Port to Project Logistics for Wind Farms. A Practical Assessment of Impacts on Transport Infrastructure.

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Abstract:

The construction of wind farms requires the delivery of hundreds of Over-Size Over-Mass (OSOM) components from a port of entry to the project site often located in regional and remote areas. Queensland has not seen a high penetration of constructed wind farms as of June 2021, however this is set to change at an accelerated rate in the next decade as the State and National electricity grids are de-carbonised and fossil fuel generators reach the end of their design operating lives.

Wind turbine technology has advanced considerably, with the scheduled equipment to be installed in Queensland ranging between 5 to 6 MW per unit, on Hub Heights upwards of 150m and Rotor diameters of 170m. Individual components weigh upwards of 200 tonnes and pose significant geometric challenges with blade lengths upwards of 85m. Each turbine requires delivery of between 12-14 OSOM Vehicles under permit and escort, thus utility scale projects can have a considerable impact on the public road infrastructure required to transport these components to site. The strategically located ports of entry for Queensland are Brisbane, Gladstone and Cairns, all of which will play a central role in this transition. Their connectivity by road to the regions for this unique freight task is integral to this transition.

Road impacts that are more localised to the project area are associated with the construction of the "Balance of Plant" elements. That is, access roads, installation hardstands, footings, substations, and electrical reticulation. These are substantial assets in their own right with each turbine requiring a reinforced concrete footing in the order of 600-700cubic meters in volume and a 1.0Ha hardstand capable of accommodating mobile cranes with a lifting capacity of up to 1000 tonnes. Delivery of the constituent ingredients can often have a more significant impact on pavements given the intensity of these deliveries that often traverse lower order roads.

This paper draws on the experience across the practical assessment and delivery of hundreds of wind turbines in each state of Australia and New Zealand. It looks at key logistical challenges of the port to site movements, management of lower order roads during deliveries of constituent ingredients while managing community expectations for disruptions to services, safety and environmental factors. It will look at specific case studies on maintenance, geometric upgrades and strengthening of pavements and bridge structures, as well as appropriate pre and post construction dilapidation assessments for these unique projects.

Finally, the paper will describe some successes and failures in the wind industry as it has emerged from its infancy over the past two decades. What went right or wrong, and opinions on avoiding past errors that may have tarnished the community's perceptions of the industry in some regions are addressed. Wind farms will play a central role in Queensland's energy future. Their transport impacts on the community can not only be mitigated, but also leave meaningful legacies of improved connectivity to the regional areas where they will be situated.

Keywords: Wind Turbine, Transport, Logistics, Pavement, Renewables

1 Introduction

icubed consulting has been an active participant in the Australian renewable energy sector, since the firm was formed in 2003. Over this period the firm has been involved in the permitting, investigation, design, and construction phase surveillance of around 50 projects, with an installed capacity of approximately 5GW of constructed wind farms. Projects have been located across Australia and New Zealand and this 18-year window into what is becoming a mainstream form of power generation provides a unique insight into a range of challenges that projects, and the communities which host them, face.

This paper seeks to describe the construction phase impacts on the transport infrastructure in the vicinity of the projects, providing lessons learned based on the authors' personal experience in the sector as it has evolved from niche to mainstream. These experiences draw from a duration of involvement in which turbine outputs have increased more than tenfold over.

Operational wind farms are low maintenance where the fuel source does not need to be extracted, processed, or delivered to the point of generation. Multi megawatt projects have full time staff undertaking routine maintenance and clearing electrical faults or trips that are unable to be resolved remotely. Therefore, site staffing levels are quite low with between 5-6 turbines being maintained per employee. Their impact on the road networks is benign.

Construction phase activities for a modern wind farm are somewhat more intense. Staffing levels during construction can be upwards of 200-300 persons across a period of 2 to 3 years. They require the delivery of considerable volumes of construction materials and are certainly a major construction undertaking. Whilst there is a great deal of variability in projects in terms of their geographic location and site characteristics, several useful statistics have been derived from some of the projects designed and documented in the recent past. Typically, a wind farm deploying 5 or 6 MW units will require the delivery of about 5,500 tonnes of materials per turbine, or 925 tonnes per MW of installed capacity. The internal access road network is typically in the range of 1.5km per turbine and is built to cater for mobile cranes operating on axle loads of up to 36 tonnes. Of these constituent materials, approximately 20% of the vehicle mass moved is turbine componentry. The remaining constituent materials are consumed or utilised during the construction of the balance of plant.

The balance of plant elements for a wind farm refers to the roads, footings, crane hardstands and electrical infrastructure needed to connect generating units to the power grid. Electrical infrastructure comprises approximately 10% of the freight task. The vast majority of this is the thermal bedding sand needed for underground cables. Pavement materials for the construction of roads and hardstands is the largest contributor to offsite road impacts at 35% of loads and the remaining 30% is associated with concrete and reinforcement for foundations. Construction water is the most significant variable, approximately 5% of the freight task is used for supply needed for the processing of earthworks, dust suppression and concrete production. Despite their significant size and weight, the primary impact on road infrastructure is not due to the transportation of turbine components. They only occupy a small proportion of the overall freight task. This paper describes a range of issues associated with wind farm development and the impacts they have on public road networks.

2 Catalyst for Building Wind Farms

Before describing the impacts of wind farms, it is useful to understand the regulatory background and market dynamics of the broader energy sector.

2.1 The Australian Wind Energy Market and Future Trends

The Australian wind energy sector has been growing steadily over the past decade. This was largely underpinned by the Renewable Energy Target, (RET), which was amended in 2015 to achieve 33TWhr of generation by 2020 (Renewable Energy (Electricity) Amendment Bill 2015). This target has been largely met and expanded upon by several projects underwritten by the ACT Government as part of their vision to source 100% Renewable Energy by 2020 (ACT Government, 2021).

