2DEGREESKELVIN

7 Mistakes made in the UK Solar Boom

A frontline insight into lessons for new emerging markets and susidy free solar to adopt

Introduction

A Brief History: UK Solar

For those of us that rode the ‘solar-coaster’ of the last few years in the UK, I think we’d all agree, its been one hell of a ride. The UK has installed over 10GW’s of large-scale ground-mount solar in 5-6 years which is a phenomenal achievement from where we were. From the relatively early days back in 2010-12 when lucrative feed-in tariffs were available (FiTs) and then on through the Renewable Obligation Certificates (ROC’s) period until the removal of subsidy support in 2016-17, this unprecedented adoption & deployment of utility scale solar assets took most by surprise.

The UK has subsequently experienced periods where solar (and other renewables) have dominated traditional fossil fuel power sources elevating the UK up in the world standings in terms of our sustainable and decarbonisation achievements & goals. Looking to the horizon, the biggest of all goals that we have now pledged is our 2050 NET-ZERO goal announced in 2019. As an industry, we cannot afford to make the same mistakes again as we did last time.

The Need for this Report

Anyone who hasn't been living under a rock for the last 12 months will have noticed that the worlds awareness of global warming and its contributing factors is increasing in momentum at pace. This global movement which has recently been spear-headed and accelerated by the likes of Greta Thunburg, Sir David Attenborough and Leonardo DiCaprio couldn't be more timely. With irreversible global environmental tipping points just around the corner we all must do what we can to turn the situation around and save the world where we all reside.

Most of us are aware that Energy is only part of the problem, and there are things we can all do (like adopting a meat free diet, driving electric vehicles and avoiding aviation) to make a significant impact, but all of these things at the moment, either cannot be imposed (as they are individuals free-choice) or aren't commercially digestible. So, for us in the renewables industry, the long-term promotion of renewables is actually one of the most achievable steps which can be made in the shortest period of time.

This brings us to the reason for me writing this article. Besides the fact that everything discussed is completely relevant to our carbon neutral, climate change engineering company, @2DegreesKelvin. The much more critical and pressing need to share these lessons learnt, is to attempt to highlight to new emerging solar markets around the world what happened in a subsidy-fuelled solar market boom. As well as the subsidy-free second wave of developments which is within touching reach. This hopefully will at least make all stakeholders involved more aware of what will more than likely happen in any future solar booms, so mistakes can be avoided, and high-quality solar PV deployment can be achieved. All of which will contribute to global warming mitigation.

As well as my own personal recollection of the period and touchpoints which companies who I worked with, I have also managed to gain some ideas from my LinkedIn network as to what their experiences were and have discussed this as well. So, without further ado, let's get into it.

Subsidy Solitaire 1

Introduction

The feasibility cross-section between power generation & Feed-in Tariff revenues and CAPEX costs took place around 2010-11 where the first wave of large scale (>5MWp) plants started to be built. In hindsight now these sites are highly lucrative as subsidies were elevated to encourage early adopters and these tariffs are grandfathered for 25 years. The main lessons learnt in this regard is for the government and their advisors to be cautious in the future about providing what could be described as excessive support based upon ultra-competitive adoption of emerging technologies. The FiT & subsequent ROC (Renewable Obligation Certificate) subsidies did what they were designed to do (encourage & maximise adoption), however the tax-payer liability is rather large.

Deadline Day

Another learning point for emerging solar markets to consider for any future subsidy scheme is the annual deadline timing. In retrospect for the UK market it really couldn't have been a worse repetitive deadline chosen. OFGEM probably thought that positioning the accreditation deadline at the end of the financial year was a sensible idea. However, this meant that the vast majority of ground mount assets were installed during the winter months in the UK and this has resulted in a glut of construction quality, reliability and in some cases health & safety conditions. Ground water levels in the UK are typically higher than mainland Europe and trenching works in many cases were hampered by standing water and extremely muddy conditions. Subsequent investigations on multiple sites which have already resulted in faults have exposed a total lack of industry standard cable laying (which was understandable in the conditions), and in some cases high voltage cables buried just under ground level. As well as cable installation, the weather also effected water ingress into substation and inverter house basements, which continues to be an issue throughout the UK fleet, and also historic and live disputes over electrical equipment & panel IP ratings. If the government of an emerging solar market was to choose a deadline out of choice, it would be suggested to position this at the end of the summer season, wherever that may fall throughout the world.

