
Inflation	6%	
WACC = discount rate (nominal)	10.0%	
Global Horizontal Irradiance (GHI) at site (historically)	2 050	kWh / m2 / yr
Guaranteed Performance Ratio (PR)	76.7%	

i) Minimum installed capacity

The procurer must stipulate the minimum required installed capacity so that all proposed solutions from bidders can deliver a minimum threshold energy yield.

ii) Operational lifetime

Although a solar PV asset can operate for longer than 25 years, a standard period must be stipulated since the assumed operational lifetime materially influences the energy yield over the assumed lifetime of the asset. Ultimately, the assumed energy yield of the operational lifetime strongly influences the LCOE. As a consequence, this parameter must be stipulated by the procurer and used as a basis by all bidders. The replacement of inverters is also necessary after 10 years.

iii) Duration of O&M contract

For the initial years of commercial operation, the winning bidder will provide operations and maintenance services for the procurer. Each prospective bidder will have their own price for this O&M service. To ensure that the pricing is directly comparable and to ensure consistency in bid responses, the procurer must prescribe the length of the O&M contract. This guide advises an O&M contract period of three years since over 80% of mechanical or electrical failures occur in the initial three years.

iv) Penalty factor for performance ratio underperformance

The performance ratio is a metric that will be explained in more detail in the next section, as it is a parameter calculated from the inputs from the prospective bidder and the procurer.

When submitting the bid, the bidder implicitly makes a statement on the performance of their offering. The procurer must stipulate a penalty factor for instances where a performance ratio is claimed, but not achieved. The penalty factor is a dimensionless parameter that the procurer introduces to express penalty payments for the disparity between the guaranteed performance ratio and actual performance ratio. A higher penalty factor simply implies higher penalties for non-performance. The penalty factor must be set high enough to ensure that the bidder is incentivised to deliver a quality product, but not so high that the penalty for marginal non-performance destroys the business case for the bidder. The procurer is at liberty to stipulate any penalty mechanism. Within EPC contracts, the penalty is typically expressed as a fraction of the revenue or as a fraction of the EPC price for a given shortfall in the performance ratio.

v) OPEX after end of O&M contract

After completion of the O&M contract, responsibility for this service is transferred to the PV asset owner (typically the procurer). As a result, it is the responsibility of the procurer to provide this cost input for all bidders as they calculate their LCOE in the RFP response.

vi) Replacements as percentage of CAPEX

Although the operational lifetime of the solar PV panel is assumed to be 25 years, there are certain components of the PV installation that may require replacement. Once such a key component was the DC/AC inverter hence the procurer has to stipulate an assumed cost for these refurbishments to ensure consistency between bids. The cost will be expressed as a percentage of the initial capital cost.

vii) Inflation

This is a macro-economic indicator used for South Africa and is referenced from the official inflation-targeting policy of the South African Reserve Bank.

viii) Weighted average cost of capital

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. The WACC level can influence the calculated LCOE for a given solar PV project. However, the purpose of the procurement process is to determine the best quality solar PV installation independently from factors pertaining to the financial standing of the bidder. For this reason, the procurer stipulates an assumed WACC and allows the bidder to compete on an equal footing in this regard.

ix) Average historical Global Horizontal Irradiance

Since all prospective bidders are submitting proposals for a solar PV installation at the same host site, it follows that the same Global Horizontal Irradiance (GHI) level should be assumed by all bidders. Therefore, the procurer gives this value as a common input to all bidders. As noted above, an overly optimistic GHI will result in an overly optimistic LCOE, i.e. lower LCOE. Some adjustment downward on this number might be advised to provide a conservative LCOE estimate. The difference between the historical GHI and the measured GHI while the plant is in operation will impact the actual LCOE but it will not impact the performance ratio.

