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The Road to Repower

Introduction

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The terms revamp & repower are relatively new to the solar PV industry, and essentially for me describes the collective adjectives to increase the assets performance, reliability, and life. In some cases, the safety of system may also be improved or upgraded.

Most solar farms are designed to last 20-25 years, and I have heard of sites in recent years with a design life of even 30-40 years which personally I think is pushing it a little, particularly in climates such as the UK.

However, when you appreciate the speed in which many sites were/are constructed under subsidy pressure in solar booms around the world and the relatively immature design, procurement & construction standards employed, then from my perspective after visiting over 10% of the UK fleet, my hypothesis is that the majority of this fleet will not make the originally proposed design life of 25 years without substantial intervention.

Systemic failures, premature deterioration and component obsolescence will prevail and along with it will be a blood-bath of warranty cases, legal adjudications and losses to investors. Afterall, someone has to pay for it.

The Opportunity

I believe that there will be a new developing market in revamping & repowering distressed assets with the ultimate priority for asset owners being their financial commitments to their shareholders and investors. This can be achieved if engineered solutions are implemented which improve performance, reliability & longevity.

Dabbling will not pay off...

This is not necessarily a market for traditional EPC's to enter who are used to this scale of project on a fresh and clear piece of land. Although several EPC's will contemplate the growing opportunity and dip their toe into this emerging market. But due to the complexity and nature of such projects their profit margins and risk profiles will jeopardise their long-term domination in my view.

I'm sure that a few of the O&M main players will also throw their hat into the ring to take on emerging revamping & repowering project opportunities, but are these types of companies suitably experienced to be delivering complex, data heavy, high volume exchange projects? I fear not. They may have done a few corrective action-based mini projects on assets they manage, but fundamentally, the majority of what they do is visual inspections and monthly reports. Trying not to be too critical of O&M companies, I know how hard they work and that they have a tough job, I have spent 8 years of my career being one. Its just from a project delivery perspective I question their resource and technical capacities, they are struggling to keep up with the growing levels of distress anyway, without contemplating larger projects.

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Will TA's chance their arm and get involved in this emerging opportunity? Maybe, certainly on the engineering side of things. I very much doubt that they will have the capacity or appetite to take on the site-based elements of the projects, as the risk profiles are too high, and they are not set up for it.

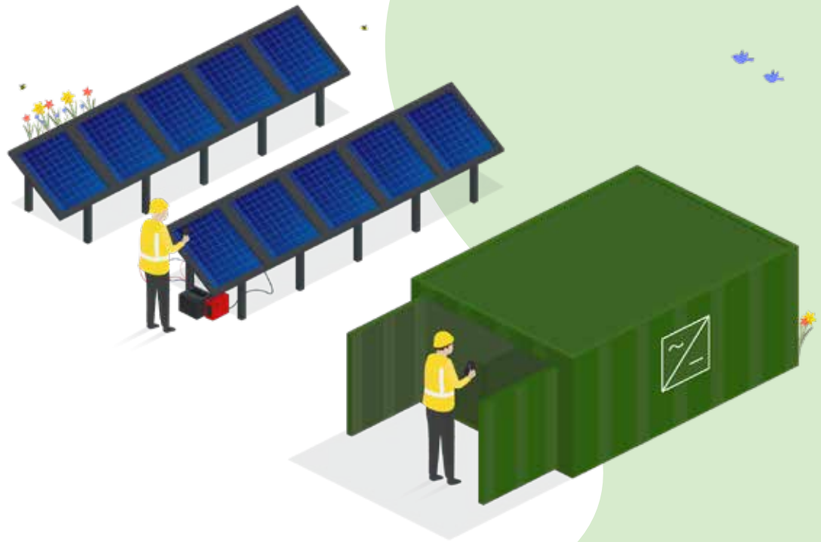
So, who will emerge as market leaders in this new repowering market? What's needed as this new market emerges is professional engineering & project management specialists to ensure these complex retrofitted projects are suitably engineered and delivered. This will no longer be cookie cutter EPC build or O&M inspection type activities, this will require a whole new suite of skills, experiences and learning which is yet to be appreciated.