The Rush

The final area which could have been dealt with in a more sensible fashion which would have been better for all concerned, was the manner in which the ROC subsidies were removed. What is clear is that in the case of the UK, the development & deployment of large-scale solar was completely underestimated and also the CAPEX price reduction (predominantly solar module prices) was unforeseen. This meant that at the time where it was justified for subsidies to be removed due to inflated grandfathered commitments and reducing CAPEX costs, the government panicked and thought that they would bring forward the deadline creating a cliff-edge closure. This caused even more chaos in the final throws of the subsidy period where sites rushed to complete, developers had dozens of sites in the pipeline which needed to be canned and the resource vacuum in terms of resources being pulled in to the solar industry was over in a flash. A more considered and gradual removal would have been a much more sensible approach.

Pump & Dump Shovel-Ready Flips 2

The Power of Profit

Having spoken to all of the different company types involved in the utility scale sector, the general consensus is that developing solar farms is where the best money is. In other words, for the risk and effort put in, developers make the biggest returns. Thats not to say that it is a risk-free activity, as significant upfront investment is required and due to the hit-rate, high rolling developers need to have multiple sites (if not dozens) in the development pipeline at any one time. However, the point here is that the 'pump & dump' strategy that developers deployed during this boom, all be it a lucrative commercial move was to the detriment of the solar industry as a whole. Substandard specifications, generic planning compliance measures and hungry investment funds wanting scale inflated shovel ready project sales and made the developers a handsome profit. If the global adoption of renewable energy sources has become more of an ethical and environmental push, then multi-layered margins will in the future be frowned upon. To minimise the levelised cost of energy, you would benefit from a vertically integrated organisation who develops the site, builds it, operates & maintains it and owns it.

Poor Planning, Poor Condition

The other contributing factor to the general condition of the solar farms developed and built during the solar boom (in the UK at least) was that the designs and system specifications were weak and immature. There are a small number of exceptions, but developers in general cobbled together basic designs, vague material & equipment specifications with their eyes on the prize of maximum profit at shovel-ready exit. Designs did not think about the long-term operability of the asset, and specifications were not specific enough, meaning the EPC's had free rein to buy cheaper materials & equipment and subsequently we find ourselves where we are today. It is also worth mentioning that the modelling & simulating of solar developments, usually conducted through a software program called 'PV-Syst' was on a wide spread basis only conducted to 'string-level' meaning that shading & other loss accuracies were not as accurate as they should be. I would strongly recommend that new builds conduct their PV-Syst simulations on a module level basis. This is more complex to model, but the accuracy levels are significantly improved, and therefore the long-term commercial modelling of the site and its production levels are much more accurate.

Standards Slipping?

It was also evident that the local planning authorities were taken by surprise by the huge uplift in solar farm planning applications. In the early days at least, they did not hold any experienced solar qualified or experienced personnel and due to the positive pressure from government to adopt renewables, I would suggest that in many cases they did not provide robust enough standards in terms of development & design expectations and probably followed the path of least resistance to get sites developed, built and on the bars. Over the last 5 years or so, the solar industry in terms of design, ecological measures and community incentive schemes has come on a long way. With this in mind, planning authorities in emerging markets should adopt high standards across the board. If we're going to do it and its going to last the full 25-year design-life, let's do it properly.

Invest in Green & Clean Renewables

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Sorry, How Much?