6. Bidder to provide inputs for procurement process

As briefly explained in the previous chapter, the bidder will be expected to provide input parameters for the calculation of their LCOE, thereby setting the basis for their bid. The parameters to be provided by the bidder are as follows:

Inputs to be provided by tenderers

Tendered system installed DC capacity	554.4	kWp
Tendered price for EPC part	10 750 000	R
Tendered price for O&M for the first 3 years	300 000	R/yr
Predicted specific energy yield during O&M period	1 840	kWh AC/kWp DC/yr
Predicted plane of array (POA) irradiance (without losses)	2 400	kWh/m^2/yr
Predicted efficiency loss after O&M period	0.8%	/yr

i) Installed capacity

The bidder will provide the installed capacity for their proposed solar PV solution. The installed capacity must equal or exceed the set minimum requirement.

ii) Tendered price for EPC

This is essentially the purchase price for the installation. Each bidder will have a different price based on their unique product offering.

iii) Tendered price for O&M contract (Year 1)

This is the purchase price for the operations and maintenance services during the first year. Each bidder will have a different price based on their unique product offering and the specific maintenance requirements for their product. The scope of the O&M contract should be clearly defined such that quotations are comparable.

iv) Predicted specific energy yield

The specific yield is the ratio of the predicted annual AC energy production for the first year divided by the installed DC capacity of the system. The predicted AC energy production comes from the model used by the bidder for the proposed solution and the historical GHI. The specific energy yield defines the numerator of the performance ratio to be discussed later.

v) Predicted plane of array (POA) irradiance

The POA irradiance is the annual irradiance as predicted in the same plane as the modules. The predicted POA irradiance comes from the model used by the bidder for the proposed solution and the historical GHI. The POA irradiance goes in to the denominator of the performance ratio to be discussed later.

vi) Efficiency loss under and after O&M period

Any operational asset suffers ageing and a general decline in performance over time. This decline in efficiency leads to a decline in energy yield in each successive year. The prospective bidder may vary this input between 0.3%/year and 1%/year guided by the module manufacturer's data sheet. High quality module manufacturers will claim a lower degradation rate, and that leads directly to a lower LCOE. The LCOE can vary by as much as 0.06 R/kWh when this input varies from 0.3%/year to 1%/year. Degradation of additional components may be included for an overall estimate of efficiency loss.

7. Evaluating the bids

7.1 Calculating the LCOE for each bidder

Calculating the LCOE for all bidders marks the key differentiator between the methodology outlined in this guideline and other more conventional modes of procurement. By evaluating and selecting a winning bid according to the LCOE, the procurer is, in fact, purchasing the PV assets that deliver energy at the lowest possible cost. The key point here is that the PV assets of lowest capital cost are not necessarily the ones that can deliver energy at the lowest cost.

The equation for calculating the LCOE incorporates the following input parameters:

- Energy production or solar irradiation
- Module efficiency, which influences the energy production
- Capital expenditure
- Operations expenditure
- Maintenance expenditure
- WACC

By using the LCOE as the selection criterion for the winning bid, the procurer selects the bid that is optimised after considering all factors that can influence the cost of delivering energy. This is a more comprehensive approach compared to an evaluation based on one single parameter (i.e. the capital cost).

$$LCOE = \frac{\text{Lifecycle cost}}{\text{Lifetime energy production}}$$

In the LCOE calculation, the net present value of all expenditures from the PV asset is determined over the operational life of the PV asset:

- Capital expense
- Operations and maintenance
- Fuel expense

Life cycle costs

The sum of all these costs is then divided by the net present value of the future value of the energy produced over the lifetime of the solar PV asset.

This calculation may be automated in an MS Excel-based tool using standardised inputs from prospective bidders. Despite the convenience of an automated tool, it is important to understand the mechanics of the LCOE calculation.

Identifying the lowest LCOE from all submitted bids may seem the easiest task so far. In reality, care must be taken to ensure that the LCOE figure is in fact credible. This requires a background check of the four input parameters provided by the bidder, which as shown in section five of this document and in the diagram below:

Parameter for checking	Nature of check
Tendered EPC price	Assess whether or not the EPC price is in line with market norms for the given size of PV installation
Tendered O&M price	Assess whether or not the O&M price has been too aggressively reduced to produce a favourable LCOE
Specific Yield	Values should be in the range of 1500 to 2000 kWh/kWp/year for fixed mounting and higher for tracked systems
POA Irradiance	This value should be equivalent to the historical GHI provided for fixed horizontal mounted systems and roughly 10% to 15% higher for ideally tilted systems, depending on location.
Efficiency loss	Values should be consistent with module manufacturer's data sheet, between 0.3% / year and 1% / year

After duly performing these checks and following up with the respective bidder to clarify any suspected misrepresentations, the lowest LCOE bid may be selected.