Whilst there is, in the author's opinion, a distinct void in federal policy, most states have set modest Renewable Energy Targets of 50% by 2030 and there is considerable activity in the corporate power purchase agreement (PPA) market (Clean Energy Council, 2021).

The states and corporate Australia has committed to a transition to renewable energy to replace an aging fossil fuel fleet (Clean Energy Council, 2021). ACT, Tasmania and South Australia are today operating their power demands with near 100% renewable energy penetration.

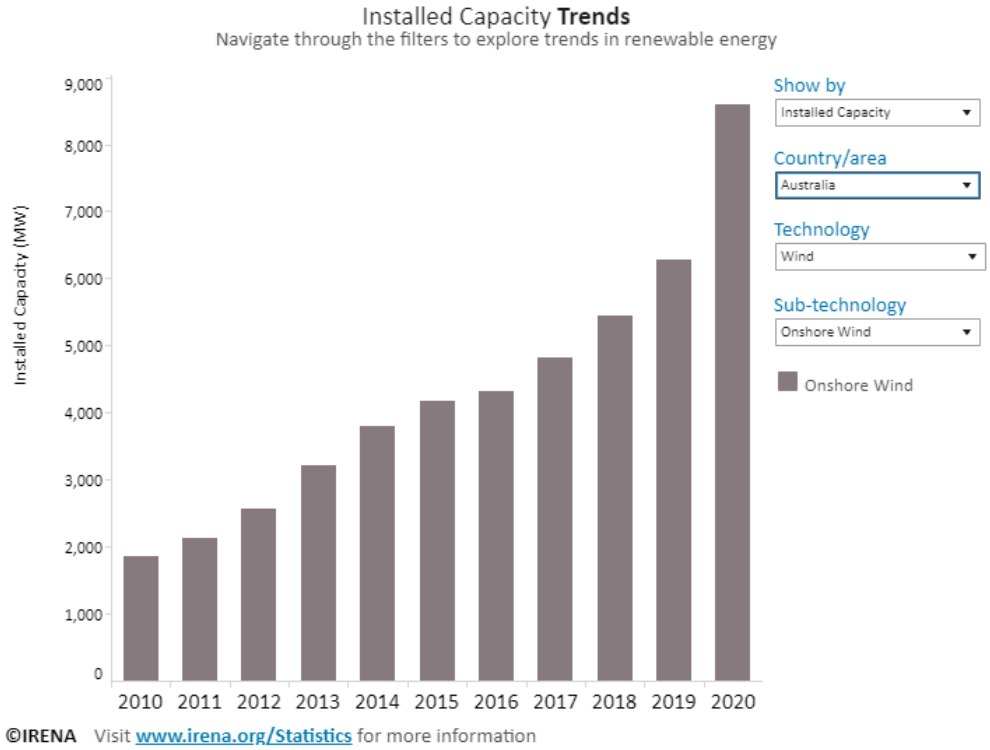

Figure 1: Australian Wind Generation, Installed Capacity Trends (International Renewable Energy Agency, 2020)

It can be seen from figure 1 that the rate of installation of wind generation is accelerating in Australia and this is set to increase in the future due to the cost advantage that this form of generation now holds over other forms of power production (Kompas et. al. 2019).

2.2 Global Drivers for Change

The world is decarbonising (United Nations 2021) and if Australia wishes to continue to be an active participant in global trade for goods and services, the nation is likely to be pressured into compliance with de-carbonisation trends. Australia is incredibly fortunate that it is rich in renewable energy resources and has the perfect opportunity to capitalise on this global trend. The International Renewable Energy Association (International Renewable Energy Agency, 2020) have published (refer figure 2) a planned energy scenario to decarbonise global energy consumption by 2050 and achieve a net-zero scenario.

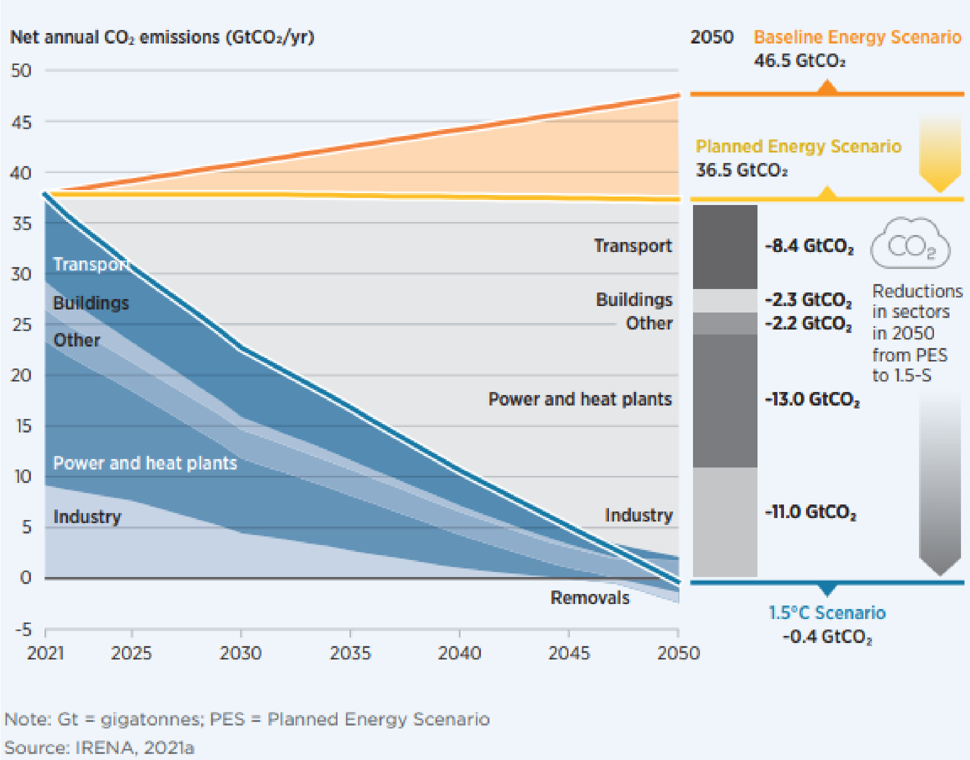

Figure 2: Planned Energy Scenario, 2050 (International Renewable Energy Agency, 2020)