So what is Revamp & Repower?

So what does the terms ‘revamp’ and ‘repower’ mean to me?

I think the term ‘revamp’ relates to potentially a range of various planned improvements or even optimisation measures which can be applied to a site to increase its performance, safety & longevity, but without major change outs or exchanges of major components.

Some in the industry may argue that repowering only occurs when you exchange/upgrade the power conversion element of the asset (i.e. the inverters). I’m not completely aligned with this view as I believe that if a sites modules (the power generating component within a solar farm) were exchanged for a higher power class (250W for 350W modules for example), then a repowering engineering exercise needs to take place. This is not just a case of swapping the components over. The string lengths & configurations need to be calculated, the effects on the inverters and protection settings also need to be factored in, not to mention the interface with the mounting structure, OFGEM and planning considerations to name a few. In my view this type of project would be classified as ‘repowering’ also.



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Repowering Projects

Introduction to Repowering Projects

The most common repowering project, although new to the industry, is the exchange of the inverter technology. Since the early 2010's, many inverter brands have come and gone, and in these cases asset owners are left with unreliable inverter sets, negative impacts to performance levels, little to no spares, no specialist technical inhouse or external expertise or support and a real question mark over the long-term viability of the asset.

Most of the inverter repowering projects I've read about in Europe involve the exchange of a centralised inverter set. Either in a 'like for like' type exchange where similar power class, inputs and outputs and footprint inverters are put in the exiting inverters place. Or, in a more interesting and innovative approach, have taken advantage of the AC & DC cable design on the site (avoiding site-wide re-cabling) and re-designed a 'centralised-string-inverter' arrangement. Placing multiple string inverters all in one collective location. This may be a containerised or a building-type structure where 10, 15, 20 string inverters are located.

This strategy brings with it a few advantages...

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1. If an inverter goes down, then it is only a small proportion of the system which is not producing compared to a much larger proportion of the site with a centralised inverter.
2. In terms of O&M, all of the string inverters are in one place rather than dotted around the field. This will save time & money in the long term.
3. String inverters are easily fixable and/or exchangeable. O&M companies will hold several spares on site, so down time is minimised.
4. Procurement quality assurance measures can be employed to ensure that this particular brand of inverter manufacturer are in it for the long term. This would not have been done several years ago.
5. Coupled with in-line IV-Curve tracing and module level real-time analysis, string inverter systems do bring several more advanced operational and asset management advantages over their centralised counterparts.

There are of course other types of revamping & repowering projects which are likely to increase and 2DegreesKelvin have been involved in already in the UK. Lets take a look at several of these now...

Module Orientation & String Configuration

A large proportion of the UK fleet were installed in a portrait orientation as more installed capacity could be squeezed onto the field. From an EPC's perspective, the more MW's installed, the more the project is worth. The strings were also strung in a way that was cheaper and more convenient to install, meaning that instead of them being, for example 22 modules strung horizontally, they were strung in U-type or C-type shapes (11 on top connected to 11 below), so that DC cable return-runs were reduced.

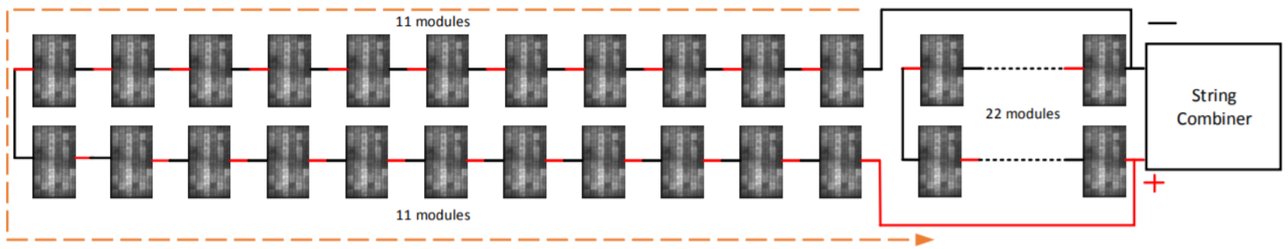
The two pronged problems on sites which have these U or C type string configurations are, that they suffer from much more pronounced row-on-row shading loses, as the shading will creep up the lower edge of the bottom row of portrait oriented modules (particularly in the winter months), and will significantly effect output power of those modules and subsequently the rest of the modules in the string. But what makes this effect even more of an impact, is that due to the U or C-type string configuration, that the shading effects every string on the site.