The banking, finance and investment sector rules the world. They generate trillions in revenue and billions in profit so let's not be that naive to think that funds and investors are investing in renewables to save the planet. They are doing it to make serious returns. In the UK alone, if there is approximately 10GW's of utility scale solar deployed, taking an average price of build cost of £800/kWp, you are looking at £8Billion invested. Most of these investors have been promised attractive returns for the lifetime of the site, and as we stand today (with a few embarrassing exceptions) the asset owners are delivering, and-some. Power revenues and subsidy support are generating significant profits, particularly on older (earlier built) sites. My hypothesis is however, that this is short-lived and asset owners need to become focused on pro-active site knowledge enhancement approaches to enable them to see issues coming before they effect theirs and their investors returns. I would estimate, based on the site inspections I have been involved with over the last 5 years, that between 60-70% of all installed sites will be generating significantly less than simulated within the next 10 years. Portfolio-wide revamping & repowering investments will be required to ensure returns are maintained, and the early adopters of this punchy strategy will be the biggest winners.

Invest in Expertise!

In the early days of 2010-12, there were only really a handful of individuals who had any technical & commercial knowledge and experience in the large scale solar industry, and of course these were people who had come to the UK from more mature markets (Spain, Italy & Germany for example). So, for the first half of the boom, fund managers and asset owners really did not have the technical & practical expertise to really know what they were dealing with. They'd been sold a hassle-free, green & clean money-making machine and didn't really appreciate the eventual necessity to invest in solar experts. So, to all of you asset owners out there who have just picked up your first few sites in emerging markets, have dreams of owning GW's of solar and do not really know the technical & practical in's and out's of solar & electrical systems, my strong recommendation would be to invest in expertise early. It will pay dividends in the long run.

Risk vs Reward

The other pre-conceived notion is that ‘solar is simple’. It’s such a simple technology that its basically ‘fit & forget’. To a large extent it is, but only if it’s done correctly. I have come from the utility power sector (coal, biomass & waste), where highly complex, multi-dimensional process systems are designed and put into service with 100 times more rigour and engineering consideration. You have liquid, gas & powder-based chemicals, pressurised water & steam systems, turbines, pumps & motors, boiling & flash points, enthalpy & entropy, combustion processes and more, even before you get to the electricity hazard part. In all of these power generation project developments you will have an array of risk mitigation strategies focused on process & personal safety. You have HAZIDS, HAZOPS, HAZCON’s, SIL Assessments, FMEA Assessments and risk registers, to name a few, all of which I have been involved with over the years. The point being, is that even though many would argue that solar is simple and developments do not justify this type of rigour, if they would have been applied, the standard of design, construction, operation and revenue generation would have been higher. Its also interesting that in the emerging subsidy-free market in the UK, that these risk mitigation strategies are starting to be applied, meaning that Hazard Operability Reviews (otherwise know as HAZOP’s), are in the EPC scope, to ensure that an elevated level of process, performance & human safety considerations have been applied to the design and construction phase. For the new emerging markets out there, I would recommend these types of approaches are adopted from the get-go.

Just Sign it Off Mr Technical Advisor 4

Lack of Solar Understanding

Before I start my rant on Technical Advisors (TA's), I wanted to be clear that there are a few companies out there (a couple of young consultancies in particular) that are doing some great work and have moved on from the UK solar boom period. Good on you, keep focusing on value and investing in real expertise.

The first obvious issue when a relatively new technology emerges and is deployed at the pace that solar was, is that the UK based consultancies and TA's only had a sprinkling of solar understanding and zero practical knowledge or understanding of how solar farms should be designed, built, commissioned and operated. The majority of the 'old-guard' TA's were established engineering consultancies which deployed their services and resources on a plethora of more traditional energy generation projects and thought that solar was a natural transition to deploy their academic resource pool to. In the absence of any real understanding they reached out to individuals who did have real solar knowledge from more mature markets.

Money for Old Rope

I'm sorry to generalise, but TA's don't have a great reputation in heavy industry generally, and more relevant to this article, in the solar industry unfortunately providing value wasn't on the top of their priority list. Notwithstanding the more established consultancy firms, the emerging renewables focused TA's have a suite of report/study templates, (which probably have all been passed down over the years from one organisation to the next), and then they deploy the optimal resource to get the job done in the most economical way possible, and of course fill up their personal utilisation rates. My on-site encounters with TA's over the last few years when we have been providing in-depth site assessments consisting of practical experience-lead audits, investigation, testing and data analysis, is that a team of graduates (not generally in a technical subject, i.e. Geography) have been headed up by one engineer with some experience, they walk around the site for 2-3 hours and take some photographs, and then have the audacity to ask us what we've found so that they can put it in their report to bulk it out a bit. This happened on several occasions with different TA's. Unfortunately, the phrase 'money for old rope' comes to mind. My recommendation to those who are commissioning TA services, is to do your homework, don't go cheap and test them first (try before you buy).

