Proceedings of the IRENA IEW Side Event:

Reaching a consensus on “grid integration costs”? A discussion of competing concepts, emerging approaches, and overall relevance

DATE: 3 June 2019
HOUR: from 12:45 pm to 13:45 pm
PLACE: UIC-P Espaces Congrès, Paris, France

Event background

As the shares of wind and solar power increase rapidly in many countries, many governments are concerned about potential “grid integration costs” of accommodating these technologies' new characteristics. Although the meaning of the concept can differ across contexts, as it gained prominence in policy circles it tended to hint that there are hidden costs to variable renewable technologies that may counterbalance their rapidly decreasing investment costs. The discussion often boils down to whether and to what extent new characteristics of wind and solar power – such as their variability, uncertainty, or location – imply new costs to the grid.

The grid integration cost concept has also been discussed and debated in academic literature over the past decade, yet a clear consensus on how the concept is defined, measured, and used is yet to emerge - or at least is not visible to the policy-making community.

Without a clear definition of grid integration costs, a range of methodologies have also emerged to measure them, but there have been sharp debates over the comprehensiveness and relevance of certain metrics and their application. Attributability of some integration costs to renewable technologies are particularly contentious. New approaches are being used and developed, however, which attempt to reflect some of the agreements around the topic, e.g. equal focus on the value of wind and solar, and the importance of system-specific context.

Against this background, this session aimed to address several questions to explore whether a consensus around “grid integration costs” is emerging. This session informed ongoing work at IRENA to develop an analytical brief which summarises the latest thinking around the concept of renewable energy grid integration costs.

Session format

This side event at IEW 2019 was oriented toward an open discussion with expert panellists and conference attendees. Following brief introductory remarks and presentation, the session had a panel session consisting of brief interventions from five panellists around pre-defined questions listed below. Following these interventions, open discussion was welcomed from over 75 attending experts in the audience (see summary of the full discussion further below).

Expert interventions

- How are grid integration costs defined and what are included?
- How are they calculated?
- For which practical purposes is this metric useful?
- What are the weaknesses of the proposed methodologies?

Panel discussion and open interventions from the audience

- What are the areas of consensus that have been reached around grid integration costs, and what are the main conceptual disagreements that remain?
- What is the actual relevance of the grid integration cost concept? How can the concept of grid integration costs best support decisions of policymakers and investors?

Session agenda

Moderator: David Daniels (Chief Energy Modeler, EIA)

12:45 - 12:50: Introductory remarks from the Moderator

12:50 - 12:55: Introductory presentation

- Asami Miketa (Senior Programme Officer, IRENA)

12:55 - 13:15: Expert interventions

- Falko Ueckerdt (Postdoctoral Researcher, Potsdam Institute for Climate Impact Research)
- Geoffrey Blanford (Technical Executive, EPRI)
- Trieu Mai (Senior Energy Analyst, NREL)
- Brent Wanner (Lead, Power Generation Analysis, IEA)
- Claire Nicolas (Energy Specialist, World Bank)

13:15 - 13:40: Panel discussion and open interventions from the audience

13:40 - 13:45: Summary from the moderator and closing

Summary of the discussion

Opening

The session was opened by the Moderator, David Daniels of the EIA, who welcomed the participants to the side event.

He noted that the session aims to begin a discussion that could lead toward building a consensus on how the community views the concept of grid integration costs.

Introductory presentation

Dr. Asami Miketa (IRENA) followed the opening of the session by introducing the background behind the topic to be discussed.

She explained that this is the 7th year that IRENA has organized a side event at the IEW, and it continues to be a n excellent forum to collect insights from top energy modelers on topics that are relevant to policy makers, and to raise awareness of policy-relevant questions for academics.

Noting the recent publication of IRENA cost data, which shows a continued trend of cost reductions in solar and wind technology, Dr. Miketa also noted that when discussing these trends with member countries IRENA is often asked about “grid integration costs”. What different countries and government officials mean by this concept varies depending on the context, but many of them are receiving messages that there can be high hidden costs to renewable energy.