7.2 Evaluating the performance ratio

The PR informs on how energy efficient and reliable the PV plant is. With the PR one can compare the energy output of any PV plant with that of other PV plants or monitor the status of your PV plant over a prolonged period.

The PR is the ratio of specific yield over the plane of array irradiance. The following factors can have influence on the PR value:

Environmental factors

- Temperature of the PV modules
- Reference irradiance, if the solar measuring station is in the shade or soiled
- PV modules shaded or soiled

Other factors

- Reporting period (daily, monthly, annually)
- Conduction losses in the wiring
- Efficiency (degradation) factor of the PV modules
- Efficiency factor of the inverter
- Orientation of the solar resource measurement station relative to the PV array

> The Guaranteed Performance Ratio (GPR) is determined from the inputs given by the client/procurer and the bidder. The bidder promises a certain performance from the PV installation under the prevailing operating conditions. Therefore, the procurer holds the bidder accountable for this guarantee or promise through a penalty if the performance or PR is not met during operations.

7.3 Evaluating the liquidated damages

The liquidated damages represents a cash payment from the bidder to the client/procurer. The bidder agrees to make such payment in the event of an underperformance of the system after the initial period of operation specified by the client/procurer. The value may be calculated as a function of the penalty factor described above, the guaranteed PR, the discounted energy production, and the discounted cost of the project along with some adjustments for inflation. The liquidated damages should be a fixed amount for each percentage point difference in the guaranteed PR and the measured PR.

8. Provide standard EPC and O&M contracts to the winning bidder

The procurer has several options regarding what EPC and O&M template to use as a basis to open negotiations with the winning bidder. For major international projects, it is common to use either the NEC4 Contract Template or the FIDIC Silver Book. These two contract types offer fundamentally different approaches in terms of how projects should be managed and conducted.

The FIDIC Silver is specifically designed as a turnkey contract, where an employer hands full responsibility over to the contractor for all design, engineering and construction. This approach expects the employer to 'wait for the keys' and to have little day-to-day management of the project as work progresses.

NEC3 envisages the project as a collaborative process, with an emphasis on contract administration. The parties are obliged to 'act in a spirit of mutual trust and cooperation', an obligation that is central to the philosophy and concept of NEC4.

Choosing the appropriate form of contract

This guide acknowledges the freedom of each procurer to select a contract form that they are comfortable with. The points below identify some of the differences between FIDIC and NEC4 contract types so that the procurer may opt for a template that better suits their needs.

Table 2: Key differences between FIDIC and NEC4 contracts

Criteria	FIDIC Silver	NEC4
Pricing structure	Lump sum price basis	Flexible (six different price options with no amendments required)
Programme	Reasonably extensive provisions	Extensive provisions including the ability to withhold payment if programme is not submitted
General testing	Reasonably extensive testing provisions included	Limited testing provisions, with detail to be included in works information
Performance testing	Provisions included to deal with this	Provisions do not deal with performance testing to be carried out by employer; if any kind of testing is to be carried out, details must be included in works information
Interaction between contractor and employer	Turnkey	Collaborative

9. Negotiate and finalise EPC and O&M contracts

The selection of FIDIC or NEC4 as a contract template serves to give structure to the negotiations to follow. Even with a sound template, specific clauses and conditions must be negotiated. It is advisable for the procurer to seek the services of an owner's engineer such that their interests are protected through this key stage in the procurement process.

The following contractual matters are not exhaustive, but give a sound reflection of the issues that typically require a discussion between the winning bidder and the procurer.

Matters under the EPC contract:

Payment terms: The EPC contract (i.e. winning bidder) must procure equipment for installation. Given the high CAPEX for such projects, the payment terms may pose a challenge for the EPC contractor from a cash flow perspective. It is important to strike a balance so that the procurer has sufficient time to process and effect payment, while the EPC contractor does not suffer excessively long periods between purchasing equipment and having their working capital replenished through payment from the procurer.

Currency risk: In many instances, key equipment items are purchased from outside South Africa. This implies that purchases are made in foreign currency. The period of time between when the procurer buys the equipment and eventual payment from the procurer can pose some currency risk due to the movement in exchange rates. It is important for both parties to clearly outline where this risk will lie.