Do Your Homework

My final irritation when it comes to TA's (and sorry to all of you out there reading this), is the low standards of technical due diligence, pre-acceptance & final acceptance sign-off. As the technical lead, developers & project/site owners were depending upon these so called experts to ensure that what was installed was what they paid for, and not only that but the design was sound, the materials and equipment were fit for purpose (and I mean actually fit for purpose for the UK, as appose if that's what they use on mainland Europe, that's fine with us), the construction and commissioning standards were industry best practice, the as-built documentation suite was developed and was accurate. The list goes on and on and when you think about the pressurised environment that everyone was in at the time, there seems to have been a perfect storm in terms of how the widespread standards of sites actually achieved their G59 connections, how the collective thousands of holistic mistakes, shortfalls, defects and missing documents were brushed over under the shadow of the pending subsidy deadline, and how these technical advisors collected healthy fees to deliver all of this whilst adding to the price point pressure further down the supply chain.

This isn't an easy fix, and certainly I generalise a fair bit when listing all of these negative elements all laying at TA's doorstep, as there were of course exceptions to the rule. Some TA's out there, particularly younger, more solar specialist in their approach have done and are doing a tremendous job and are focused on customer value and applying technology to accelerate this value. However, the proof is in the puddling for the majority of sites that I have assessed at least, the standards just weren't there and stakeholders requiring a TA as part of the list of requirements that an investor needs, should do their homework, check their references and the standards of the resource that will be put on your projects. Geography graduates are no longer acceptable.

Focus on CAPEX over OPEX
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The Problem with Shortcuts

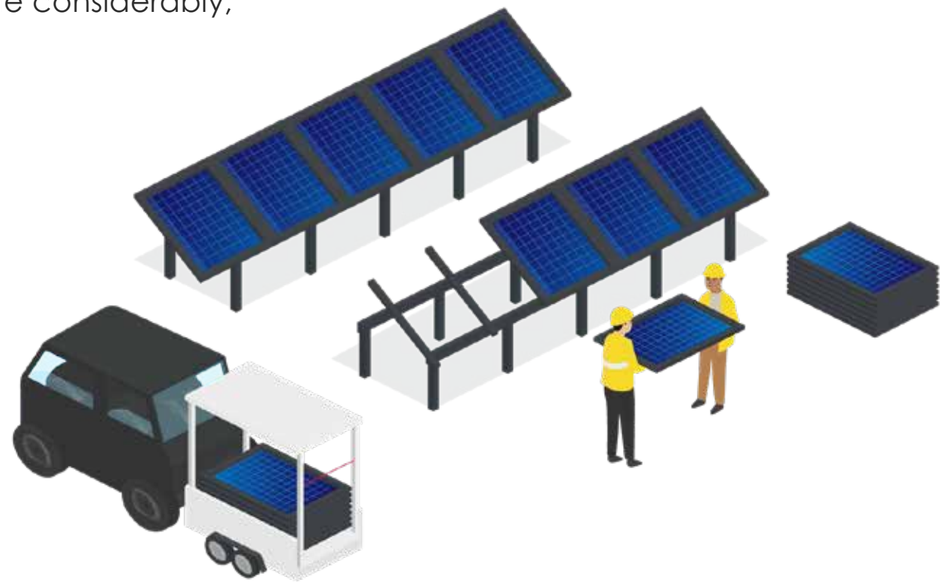
I've had the perhaps unique perspective where I have been involved in the development process, the design & build process and then subsequently the Operations & Maintenance (O&M) process on the same sites. Therefore, I've seen the developers focus of their exit price and building pipeline. I've seen the EPC's (general approach) to maximising profits and installing in the most efficient way possible whilst complying with the contract. And then the birth of O&M companies who inherited industry standard and TA specified O&M scopes which were static and generic in most cases.