However, governments are deploying more renewable energy because their energy systems see net benefits compared to the alternative. Although gross costs of renewable additions are likely to be smaller than their gross benefits, it does make sense for governments to know the gross costs in order to design policies that allow for their fair distribution. The literature on the topic of grid integration costs all seems to highlight the methodological challenges to meaningfully define the concept, in terms of what can be attributable to the special characteristics of variable renewable energy (VRE); namely, that they are variable, uncertain, location specific, and non-synchronous.

Dr. Miketa explained that from IRENA’s point of view, interest is the policy relevance of whatever metric is proposed, and a key issue in that regard is one of presentation. There appear to be two schools of practice around this – for example, the metric of “system LCOE” adds grid integration costs on top of the LCOE of VRE technologies. However, this is often used without proper political context and prone to mis-interpretation.

Alternatively, one can compare the total system costs of two scenarios with different shares of VRE. While this is more straightforward, in practice it also faces methodological challenges. For example, the scope of the models (or system boundary of the models) used to calculate the total system costs essentially defines what aspects of cost are captured. This is increasingly relevant as the system boundaries of power system modelling are changing to include electrification of end-use sectors and demand side participation.

Dr. Miketa noted that a short note on integration costs was recently published by some members of the IEA's technology collaboration programme Wind Task 25, to which staff from both IEA and IRENA contributed. Although this note does not necessarily represent IRENA's official view on the topic, many at IRENA endorse the note's perspective that the calculation of total system costs for two future scenarios is a preferred approach.

A number of open questions remain, however – e.g. In future energy systems where flexible power systems with high shares of VRE are standard, will the concept of "costs" from variability actually remain relevant? She personally wonders if some of the grid integration costs identified in such an exercise are perhaps better labelled as costs of inflexible systems rather than costs of VRE.

In this session, Dr. Miketa noted that she was looking forward to hearing the panel and audience's thoughts on some specific questions that have been developed to guide discussion and inform an issue paper to IRENA member countries, including:

- How are grid integration costs defined and what are included?
- How are they calculated?
- For which practical purposes is this metric useful?
- What are the caveats of the proposed methodologies?
- What are the areas of consensus that have been reached around grid integration costs, and what are the main conceptual disagreements that remain?
- What is the actual relevance of the grid integration cost concept? How can the concept of grid integration costs best support decisions of policymakers and investors?

Expert panel – Invited interventions

Introducing the panel of invited speakers, David Daniels noted that everyone also recognizes there are more experts on this topic in the audience at IEW, so the idea is to first hear slightly differing opinions and then open the discussion.

Falko Ueckerdt (Potsdam Institute for Climate Impact Research) began by first covering more background based on Dr. Miketa's categorisation of total costs vs. system LCOE, noting that both are valid approaches while total costs wouldn't need integration costs as a metric, but system LCOE would. Integration costs are defined as additional costs on the system level – i.e. costs imposed by adding renewables that are not connected to their pure generation costs.

He continued by stating that integration costs are helpful as policy makers, industry, other energy stakeholder and society, like comparing technologies based on a simple metric. A pure generation cost (LCOE) might be misleading: e.g. we saw that renewable costs are in the range of fossil fuels, but this does not mean they are competitive from an investor or total cost perspective. However, you don't see that in the metric of LCOE, as it's simplified, and we shouldn't think investors invest in technologies only because their LCOE is going down.

He noted that when he started working on this ten years ago, the context was a very technical one, with engineers mainly focused on balancing costs, and requirements for short-term balancing reserves. In a couple of papers, Lion Hirth, Falko Ueckerdt and others connected an economic view on variable renewables and other generating technologies with the technical integration cost research.

Their research broadened the integration cost concept to include economic elements, suggesting a twofold perspective: They showed that the concepts of system LCOE and market value are equivalent and that integration costs can be defined from a cost or an economic value perspective. IEA's VALCOE now applies a value perspective.

As a result, a major component of integration costs are profile costs, which is the cost of underutilised capacity in the system because you add solar or wind where they have low capacity credit. This can be partly fixed with storage and other flexibility, but all such costs can be added under the heading of profile costs. Balancing costs are seen to be smaller (e.g. less than 1c/kWh for wind and solar). Grid costs should not only include investment costs in grids, that are rather low, but also the cost of not having the grid in place in time, which could be significant.

The last point made is not to use integration costs against wind and solar, specifically during the transition point – don't punish them because they are newcomers, and because they are put into a system that is not prepared for them. So the costs occurring due to non-renewable-friendly systems should not be attributed to wind and solar, specifically as many countries decide moving towards renewable-based systems.