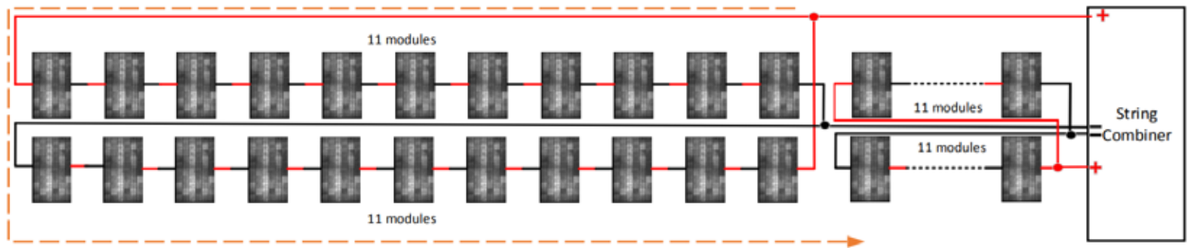
Module Orientation & String Configuration

If the modules were landscape orientation, then shading on the bottom sixth or third of the module will have a much smaller impact on production due to the modules bypass diode design. Also, if the strings were strung horizontally, then the shading loss effects would only affect the bottom row modules/string on site. The upper rows would remain in full sun and producing well. Certain inverter sets can be strung with bottom strings and others with tops, or they can be spread out to increase site-wide design efficiencies.

Significant yield improvements can be gained in reconfiguring the module orientation and string design on a tightly packed site, which will payback in a short number of years and for the rest of the asset's life. In many cases the exchange for higher quality DC cable and DC connectors also has a significant impact on RISO faults and inverter trips which is another advantage.

The high number of assets with portrait orientation modules and distressed DC systems in general will force the market to change orientations and in doing so fully exchange the DC systems.





Horizon Line Shading

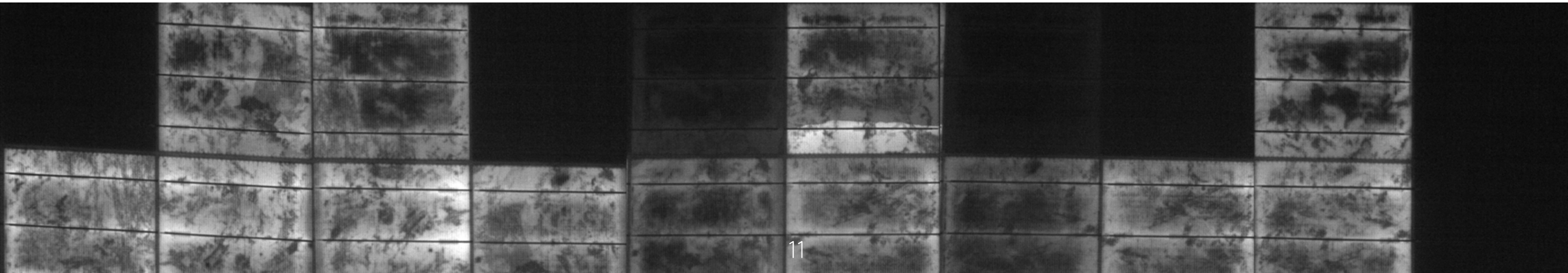
I have seen on a number of sites over the last few years where trees, many of which are protected by tree preservation orders, are causing substantial horizon-line shading on the Southerly and Westerly corners of the site, and subsequent production losses. These trees and their growth rates could have been accurately modelled but were not. In the cases I was aware of, tree growth rates were also significantly underestimated. So, what do you do? Its only going to get worse. They are protected by preservation orders so you cannot just chop them down.