But lets be clear, the selection of the equipment & materials that are installed to formulate a solar asset are usually dictated in some way by the planning footprint & controls, the connection capacity and the ferociousness of the EPC price competitive environment. If a portfolio owner wants to build a reliable, high performing set of sites which will last the design-life and be worth top dollar, then they invest in the CAPEX making sure that the design is optimised, the materials & equipment selected are truly fit for purpose, they invest in pre-construction quality checks to ensure that the site is in perfect condition from day one of operation, they invest is top quality TA's to cross-check all of these elements. However, if any of these areas are cut due to short-sighted CAPEX savings, then it directly effects the levelised cost of electricity and the overall project profitability goes down. If you scrimp and save upfront, it will cost you more in the long run. In the UK the evidence of this is starting to show itself, as we are getting into the 4-8 years of operation stage and we are witness to CAPEX shortcuts which manifest themselves as losses of production & yield, availability, reliability, safety & longevity issues. Buy cheap, buy twice.

Portrait vs Landscape

Going a bit deeper into the basic design of ground mount solar arrays, the other gripe I have which we see a lot in the UK at least, is that the way the site has been designed. In many cases the layout is focused on maximising installed capacity and to save on build materials. So, the basic concept here is to cram as many MWp's on the land footprint as possible with as little materials as possible. In some cases, this makes sense, but in the majority it doesn't. Designers following commercial instruction and EPC norms lay down array configurations which essentially contributed to higher returns. One popular play was to go with arrays in a portrait arrangement (to maximise installed capacity) and to string the modules in a horse-shoes configuration which saved cable. The major long-term and compounding issue with this approach is that you maximise the effects of row-on-row shading which covers all three diodes on each panel for a lengthy period of the winter months, and if the strings are strung in a horse-shoe configuration, then this effects every string on the site considerably, compared to only half if they were strung horizontally, costing a little more on cable.

The additional spend on cable is peanuts compared to the revenue returns of the correct stringing method. Stakeholders have become savvy to this and there has been a noticeable shift to landscape configurations and lifecycle returns in terms of stringing configurations, so new builds need to be locked into this easy win during a pre-construction phase of development.



Managing Sites

We mustn't forget that with all of this front loading, including developers, EPC's & TA's, its actually the O&M company that has to deliver their scope of work with only scraps available at the end of the value chain budget. And of course in most cases the O&M has had no input to the design and has to find the balance between being a competent, prudent and professional service provider and communicating everything to everyone, and also not placing the EPC in hot-water with regards to design, equipment, materials and installation standards. O&M's have a tough job to get it right, and with the market consolidating, there is little room for small to medium scale outfits as they are pushed out by larger multinationals with GW's of scale and large balance sheets. O&M companies inherited European norms in terms of prices and scope. These have progressed aggressively over the last 3-4 years, with prices going down and scope expectations going up. Even though the newly formulated O&M Best Industry Practices guidance document has been developed by contributors in Solar Power Europe and the Solar Trade Association, where an O&M performance incentive concept is recommended, I am yet to see this being adopted in any way in the market. O&M's generally now have stripped back scopes, with a list of extras that can be called upon if needed. They also hold a lot of risk in terms of liquidated damages, on performance, availability, response and rectification times. This has and will continue to put O&M companies out of business. This works if the objective is minimising OPEX, but in my view is very short-sighted and owners will pay for this short to medium term play when the sights mature. We are already seeing sites that are underperforming just because of lack of professional O&M alone, not to mention design & build quality. Owners need to think about a more 'partnering approach' with their O&M's and value realistic OPEX into their models. Supporting them with financial incentives to maximise their value. The role of the 'Asset Manager' also needs to come under some scrutiny in my view, as their roll in all of this is transitioning from a functional commercial role, to convincing asset owners that they too can add value in a more strategic and technical way. I agree this is necessary, as in most cases they are taking zero risk and generally just administer the power sales and subsidy revenues of sites and portfolios, and beat-up the O&M due to lack of performance. The asset owner who finds a professional and forward-thinking asset manager and O&M contractor in a tri-party partnership will win in the end in my view.

