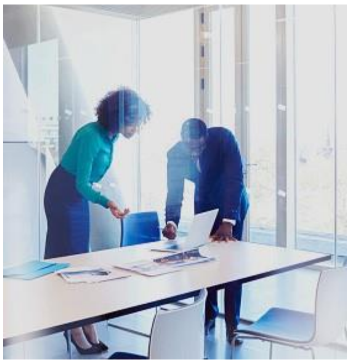
GHD Advisory



Ancillary Service Benefits for Marinus Link

TasNetworks

4 December 2019

Executive summary

GHD (we/us/our) was engaged by TasNetworks to investigate the potential market benefits that may be achieved with the introduction of a second interconnector between Tasmania and Victoria – the Marinus Link (Marinus). Marinus will be a 1,500 MW HVDC link, constructed in two 750 MW phases.

Our review of potential market benefits has focused on two key areas:

- Frequency Control Ancillary Services (FCAS)
- System Restart Ancillary Services (SRAS)

With the addition of a second interconnector (Marinus), Tasmania will be able to participate fully in the mainland FCAS market (rather than in part, as is currently the case). We have assessed the potential FCAS benefit that would arise as a result of greater market participation following the construction and commissioning of Marinus. Our analysis has drawn on historic data (for FCAS cost and volumes) and uses long run average prices as proxies for the underlying costs of FCAS provision. Marinus is being designed with a 10 to 20% short term (up to fifteen minute) overload capability, enabling it to provide bi-directional FCAS even when operating at full nominal power flows.

The calculated benefits are dependent on expected percentages of global – as opposed to local – Tasmanian FCAS enablement, and the expectation that recently observed contingency percentages would continue in the future without Marinus. Recently observed percentages of global regulation enablement, however, are historically low. We have therefore calculated a lower value of benefits on the assumption that regulation global percentages would return to their previously higher levels. The alternative assumption of continuing lower global regulation enablement percentages in the future, if dispatch constraints bind more frequently in the absence of Marinus, leads to a higher value of estimated minimum benefits

Drawing on our analysis, we conclude that construction and operation of Marinus will:

- Overcome locational constraints that prevent Tasmania being fully active in the mainland FCAS market and vice-versa
- Allow Tasmania to join the mainland market thereby creating a NEM wide, extended global FCAS market
- Increase competition in the provision of FCAS in both Tasmania and the mainland, particularly during times of global (e.g. mainland interstate interconnector) constraints
- Eliminate technical constraint legacy of Basslink:
  - A ‘no-go zone’ exists during the power flow reversal when FCAS services on both sides have to be supplied locally
  - The ramp rate of 200 MW / 5-minute Dispatch Interval can be relaxed and reflect actual capability to deliver the service
  - Maximum import and export limit will be more flexible by specifying Marinus with a short term overload, allowing HVDC to perform in a similar way to an AC line and avoiding market separation for some FCAS services when HVDC operates on the limit. Consequently it may be possible to simplify the existing two areas of AGC control to a single area system that controls all generators. This would bring a significant improvement to FCAS control

- Reduce the cost of provision of FCAS to both the mainland and Tasmania by a conservative present value (PV) of $148 million (to three significant figures) over the economic life of Marinus. This is based on a 5.9% pre-tax real discount rate. At a lower level of global regulation enablement the present value of benefits could be up to $474 million

In relation to SRAS, we consider that access of power from Tasmania by mainland regions via a grid forming Voltage Source Converter (VSC) HVDC link (and vice versa) creates a possible future option for eliminating the need for black start units in Tasmania and Victoria. This would allow for the costs of procuring SRAS to be reduced. However, we have not attached a monetary value to this potential benefit because we assess the necessary changes to AEMO policies and procedures as being beyond the scope of this report.