Insurance: The procurer has the right to stipulate an appropriate insurance package for the assets in line with their organisational policy and expert views from the owner's engineer. This insurance premium is commonly included in the EPC price, but it is nonetheless important to ensure sufficient cover for the asset.

Retention bond: This bond protects the procurer after installation and commissioning is completed. It guarantees that the contractor will carry out all necessary work to correct structural and/or other defects discovered immediately after completion of the contract, even if full payment has been made to the contractor. The terms of such a bond should be discussed before finalising the EPC contract.

Battery limits: Clear indication must be given in terms of where the EPC contract boundaries meet the boundaries of the infrastructure belonging to the procurer.

Matters under the O&M contract:

Scope and division of

Responsibilities: To price the O&M contract accurately, the responsibilities of each party must be outlined. This includes details such as the regularity of maintenance checks and performance monitoring.

Payment terms: As already described, payment terms are typically a cash flow management issue for both parties. An agreement must be reached regarding the payment interval under the O&M contract (i.e. monthly or quarterly), as well as the number of days allowed for the procurer to effect payment to the O&M contractor.

Warranties: The procurer will typically prescribe their desired warranties period for critical components of the solar PV installation. Where the manufacturer warranty on a given item does not meet the requirements of the procurer, the O&M contractor may price in the purchase of extended warranty and typically pass this through to the procurer.

CONCLUSION

An approach to procuring solar PV assets was developed where LCOE is used as the primary parameter for ranking compliant bids. This is a more comprehensive approach to evaluating the price of solicited bids because the LCOE captures the value that the PV asset brings to the procurer while also finding an optimised combination of the following parameters:

- EPC cost
- O&M Costs
- Performance Ratio
- Operational lifetime of asset

The guideline ensures that this optimised outcome is incorporated into the evaluation process of a public EPC tender.

The methodology was applied for the first time by a public entity in South Africa when the CSIR procured their solar PV systems. Using the process outlined in this guideline, the respective competitive LCOE values being achieved.

Plant type	Peak capacity	Achieved LCOE and year
Ground-mounted single axis	558 kWp	0.83 R/kWh in 2015
Roof top	250 kWp	0.87 R/kWh in 2016
Ground-mounted dual axis	203 kWp	1.00 R/kWh in 2016

This guideline will be made available to other public entities to procure PV assets (rooftop or ground-mounted) in a cost-optimal manner.

CSIR ENERGY CENTRE

The South African energy transition is a move towards a more sustainable and cleaner energy system. Such a transition brings with it significant disruptions and challenges. They stem from the fact that the energy system of the future will, with all likelihood, be more decentralised and distributed and therefore significantly different in its architecture from what we know about energy systems today. That brings technological, socio-economic and ecological changes with it. The CSIR therefore established an Energy Centre in July 2014 with a mandate to define and implement the organisation's energy research agenda. The CSIR Energy Centre hosts all energy-related research whose primary focus is on energy, and works closely with other CSIR researchers on energy-related research topics for which "energy" is not the primary focus.

VISION

The CSIR Energy Centre provides the knowledge base for the South African energy transition and beyond. It will be the first port of call for South African decision makers in politics, business and science to advise them on the energy transition. This transition is a move towards a more sustainable and cleaner energy system and will ultimately lead to energy being used more efficiently and supplied by significant share from renewables in the primary energy supply. The Centre also leverages on the lessons from the South African energy transition to support the creation of sustainable energy systems for other African countries.

MISSION

The Energy Centre's activities are guided by the desire to help develop a sustainable energy system. The specific objectives are:

- To conduct directed research in emerging energy technologies and system integration;
- To prove the concept of emerging energy technologies and systems;
- To demonstrate energy technologies and systems in the South African context and to support their commercialisation;
- To conduct directed research towards the understanding of how to optimally design, build and operate cost-efficient, reliable and sustainable energy systems;
- To find optimal pathways for the expansion and operation of energy systems through modelling and simulation;
- To advise policymakers on market design and regulatory concepts for the integration of new energy technologies;
- To provide support to South African industries on key energy-system-related decisions; and
- To provide thought leadership for the energy research agenda in South Africa and in the region.

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