An accurate model of the horizon line needs to be captured and this in turn needs to be represented in a module level PV-syst simulation to present its true impact on the production of the site. We then target areas which are worse effected and design and install focused optimisation technology. Module and/or String based MPPT trackers can be deployed to the worst affected areas and the shading loss effect can be minimised. Projects that we have worked on have seen 2-3% yield increases which retrofitting this technology to approximately 6-7% of the strings on site, providing the asset ownerwith an 18-month payback. These types of project do however need proper engineering and considered thought. It’s not a simple plug and play, you will need engineering specialists to conduct a study and design retrofit details.

PID Healing

PID or Potential Induced Degradation as its full name, is caused by polarisation & leakage currents on solar farms and modules in particular. Modules with a negative potential to earth, generate an equally high negative voltage between the cells of the module frame. As a result, electrons flow out via the frame & increase the polarisation. This causes cells closer to the frame (outside cells) to start to degrade and this phenomenon spreads inward and if left untreated will cause catastrophic damage to the cellsand significantly degraded module, string and inverter output.

PID can be identified in extreme cases in data monitoring platforms, comparing strings with each other and lower producing strings may have a PID effect. Another way to detect PID is the use of IV-Curves using specialist test equipment to create power curves and in stable irradiance conditions the irregular shape of the curve would suggest PID. You can also see the PID effect (checkerboard patterning) in aerial thermography surveys, but unfortunately in some cases this has proven to be other types of operational conditions instead, so is not a slam dunk. The best way to detect and confidently diagnose PID is with Electroluminescence testing. This form of testing can detect even early onset PID clearly and can provide indisputable evidence in warranty claims or in the justification of funding a rectification solution.



PID Healing

There are several technology options on the market for PID healing. These pieces of hardware are connected to the DC circuit on site and restore the natural flow of electrons by providing a night-time circulation of voltage. Some systems are better than others and 2DegreesKelvin have a very strong partnership with a world leader in this area and as of the time of writing this book we have installed systems on over 260MWp of solar farms.

The interesting thing is, that PID is everywhere in crystalline modules, even so-called 'PID Free' modules, they all have PID. It's just whether the effects are measurable or visible. This type of technology can be fitted to any system & would have the biggest effect on modules where PID is mature (some cases >20% restored power), but amazingly will have a site-wide effect of >2-3% output on a site with no visible or measurable PID.

I believe there is a strong case for installing these types of technology systems to assets purely for performance gains alone. Not to mention PID prevention for the future, and more critically that they can be fitted on sites that are currently negatively grounded which is a massive health and safety hazard (i.e. negatively grounded sites can be disconnected, removing the health & safety hazard of personnel electrocution on site).

This type of technology is a form of antidote to module degradation and is a slam-dunk no-brainer in terms of investment v's payback.

Anti-Reflective Module Coatings

Over the last few years there has also been the development of a proprietary application of anti-reflective and anti-soiling coatings, which can be applied to solar modules to increase light absorption, minimise soiling and therefore increase production levels.

Module manufactures started applying this nano technology to their glass fronted modules several years back. However, there are a proportion of crystalline modules types installed prior to 2012 and the majority of thin-film modules out there on the market, where an anti-reflective coating was not present.

These types of coating are applied to modules and across entire sites where solution providers are achieving 3-4% performance increases relating to the anti-reflective coating, and in some regions of the world a further 5%+ from the anti-soiling element (particularly in dusty & dry locations).

This technology is maturing and in particular the application processes of array mounted applicators is moving forward at pace. It's critical of course that product developers ensure that retrospective coatings applied will not invalidate warranties, will last a long period of time, will not be worn away by annual cleaning and most importantly for asset owners, provide a sizable ROI.

Watch this space, 2DK are developing relationships this year to add this type of performance-enhancing solution to our service portfolio.