Contents

Figures

Tables

Appendices

Disclaimer

This report has been prepared by GHD for TasNetworks and may only be used and relied on by TasNetworks for the purpose agreed between GHD and the TasNetworks as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than TasNetworks arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.3 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by TasNetworks and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1. Introduction

1.1 Background

TasNetworks is undertaking a Regulatory Investment Test for Transmission (RIT-T) for a second Bass Strait electricity interconnector, the Marinus Link (Marinus). In the National Electricity Market (NEM), frequency is maintained within operable limits by procuring frequency control services (traditionally supplied either by generators or large loads) in the Frequency Control Ancillary Services (FCAS) markets. The mainland and Tasmania are managed by two separate Automatic Generation Control (AGC) systems due to the technical design of Basslink. This causes the FCAS markets in Tasmania to operate separately from the mainland NEM FCAS market (about 40 per cent of the time) thereby incurring higher costs than would otherwise be the case.

The proposed incorporation of a short term overload capability will enable Marinus, as a HVDC link, to behave in a similar fashion to AC transmission. Thus, the proposed technical specifications of Marinus incorporating a 10 to 20% short term (up to fifteen minute) overload capability, will allow the entire NEM to benefit from a single AGC system and allow for NEM wide procurement of FCAS. This will provide Tasmania and mainland NEM regions access to the lowest cost FCAS as a single market.

FCAS are required to maintain NEM operating frequency within prescribed limits. Frequency of operation departs from the nominal 50 Hz whenever there is an imbalance between generation and load (MW) at any instant of time. If load is greater than generation, frequency falls proportionately, conversely if generation is greater than load, frequency increases proportionately. In this report we demonstrate that Marinus will enable more economical sharing of FCAS resources between Tasmania and the mainland.

The transition from predictable fossil fuel generation to intermittent and less predictable renewable energy generation has increased the need for FCAS in the NEM. Concomitant with this transition is a reduction in the ability of the energy system to control frequency. This is as a result of a number of factors including the removal of any requirement for generators to provide mandatory primary frequency response, declining inherent inertial support from traditional synchronous generators, increasing occurrence and scale of miss-match between generation and load as well as the retirement of fossil-fuelled generation, traditionally the providers of FCAS.

Growing battery storage capacity in the NEM has demonstrated the capability of this technology to control frequency and supply ancillary services. Both large-scale and distributed battery storage could play an increasing role in offsetting growth in both volumes required and the costs of procuring FCAS. However, current proposals for large scale battery developments are concentrated in mainland regions, and any qualitative and cost advantages may only be fully realised via strong interconnection between regions.

1.2 Scope

GHD (we/us/our) was engaged by TasNetworks to estimate the changes in ancillary services costs to the NEM arising from the commissioning of Marinus. Our net benefit calculation is based on section 3.6 of the application guidelines for RIT-T issued by the Australian Energy Regulator (AER) in December 2018. Our scope of work is limited to assessing the quantitative benefits in respect of relative reduction of costs of provision of FCAS or SRAS for existing FCAS and SRAS markets. We also comment qualitatively on future FCAS products that might arise. All other potential impacts on the NEM that Marinus may provide are excluded from our scope of work.

1.3 Assumptions

In undertaking this assignment, we have assumed that all publicly available data published by the Australian Energy Market Commission (AEMC), Australian Energy Market Operator (AEMO), AER and other statutory, regulatory and jurisdictional authorities and utilities is complete and correct.