Geoffrey Blanford (EPRI) proposed to offer a different perspective on grid integration costs, how to interpret them and whether they're useful. First, he noted that most modellers probably agree on the fundamental attributes of how to represent renewable energy in an electricity system model – those are not in question, and this topic is rather a question of how to talk about it and how to communicate the economics. From this perspective, he thinks the grid integration cost metric is not so useful, for several reasons.

First, when talking about a system integrating VRE, it's important that you include the attributes of the system that are impacted by them – sufficient temporal resolution, spatial resolution, operating reserves, system inertia. There are two main reasons why this could be problematic for grid integration costs. The first is that the gap in the true costs from what your model comes up with is dependant on the resolution, which is problematic for comparing across approaches – if your model has these aspects then your grid integration costs are zero, since they're already accounted for in the explicit endogenous dynamics, but if you have a simpler model that tries to somehow reflect these things, then the definition depends on just how unresolved your model is, making it hard to compare. The second point is that a technology's system LCOE is no more informative than the LCOE, because decisions between technologies in the electric system are not based on a single cost metric whether it include all the aspects or not – it is rather about the optimal contribution of different resources.

Their communication has instead focused on what the value of a profile is in a particular system. This depends on what other resources are there, prices, policy incentives, how profiles lines up, storage costs, etc. – essentially what are all the things that determine the resources integration into a system. You need a model to assess this and it will change as a function of everything. He feels talking about the value of a resource profile, and how it changes as the system changes, is the better way to communicate.

Trieu Mai (NREL) began by reiterating the historical point that in the earlier engineering-focused days of integration cost discussion, it was largely restricted to balancing costs and using detailed simulations to better understand operating reserves and their cost. Falko and his colleagues made an important contribution by focusing more on the long-run aspects of integration costs, representing a change in how the definition has evolved over time.

In terms of that longer-run definition of integration costs, it is seen that an addition to the direct generation costs that will then enable you to compare technologies. Another way to think about it is that additional piece is the difference between a benchmark price minus the system value of VRE, so there is a link back to the value perspective which he would agree deserves more of an emphasis.

Although the system LCOE work is indeed seminal and comprehensive, he offered three issues for discussion. The first relates to the need to always add the additional integration costs to direct costs – if you omit the direct costs from the conversation, you're losing the ability to make any relevant comparison. The second is that integration costs truly should be applied across all technologies – some may even have negative costs in this regard, but the literature has overemphasized renewables in these analyses. The third is a more nuanced point, in that the literature has mainly focused on metrics in per MWh units. That normalisation by a physical unit can actually start distorting representation of technologies in terms of the dollar value of generation over time, or grid services provided (where MWh may not be the relevant unit). Given that you need to calculate the system value of different technologies in order to calculate integration costs, he feels the extra step could be unnecessary, and the focus can remain on system value. An additional recommendation could be to compare the ratios of system value and costs of each technology.

Brent Wanner (IEA) continued from the perspective of the World Energy Outlook work, where a key question is "When are technologies competitive?" The issues underlying that question relate to when policy support ceases to be necessary, and when technologies can be deployed on their own in markets. That is linked of course to the cost of technologies, but also the value streams and revenue opportunities for a given technology. To him, central questions are how these aspects are assessed, allocated to certain technologies, and whether this reflects what investors see (and therefore how relevant it is to them versus a system planner). As the WEO takes the system planner perspective, they do think about whether they are in all of the costs and value opportunities for each technology in a consistent way. Renewables have tended to be the focus of investigation as that's where the biggest changes are.

Analysts need to return to the original question to gauge relevance of their work, e.g. whether it is about profitability for private investors, or about whether a technology is part of a cost-effective solution from the system planner perspective. The approaches of looking at system LCOE or at two future systems are related but difficult to separate – ultimately there is a very large existing fleet in the world, and answers about what to do next are very much contingent on given systems. For this reason he is wary of comparing two systems at an end point, as this comparison can be so contingent on how you arrived at those future systems.

For their work, they see value in having a single metric, combining the LCOE with some of the additional elements discussed that they found the least contentious – e.g. changes in energy value and contributions to system adequacy – in the value-adjusted LCOE. Grid related costs were seen as so system- and location-specific that they were intentionally left out of the metric used. The goal is to then build on the metric with inclusion of other externalities that governments would consider, and if they're priced, investors as well.