Warranty Claim Exchanges

The Ageing Asset Problem

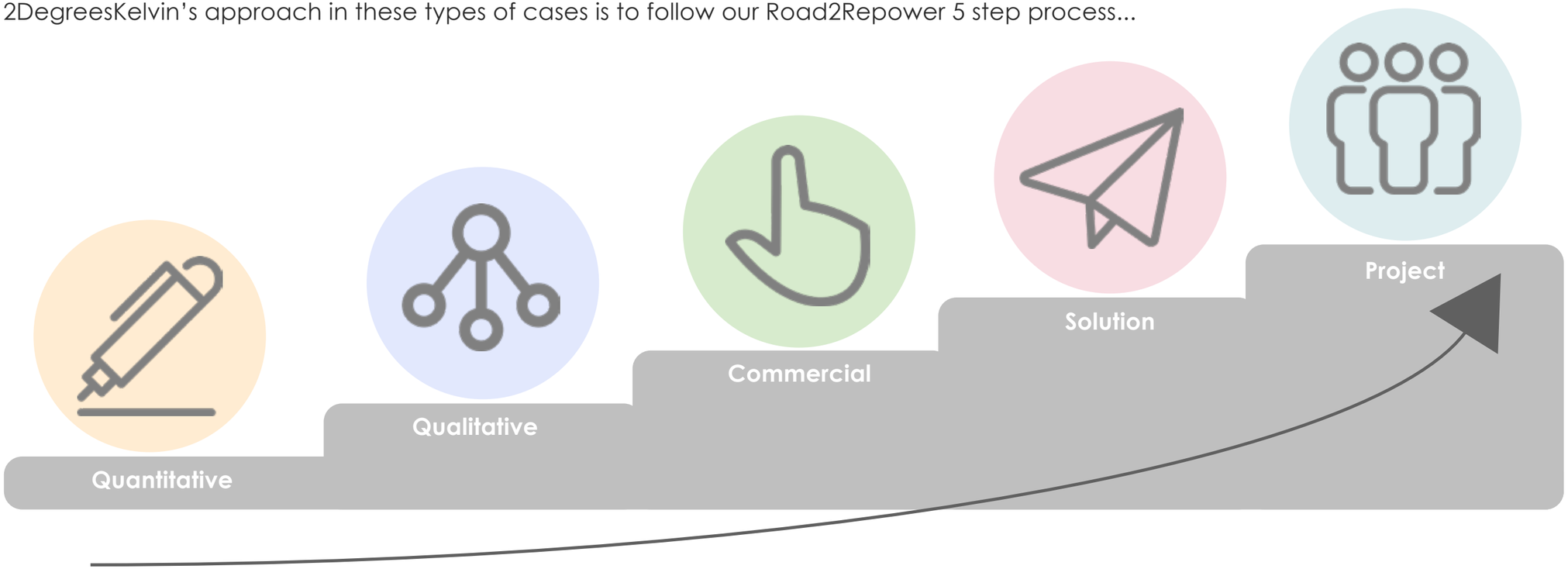
With assets ageing all over the world, owners are starting to focus more on product warranties. If the PAC (Preliminary Acceptance Certificate) to FAC (Final Acceptance Certificate) period is over (which is usually the first two years of operation), then the EPC from a performance guarantee perspective walks away, and so whoever takes on the plant takes on the liability for the product guarantees and warranties.

The other situation which seems to be developing is that asset owner/operators do not hold enough spare parts, and these are being depleted at a rapid rate. We have seen multiple examples where due to lack of spares; different manufacturers of modules are being inserted into strings. In some cases, even with different power classes. This will cause system inefficiencies and warranty related risks will rise. As module power classes and module dimensions rapidly increase, this is becoming an issue and asset owners/operators will be faced with more extreme revamp/repower requirements. This of course is also happening with inverters and HV equipment.