Key features in this scenario are depicted in figure 3; Energy efficiency to cap demand and then using cheap renewable energy to power our economies. Storage will be provided using reimagined technologies such as Hydrogen Production (Australia's Chief Scientist, 2019). Thermal Coal will still be a useful part of this future as a generator of carbon dioxide for capture and reformation into methane. More importantly, the industry will still produce fly ash to support the production of high quality, low heat concrete and provide fillers for asphalt production.

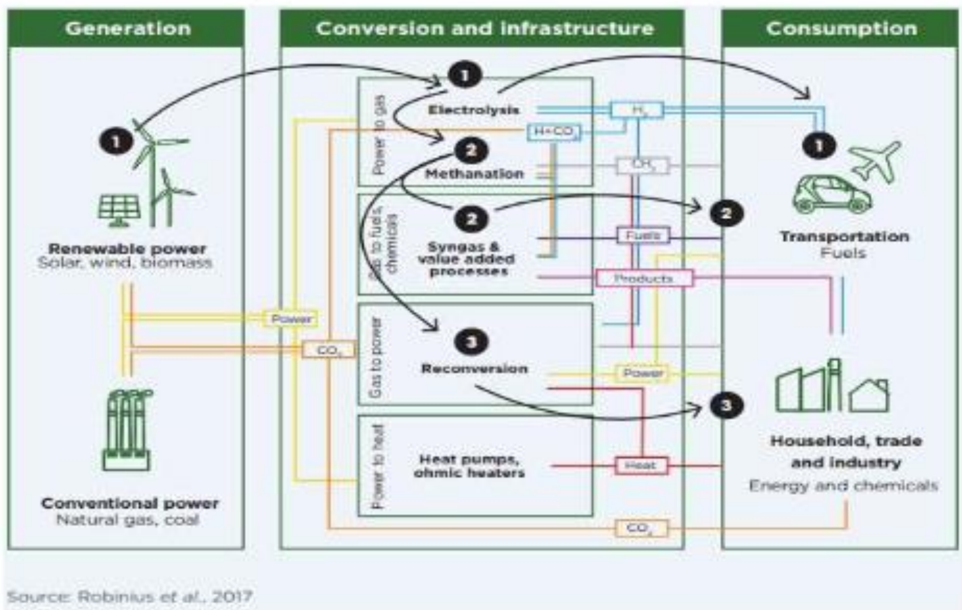

Figure 3: Planned Energy Scenario, 2050 (Robinius et. al. 2017)

3 Evolution of Wind Turbines

The first 22kW three bladed grid connected turbines were installed nearly 40 years ago in 1982. Today, onshore units are offered at more than 7MW and offshore units up to 15MW. Over the past 2-3 years the pace of development has been astonishing with Original Equipment Manufacturers (OEMs) developing more efficient machines capable of achieving high-capacity factors in low wind regions such as Queensland, on increasingly taller hub heights (refer figure 4).

Locally, the first mainland grid connected wind farm was commissioned in 2000 at Windy Hill, on the Atherton Tablelands. This project has an installed capacity of 12MW and consists of 20 x 600kW units, with a tip height of 68m and a rotor diameter of 44m (RATCH, 2021). The nearby Kaban wind farm, which reached financial close in September 2021, will have an installed capacity of 168MW and consists of 28 x 6MW units, with a tip height of 230m and a Rotor Diameter of 162m (NEOEN, 2021).

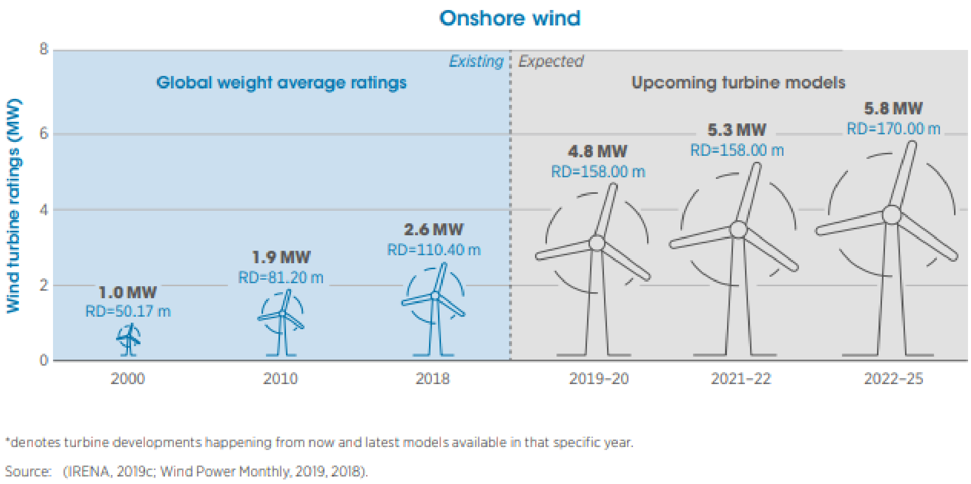

Figure 3: Onshore Wind Turbine Development (IRENA, 2019)

Practical limits for road transport are reaching a ceiling now. Unless there is a change in technology, nominally in terms of concrete hybrid towers, two-part blades, or blade transport systems, then wind turbine tip limits of around 230 -240m will likely become normalised.

