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New Zealand Government – A Vision for Hydrogen in New Zealand – Green Paper – WSP Submission

To whom it may concern

WSP are delighted to have this opportunity to make a formal submission in relation to the New Zealand Governments – A Vision for Hydrogen in New Zealand – Green Paper, which was released in in early September 2019, asking for feedback on 18 specific questions.

WSP has reviewed the published Green Paper and have decided that we have specific experience in this matter, both within our current activities in New Zealand and our WSP global activities relating to Hydrogen.

We hope you will find our feedback to each question, both useful and thought provoking. Generally, we have endeavoured to concentrate on aspects of "Green Hydrogen", as clearly and rightly, this is a current focus for the New Zealand government. WSP is fortunate to be a global company which focuses on continuing to create what matters for future generations alongside a global network 49,000 people strong.

WSP is one of the world's leading engineering professional services consulting firms. We are technical experts and strategic advisors including engineers, technicians, scientists, planners, surveyors, environmental specialists, as well as other design, program and construction management professionals. We design lasting Property & Buildings, Transportation & Infrastructure, Resources (including Mining and Industry), Water, Power and Environmental solutions, as well as provide project delivery and strategic consulting services.

With 2,500 talented people in 22 offices across Australia and New Zealand, we engineer projects that will help societies grow for lifetimes to come. Particularly in this region we are seeing a huge increase in renewable energy infrastructure which we know provides a huge opportunity to develop Green Hydrogen production initiatives and benefits to these communities and the wider globally community.

We would welcome the opportunity to discuss any related Hydrogen matters, and in the meantime should you have any questions about this submission, please don't hesitate to contact Les Pepper.

Yours sincerely

Les Pepper
Energy Project Manager/Asset Management Consultant

New Zealand Government

Green Hydrogen Strategy

A Vision for Hydrogen in New Zealand – Green Paper Submission Questions – WSP Responses

Question the existing/
Imagine the impossible/
Create the enduring

WSP

Overview

The New Zealand Government is seeking feedback on the questions listed below, which are included in the attached: A Vision for Hydrogen in New Zealand Green Paper.

Introduction to WSP in New Zealand:
WSP (formerly Opus) is one of the world's leading design and engineering professional services consulting firms.

With our unrivalled local knowledge of New Zealand and global network of experts, our focus is on designing solutions where our local communities and environment thrive.
We are strategic advisors and technical experts including engineers, technicians, scientists, architects, planners, surveyors, environmental specialists, as well as other design, program and construction management professionals.

We design future ready solutions in Property & Buildings, Transportation & Infrastructure, Water, Power and Environment, as well as provide project delivery and strategic consulting services.
With 1,900 talented people in 40 offices across New Zealand, we engineer projects that will help societies grow for lifetimes to come.
For more information, please visit our website: www.wsp.com/nz

WSP Global:
WSP is one of the world's leading professional services consulting firms. We are dedicated to our local communities and propelled by international brainpower. We are technical experts and strategic advisors including engineers, technicians, scientists, architects, planners, surveyors and environmental specialists, as well as other design, program and construction management professionals. We design lasting solutions in the Transportation & Infrastructure, Property & Buildings, Environment, Power & Energy, Resources and Industry sectors, as well as offering strategic advisory services. With approximately 48,000 talented people globally, we engineer projects that will help societies grow for lifetimes to come. For more information, please visit our website: www.wsp.com

Response Methodology:
The feedback listed below for each Green Paper question has been provided by a selected group of experienced WSP staff from New Zealand and around the globe, including the Australia, UK and Sweden. This submission has been led by members of the WSP Power Team in New Zealand.

We have included all relevant feedback comments from this group and have endeavour to highlight the key feedback points for ease of reading. As we have found whilst collected additional information on this topic, Hydrogen is very topical and globally there is a lot of activity and innovations being published. We have tried to look at what we see happening with Green Hydrogen around the world and comment or advise on how we think this could benefit New Zealand. WSP is currently assisting a number of Hydrogen developments in New Zealand, which is increasing our local knowledge of this fuel for the future.

For any further advise or information, please
contact our lead WSP author for this submission –
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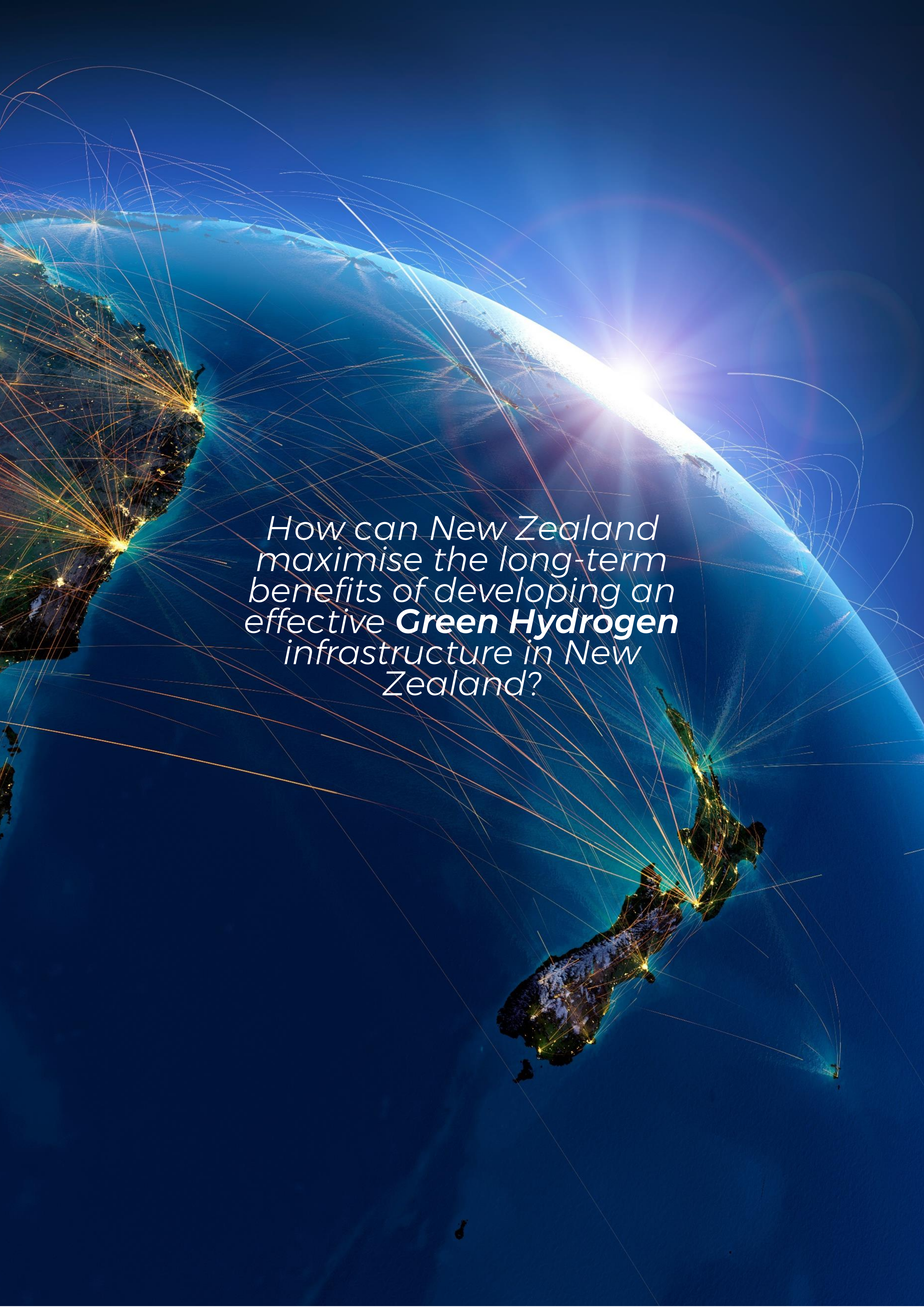
Green Hydrogen



How can New Zealand maximise the long-term benefits of developing an effective ***Green Hydrogen*** *infrastructure in New Zealand?*

Feedback *Questions*

Hydrogen storage *and distribution*

1a What is the role of Government in developing hydrogen for storage and distribution?.

Key points:

- Provide strong leadership to maintain New Zealand's "Clean Green" image globally.
- Help the establishment of a market for hydrogen, using tax incentives to promote investment (if linked to Green Hydrogen). Allow free market to establish initially
- Develop an overarching National Renewable Energy Strategy.
- Create and fully endorse a National Hydrogen Strategy.
- Create an effective ETS.
- Create a "Panel of Green Hydrogen Technologies Experts".

- Develop hydrogen parks, conduct up-front consenting to compress the time frame, initiate pilot projects.