A 2DegreesKelvin Approach

From my experience in the UK over the last few years the majority of warranty claims related to the modules, with the minority spread over the other main solar system components (including inverters, switchgear & transformers, cabling, connectors, CCTV systems and the structure). If we focus on modules for a second, but the same process can be applied to any component. Asset owners are looking at their assets, they are seeing potential PID, delamination, snail-trails, discolouration, backsheet issues, junction box issues and they are thinking… What impact is this having on the performance of the plant and its accumulative and compounding effect on revenue and can I justify an investment?

2DegreesKelvin's approach in these types of cases is to follow our Road2Repower 5 step process...



Road2Repower: 5 Step Process

1 - Quantitative Assessment

If you don't know how widespread the problem is then how do you know what testing methodology and sample size to choose? If it only effects a very small number of modules or compontents on site, then is it worth taking the more expensive next steps? We usually devise some sort of quantitative survey with an agreed inspection methodology which will gather suitable evidence to be used if needed at a later stage of the claim or investment project.

2 - Qualitative Assessment

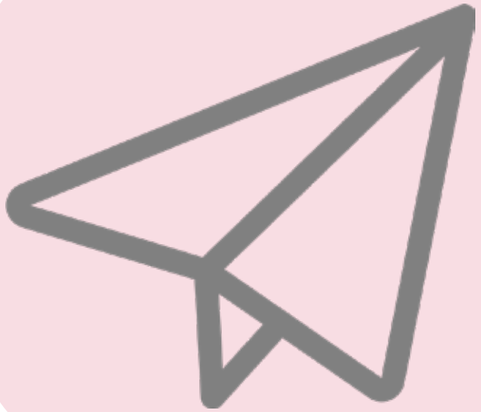
Depending on the issue, the quantities involved and other factors a qualitative testing and/or investigation procedure will be devised with the sole objective of attempting to prove or disprove the effect that this issue is having on the performance, reliability, safety or longevity of the asset. This can be done through mobile module testing, in-situ electroluminescence testing, string, IV, Shunt & Series resistance testing, even in some cases by a thorough analysis of the production data.

3 - Commercial Assessment

Using the outcome of the quantitative and qualitative assessments, apply the learnings to the asset in question. Multiply up the compounded losses and present an impact model which shows the site owner or interested stakeholder what the power and commercial impacts truly are. This should be backed up with accuracy ranges and assumptions.

4 - Solution Proposal

If the outcome of the first three steps is sufficient, and the accumulated or live losses are at a level to warrant exploring what you can do about it, then this penultimate step is justified. There is always something you can do to improve the situation. Whether that be a re-design, physical on-site adjustments, retrofittable technology solutions or operational strategy adjustments. There are solutions out there, and it is up to the Revamp/Repower specialist to clearly define the solution, its benefits and how it counteracts the losses or negative operational condition of the asset.



5 - Project Delivery

It is essential that the site owner or stakeholder responsible for the delivery of a solution contracts an expert in the field. Revamp & Repower projects are notoriously complex, bitty, awkward and difficult. It takes an organisation who is familiar with data heavy, quality assurance focused, high volume components, team & logistical management, O&M awareness (not to wreck the site) and technical & commercial strength. All of this is a specialist area of the market which is only just emerging.

How do you know if your asset is suitable for revamping or repowering?