Claire Nicolas (World Bank) continued from a different perspective of systems that don't necessarily have enough existing capacity, and are expanding quite fast. In that sense, VRE are not expected to replace or displace existing technologies. VRE are now cost-competitive using conventional metrics, but they also bring valuable new dimensions related to energy security and development of wider infrastructure with their deployment.

When assessing new VRE projects in this context, usually the first issues addressed are related to methods of dispatch, control and forecast generation. Introducing or improving those aspects are necessary whether or not VRE are introduced, so in that sense they are not additional. A similar dynamic is typically seen in transmission networks, which often need reinforcement whether countries would like to integrate VRE or not. In that sense, all of the cost related to capacity building, system upgrades, and T&D improvements are covered under the expansion of the energy system.

The unique aspects that could be attributed to VRE in this context would be lack of spinning reserve and lack of storage. An example was given in Senegal, where ca. 60 MW of solar additions are requiring new measures related to curtailment. In Djibouti, VRE capacity could represent a doubling of overall capacity in a few years, which introduces many unknowns. They also identify a lack of ancillary service markets as a missing piece in most of their client countries, which could promote flexibility in currently inflexible power purchase agreements, and potentially create a case for storage investment.

Open interventions from the audience and panel discussion

Following the panel interventions, the Moderator David Daniels opened the floor to the audience, noting that this appears to be one of the instances in which modellers are put in the position of being ahead of policymakers and reality – e.g. capacity markets and ancillary service markets are not in place everywhere, but modellers must do something to represent their evolution and how value and costs will be captured. He highlighted key concepts that were raised, including the importance of both system cost and value, location and timing, composition of existing systems – there appears to be consensus on their importance and some aspects of how to model these things, but less so on why we do it and who metrics are being communicated to (e.g. investors, policy makers, system planners).

Gunnar Luderer (Potsdam Institute for Climate Impact Research) first noted that he felt the discussion was very valuable, and agrees that the systems value perspective is useful and should be applied across technologies. He wonders whether it should not only be applied for supply technologies, but also for demand technologies, given their temporal profiles are also important. He feels it would be important to mainstream this perspective into private sector and policymaker decisions, particularly in terms of power market design to align incentives for system friendly supply and demand fostering integration of variable renewable energy, e.g. via flexible loads.

Marie Münster (DTU) liked the point made of not just talking about integration cost renewable costs, but rather system value of different technologies. Coming from Denmark, which is a non-nuclear country – how big of a problem are nuclear integration costs if they're considered? She is surprised to see so much nuclear in scenarios when we also hear nuclear is much more expensive. **Brent Wanner (IEA)** responded noting that the WEO work reflects country-level tracking of policy and phaseouts/expansion plans for nuclear. In terms of integration costs, their VALCOE metric is applied across technologies – nuclear power is generally operating at high capacity factor and contributing to system adequacy, but not contributing to flexibility, so its value is usually around the average. That dynamic is contingent on the design of markets, however, and if flexibility is given a higher value then you could see nuclear power providing flexibility. **Trieu Mai (NREL)** added that in terms of nuclear, we haven't studied it enough – e.g. there are difficult questions about other sources of integration costs that would affect nuclear, such as network upgrades and ancillary service needs. It is often underappreciated that a lot of ancillary service markets in the US were designed around issues related to single large plants, and nuclear plants do contribute to the need for reserves. Even the system inertia issue which is typically considered as a result of non-synchronous VRE is related to nuclear or a large contingency plant.

Brian O'Gallachoir (University College Cork) first addressed the question of relevance for such metrics, noting that there is a risk that typical cost statistics do give policymakers a false impression, and that metrics discussed here can be beneficial to provide a reality check. Also in terms of relevance, it's useful to consider what's competing with electricity. For example, in Ireland there is a challenge meeting inertia requirements with high VRE penetration. There is also material bioenergy potential related to freight that could ease the problem, but it's a question of how to fairly compare such a solution against renewable electricity (which could even be used to produce hydrogen for freight in place of bioenergy). **David Daniels (EIA)** commented that this intersects well with the points Geoffrey and Trieu made in their interventions, that comparing direct technology costs is becoming less and less relevant.