Developers are cautious of the future progress of OEM's and projects being conceived with 300m tip heights to future proof the Development Approvals being sought.

Modern wind turbines are capable of producing energy at capacity factors of greater than 50% and are able to provide energy into the grid at rates less that the cost of fuel for both natural gas and high- quality thermal coal (Energy Matters, 2021). As storage technology and power to fuel technologies become more economically attractive, due to the weight of investment in these areas, renewable energy penetration is set to accelerate in the decades to come (IRENA, 2020).

4 Components of a Wind Farm

Grid connected wind farms comprise of three main elements: electrical balance of plant (EBoP), civil balance of plant (CBoP) and the wind turbine generators (WTG). These elements impact the external road network in slightly different ways based on their constituent materials.

4.1 Electrical Balance of Plant

The electrical balance of plant refers to the part of the project required to collect energy from the turbines and transmit it via power quality and transformation equipment to the grid. Whilst Western Australia and the Northern Territory operate isolated grids, the majority of Australian power consumers are connected to the National Electricity Market (NEM), which extends from Queensland to South Australia and includes Tasmania. The NEM is the longest interconnected network in the world.

Electrical construction activities contribute to approximately 10% of the freight task by mass, and only 2 or 3 OSOM Deliveries. It also contributes approximately 15% of overall project cost.

Key elements of the electrical system are;

- Main Power Transformer/s and connection substation including power quality equipment such as filter banks and reactive plant (refer Plate 1)
- Underground Electrical Cable, typically operating at 33kV (refer Plate 2)
- Overhead Power Transmission refer (refer Plate 3)

Plate 1: 220/33kV Substation – Dundonnell Windfarm, Victoria

Plate 2: 33kV MV Power Cable - Crudine Ridge Wind Farm, NSW

Plate 3: 275kV Overhead

4.2 Civil Balance of Plant

The civil balance of plant refers to the part of the project required to support the turbines and enable deliveries and erection of the turbine components. These activities contribute approximately 65-70% of the freight task by mass and typically only require OSOM deliveries for construction plant, mostly Quad Axel Floats. The civil balance of plant contributes to 15-20% of the overall project cost.

On a typical wind farm, access tracks are between 5.5 – 6.0m wide, rated to 250kPa for track mounted crawler cranes and axel load rated up to 36 tonnes per axle to facilitate the movement of mobile cranes. Widening is often provided at bends and gradients are preferably limited to 15% (refer Plate 4).

Plate 4: Typical Track – Ararat Windfarm, Victoria

Footings are reinforced concrete, gravity pads in the order of 600 – 700 cu.m, cast in a single pour at the rate of 3 – 4 per week (refer Plate 5). Larger pours can be over 900 cu.m.

Plate 5: Gravity Foundation – Dundonnell Windfarm, Victoria

Hardstands for the main crane and storage of all components are in the order of 4,000 to 5,000 sq.m, with variable load rating, typically to 250kPa, with axle loads up to 36 tonnes. Maximum slopes of 1-2 % are typical (refer Plate 6).

Plate 6: Component and Erection Hardstand – Mt Mercer Windfarm, Victoria

Depending on the site geotechnical and terrain conditions, civil balance of plant presents the greatest opportunity to reduce impacts on public roads.

4.3 Wind Turbine Generators

Wind turbine components represent almost all the Oversize Over Mass (OSOM) freight task, but approximately only 20% of the overall tonnage of materials. One turbine is typically delivered from the port of entry to the project site over a period of 3-4 days. There is a period of pre-erection installation that is completed while the components are laid out on the laydown areas, adjacent to the completed footing (refer Plates 7 and 8). Once all elements have been prepared, erection can commence. Aside from the OSOM deliveries, each turbine has a collection of equipment that is delivered in 40' containers, some 6-8 per turbine.

Plate 7: Tower Components – Bango Windfarm, NSW

Plate 8: Blade Components – Bango Windfarm, NSW

Typically, a smaller crane, in the order of 300t Safe Working Load (SWL) will be used to pre-install the bottom 2 or 3 tower segments, prior to grouting them in position and securing them to the footing. This crane will then be used to assemble the boom on the 'Main Crane', usually a 750 – 1000t SWL Pin Jib style mobile crane (refer Plate 9). The crane itself takes around 2 days to assemble and then, depending on the wind conditions and the opportunity to safely erect turbine components, it will take around 2-3 days to complete the install (refer Plate 10). Once the turbine is erected, a further 2 days are required to disassemble the crane and relocate it to the next turbine position.

Plate 9: Main Crane Assembly – Sapphire Windfarm, NSW

Plate 10: Main Crane Operating – Moorabool Windfarm, Victoria

For multi megawatt wind turbine units, wind farms typically see an erection rate of around 1 turbine per week. This is a rate that is heavily influenced by the prevailing weather conditions and will continue to low as turbines become larger and critical lifts become more complex.

Mechanical and Electrical fit out crews then commence installation of the internal equipment and undertake pre-commissioning.

Once the turbine is connected to the grid and 'back energised' it can be commissioned, and compliance testing can commence. These tests ensure the machine is operating in accordance with the Australian Regulators rules. Once all compliance testing is completed, the wind farm is considered completed and operational (refer Plate 11).