WSP's response to this question:

- Provide strong leadership to maintain New Zealand's "Clean Green" image globally.
- Allow a competitive market to fund and establish hydrogen for storage and distribution infrastructure and network coverage, until such time that Government needs to intervene.
- Develop an overarching National Renewal Energy Strategy in which Green Hydrogen is included in developing a National transition plan.
- Develop tax incentives to promote investment (if linked to Green Hydrogen).
- Create a "Renewable Energy Transition Panel" to assist government agencies.
- A role of leadership and as an enabler to develop Green Hydrogen infrastructure in NZ.
- Collaborate with potential overseas markets to promote our Green Hydrogen supply and products.
- Create and fully endorse a National Hydrogen Strategy. This strategy will form part of the NZ Governments goal to reach 100 percent renewable electricity by 2035 and to transition to a clean, green and carbon neutral economy by 2050.
- Create a "Panel of Green Hydrogen Technologies Experts" to assist developers and to advise Government regarding new innovations, opportunities and hazardous area controls in relation to in Hydrogen storage and distribution.
- Undertake public awareness programmes to foster and promote the long-term benefits of Green Hydrogen use in all facets of our communities.
- Make more special funding available for Green Hydrogen development and R&D initiatives which can provide sound long-term cost benefits and environmental sustainability.
- Ensure Hazardous Gas Regulations and Pressure Regulations cater appropriately with new initiatives and technologies associated with Green Hydrogen production, storage and distribution. This will also involve Hazardous Substances and New Organisms (HSNO) Location Compliance certifiers to be trained regarding new technology Hydrogen facilities. New Zealand has adopted high standards in these areas already, but there is a need to ensure these requirements allow for the introduction of new initiatives, technologies and opportunities.
- Make adjustments to the RMA is lessen the "Red Tape" involved in these sometimes-unique innovation developments.
- Demand government departments show initiatives to increase their internal usage of Green Hydrogen.
- Create an effective ETS that drives movement to more effective low emissions alternatives. This will make high carbon emitters less cost effective and create cost benefits for Green Hydrogen options. But a balance is important in our restricted economic environment.
- Assist NZ manufacturers to develop cost effective construction methods and processes to enable them to build local Green Hydrogen storage vessels to meet growing demand.
- Identify "hydrogen clusters" to effectively target specific cities, industries etc. with a high potential for acceptance and adaptability for hydrogen applications. These hydrogen clusters should have a well-developed distribution infrastructure, and they should be connected with each other through "hydrogen corridors", which enable transport between the clusters.
- Identify and make strategic sites (hydrogen parks) available for hydrogen generation, storage, and transmodal transfer (truck to train, train to ship, etc) facilities. Initiate up front consenting activities for the hydrogen parks so design and construction can proceed without undue delay.
- Initiate pilot projects that advance hydrogen storage, transport, and use. Encourage companies to bid or compete for the opportunity to develop the pilot project.

1b What are the challenges for using hydrogen for storage and distribution?

Key points:

- A reliable, complete storage and distribution network will be required at cost effective rates for users.
- Strategic feasibly, lead times and technology redundancy.
- Competition with BEV's.
- Myths around the inherent dangers of Hydrogen infrastructure.
- RMA "Red Tape".
- Finding sites and consenting could be time consuming if left to private companies only.

WSP's response to this question:

- Investment costs, zoning and logistics requirements may affect financial liability of establishing full network coverage that may impede in take up hydrogen solutions.
- Emerging innovation in energy technologies may make large infrastructure investment risky if later become redundant (such as improved batteries and BEV's).
- Transporting hydrogen via road is unfavourable in strategic context (desiring to get vehicle especially heavy vehicles off roads), transport of hydrogen will likely be liquid which may pose safety risks.
- BEV solutions would not require same level of investment and are currently more energy and cost efficient, this may be competing technology.
- The production, transport and storage technologies for hydrogen are relatively mature, but are yet to be tested as part of a viable large-scale supply chain. (cited: Australian Government COAG Energy Council National Hydrogen Strategy).
- Potential safety risks - in June 2019 a car Hydrogen refuelling station exploded in Sandvika, Norway which prompted Toyota and Hyundai to freeze sales of its hydrogen fuel cell vehicles. (https://interestingengineering.com/hydrogen-fueling-station-explosion-halts-fuel-cell-car-sales-by-toyota-hyundai)
- in June 2019 a car Hydrogen refuelling station exploded Santa Clara, California.... "resulting in hundreds of fuel-cell vehicle owners had no choice but to park their cars due to a hydrogen fuel shortage". (https://www.cnet.com/roadshow/news/hydrogen-fuel-cell-car-california-explosion/)
- NZ Hazardous Gas Regulations and Pressure Regulations are very strict and don't always align with appropriate international standards.
- RMA "Red Tape" can make developments marginal.
- Hydrogen storage vessels are generally very bulky, heavy and costly.
- Rivalry between competing low emission fuel sources for increased market share.
- Solid financial information is required to assess the long term overall benefits of all current emerging low carbon emission fuels/energy sources such as Hydrogen, Hydro, Geothermal, Wind, Solar, Biofuels, Tidal/Wave etc.
- Consideration for proposed assets and retrofitting needs to be carefully considered, as transporting hydrogen via pipeline would require three times more volume to supply the same amount of energy as natural gas, due to the energy density of hydrogen.
- Designs need to consider increased leakage potential of hydrogen due to it being a very small molecule.
  New standards for hydrogen management, safety and design will need to be produced and followed.

- Designs for hydrogen fuelling stations need to be built into road networks (on site production, pipeline or tanker).
- Re-purposing natural gas networks may not always be possible depending on the pipeline material; at lower pressures PE pipe would be used and at higher pressure pipeline would need to be constructed of appropriate metallurgy to avoid hydrogen embrittlement.
- Potential for hydrogen embrittlement of high strength stainless steels (also known as hydrogen induced stress corrosion cracking). This is an additional risk / consideration for piping and pressure equipment involved with the conveying of hydrogen and is commonly found in oil and gas industries internationally where hydrogen sulphide if often present. With additional design, fabrication, and QA measures in place this problem can be protected against, usually by post-manufacture treatment (annealing etc, to reduce localised hardening) of the pressure equipment materials. Refer to NACE MR 1075. This will be a challenge when dealing with hydrogen relative to other gases, however not by any means unsurmountable.
- Energy losses in several steps of the process compared to competing low emission fuel sources. Hence, hydrogen is less suitable for short term storage than batteries for example.
- High investment costs for hydrogen fuelling stations.
- Identifying storage and transport sites accessible by road and rail but away from dense populations will be challenging, a good role for central government.

1c What are the opportunities for using hydrogen for storage and distribution?

Key points:

- Heavy industry positioned for transition, if government offers tax incentives.
- Producing Green Hydrogen, via plentiful renewable energy sources.
- Hydrogen can be used like a battery
- Produce Green Hydrogen at low electricity market prices, store and use at later time when cost effective.
- Find strategically located sites with multiple production, storage, and use options supported.
- Explore use of KiwiRail or other government owned entities for synergistic production, transport, and use of H2.

WSP's response to this question:

- By producing Green Hydrogen as a priority, via plentiful renewable energy sources, this product can deliver high value returns, especially in the international low emissions energy market.
- Existing good condition natural gas distribution pipework networks can be utilised to distribute Hydrogen around locations. Offsetting natural gas usage, whilst utilising existing pipework infrastructure. End user appliance burner upgrades are required, but executed correctly, significant emissions reductions can occur. City of Leeds (UK) is a good example of this fuel transition.
- Hydrogen can be used like a battery
- The timing of Green Hydrogen production and the timing of end user use, can be of huge benefit and cost saving over time.
- Energy storage with hydrogen is much more suitable for long term storage than batteries.
- By identifying isolated areas for storage depots near railways, highways and ports, the government can maximise opportunities for production, transport fuel use, and distribution. Good example would be using wind farms for H2 production and storage when the grid price is low, then use for grid power later, transport fuel, overseas export, or whatever use makes economic sense.
- NZ Government owned KiwiRail would be a great example of storage, distribution, and use synergy. They have large pieces of brownfield land for storage sites, rail lines to ports for export, full scale H2 locomotives are already being tested in Germany and Japan. So KiwiRail could be a key component and H2 trains could eliminate the need for electrification of rails in remote locations.

Developing the *complementary role of electricity and hydrogen*

2a What is the role of Government in developing the complementary role of electricity and hydrogen?

Key points:

- Promote both technologies and promote collaboration under strategy.
- Provide market governance and competition oversight.
- Create a "Panel of Green Hydrogen Technologies Experts".
- Green Hydrogen can be produced using renewable electricity, during periods of low electricity markets cost rates.
- Identify and fund strategic pilot projects and sites to demonstrate feasibility.
- Use ETS to internalise the full cost of carbon emissions and favour H2 production.

WSP's response to this question:

- Allow and promote both technologies to compete in collaboration under National Renewable Energy Strategy.
- Educational and communication campaigns promoting pollution free, carbon neutral renewal energy and promoting the energy transition. (for example, advertising campaigns, international events hosted in NZ and so on, encourage international investment).
- Ensuring that the nation's most valuable (productive) renewable energy locations invest in most energy efficient solutions with the greatest value to community (environmental outcomes, reliable cheap energy cost, raise

standards of living, generate to national wealth (not necessarily financially measured).