The Module Delusion
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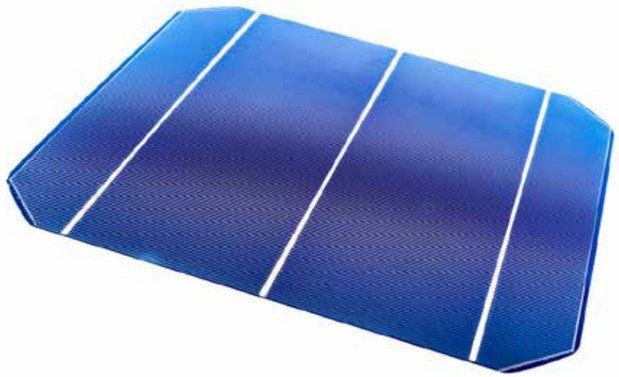
The Solar Module

On to solar panels or modules as I call them. This is the core technology element of any solar asset. Solar PV (or photovoltaic) module prices have plummeted over the last 10 years, efficiencies and watt outputs have evolved significantly and it is this that has accelerated the global adoption of this renewable technology. Historically the purchase price of the modules would have been the biggest collective expense to any solar installation, contributing to over 50% of the total build cost. This percentage is coming down as prices reduce. However, the overwhelming emphasis of material/equipment selection when it comes to risk is focused on the modules. The module manufacturing market is massively competitive and saturated. Many companies have come and gone as it is a massive capital investment to set up and success in not guaranteed. They are all jostling for position to become a 'Tier 1' supplier on the Bloomberg list. This list is formulated on financial status of the company and doesn't necessarily reflect the quality of the panels. But in many cases hasn't been understood and poor purchase decisions have been made without any pro-active due diligence. Material checks, manufacturing facility audits and bill of material testing documentation production have only been checked in the minority of cases. I am also aware of cases in the early days where the provenance of solar cells, module serial numbers and nameplates were falsified, meaning that testing documents & modules provided did not line up. This of course means that so-called 'Teir 1' modules have been purchased in massive volumes, installed in the field without any checks and now we are seeing wide-spread manufacturing related defects which are seriously affecting the output of the site. In the last 18 months, we are aware of sites which need complete replacements of modules due to these defects.



Keep Quality Assurance

To reduce the chances of this crippling loss during the adolescent period of any given site, I would strongly recommend as well as the focus on manufacturing facilities and their material selection and manufacturing quality, that developers and asset owners invest in pre-construction quality sampling to eliminate loss generating defects from day one of operation. Applying general inspection principals, modules can be checked as they arrive on site with mobile module testing simulators and Flash & Electroluminescence (EL) measurements taken to check against the manufacturing tests, ensure that they are within the understood nameplate tolerances, ensure they are from manufacturing batches and facilities that you have been lead to believe and ensure forensically that no damage has been caused by the shipping & transportation process. If defects are found, sampling numbers are increased.

Then utilising either spot-check or high-volume EL technology, once the modules are installed into the field, modules can be checked to ensure that module handling on site and installation standards are being met and that no damage is inflicted as the modules are being installed. This process will improve the focus of the EPC on increasing installation standards, it will ensure that no damaged (loss generating) modules are installed from day one of operation and also will start the process of having a EL fingerprint of the site which will add value to the asset if it was sold at any point. The upside of which massively outweighs the CAPEX investment.

Who's to Blame?

The final module-based lesson that I think should be shared which needs to be focused upon for new build, is the balance between cheap & effective installation teams, and due to this cheapness or lack of suitable supervision or specified standards, the installation of latent defects from day one of operation. In the UK it's a topic that causes frequent industrial relations issues. 'British Jobs for British People' is the phrase held aloft on picketing placards. The issue is for the solar industry, that when labour was required to install 10GW's worth of solar farms, firstly no one in the UK knew how to install solar on a large scale, so we had to look elsewhere. Secondly, British prices for labour are expensive when compared with mainland European labour rates, and finally (and this is a bit of a generalisation), British people wouldn't do this type of work for the money that our European friends would.