Plate 11: Operational Windfarm – Granville Harbour Windfarm, Tasmania

5 The Freight Task

The overall freight task for a wind farm typically occurs over an extended period of time as the project progresses through a number of critical stages;

- Enabling works, tracks and hardstands
- Foundations and electrical balance of plant
- Turbine component delivery and offloading
- Turbine erection

It is not unusual and is in fact beneficial for the bulk of the enabling and foundation works to be completed prior to delivery of the wind turbine components. Where this is not possible, the projects are generally of such a magnitude that the final civil or electrical balance of plant construction scope is being completed in areas of the wind farm almost entirely isolated from delivery and erection activities. OSOM vehicles and cranage present a range of hazards best separated from the construction of the balance of plant where possible.

5.1 Over-Size Over-Mass

Each turbines components collectively require between 12 – 14 OSOM deliveries and there are four main transport configurations for the various parts. All loads are conveyed to site under strict permit requirements issued by the National Heavy Vehicle Regulator (NHVR) who co-ordinate these approvals with all state and local authorities for the port to site route. The different configurations are depicted in plates 12 to 15 and are selected based on the element being conveyed, structure limits, overhead obstructions and the like.

Plate 12: Book End Trailer, used for large diameter Tower Segments

Plate 13: Beam Trailer: used for long tower segments, switchroom

Plate 14: Heavy Load Platform: used for gearboxes, nacelle, shorter tower segments, main power transformers

Plate 15: Telescopic Trailers for blade deliveries

Whilst the OSOM deliveries are large, and the blades are awkward, they operate under very strict conditions with pilots and police escorts. Careful route selection and journey management is important and, performed well, results in very little inconvenience to the wind farms host communities.

Trailers are configured to limit row loads to less than 16.5-17 tonnes and normally operate on a 4.2 – 5.5m wide track, where loads are spread across each of the 8 tyres provided on each row.

5.2 Heavy Vehicles

Over 80% of the freight task associated with the construction of a wind farm is comprised of normal Heavy Vehicle Transporters, which are allowed to operate unrestricted on Australian roads every day. Where the selected route permits, there are benefits in deploying prescribed vehicles including B- Doubles and Type A Road Trains operating Higher Mass Limits. While not essential, any measures that reduce the number of interactions with other road users is a reasonable approach. However, this is not always possible due to network limits on existing pavements and or structures on the required route.

6 Road Network Impacts

The operational phase of a completed wind farm has little to no impact upon road networks due to limited traffic generation. As such, any upgrades required to facilitate construction of any given project will be adequate for these purposes. During the construction phase, major routes used for the delivery of heavy aggregates should be subject to a well-conceived construction phase traffic management plan (TMP) due to them contributing most of the heavy vehicle movements.

Construction of wind farms have three primary impacts on road networks, which have been described in more detail below.

6.1 Geometric Requirements

The most significant contribution to network upgrades is associated with component delivery using the OSOM fleet configurations described in Section 5.1 of this paper. Turbine classes being delivered into the Australian Market at this time require the transport route from port to site to observe some key parameters;

- Vertical Curves – 500m but up to 700m VC limit depending on the trailer configuration – Existing Causeways are typically an issue (figure 5).
- Horizontal Curves – 120m when the road pavement width is 6.0m or more
- Tee Junctions* – 60m truncations (plate 15).
- Cross fall, 3% Crown and not more than 5% superelevation or adverse crossfall
- Road Width 6.0m, allows Beam Trailers to operate on a 5.0m outer track width

Consideration should also be given to providing passing opportunities for other road users. Component deliveries are typically spread over an extended duration and at most there are 3-4 OSOM deliveries to site per day. Inconvenience is insignificant when project TMP's are well conceived, and pilots are familiar with the opportunities provided in the design of these offsite upgrades.

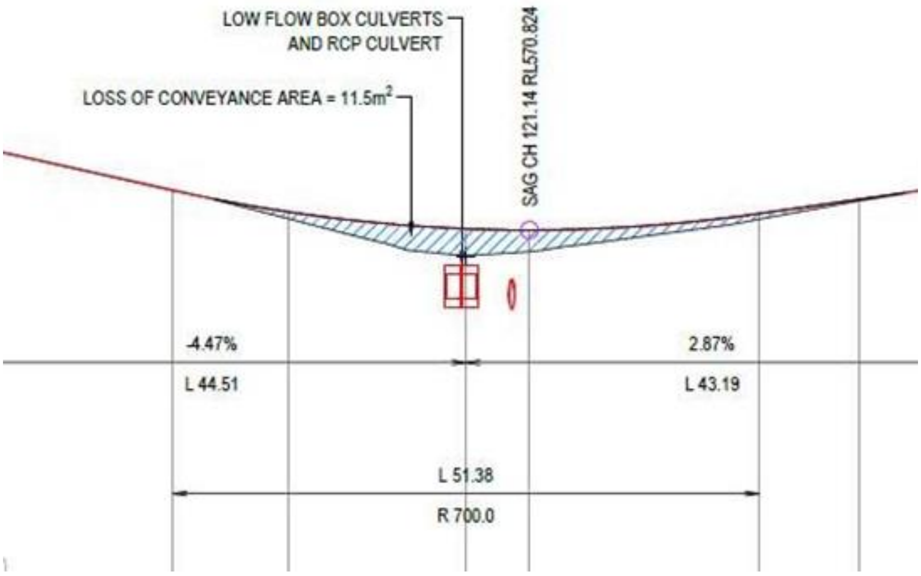

Figure 5: Floodway upgrade to correct Vertical Curve Constraint

* Tee junctions in urban environments can be problematic where the road reserve may not present adequate space. In these circumstances the proponent may need to enter into a private licence agreement to facilitate OSOM manoeuvres, figures 6 and 7