- Create a “Renewable Energy Transition Panel”.
- Smart Government policy and financial sector investment will be required to scale-up production and reduce costs, which will stimulate demand and market development. A ‘proper’ cost of carbon (via the ETS) would rebalance the costs in favour of hydrogen over natural gas.
- Create a “Panel of Green Hydrogen Technologies Experts” to assist developers and to advise Government regarding new innovations, opportunities and hazardous area controls in relation to the complementary role of electricity and Hydrogen.
- Green Hydrogen, produced via plentiful NZ renewable electricity sources (e.g. Geothermal, Wind and Hydro etc.) can deliver a superior low emissions energy product.
- When Green Hydrogen can be produced using renewable electricity, during periods of low electricity markets cost rates (during off peak load periods), this enables the Hydrogen to be utilised during higher priced periods, creating improved price control. This storage advantage can assist electricity networks to manage peak demand periods, resulting is less infrastructure capital expenditure. Timing of low cost production and the ability to store Green Hydrogen, for delayed uses during peak (high cost) power demand periods, this a key factor.
- Create and fully endorse a National Hydrogen Strategy. This strategy will form part of the NZ Governments goal to reach 100 percent renewable electricity by 2035 and to transition to a clean, green and carbon neutral economy by 2050. The 100 % renewable target is going to be very dependent on factors such as weather patterns and negative effects of climate change on the NZ environment.
- The Governments proposal to launch into negotiations with other countries to remove tariffs on environmental goods such as solar panels or wind turbines, and curb fossil fuel subsidies, is a great initiative. This could be extended in time to remove tariffs on other items specifically related to Green Hydrogen such as specialist Geothermal and Hydro Power Plant equipment, Green Hydrogen production equipment such as Electrolyser equipment, specialist Hydrogen transportation, distribution, storage and dispensing equipment. Any assistance to improve the cost benefits of developing infrastructure supporting the growth of Green Hydrogen would help these initiatives to move forward.
- Government needs to remove existing “Roadblocks” such as the RMA. Consenting pinch points need to be mitigated where possible.
- Government needs to develop “Incentives” such as: tax relief, R&D funding, Capital funding / loans.
- The current Government vision of achieving a low emissions economy based around greater electrification and the next generation fuels, such as Hydrogen is a valid proposition for NZ’s future.
- The Government can assist with R&D into the viability of other forms of electrolysis production of Green Hydrogen in the NZ environment, such as Proton Exchange Membrane (PEM) electrolysis methods. PEM electrolysis methods currently have overall efficiencies in the 80% range and are expected to increase even up to 86% efficient in the near future.
- Provide support (e.g. economic incentives) for existing renewable energy producers to produce hydrogen from electricity surplus.
- Create strategic pilot projects through competitive bids (like MBIE RS&T investment agency or Green Investment Fund) to demonstrate feasibility of synergistic H2 and Electricity production.
- Identify and consent hydrogen parks for renewable (wind and solar) electricity generation and H2 storage.

Geothermal Generation Plants

2b What are the challenges for achieving this complementary role of electricity and hydrogen?

Key points:

- Significant renewable generation growth likely across NZ.
- Green Hydrogen vs EV’s.
- High investment costs.
- ‘Dry Year’ electricity supply risk needs careful planning and support.
- Complex enterprise to initiate. Start with pilot plants and ramp up with learnings from the pilot experience.

WSP’s response to this question:

- Ensuring that corporate profit driven motives don’t establish an energy market that corners or monopolises the markets and or hinders environmental outcomes.

- Ensuring that the nation's most valuable (productive) renewal energy locations invest in most energy efficient solutions with the greatest value to community (environmental outcomes, reliable cheap energy cost, raise standards of living, generate to national wealth (not necessarily financially measured).
- As indicated in the Green Paper document, a significant increase in New Zealand's renewable energy generation capacity will be required. This is as a result of desired increased electrification, hydrogen production via electrolysis and the retirement of existing fossil fuelled thermal power plants. A large part of this increased load capacity is expected to be derived from additional wind and solar generation units. This demand growth needs to be well planned and funding support is likely to be required. With this significant shift in the make-up of the generation fleet, adverse effects on the security and stability of the national HV grid will need particular attention by Transpower. There may also be a need to modify the Wholesale Electricity Market Rules to reflect this change in the national generation fleet, to keep prices under control.
- During a "Dry Year" in New Zealand, there will be less spare renewable energy available than there would be in a "Normal Hydrological Year'. So, this will place extra pressure on the economic availability of renewable energy for economic Green Hydrogen production. Already this year in October, November and December, Transpower is signalling a shortfall in supply to the electricity market at times due to a large number planned outages by generators across both islands. Clearly our current electricity production capacity is already at times being stretched, which raises the risk of power shortages and possible power outages.
- Some consumers believe electricity should be directed more to industrial electrification, EV's and other forms of electricity diversification.
- Clear guidelines need to be drawn as to when Green Hydrogen is the better option and where other fuels provide a superior long-term advantage.
- Producing Green Hydrogen on a large scale via electrolysis would require massive infrastructure investments in additional renewable energy plants around NZ.
- If Green Hydrogen results in a growth of smaller sized renewable energy electricity generation plants, connected to the Grid and spread around NZ locations, this may cause Transpower (the grid System Operator) some grid security issues. This is due to the effects of increased growth in low inertia generation units on grid system security plans. Transpower may be forced to mitigate this, adding additional transmission costs to power bills.
- High investment costs for implementing hydrogen production and storage.
- There are a lot of moving parts to having an integrated electricity and hydrogen production and storage system. Best approach is to get small pilot projects off the ground quickly and learn from those.

2c What are the opportunities for this complementary role of electricity and hydrogen?challenges for achieving this complementary role of electricity and hydrogen?

Key points:

- Used effectively, both electricity and Green Hydrogen can complement each other.
- Remote location Green Hydrogen production opportunities.
- Timing of low cost production and the ability to store Green Hydrogen, for delayed end user consumption during peak (high cost) power demand periods.
- H2 storage may have lower environmental impacts than pumped storage hydro's or batteries.

WSP's response to this question:

- Free market will decide cost optimum solution.
- Innovation may see hydrogen as viable future fuel for aircraft and shipping.
- Hydrogen could compliment gaps in BEV and electricity.
- Optimising NZ bountiful renewable energy resources for best combination use between electricity and hydrogen with delivery technologies (for example as cars battery, heavy vehicles hydrogen).
- Hydrogen can enable renewable electricity units to provide an even greater contribution by using the low-carbon energy to be produced.
- 100% Green Hydrogen fuelled Gas Turbines (GT's) and Combined Cycle Gas Turbines (CCGT's), electricity production facilities are being developed due to the high energy content of Hydrogen. Many existing GT and CCGT units are already able to handle co-firing of hydrogen and natural gas. This would allow a timing offset and enable this existing facilities to move away from Natural Gas.
- Used effectively, both electricity and Green Hydrogen can complement each other and provide an advantage to NZ over many of our international revivals.
- Excess renewable energy can be stored as hydrogen from electrolysis (power-to-gas) and has wide ranging uses.
- Timing of low cost production and the ability to store Green Hydrogen, for delayed end user

consumption during peak (high cost) power demand periods.

- Hydrogen has been utilised alongside electricity for a long time in the generation of electricity. Large salient pole generators, used in large thermal power stations like Huntly Power Station (both on the older Rankin units and the newer CCGT units) uses pure hydrogen as the medium inside the stator assembly in which the rotor rotates in at high speed (3.000 rpm at the shaft). Generally pressurised to 3 Bar and critical to be able to keep the generator cool whilst running. So the technologies and awareness of pressurised hydrogen is well understood within parts of the electricity sector, along with many other sectors.
- Green Hydrogen could open up many more opportunities for groups and communities, especially in more remote areas of NZ. Green Hydrogen can be produced locally, utilising a local renewable energy production facility (e.g. Geothermal or Wind generation), then stored and transported by trucks to end users or exported internationally via ports.
- A small scale Green Hydrogen production facility (1.5MW or approximately a maximum production capacity of 250Nm3/hr of Hydrogen) could have a capital development cost of around 5 to 6 million $NZD. This may enable this generation plant to not have to rely on a HV grid connection, but alternatively supply the local power distribution network during (high price) peak power demand periods and produce Green Hydrogen during (low price) off peak power demand periods (night periods).
- Hydrogen could be used as a suitable long-term storage means to 'unlock' the potential for overbuilding of NZ's most cost effective renewable electricity generation source: Geothermal. For example, during the 24-hourly cycle from say 11pm to 5am when electricity demand is low, excess geothermal generated electricity can be used to create and store hydrogen. Then during periods of high electricity demand (be it on a daily or multi-yearly cycle), the stored hydrogen can provide electricity balancing. This allow geothermal energy to be stored and dispatched in a similar way that currently hydro lake storage is used.
- Hydrogen would probably have a lower environmental impact than hydro lake storage which is already in short supply.
- The storage and transportation of Hydrogen can allow otherwise impracticably inaccessible or remote areas with renewable electricity potential, to be utilised. For example, a remote hydro or geothermal resource, that is not economically feasible to build and connect electricity transmission lines, could be built instead on the basis of the energy being 'transmitted' via hydrogen fuel cell road truck transport, rather than costly and visually impacting electricity transmission lines.
- The use of hydrogen can help reduce peaks in the electricity system and make it more stable.
- With more fluctuating renewable energy sources entering the market, the importance of energy storage options increases.

Benmore Hydro Power Station, Otago, South Island, NZ

Supporting *hydrogen use for the transport sector*

3a What is the role of Government in supporting hydrogen use for the transport sector?

Key points:

- Promote Green Hydrogen use in large vehicles (heavy-duty logistics).
- Provide tax relief for Green Hydrogen fuelled road vehicles.
- Use government owned enterprises like Kiwirail or ports to demonstrate feasibility of hydrogen in transportation.

WSP's response to this question:

- Promote Green Hydrogen use in large vehicles (heavy-duty logistics) such as trains, trucks, buses, ships etc.
- Provide tax relief for Green Hydrogen fuelled road vehicles.
- Create a "Panel of Green Hydrogen Technologies Experts" to assist developers and to advise Government regarding new innovations, opportunities and hazardous area controls in relation to Green Hydrogen use in the transport sector.
- Identify "hydrogen clusters" (with potential for implementing several hydrogen refuelling stations), that should be connected with each other through "hydrogen corridors" (refuelling stations strategically placed along heavily trafficked highways between the cluster cities).
- Provide incentives that don't only favour BEVs. "Technology neutral" incentive scheme.