Therefore, EPC's (in the majority of cases) employed cheaper multi-national labour pools, who would come over to the UK, work incredibly hard for short intensive periods (sometimes camping on site) to get the sites constructed at break-neck speed. Although not in all cases I'm sure, but combine the 'job-a-knock' nature of the offering here with minimal quality standards and installation norms, and unfortunately you will understand that on the vast majority of sites I have assessed and therefore you'd think could be assumed on a fleet basis, this haste has installed loss generating defects everywhere. Defects caused by transportation, unpacking, handling and mounting have not been caused intentionally, but perhaps the lack of awareness and knowledge of these installation teams could have been improved and would have a direct impact of power generation, project returns and countless hours of finger pointing when it comes to who's to blame when defects are found. And of course, now these defects are there, asset managements & O&M's are looking closer and they find these issues, who's to blame, because someone has to pay for it.

We do it this way in Europe
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UK vs Europe

Again, not wanting to be too negative about this particular area of potential improvement, but what I encountered during the boom was that the vast majority of EPC's (principal Contractors) who were responsible for building the solar farms were from mainland Europe and in particular the more mature solar deployed nations. My concern which developed through observation and being involved in multiple installations is that there was a worrying discrepancy between the UK regulatory requirements relating to electrical standards & safety, and the practices that were being deployed by the majority of EPC's. Feedback received from multiple EPC's was that the UK requirements were very strict and where possible if they could get away with doing things the European way, they would. This isn't to say that standards did not improve. I think most of the contractors and individuals were forced to drastically improve their overall site & constructions safety, electrical safety rules, isolation & switching procedures and cable laying & termination quality. I wasn't aware of many serious incidents during the period, well non which made the press, but this was more luck than judgement.

The major concern is that many of the emerging markets are in countries that do not have the heritage and advancements in electrical & construction safety. This is an area to really focus in on in places like India, South America, China and even Australia over the coming years.

Planning Headache

Another area which I think took the European EPC's by surprise was the extent of planning measures which needed to be applied to each site. Feedback I received was that the measures adopted to sites in mainland Europe were nowhere near as extensive. Wild-flower meadows, native hedgerows, wetland & pond restorations, bat-boxes, badger gates, log-piles, beehives & deer-fences to name a few. In many cases these all became an after-thought and in some cases have caused issues which need ongoing management for the life of the asset. Wild-flower and grass seeding specifications for example were heavy, devised by UK TA's & Planning authorities and European EPC's were not familiar with these specialist areas, meaning many sites simply did not get planted with them, some were planted wrongly, and others were over planted. Add to this the specific grass/vegetation management measures required which were/are often ignored and you have many sites which are not compliant. The lesson here is for EPC's to get into the detail and make sure they understand the local planning requirements deeply. Partner with local specialists and embrace biodiversity.

Dear Stakeholders...

The final warning which I want to identify to new markets comes down to resources. As previously discussed, you can only parachute in so many roles and labour from cheaper regions or it starts to affect the quality of the end product. As the market progresses and more and more demand grows on skilled and experienced resources, there will be a requirement for local, regional or national resources which may need developing and more advanced supervision. All of this creates a labour vacuum in the case of the UK following the rapid removal of the subsidies, which created a large volume of solar oriented labour which found themselves out of their jobs. This is not an easy fix, but a situation which all stakeholders need to be aware of in new markets.

Wrap Up

Solar development is never going to be perfect but if emerging markets and the subsidy-free wave of deployment adopts these 7 areas of learning from the UK solar boom, they will be maximising their chances of long-term asset performance & solar technology implementation.

I would welcome all of my network's views on this report and its content. If I have missed any glaringly obvious lessons, please chip-in and share.

If anyone wishes to discuss any of this with me, then please get in touch via LinkedIn (www.linkedin.com/in/john-davies-ceng)...

...or email (john@2degreeskelvin.org).

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