Lisa Göransson (Chalmers University) noted she shares the concern over long-term integration costs, but also thinks that system value or profile value won't solve the whole problem as they're so system dependant. With that in mind, maybe we should avoid making it easy for policy makers to take such simple approaches. To some extent this is what the energy modelling community is for – tools used can find balancing points between different technologies, rather than relying on simple metrics. **Geoffrey Blanford (EPRI)** felt this was well-said, and noted that even if you have fully inclusive system integration costs for two technologies, it doesn't tell you anything about the optimal share or if one is in the money and one is out – in equilibrium analyses cost is equal to value, so if you have something that might be greater in cost it is still in the mix because it's value is high, and vice versa. Channelling the reality represented in models into decision making could be more effective than using a simple metric.

Bent Erik Bakken (DNV-GL) explained that in their modelling they have a concept called receiving price, because the average price received for solar may be lower than other plant, solving some of the issues they see. For example, when talking to decision makers they see they are totally confused in discussions of LCOE, and ask why there is anything else besides solar PV being invested in.

Gunnar Luderer (Potsdam Institute for Climate Impact Research) argued that the previous intervention gives an example of why the system value metric could be useful, by placing it in front of policymakers and explaining how the value of certain technologies like wind could deteriorates after a certain with increasing share if no measures are taken, and how integration measures such as flexible demand and grid integration can help to maintain the system value of wind and solar electricity.

Oliver Broad (UCL) raised a question related to the developing country context, and the notion that grid integration costs are more akin to overall development costs – how is this considered by local stakeholders, and do they grasp the distinction between that and other system's contexts? Is it more of an advantage or disadvantage? **Claire Nicolas (World Bank)** responded, first agreeing with previous interventions that the concept of LCOE is no longer very relevant given system-dependency. In developing countries, for example, the fact that solar and wind farms are very fast to construct alone brings significant value versus large conventional plants. In terms of the question, utilities up to two or three years ago were reluctant about VRE since they were listening to the conversation in developed countries, and were worried that they would see major disruptions. This is less the case now, particularly due to better prospects for battery storage technologies, and more familiarity with VRE impacts.

Brent Wanner (IEA) added a final point, noting they see in markets and power systems around the world that the vast majority are driven by policies – e.g. 90% of investment is closely linked to policies. It therefore matters enormously that policy makers understand more than direct costs. As an energy modelling community, it is important to move forward to reach a consensus on this discussion, as it is central to future evolution of systems and directly linked to policy and what will be built.

David Daniels (EIA) wondered if some of the remaining disconnect comes from whether we are speaking to policy makers thinking at the system level, versus those interested in project-specific cost-benefit analysis (where LCOE is perhaps more relevant). These are two very different ways of looking at the system. **Falko Ueckerdt (Potsdam Institute for Climate Impact Research)** took up this point by noting that both perspectives, cost and value, are equivalent and can be chosen depending on the context. In addition, if policies are designed well, e.g. with a market premium concept, then the investor at project level should see integration costs via a decreased/increased value reflected in the price signals they receive.

Closing remarks

Asami Miketa (IRENA) closed the session by thanking everyone for their participation, and noting that when they talk with government officials, they are often looking mainly at immediate costs and the distribution of those costs. This presents a discrepancy with energy modellers who sometimes have a wider perspective – therefore it is important when communicating with policy makers to be clear about what costs we are talking about, e.g. social versus their distributed private costs.

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IRENA will be taking this conversation forward through future work, and welcomes continued engagement with the academic research community around events such as the IEW.

We encourage readers of this summary who may have existing or upcoming work on the issue of grid integration costs to be in touch, for potential inclusion in IRENA's activities.

Relevant references from session speakers

David Daniels, Ian Mead, Chris Namovicz, and Manussawee Sukunta. 2019. *How well do competitiveness metrics explain electricity generation capacity expansion decisions? Using LCOE, LACE, and VCR to interpret AEO2019 results*. U.S. Energy Information Administration (EIA), Washington DC, US.

Trieu Mai, Matthew Mowers, and Kelly Eurek. [Forthcoming]. *Competitiveness Metrics for Electricity System Technologies*. National Renewable Energy Laboratory (NREL), Golden, CO, US.