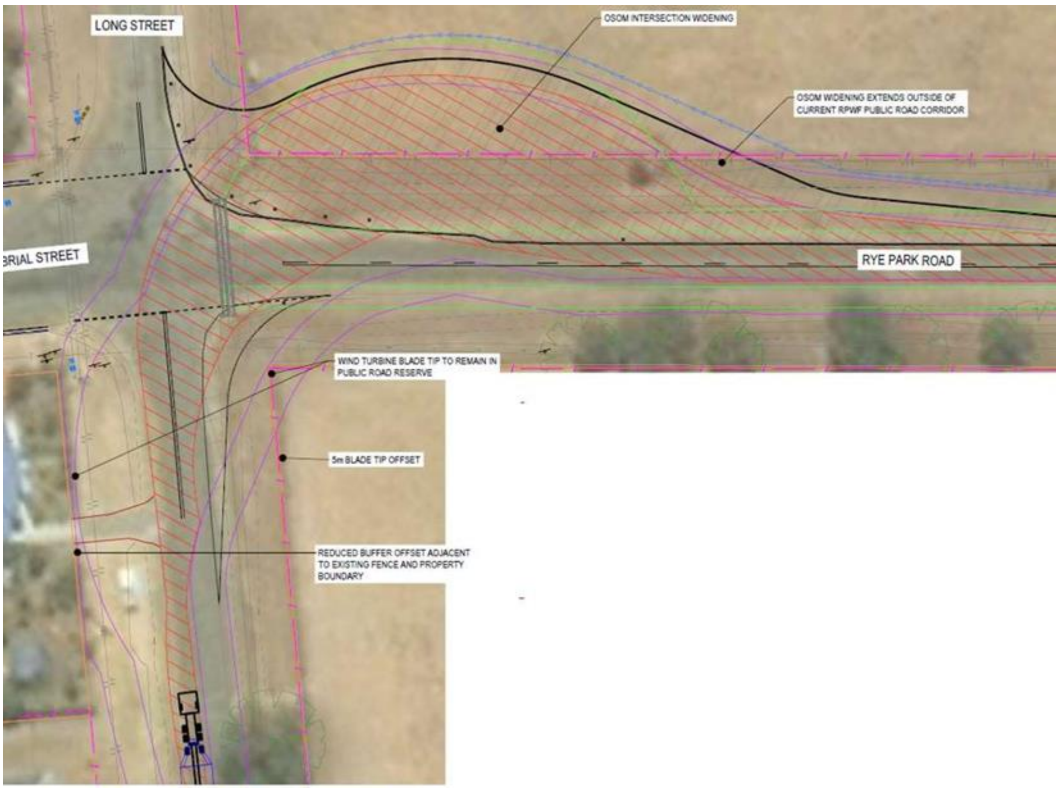

Figure 6: Tee Junction Alterations in Urban Setting

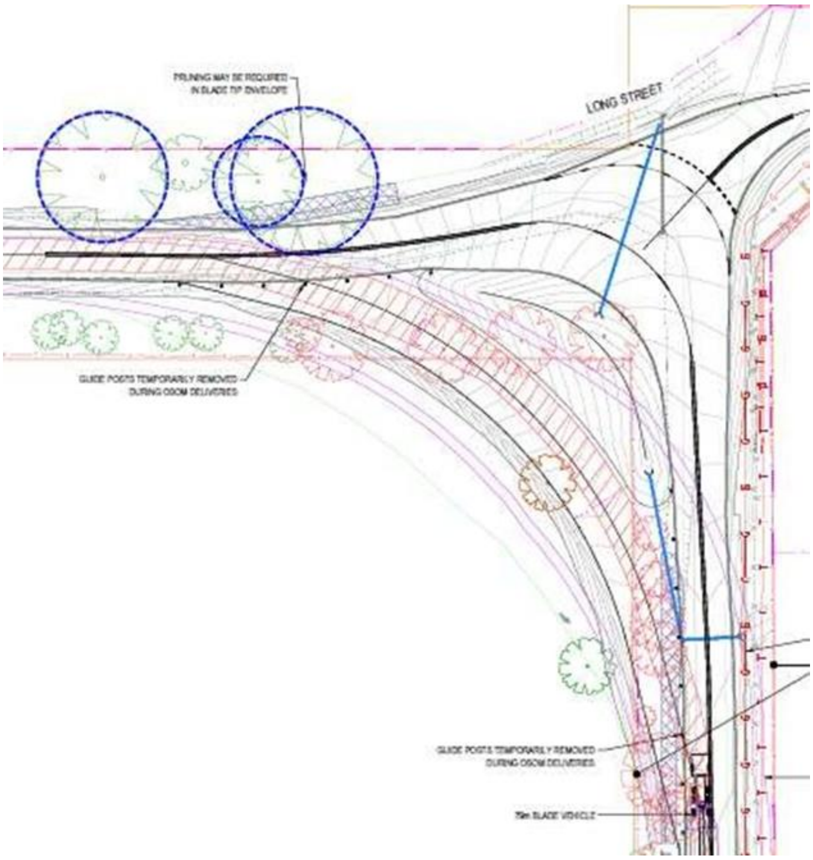

Figure 7: Tee Junction Alterations in Urban Setting, Slip Lane Configuration

The trafficable width of roads is also important and whilst it is not a particular requirement for OSOM vehicles to travel on sealed roads, consideration should be given to background traffic and impacts on other road users. More detail on this is presented in section 6.3 of this paper.