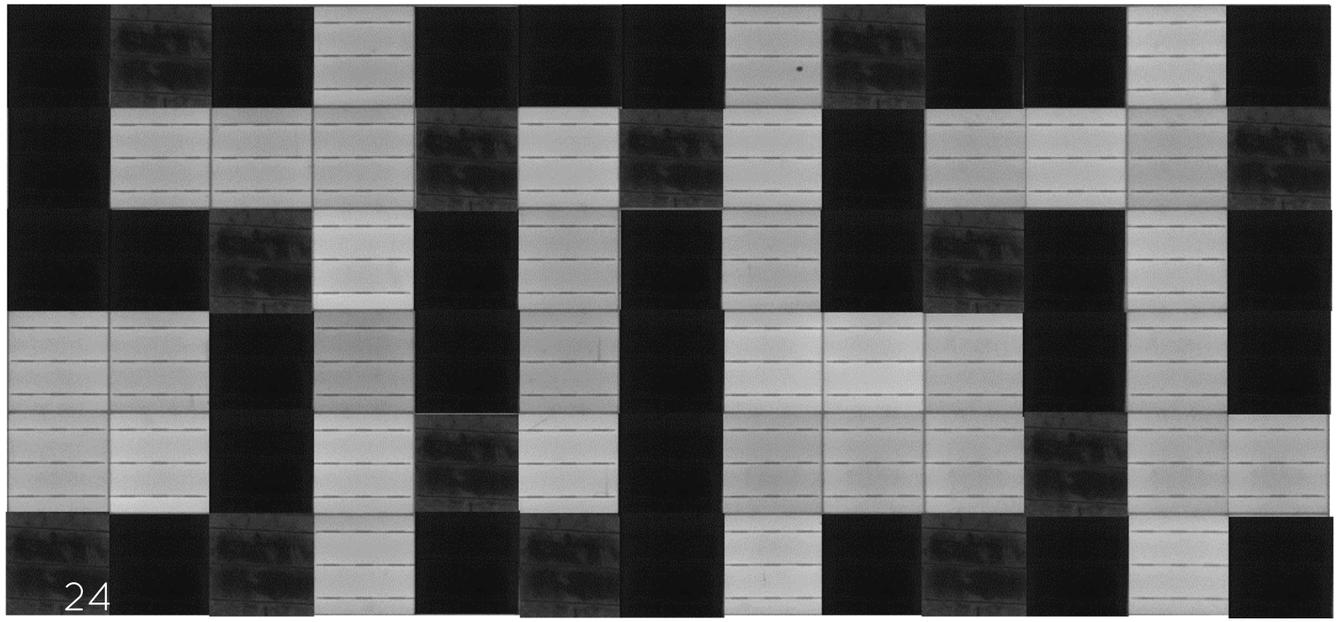
Site Optimisation Suitability (SOS)

2DegreesKelvin have developed our Site Optimisation Suitability process, or SOS as we refer to it. This is a free process where we ask asset owners/operators to populate a questionnaire on their assets relating to date of installation, component make, models and quantities, design details, operational performance, critical spares holdings etc. Each area is weighted and based upon our own and trusted partners historic test data and warranty claim experiences, we are able to generate an SOS rating for any given site (out of 100). The higher the rating, the more suitable that specific site is for improvement, optimisation, revamping or repowering solutions.

The next step once we've established this rating, is to present to asset owner/operators which strategies should be considered and provide estimated performance, reliability, safety & longevity gains, and associated return on investment figures.

Following that of course 2DegreesKelvin will provide a detailed service delivery offer and aim to deliver service excellence to deliver the project on time, on budget and in a safe manner.

If you are interested in us applying our SOS process to your assets, please get in touch.



Road to Repower Summary

So, you know that your asset is a possible candidate for revamp or repower. You have gone through the initial stages of the quantitative and qualitative assessments to understand the scale and severity, then you know what your options are, and you are now in a position with a well thought through solution based proposal and delivery plan. You are ready to contract with a revamp/repower specialist to deliver the project to enable your returns. The next step is to pull the trigger!

For those asset owners considering repowering or even if you have older assets which may well have an opportunity to increase yield, safety & longevity, I would be wary of whom and which type of organisation you partner with on such projects. This is not for the faint hearted, but if its done correctly it will be very rewarding.

I cannot emphasise enough the importance of a professional, technically strong, project delivery expert being contracted to deliver your revamp & repower projects. If the price seems reasonable or heaven forbit cheap, then there's something wrong. These projects are complex, challenging and will throw up surprises at every turn if they are not prepared for.

By cheap, buy twice. Happy repowering people!

Wrap Up

2DegreesKelvin welcome your thoughts at the following channel streams...

https://www.linkedin.com/company/2degreeskelvin/

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https://www.2degreeskelvin.org/

https://www.youtube.com/channel/UCxg46deuZITGb8WHG_1XSFg

If you would like to set up a consultation with John, then please use the email above.