- Provide incentives that don't only favour BEVs. "Technology neutral" incentive scheme.
- In-line with the hydrogen cluster or park concept, the NZ Government owned KiwiRail would be a great example of storage, distribution, and transport fuel use synergy in one entity. They have large pieces of brownfield land for storage sites, rail lines to ports for export, full scale H2 locomotives are already being tested in Germany and Japan. So KiwiRail could be a key transport component and H2 fuelled trains could reduce diesel pollution and eliminate the need for electrification of railroads in remote locations.

Hydrogen Fuelled Tug Boat

3b What are the challenges when using hydrogen for mobility and transport?

Key points:

- Hydrogen may not have market dominance in transport and mobility.
- Heavy storage vessels.
- A reliable Hydrogen supply network across NZ.
- High investment costs for both hydrogen fuelled vehicles and hydrogen refuelling stations.
- To keep costs reasonable, only have a small number of H2 fuel stations for trucks.

WSP's response to this question:

- Investment costs, zoning and logistics requirements may affect financial liability of establishing full network coverage that may impede in take up hydrogen solutions.
- FCEV's compete with BEV's with BEV's currently dominant and seen as emerging dominant player in transport and mobility.
- Transporting hydrogen via road for refuelling stations is unfavourable in strategic context (desiring to get vehicles especially heavy vehicles off roads), transport of hydrogen will likely be liquid which may pose safety risks.
- Potential safety risks for refuelling stations (see detailed point earlier).
- Network coverage.
- Heavy storage vessels are generally required for Hydrogen powered vehicles. So Hydrogen is not as viable for smaller vehicles such as cars.
- A reliable Hydrogen supply network across NZ will need to be provided to give refuelling options and ensure transport ranges can be maximised for fleet efficiencies.
- The functionality of hydrogen mobility depends on an already implemented refuelling infrastructure.
- High investment costs for both hydrogen fuelled vehicles and hydrogen refuelling stations.
- Hydrogen fuelling stations for all the cars in NZ probably not practical in the next decade. Focus on trains, trucks, ferries.

Hydrogen Refuelling Process

3c What are the opportunities for using hydrogen for mobility and transport?

Key points:

- Reducing C02 and pollution.
- Future potential application of hydrogen for fuelling aircraft (a heavy C02 emitter).
- Defer use of high carbon emission fuels such as diesel and petrol.
- Hydrogen currently can offer longer range possibilities than is currently available from larger EV solutions.
- Green Hydrogen can be produced locally reducing reliance on fossil fuels from foreign markets.
- Hydrogen can be better suited to trains, trucks, and ferries than batteries and reduce the requirement to electrify railroads.
- Hydrogen powered trains are already in service in countries like Germany.

WSP's response to this question:

- Reducing C02 and pollution if production of hydrogen is green vs current fossil fuels; diesel, gas and petrol.
- Hydrogen is currently more feasible for energy intensive mobility and transport (such as heavy trucks and future potential of aircraft, shipping) which are heavy C02 emitters.
- Rail could be viable for rail that is not electrified or practicable to electrify.
- Defer use of high carbon emission fuels such as diesel and petrol.
- Hydrogen currently can offer longer range possibilities than is currently available from larger EV solutions.
- In the more remote NZ regions, producing Green Hydrogen locally for local transport and farming needs will add benefits such as less fuel distribution costs and providing local employment.
- As increased international oil market pressures and costs impact on imported fossil fuel supplies in NZ, more opportunities for alternative fuels like Hydrogen will become viable. The ability for NZ to lessen the reliance on international oil supplies is a major benefit for the increased development of locally produced non-fossil fuels such as Green Hydrogen.
- Green Hydrogen can be produced locally reducing reliance on fossil fuels from foreign markets.
- Hydrogen refuelling is more similar to conventional fuelling than BEV-charging (hydrogen refuelling only takes about 3 minutes). This increases the potential for consumers and the public to adapt to the new technology.
- Hydrogen refuelling is standardized (not the case for BEV-charging, where different adapters are needed for different vehicle brands).
- Use trains to transport H2 long distances and H2 as fuel for trains. Repurpose Kiwirail capital from electrification to H2 demonstration projects.
- Examples from overseas like InnoTrans 2016 in Berlin where they are using the Alstom manufactured Coradia iLint CO2-emission-free regional train. The Coradia iLint is the world's first passenger train powered by a hydrogen fuel cell, which produces electrical power for traction. This zero-emission train emits low levels of noise, with exhaust being only steam and condensed water. The iLint is special for its combination of different innovative elements: clean energy conversion, flexible energy storage in batteries, and smart management of traction power and available energy. Specifically designed for operation on non-electrified lines, it enables clean, sustainable train operation while ensuring high levels of performance. The iLint was designed by Alstom teams in Salzgitter (Germany), their centre of excellence for regional trains, and in Tarbes (France), centre of excellence for traction systems.

Alstom's Coradia iLint CO2 - emission free regional train

Encouraging *the use of hydrogen for industrial processes including process heat supply*

4a What is the role of Government in encouraging the use of hydrogen for industrial processes including process heat supply?

Key points:

- Provide incentives to industries.
- Assist / promote seed funding.
- Fix ETS rules to fully recognise offset value for methane and other greenhouse gases.

WSP's response to this question:

- Assist / promote seed funding (such as business cases / feasibility studies) through tax incentives funding grants, research and development, case study publication /sharing/ marketing via communications plan (such as conferences, websites, email etc).
- Provide incentives to industries to look at swapping to Hydrogen fuel sources.
    - Swedish example: Steel production with hydrogen instead of coal. The project is called Hydrogen Breakthrough Ironmaking Technology or "HYBRIT", and has been developed by companies in collaboration with the government.
- Set tighter restrictions on local air emissions to force the development of alternative fuel sources such as Green Hydrogen.
- EECA could play more of a role in assisting in funding studies to look at alternative fuel options and conversion costs.
- Create a "Panel of Green Hydrogen Technologies Experts" to assist developers and to advise Government regarding new innovations, opportunities and hazardous area

controls in relation to Hydrogen for industrial processes.
- If ETS is set up correctly, then H2 processing will be favoured over hydrocarbons. If the ETS pricing rules are consistently applied and emissions verified, then industries will make rational investments to manage their costs.
- Sponsor competitive development of large scale fuel cells for industrial and grid use.

4b What are the challenges for using hydrogen in industrial processes?

Key points:
- Competition in some regions with existing fuels such as coal, gas, wood/biomass and electricity.
- Cost of changing / converting industrial process plants.
- Awareness of opportunities of alternatives such as the use of Green Hydrogen.
- Low level of industrial "know-how".
- Improve and scale up of fuel cell technology.

WSP's response to this question:
- Hydrogen use in heavy industry is still developing internationally, thus early adopters pay may a premium.
- Competition in some regions with existing fuels such as coal, gas, wood/biomass and electricity.
- The cost of changing / converting industrial process plants over to Green Hydrogen will be restrictive for many plants.
- Awareness of opportunities of alternatives such as the use of Green Hydrogen needs to increase and be supported by central government agencies.
- Low level of industrial "know-how" (not commercialized).
- A significant challenge will be developing price competitive large-scale fuel cells would be a much more efficient use of Hydrogen as an electrical source than direct combustion.

4c What are the opportunities for the use of hydrogen in industrial processes?

Key points:
- Where locations are close to renewable energy sources, hydrogen could be produced locally.
- Many industries produce hydrogen as a by-product.
- Industrial scale fuel cells can create a lot of opportunity for zero carbon manufacturing.
- Sponsor competitive development of large scale fuel cells for industrial and grid use.

WSP's response to this question:
- Opportunity for industrial process chemical symbiosis.
- Reduced C02 and potentially pollution.
- Where equipment is aging and due for renewal (replacement), transition into hydrogen solution could be well timed, required and have to be costed anyway.
- Where locations are close to renewable energy sources, hydrogen could be produced locally. Initial technical and capital funding support would be required to be made available.
- Hydrogen could open up many more opportunities for groups and communities, especially in more remote areas of NZ, as Green Hydrogen can be produced locally (using geothermal and wind generation) and then stored and/or used for process heat for applications like glasshouses, timber drying and food processing etc.
- As older industrial plants reach the end of design life/economic performance KPI's, Green Hydrogen fuelled alterative could be an option for re-powering / re-fuelling future re-development options. Initial technical and capital funding support would be required to be made available.
- Many industries produce hydrogen as a by-product. This can generate a new revenue stream for the industry.
- Fuel cells generate heat as well as electricity so process power, space heating, and cooling requirements can be met by Hydrogen at a high level of efficiency without carbon emissions.

Decarbonisation *of our natural gas uses*

5a What is the role of Government in encouraging hydrogen uptake for decarbonisation of our natural gas uses?

Key points:

- A clear decarbonisation Government policy direction is required.
- An effective ETS could make natural gas alternatives more viable.
- Enable building, plumbing, and electrical codes to allow hydrogen use in new developments.

WSP's response to this question:

- A clear decarbonisation Government policy direction is required.
- An effective ETS could make natural gas alternatives more viable.
- Controls on future expansion options for the natural gas networks.
- Protect residential users to ensure option remains in the near future. Encourage Industrial user to move to alternatives.
- Where locations are close to renewable energy sources, Green Hydrogen could be produced locally. Initial technical and capital funding support would be required to be made available.
- Create a "Panel of Green Hydrogen Technologies Experts" to assist developers and to advise Government regarding new innovations, opportunities and hazardous area controls in relation to Hydrogen alternatives to natural gas.
- Provide incentives for use of community (district) based fuel cells which can provide clean electricity as well as district heating and cooling.