6.2 Structures

Generally, state-controlled roads will have a higher standard of infrastructure capable of catering for the OSOM delivery fleet associated with the construction of a wind farm. Lower order roads, typically controlled by Local Authorities may have structures which are more problematic due to their age and condition. Older bridge structures, or larger culverts, should be assessed with an appropriate degree of care. Where records of the as-built structure are limited, it is appropriate to undertake load testing and model validation to ensure the freight task will not compromise the asset (refer to figure 8, plates 16 and 17).

Generally, based on this type of assessment over several projects across a range of state and local government areas:

- OSOM are escorted and typically limited to 17t Axel Loads, on a 4.2 – 5.0m Track Width and 4 sets of Dual Tyres per Row. Row Spacing Typically 1.8m and operate with load compensating hydraulics to ensure even load distribution.
- Loading of shorter bridges and culverts will typically be governed by prescribed vehicles operating on higher mass limits (HML), such as B Doubles and Quad Dogs delivering heavy aggregates.
- Small culverts are typically not an issue unless they have previously been compromised or are in poor condition, however larger spans and older bridges, particularly timber bridges often require upgrades.
- Having completed this type of analysis on quite a few older bridges, it has been found that older structures capable of sustaining 2 lanes of T44 design vehicles will adequately cater for the OSOM freight task. In some instances, projects have precluded the used of HML's for the broader project freight task, but OSOM deliveries over these structures have been allowed.

- Loading of longer span bridges or the central headstocks for multiple span bridges can be compromised by the overall mass of the OSOM vehicle, whose length can often exceed the span of the entire structure being traversed.

Plate 16: 1940's Bridge – Lal Lal Windfarm, Victoria

Plate 17: Load Testing of 1940's Bridge – Lal Lal Windfarm, Victoria

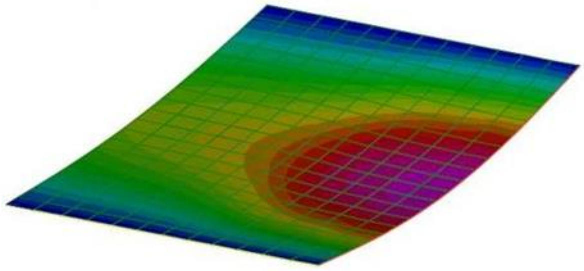

Figure 8: FEM Analysis of 1940's Bridge

In the example presented in plates 15 and 16, the existing structure was shown to have an adequate rating factor to permit use by the OSOM fleet delivering components to the windfarm. Prescribed vehicles operating HML's were precluded from use due to an inadequate rating factor when multiple lane loading was considered in the analysis.

6.3 Pavements

All roads on the transport route need to be considered as part of the project Transport Impact Assessment (TIA). As with structures, State controlled and higher order LGA roads generally have adequate pavement strength and formation width to facilitate construction of a wind farm. Lower order roads (LOR) need careful consideration and depending upon the nature of these assets and background traffic, some degree of intervention is often required. At minimum, a comprehensive pre- construction phase dilapidation survey should be undertaken to ensure that post construction the assets are maintained to a standard equal to, or better than that which existed prior to construction.

Where the scale of the project and background traffic deems a full pavement upgrade and new seal is appropriate, the IPWEA LOR manual is a reasonable guide for industry. Where low use lower order roads are being used for access, upgrading to a gravel road standard is adequate for the purposes of construction. In this instance, Austroads Part 6 – U3 is generally sufficient to build a wind farm.

One example of more robust upgrades associated with a project is depicted in plates 17 and 18. The Road is located on the basaltic plains of Western Victoria and comprised a narrow seal over variable thickness of scoria gravel, due to its prevalence in the area. This project was a larger wind farm, with 80 turbines, so it was deemed appropriate to upgrade this road for a distance of 8.2 km. The LGA was satisfied that a LOR standard be adopted and a seal with of 6.2m was used on a 6.6m formation. Pavement strengthening was also deployed where the typical upgrade standard included a 200mm pavement overlay.

Plate 18: Before - Woorndoo-Streatham Road, Dundonnell Windfarm, Victoria

Plate 19: After - Woorndoo-Streatham Road, Dundonnell Windfarm, Victoria

Certainly not all roads on the network need to be upgraded to a sealed standard. Project roads are unsealed and perform adequately, thus where background traffic is limited, a geometric upgrade to an existing unsealed road will usually be sufficient. The Crudine Ridge Windfarm in NSW shows an example where approximately 20km of road was upgraded through some steep, winding, heavily vegetated terrain. Upgrades to a higher standard would have necessitated considerable removal of vegetation to address the potential roadside hazards that accompany a higher speed environment provided by a sealed road. In many instances, including this one, it is difficult to obtain a development permit for such extensive tree removal, especially given that during the operational period wind farms are relatively low traffic generators.

The Crudine Ridge project for example will generate approximately 8-10 light vehicle movements per day and 4-5 HRV Loads per month for scheduled servicing. Given background traffic on this road was only about 50-60 vehicles per day this was deemed to be an acceptable outcome for the LGA.

Plate 20: Before - Aarons Pass Road, Crudine Ridge Windfarm, NSW

Plate 21: After - Aarons Pass Road, Crudine Ridge Windfarm, NSW

Pavement design methods for these offsite upgrades has not been discussed in this paper. Austroads and the relevant state and LGA supplements are used in all of these examples. Internal to the wind farm, tracks require a very different approach as these unsealed roads are subject to very high loads from the crane fleet which, for convenience and speed, traverses the site at least partially rigged with the boom up. Strength based methods are used in these situations such as The British Research Establishment Guidelines for Tracked Plant, BRE 470 and Giroud & Han (2004) Design Method for Geogrid-Reinforced Unpaved Roads. These methods are beyond the scope of this paper, however they typically result in pavements that are in the order of 200-300mm thick in subgrade conditions where the undrained shear strength is in the order of 80 -120 kPa, roughly equating to an insitu CBR of 10-15%.