5b What are the challenges for hydrogen to decarbonise the applications using natural gas?

Key points:

- More promotion and awareness of Green Hydrogen technologies and developing benefits.
- Make conversion options and costing information more freely available.
- If NZ wants faster adoption of Hydrogen by the retail market than solar has had, then it will need to offer incentives, possibly tax credits (like the rapid uptake of Kiwisaver) or something similar.

WSP's response to this question:

- There needs to be more promotion and awareness of Green Hydrogen technologies and developing benefits.
- Many residential uses would face considerable costs to convert to using hydrogen, even if it was available at the road side network.
- Make conversion options and costing information more freely available.
- General public needs more information on options and hazard controls relating to hydrogen.
- The general public and single-family houses may be the last to adopt Hydrogen technology. There may need to be incentive programs to get complete conversion.

5c What are the opportunities for hydrogen to decarbonise our gas demand?

Key points:

- Natural gas pipeline networks can in some cases be utilised to distribute Hydrogen.
- Community or district-based fuel cells which can provide clean electricity as well as district heating and cooling in new developments would be high value pilot projects, especially for high density areas.

WSP's response to this question:

- Natural gas pipeline networks can in some cases be utilised to distribute Hydrogen.
- An example of this imitative is a project in the UK for the City of Leeds - H21 North of England
    - https://www.northerngasnetworks.co.uk/2018/11/23/hydrogen-blueprint-unveiled-to-make-over-3-7-million-homes-near-emission-free-by-2034/
    - https://www.h2-international.com/2018/09/03/h21-leeds-tests-switch-to-hydrogen/
- Other examples include this project in Canada:
    - https://www.enbridgegas.com/Natural-Gas-and-the-Environment/Enbridge-A-Green-Future/Hydrogen-Storage
- Natural gas is currently not reticulated (via natural gas pipeline networks) to all regions of NZ It is restricted to main stream areas of the of the North Island of NZ. Other areas rely on bottled of tanker LPG distribution. Green Hydrogen could become a viable alternative local or distributed option, firstly in areas without current natural gas pipeline networks and in future become a more environmentally friendly option for the whole of the country.
- Community or district-based fuel cells which can provide clean electricity as well as district heating and cooling in new developments would be high value pilot projects, especially for high density areas.

Producing *hydrogen in sufficient volume for export*

6a What is the role of Government in producing hydrogen in sufficient volume for export?

Key points:

- International trade negotiations, strategic agreements and lobbying foreign investment.
- Ensure on green hydrogen which is also produced without pollution is lawful exported only.
- Help to develop a premium Green Hydrogen product to assist marketing this internationally.
- Provide direction and support for the development of port facilities dedicated to the export of Green Hydrogen.
- Only 4% of global Hydrogen production is "Green".
- Extend the 100% pure NZ brand to include Green NZ Hydrogen.
- Set up transport infrastructure with intermodal transfer locations (Kiwirail).

WSP's response to this question:

- International trade negotiations, strategic agreements and lobbying foreign investment.
- Ensure on green hydrogen which is also produced without pollution is lawful exported only.
- Help to develop a premium Green Hydrogen product to assist marketing this internationally.
- Clear National Hydrogen Strategy to give investor more certainty for their funding business cases.
- Encourage or provide incentives for the use of off-peak renewable electricity, to produce large volumes of Green Hydrogen for storage and transportation to international clients.

- Provide direction and support for the development of port facilities dedicated to the export of Green Hydrogen.
- Create a "Panel of Green Hydrogen Technologies Experts" to assist developers and to advise Government regarding new innovations, opportunities and hazardous area controls in relation to Green Hydrogen international exports.
- There is an opportunity for the NZ Government to take a lead role is supporting the production of Green Hydrogen as currently only 4% of global Hydrogen production is "Green". The NZ Government has an opportunity to play a lead role in the global uptake of Green Hydrogen.
- Extend the 100 % pure NZ campaign (or similar) to gain price premium for green NZ Hydrogen.
- Provide infrastructure (siting, transport), consenting, and pilot project funding to launch program.

6b What are the challenges for hydrogen if produced for export?

Key points:

- Hydrogen production is a slow, high pressure process.
- NZ is a long way from many Hydrogen customers.
- Tax governance and oversight supported by policy and frameworks.
- May be in the "greater good" not to export energy since energy is wasted used in transport and may be more viable assist and support nations to building their own capabilities.
- Production needs to be scaled up significantly in order the achieve economic feasibility.
- Rapid establishment of intermodal transfer infrastructure may require input from Government.

WSP's response to this question:

- Green Hydrogen production (electrolysis method) relies on importing and setting up specialist, expensive hydrogen production plant (e.g. Hydrogenics from Belgium) https://www.hydrogenics.com/
- Tax governance and oversight to ensure that corporations to not transfer profit to offshore tax havens and thus the community loose tax revenues that could be invested into society betterment.
- The "greater good" for an environmental perspective may be to encourage other nations to produce their own renewal energy other than promoting export energy (particularly for smaller Pacifica nations), or perhaps use exports to enable establishment.
- Significant levels of new investment will be needed to successfully commercialise and scale a global hydrogen industry - COAG Energy Council Hydrogen Working Group estimates to meet the Hydrogen Council's estimates of providing up to 18% of the world's final energy demand by 2050, global annual investments of between US$20 to $25 billion are needed for a total investment of about $280 billion by 2030 (Hydrogen Council (2017), Hydrogen Scaling Up – A sustainable pathway for global energy transition, (page 66).
- Hydrogen production is a slow, high pressure process that needs to be located directly beside renewable energy production locations (tapped off prior to Grid connection).
- Specialised land transport and ports facilities need to be set up.
- NZ is a long way from many Hydrogen customers such as Japan, China etc.
- Generally, the following plant items and site infrastructure items need specialist technical design inputs in the development of a remote, stand-alone Green Hydrogen electrolyser production facility:
  - Feed water to Electrolyser.
  - Electrolyser drain outlet.
  - Electrolyser to Compressor.
  - Compressor to Filling station.
  - Filling station to cylinder trailer.
  - Nitrogen panel electrolyser / compressor / trailer filling station.
  - All system vents (Hydrogen, Oxygen, Nitrogen).
  - AC power in to the plant.
  - AC power LV to Electrolyser / Compressor.
  - Backup power.
  - Instrument air system.
  - General site movement's assessment.
- Production needs to be scaled up significantly in order the achieve economic feasibility.
- General public must be comfortable that large production and storage facilities are safe.
- Establishment of intermodal transfer infrastructure at ports may require central government intervention.

Hydrogen Electrolyser Unit

6c What are the opportunities for hydrogen if produced for export?

Key points:

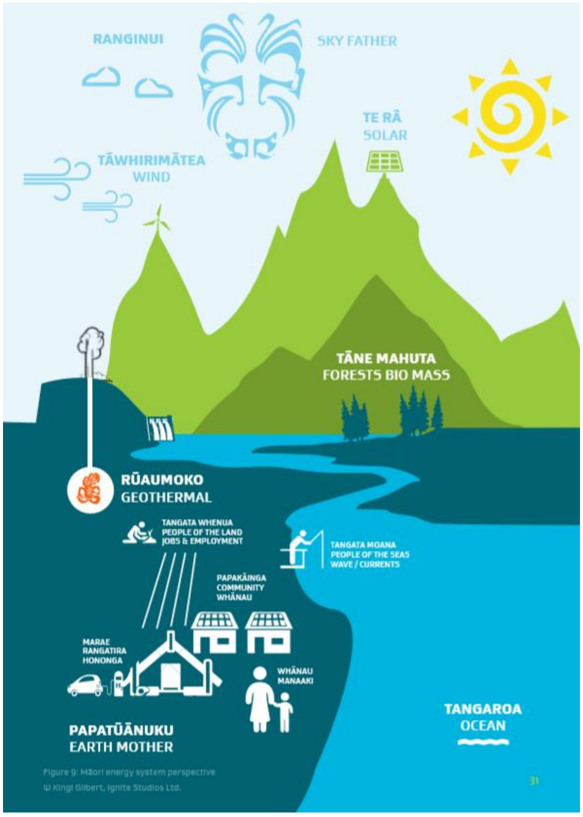
- A potentially sustainable, renewable, pollution free and environmentally friendly export commodity generating nation wealth.
- Existing Natural Gas pipeline networks could be made available to transport.
- Global developments in Hydrogen is increasing.
- Employment, technical skills and construction services in Hydrogen could be also exported.
- Oxygen as a by-product of Green Hydrogen production.

WSP's response to this question:

- New Zealand especially if an early adopter could also develop and export technical services and construction services capabilities that could be exported building skills, jobs and tax revenues, NZ could be become an innovator and R&D developer.
- Tax revenues for betterment of communities.
- Employment.
- Existing Natural Gas pipeline networks could be made available to transport hydrogen to ports, distribution locations and end users.
- It trucks are to be used, these should convert to be fuelled by Hydrogen.
- Port facilities like New Plymouth could benefit from the development of Hydrogen storage and shipping transfer facility developments.
- Port facilities could be developed to enable large scale Green Hydrogen storage and gas transfer systems to provide rapid product transfer systems to specifically designed Hydrogen shipping vessels.
- Should NZ have their own fleet of specifically designed Hydrogen shipping vessels? Both powered by Hydrogen and specifically designed for hydrogen distribution around NZ, the South Pacific and other international markets.
- Link in with Australia with shipping and storage facility development of our region.
- Globally, there are several hydrogen-related announcements and developments:
    - Germany is a leader with; hydrogen trains in service, 100 hydrogen fuelling stations, and plans for hydrogen plants.
    - Japan has a Hydrogen Strategy with the aim of hydrogen becoming cost-competitive with fossil fuels.
    - Australian state and federal governments have invested in pilot schemes for brown coal gasification and electrolysis. The most advanced project proposes exporting hydrogen to Japan.
    - Australian research has demonstrated the feasibility of utilising membrane technology to convert ammonia to high-purity hydrogen for use in fuel cells, which could significantly accelerate H2 fuel cell end use applications.
    - The UK has projects covering gas grid injection, 100% hydrogen networks and power-to-gas, as well as hydrogen bus fleets in various cities, and a £20m low-carbon hydrogen innovation fund.
    - Korea has published hydrogen economy roadmaps with a target to shift all commercial vehicles to hydrogen by 2025, and financially supported refuelling stations.
- If hydrogen is produced through electrolysis, oxygen is also produced. The oxygen can be sold to e.g. hospitals, which generates further revenue streams for the hydrogen producer.
- Railroads already extend to most ports and Hydrogen trains can carry Hydrogen cylinders making rail transport of green Hydrogen a low impact high value export commodity.

Opportunities *of hydrogen to Māori*

In addition, we welcome your feedback about the opportunities of hydrogen to Māori and how this will support their aspirations for social and economic development.



Key points:

- Māori Iwi's have access and landholdings adjacent to renewable energy sources.
- Hydrogen could open up many more opportunities for Māori groups and

communities, especially in more remote areas of NZ.

- Māori Iwi's could generate wealth, improving communities and providing employment opportunities.
- A small scale (1.5MW) Green Hydrogen production facility could have a capital development cost of around 5 to 6 million $NZD.
- Major opportunity to educate Māori engineers and technicians in the technology.

WSP's response to this question:

- Many Māori Iwi's have access and landholdings adjacent to renewable energy sources/facilities to enable them to locate Green Hydrogen production facilities on their own land (e.g. Tuaropaki Trust at Mokai Geothermal Power Station near Taupō).
- Hydrogen could open up many more opportunities for Māori groups and communities, especially in more remote areas of NZ, as Green Hydrogen can be produced locally then stored and transported by trucks to end users or exported internationally via ports.
- Many Māori groups now have access to large capital funds which they could use to develop and partner with investors for Green Hydrogen production, storage and distribution network developments.
- Create a "Panel of Green Hydrogen Technologies Experts" to assist specific Māori developers and to advise Government regarding new innovations and opportunities in Green Hydrogen developments.
- Green Hydrogen could open up many more opportunities for Māori groups and communities, especially in more remote areas of NZ. Green Hydrogen can be produced locally, utilising a local renewable energy production facility (e.g. Geothermal or Wind generation), then stored and transported by trucks to end users or exported internationally via ports.
- A small scale Green Hydrogen production facility (approximately 1.5MW) could have a capital development cost of around 5 to 6 million $NZD. This may enable this generation plant to not have to rely on a HV grid connection, but alternatively supply the local power distribution network during (high price) peak power demand periods and produce Green Hydrogen during (low price) off peak power demand periods (night periods).
- Development of hydrogen facilities on Iwi land using Iwi resources represents a real opportunity for young Māori to gain experience, education, and training in the technology and to directly participate in building NZ's energy future.

Promotional *Information*

What can WSP offer:

1. Provide WSP ANZ and WSP global promotional information on hydrogen capabilities and experience offerings that could assist in NZ.
2. Current projects WSP is currently involved with regarding Hydrogen in NZ.
3. Current associated project WSP is involved with relating to associated Renewable Energy development projects (Hydro, Wind, Geothermal, Solar, Biogas etc).
4. Current related Hydrogen projects which WSP globally in involved with, which could be of interest and have relevance to the New Zealand environment and future needs.

WSP in NZ

WSP is rapidly expanding the services we provide to the energy sector.

We provide strategic, technical and operational services to energy projects all over New Zealand. WSP has been part of New Zealand's energy landscape for over 50 years and in Canada, WSP has been involved in the energy market for 100 years. We have been involved with many of New Zealand's most significant energy projects and are well connected to all major infrastructure (Ministry of Works, Works Consultancy, Opus, WSP Opus and now WSP).

The world is increasingly dependent on the energy industry for reliable and uninterrupted supply. WSP helps to meet this need by planning and designing highly resilient engineering solutions for new energy infrastructure. People also look to us for leadership when it comes to energy management as we have a long history of successful energy consumption reduction in industry, buildings, transport and the residential market.

Our capability and experience in power covers:

- Power Generation
- Power Transmission
- Power Distribution
- Powering Infrastructure
- Oil and Gas
- Strategic Advisory
- Renewable Energy
- Engineering Expertise
- Master Planning and Feasibilities Studies
- Project Management
- Contract Management

Next Steps:

Develop a following up action plan for Specialist Strategic Advisory to government supporting New Zealand's Energy Transition in line with 2035 and 2050 climate initiatives.

We offer strategic, technical and operational expertise to projects right across the energy mix. Whether it's supporting the infrastructure that powers us all, designing 'green' buildings, helping organisations to reduce their footprint, planning to ensure the lights stay on in the residential market – we're there.

We support the energy transmission and distribution market with a wide range of services including property and land acquisition, environmental planning, design guidance, geotechnical work, civil and structural engineering, asset disposal, facility management and project management. Our skills are highly sought after by the oil and gas sector, for both on and offshore projects.

Because of our scale and geographic reach, we are in a unique position to work with many energy clients simultaneously– something our clients really value. We have 40 local offices and a network of laboratories throughout New Zealand. WSP is a member of the Green Building Council in New Zealand and Australia.

WSP in NZ is a signatory to the Climate Leaders Coalition, and has set science-based carbon reduction targets, with a goal to be Carbon Neutral by 2050. We have begun efforts to reduce our emissions by switching 30% of the pool fleet to electric, introducing the new air travel rules, and will shortly launch the Green Team.

WSP Global Experience:

The role of hydrogen cuts across business sectors, so cannot be considered in silos, and as a multi-disciplinary consultancy WSP can tackle the whole challenge.

WSP has an established oil and gas team in the UK with transferable experience in natural gas, providing services such as:

- Design of gas distribution infrastructure, at all pressure tiers and design stages.
- Technical due diligence.
- Pre-feasibility and feasibility studies.
- Pre-FEED and FEED services.
- Owner's & Lender's engineer.
- Pipeline routing studies.
- Site selection studies.

Internally we have established a Hydrogen Working Group; the objective of this has been spreading an internal awareness about hydrogen as an energy vector and further educate those in the multi-disciplinary group on how the market is developing, as well as a technical awareness. This has led to publishing several thought leadership pieces on hydrogen. Furthermore, WSP is a member of the Advisory Board of the Decarbonised Gas Alliance, which advocates for hydrogen and other decarbonised gas technologies.

Additionally, the industry team at WSP have experience and capability in the design of hydrogen pipework, as is detailed in the project references below.

WSP's hydrogen experience encompasses the entire hydrogen value chain. Key project experience includes:

TECHNICAL DUE DILIGENCE – HYDROGEN / AMMONIA / UREA COMPLEX

WSP undertook a technical due diligence for a proposed world-scale fertiliser complex. Our scope of work included a detailed assessment of the advanced process technology employed for hydrogen synthesis and purification. Our report was utilised by our client to support their engagement with government agencies and financial institutions.

HYDROGEN SITE SELECTION STUDY

WSP has been engaged to perform a site selection study to identify optimum locations to establish a large-scale electrolysis-based hydrogen production facility in the UK. Our scope includes identifying the key selection parameters, identifying and ranking potential locations for the *facility,* undertaking preliminary engineering design and providing guidance on planning and permitting requirements.

UK GOVERNMENT CCS INNOVATION

WSP acted as the government's technical advisor, monitoring a project evaluating the production of hydrogen by electrolysis for utilisation in the production of Substitute Natural Gas from captured CO2. WSP provided technical oversight and guidance, where appropriate, to the project developer.

UK GOVERNMENT 2050 INDUSTRIAL DECARBONISATION ROADMAPS

WSP and partners DNV-GL were retained to develop a series of decarbonisation roadmaps for eight energy intensive industries. A broad range of decarbonisation technologies were identified and evaluated, including the use of hydrogen as an alternative fuel in sectors including glass and ceramics manufacture, alternative low-carbon hydrogen production technologies in the chemicals and refining sectors and use of hydrogen in Direct Reduced Iron processes in the iron & steel sector. In addition, we organised a series of stakeholder questionnaires, telephone interviews and sector workshops in order to maximise stakeholder engagement in the process and align the project output with stakeholder aspirations.