The quality of internal tracks is of critical importance as the demurrage costs at Port or standdown rates for the crane fleets can be considerable. Also, with main cranes comprising a capital cost of $10- 20 Million, the cost of a pavement failure can be considerable.

7 Opportunities for Improved Project Outcomes

There are a range of opportunities for improved project outcomes which are primarily aimed at reducing the overall freight task and therefore interactions with other road users. While there is little that can be done with the OSOM aspect of the projects, careful planning of the transport route and delivery schedule is an important feature on any project. Simple initiatives, such as heavy vehicle traffic bans during school bus operating hours are helpful in delivering projects safely.

7.1 Local Resourcing

The civil balance of plant is the highest trip generator on a wind farm and comprises some 65-70% of the overall freight task. Much of this is associated with the pavement materials for access tracks and where suitable geotechnical conditions present on site many of these vehicle movements can be eliminated.

7.1.1 Site Won Pavement Materials

Making best use of a site's natural assets is a key opportunity and use of the site earthworks (refer plate 21), or a designated quarry (refer plate 22), to manufacture site pavements and erosion control rip rap should be explored where possible.

Plate 22: Deep Cutting Spoil used for Rock Fill and Processed for Pavement Materials - Lincoln Gap Wind Farm, South Australia

Plate 23: Site Quarry Processed for Pavement Materials, Dundonnell Windfarm, Victoria

With appropriate controls, this approach can result in superior project outcomes due to the elimination of thousands of heavy vehicle movements from the public roads surrounding the project.

7.1.2 Rock Fill Techniques

Rock Filling Techniques are a viable option for significant embankments. Depending on the prevailing weather conditions between 5-10 % of the freight task can be associated with the supply of water for processing of embankment fill.

Rock fill (refer plate 23) can have a meaning reduction on the overall freight task for a wind farm because it requires very little water to achieve appropriate states of consolidation and appropriate load carrying capacity. Placement of rock in this fashion also results in a considerable reduction in the projects embodied energy given the avoided crushing of these materials prior to formation of the embankment.

Plate 24: Rock Fill Embankment, Dundonnell Windfarm, Victoria

7.1.3 Harvesting of Precipitation

Depending on the prevailing weather conditions between 5-10 % of the freight task can be associated with the supply of water for processing of embankment fill. It is also a key tool in managing dust during construction. Key techniques can be employed to minimise the need for importing of water, other than the obvious measures of installing bores, where there is an adequate resource, or constructing temporary collection and storage dams. Deep ripping of the road alignments and where relevant, pre-blasting well in advance of earthworks operations is a useful technique to enhance the moisture condition of materials ahead of major earthworks operations.

7.1.3.1 Dust Suppression Additives

Water can be a sparce resource on project sites. In instances where the harvesting of precipitation is not possible, wind farm projects have explored and implemented the use of chemical dust suppression additives or bituminous sealing. The use of dust suppression additives can, if managed well, significantly reduce the volume of water necessary to control access road dust. These techniques can further reduce the requirement for HVR loads between the project site and publicly accessible water stands or pump stations. Subgrade Stabilisation.

Not every site has an abundance of rock resources and in some settings, the nearest hard rock quarry can be a considerable distance from the project location. Stabilising is also a very useful technique, to create a suitable working platform for the cranes and project component deliveries. A recent project in the Wimmera region of Western Victoria (refer plates 24 and 25) was such a candidate where the round trip to the nearest quarry was some 240km. In this instance roads and hardstands were stabilised a depth of 400mm. The formation was then protected with a nominal wearing course of only 100mm of crushed rock. This process saved thousands of heavy vehicle interactions with the general public.

Plate 25: Subgrade Stabilisation, Murra Warra Windfarm, Victoria

Plate 26: Completed Pavement, Murra Warra Windfarm, Victoria

7.1.4 Overhead Transmission

Approximately 6-7% of the overall freight task for a wind farm is associated with the delivery of thermal bedding sand for the internal collector cable system. Where visual impacts can be mitigated, installing overhead transmission lines instead of underground cables can significantly reduce the required importation of these materials to a site.

8 Lessons Learned

As the wind industry has matured from a niche market to a mature player in our energy transition, there have been several lessons learned over the years. Noting that this is not a comprehensive list, some of these as they relate to road networks are:

- Engage with the local community early and frequently. Requirements change as the project evolves from establishment, enabling works (balance of plant), component delivery, turbine erection, commissioning and operations.
- Maximise the use of natural resources on the site where possible, especially when pavement materials can be sourced.

- Ensure appropriate dilapidation data is available on parts of the networks being used for the entire freight task, including delivery of heavy aggregates.
- Undertake maintenance frequently and early during the construction of enabling works.
- Provide passing opportunities for other road users on the OSOM route and ensure they are well signed.
- Ensure the OSOM Pilots are familiar with the design intent of the project and any abnormal conditions, for example, adverse crossfalls, or narrow bridges.
- Reduce interactions with the general public where possible, avoiding peak periods such as school bus times.
- Encourage car-pooling and where practical provide bus services for the labour force during construction activities.

9 Conclusion

Wind farms will form a central part of Australia and Queensland's transition to a decarbonised economy. There are major construction activities that, done well, can make a valuable contribution towards regional economies, with little noticeable adverse outcomes. Well-conceived Traffic Impact Assessments, Traffic Management Plans and planning of network upgrades are an important feature in ensuring that the community expectations are met in terms of disruption and a positive legacy from betterment of local road networks is achieved.

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