HYDROGEN PLANT MODIFICATIONS

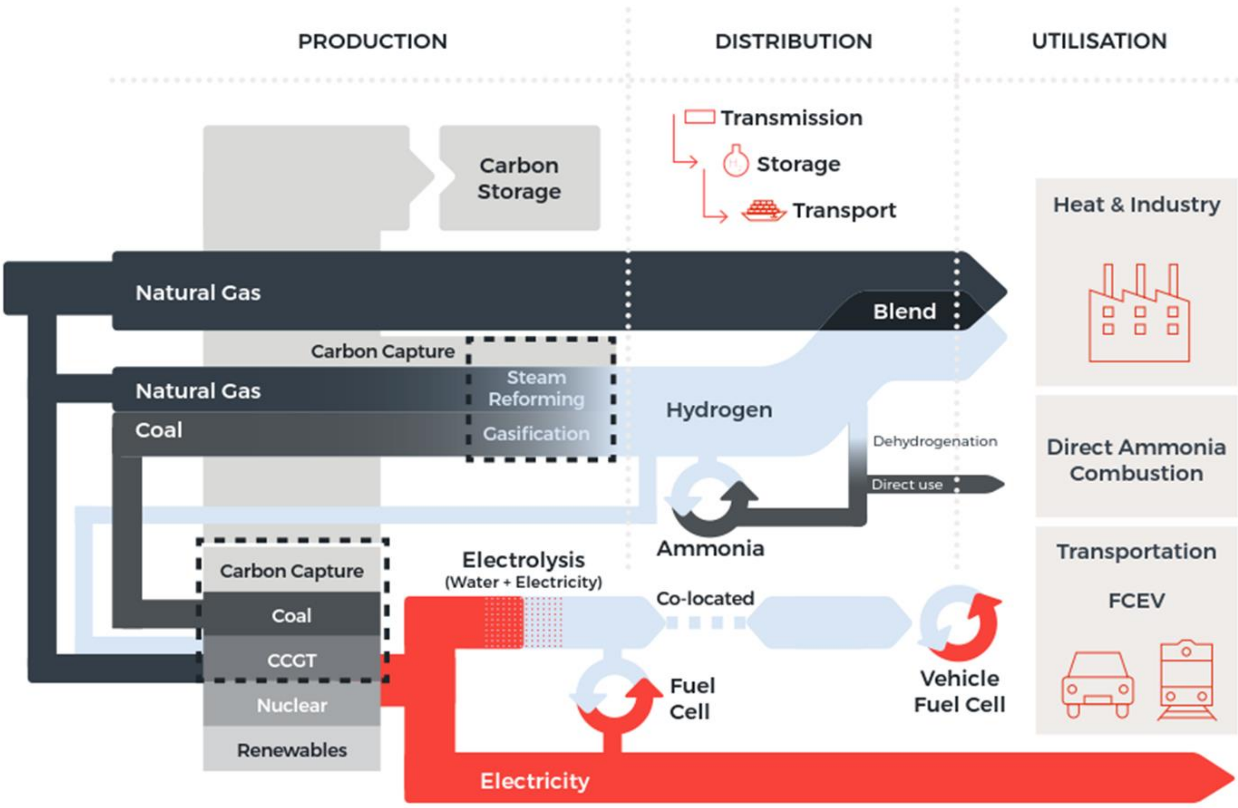
WSP has a long-term partnership with a major chemicals company, whose facilities include a steam methane reformer (SMR) hydrogen production plant. WSP have undertaken several hydrogen piping modification projects, including engineering design and project delivery.

HYDROGEN FUEL CELL ELECTRODE MANUFACTURING PLANT

Designed, manufactured and supplied a bespoke catalyst milling and application package to a fuel cell plant. As well as design, carried out project management and commissioning of the package.

HYDROGEN FUEL CELL PORTABLE POWER

We are providing technical support to a client looking to develop a ground-breaking portable power device utilising an innovative design of hydrogen fuel cell.



Hydrogen vs. EV Technologies

Research Areas currently being looked at:

- Initiatives to drive the uptake of Hydrogen fuelled transportation
- Driving themes
- Climate Policy Initiatives
- R&D initiatives
- Carbon Pricing
- Transport Planning

Business Initiatives

- In March 2017, Alstom successfully performed the first test run at 80km/hr of the world's first hydrogen fuel cell passenger train.
- In August 2017, Hyundai unveiled its latest hydrogen fuel cell SUV.
- An alliance of 11 Japanese firms, including automakers and energy firms, has pledged to build 80 fuelling stations for hydrogen fuel cell vehicles by 2022.

Regional Initiatives

Australia

- ACT Government will partner with ActewAGL, Neoen, and Hyundai to open a pilot hydrogen refuelling stations in the Nation's Capital Government of South Australia – A hydrogen roadmap for South Australia • In January 2017, representative from the Australian Maritime Safety Authority and Japan's Transport Ministry signed an agreement to commence the world's first pilot project for the shipping of liquid hydrogen from Australia to Japan.

Europe / United Kingdom

- Joint Initiative for Hydrogen Vehicles across Europe (JIVE) Investment in hydrogen buses • In November 2016, the London Mayor announced that no more diesel double-decker buses will be procured in London after 2018.
- In March 2017, the UK Government announced a new £23m fund to accelerate the take of hydrogen vehicles and boost the creation of hydrogen fuel infrastructure.

North America

- In August 2016, the California Air Resources Board announced 1,300 new hydrogen fuel cell vehicles had been deployed in California.

Japan

- By 2020, Japan is targeting 40,000 hydrogen fuel cell cars and 100 buses on the road, and 160 hydrogen re-fuelling stations.

China

- In March 2016, the world's first hydrogen powered tram commenced service in Qingdao.

South Korea

- In March 2016, the South Korean Government announced a long-term program to replace 26,000 CNH buses with hydrogen fuel cell buses.

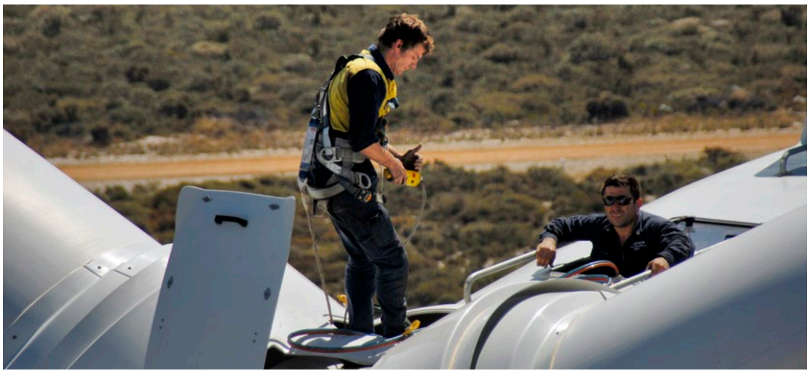
World Energy Consumption Outlook

- In its International Energy Outlook 2019, the EIA has assessed that the worlds energy consumption will grow by nearly 50% between 2018 and 2050.
- Most of this growth comes from non-OECD countries and is driven by their strong economic growth. This is particularly the case for Asia.
- Renewable energy electricity generation is seeing the most growth worldwide. But many countries are limited in the access to the required resources and funds.

Appendix A
WSP Wind Capacity

Wind Energy Services

A full suite of multi-disciplinary wind energy services under one roof.



WSP is a leading service provider in the NZ-Australian wind industry with a track record spanning more than 20 years of successful project delivery across planning, execution, and operational phases.

Our clients; wind farm developers, owners, contractors, and investors, benefit from a broad scope of multidisciplinary services under one roof. This facilitates a single and accountable point of contact to ensure all services are delivered in coordinated and timely manner.

Our open and flexible approach is to work with clients to understand their specific project and agree on the most appropriate and efficient approach to a given work package. We pride ourselves on offering our clients the right knowledge at the right time.

PROJECT INVOLVEMENT

Alinta, WA
Ararat, VIC
Boco Rock, NSW
Burgos, Philippines
Capital, ACT
Cathederal Rocks, SA
Ceres Development, SA
Clements Gap, SA
Collgar, WA
Mount Emerald, QLD
Hornsdale, SA
Lake Bonney, SA
Lincoln Gap, SA
MacArthur, VIC
Mill Creek, Wellington
Nirranda South, VIC
Oaklands Hill, VIC
Portland (multiple stages), VIC
Snowtown, SA
Stockyard Hill, VIC
Te Apiti, Manawatu
West Wind, Wellington

OUR SERVICES

- Owner's Engineer
- Lender's Engineer
- Detailed design

Technical Wind

- Wind monitoring and data management
- Wind resource and energy yield assessment
- IEC site suitability assessment
- Layout development and optimisation
- Power curve testing
- Operational performance assessments
- End of warranty inspections

Electrical

- Grid impact system studies and access standards
- Connection application
- Commissioning compliance review including model validations
- Primary and secondary plant design

Civil and Structural

- Footing design; gravity, anchored, and pile
- Optimising turbine foundations for site conditions
- Ground-structure interaction analysis
- Balance of plant design; access tracks, transmission tower & substation footings

Geotechnical

- Ground investigation; boreholes, test pits, cone penetration, geophysical surveying, laboratory testing, ground condition reports (bearing capacity, settlement, sub grade strength), groundwater assessment, geotechnical risk assessment
- Construction verification

Environmental and Planning

- Environmental impact assessment and management
- Ecological monitoring and assessment
- Statutory planning
- Stakeholder engagement

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wsp.com

WSP is one of the world's leading engineering professional services consulting firms. We are dedicated to our local communities and propelled by international brainpower. We are technical experts and strategic advisors including engineers, technicians, scientists, planners, surveyors, environmental specialists, as well as other design, program and construction management professionals. We design lasting Property & Buildings, Transportation & Infrastructure, Resources (including Mining and Industry), Water, Power and Environmental solutions, as well as provide project delivery and strategic consulting services. With 4,610 talented
people in 62 offices across Australia and New Zealand, we engineer projects that will help societies grow for lifetimes to come.

Relevant Experience
& Track Record

WSP Opus has depth and breadth of experience in wind projects worldwide. The nominated project team have extensive experience in New Zealand and Australia, combined with knowledge shared throughout the company.

Project West Wind Farm

Wellington, New Zealand
Client: Meridian
2000-2009

Role: Detailed Design and Construction Supervision

Project West Wind comprised of 62 wind turbines located in complex terrain on Wellington's west coast. The project also included the construction of 33 km of new roads through steeply undulating and sloping terrain. Road and platform construction involved the movement of approximately 1,800,000 m3 of cut to fill/disposal.

This project was delivered in three phases: Feasibility (2000-2004), Consenting (2005-2007) and Construction (2007-2009). WSP Opus provided:

- Excellent understanding of ground conditions to road design / alignment, turbine foundation pad design and substation foundation design;
- Innovative civil design solutions – e.g. design to bypass the main HVDC cables at Oteranga Bay;
- Contractor involved design – collaborative design and SEMP development with Higgins;
- Excellent relationship with Meridian Energy established; and
- Collaborative working environment with the client and other consultants (Higgins, Beca, Vestas and the landowners).
- Construction supervision with respect to the turbine and substation foundations
- Geotechnical monitoring of earthworks, turbine foundations and turbine platforms supporting the 400 tonne crane during the construction phase.

The geometric design of the road and turbine platforms was divided into two components with Beca undertaking one of these components. A collaborative approach and working relationship was used to define/agree standards and design philosophy for provide a best for project outcome.

Track Record

WSP Opus was proactive with the client during the investigations, design and construction phase to ensure the project was delivered on time and within budget. Regular discussions were held with all project parties to exchange information and to allow site works to continue without costly delays.

Mill Creek Wind Farm

Wellington, New Zealand
Client: Meridian
2004-2014

Role: Detailed Design

WSP Opus completed the site investigation, assessment of ground conditions and risk, testing and inspection of foundation conditions along with certification of turbine foundations for this 31-turbine wind farm. We also carried out a preliminary site and access route appraisal, feasibility, consenting and costing was also completed as well as an assessment of environmental effects and risks.

We provided:

- Preliminary site and access route appraisal
- Preliminary design of all aspects of this windfarm
- Site investigations, assessment of ground conditions and risk
- Assessment of environmental effects and consenting
- Innovative road design for the significant upgrade of the main public access road to cater for over dimension loads.
- Developed (in collaboration with the Contractor) a bespoke pavement for upgrading Ohariu Valley Road and internal access roads to carry construction traffic and overweight loads.
- Geotechnical design of road embankments over a landfill (construction access road went through Spicer Landfill in Porirua)
- Assessing and testing council bridges under overweight loads.

Track Record

All services were completed on time and budget, successfully consented and all quality assurance requirements were met.

Te Apiti Windfarm

Manawatu, New Zealand
Client: Meridian
2004-2014

Role: Detailed Design and Construction Support

We provided services included site investigation, assessment of ground conditions and risk, testing and inspection of foundation conditions along with certification of turbine foundations for this 55-turbine wind farm, based in the Manawatu Gorge, 10 kilometres from the city of Palmerston North.

We also provided design services for this project, including preliminary site and access route appraisal, feasibility and cost appraisal, turbine site selection, and an assessment of environmental effects.

Feasibility (2000-2002)

- Port to Site Transport Feasibility Studies
- Internal Core Site Transport and Road Construction Feasibility Studies
- Concept Design Turbine Foundations & Roading (Geotechnical, Geometric & Structural)
- Preliminary Geotechnical Assessments

Consenting (2002-2003)

- Preliminary Design Turbine Foundations & Roading (Geotechnical, Geometric & Structural)
- Resource/Planning Consent Application (Assessment of Construction Effects)
- Expert Witness at Council Hearings

Construction (2003-2004)

- Detailed Design Turbine Foundations & Roading (Geotechnical, Geometric & Structural)
- Construction Monitoring/QA turbine foundations/geotechnical

Track Record

All services were completed on time and budget, successfully consented and all quality assurance requirements were met.

Stockyard Hill Wind Farm

Ballarat, Australia
Client: Goldwind
2018 – ongoing

Role: Owner's Engineer

We were appointed as Owner's Engineer to assist Goldwind during the construction phase of Stockyard Hill Wind Farm. The Stockyard Hill Wind Farm is a wind energy project located 35 km west of Ballarat in Victoria's central highlands, with an approximate nameplate capacity of 530 MW. This is the largest wind farm under construction in the Southern Hemisphere.

Key duties include:

- EPC and NSP design document review
- Project meeting attendance
- RFI response
- Site inspections and meetings
- Specialist site visits (geotechnical, electrical, mechanical, SCADA, general BOP, FAT inspections and environmental compliance inspections)
- Safety risk review workshop attendance (HAZID, HAZCON, HAZOP)
- Monthly reporting and maintaining an issues and risk register
- Ad hoc technical and commercial support
- Contractors claim assessment

Track Record

Our role as Owner's Engineer is still active and is progressing well, with design documentation reviews completed and currently in the site inspection phase. We are currently performing under budget and have received positive feedback from the client. We have provided ad hoc technical advice on the late addition of synchronous condensers to the project. We have also provided Quality Services inspections for a number of components.

Yandin Wind Farm

Australia
Client: Alinta
2019 – ongoing

Role: Lender's Engineer

We were appointed to conduct technical and environmental due diligence in order to outline key risks that will assist Alinta and investors with technical, regulatory, environmental and social assessment of the project as a basis of providing finance. This included review and assessment of two OEMs and their Wind Turbine Generator's (WTG) under consideration for the project.

Key scope items included:

- Review and analysis of information provided by the Client.
- A review of the turbine technology and its related risks
- Review of preferred EPC Contractor/Turbine manufacturer (and sub-contractors) and their track record in managing wind projects/EPC Contractors
- Review of site location and wind resource, and turbine site suitability
- Review of balance of plant and SCADA requirements
- Assessment of the construction process, contractors, schedule and costs
- Review wind resource analysis and Annual Energy Production (AEP)
- Assessment of the grid connection and any material constraints on the network (including MLF for the site)
- Review of key agreements including EPC Contract, O&M Agreement, Asset Management Agreement, Maintenance and Services Agreement and Connection Services Agreement.
- Review status of development consent, approvals and environmental management
- Review technical inputs to the financial model.
- Participation in Q&A and meetings
- Provide technical due diligence report, suitable for third party reliance to Project equity parties and financier's.

Track Record

The project is in the final stages, where we are actively responding to equity parties Q&A. Throughout the project we have been very flexible and adaptable, responding to changing client needs.

Collector Wind Farm

NSW, Australia
Client: Ratch Corporation Australia (RAC)
2019 - ongoing

Role: Owner's Engineer

The Collector Wind Farm is a wind energy project located approximately 55km north east of Canberra and 35km south west of Goulburn situated in the NSW Southern Tablelands along the Cullerin Range. It will consist of 55 WTGs Vestas with a capacity of approximately 230 MW.

We have been appointed as Owner's Engineer to assist RAC in the pre-financial close phase for the wind farm. Key duties include:

- Technical specification development and input to contractual guarantee schedules as part of the EPC and O&M Contract including negotiation with the EPC & O&M Contractor
- Assistance in the negotiation of a Connection Agreement with the local Network Service Provider (NSP), Transgrid, and review of technical requirements
- Assistance with GPS development and due diligence by the NSP including an assessment against NER S5.2.5.12 (impact on network capability)
- Review of status and next steps in the approvals process including development of a priorities and dependencies register, with a future-focus for contractor delivery in terms of mitigation practicality and relevance
- Prepare gap, risk and liability analysis review of extant and current planning and environmental assessments
- EMI assessment for the planning approval
- Desktop flood risk assessment
- Initial civil concept design review

Track Record

Based on the success of the above services, we are finalising our engagement with the client as the Owner's Engineer during the construction phase of the Collector Wind Farm.

Antarctica Wind Farm

Ross Island, Antarctica
Client: Meridian Energy & Antarctica New Zealand
2007 – 2009

Role: Design and Construction Supervision

WSP Opus worked with Meridian Energy and Antarctic New Zealand to install and commission three wind turbines to generate electricity for Scott Base and the American McMurdo Station. We selected 10 sites for the 3 wind turbines, designed and oversaw the construction of the innovative 'spider' foundations which hold the turbines in place. This wind turbine foundation structure is now almost halfway through its 20-year design life, and to date has performed without any problems.

The team had to work within a highly sensitive Antarctic environment, therefore minimising the disturbance of the natural environment (soil, air and sea) consider the removal and disposal of all construction debris and waste, as well as sustainable construction materials. A normal in-situ concrete wind turbine foundation was not practical because of the lack of suitable concrete batching, mixing, transport and heated curing facilities in the sub-zero temperatures on site. All the steelwork had to be tested to ensure it complied with the standards required to withstand the extremely low temperatures.

We had to overcome the logistical challenges of severely limited site access, a very small construction window (November to February), and the need for a very high degree of construction accuracy. The interface between the WSP Opus foundation structure and the wind turbine tower had to be constructed to a level within a tolerance of 1mm in 2400mm. This tolerance was achieved on site using friction grip bolt joints in the WSP Opus steel foundation structure, one part of the innovative design.

Track Record

Close collaboration with Enercon, who designed the tower section, meant modifications along the way ensured timely delivery within the critical construction window. Late in the developed design state Enercon advised that the overall structure had to be outside a certain natural period range. WSP Opus analysed the structure and it was found to be within the range. The team then reduced the pitch circle of the foundation blocks to increase the period. The detailing of the steel substructure was modified to suit and proceed to fabrication within the time available prior to transporting to the ice.

Extensive design and construction in Antarctica, both from Ross Island and Scott Base, has provided innumerable lessons, in practically every area from site investigation, foundation design, collaboration, logistics and construction. These lessons give us a huge depth of knowledge and experience to apply to other Wind Farms.