2. Marinus

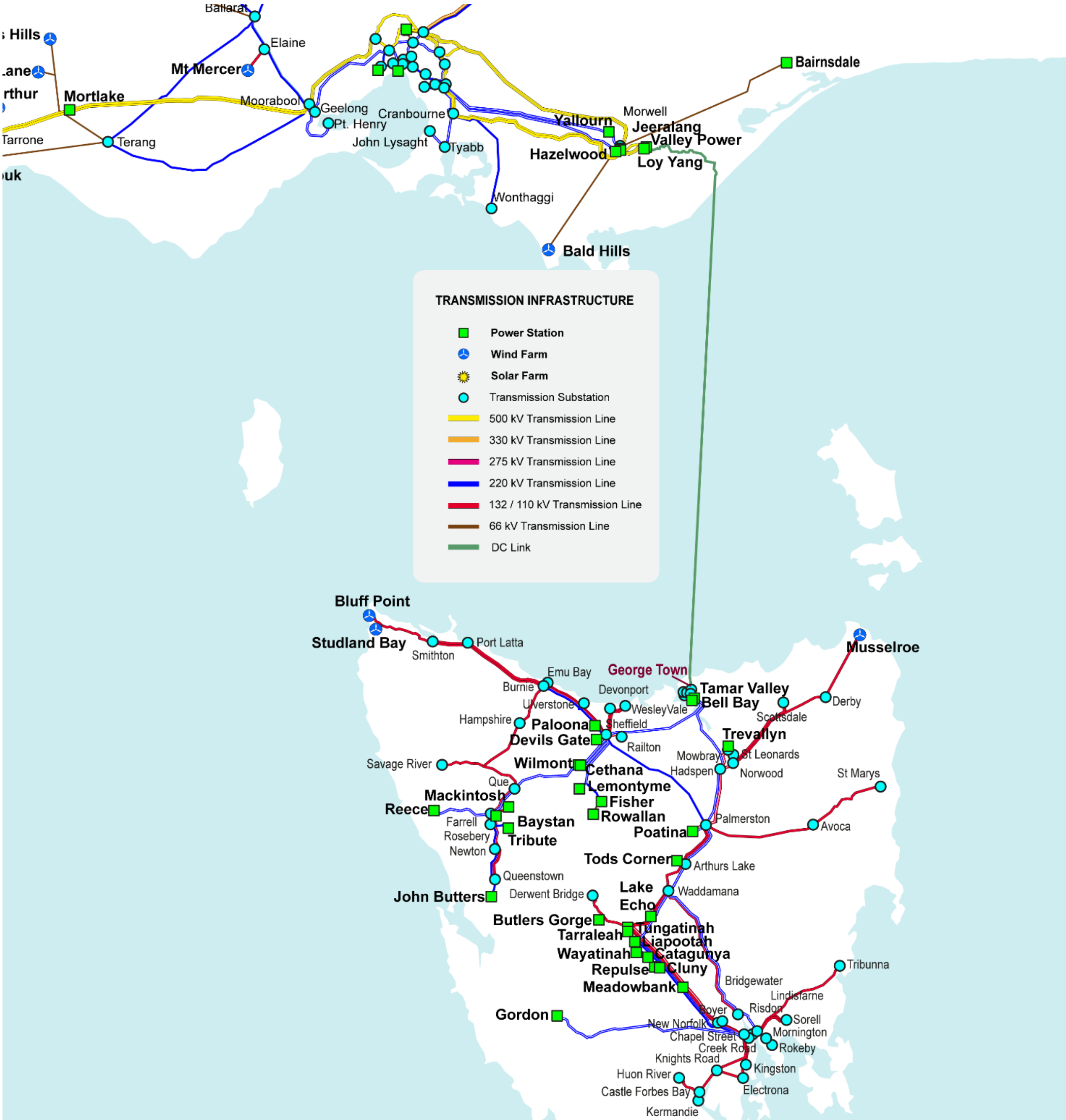
TasNetworks is undertaking a RIT-T for a second Bass Strait electricity interconnector; Marinus. An initial Feasibility Report released by Project Marinus mentioned, qualitatively, the ancillary service benefits Marinus could provide to the NEM.

Figure 1 shows the extent of the existing transmission network in Victoria and Tasmania proximate to the Bass Strait, and Figure 2 shows a conceptual route for Marinus. Marinus will connect converter stations located in the Burnie area in north-west Tasmania to converter stations located proximate to the Hazelwood substation in the Latrobe Valley in Victoria. Marinus has a target in-service date of 2027-28.

Marinus will provide an additional 1,500 MW of bi-directional transfer capacity between Victoria and Tasmania and will comprise two 750 MW cables. Marinus will complement the existing interconnector Basslink. HVDC Voltage Source Converter (VSC) technology will be used to enable controllable transfer of power over a distance of up to 340 km across Bass Strait.

A benefit of Marinus is that, incorporating the VSC and bidirectional cable with overload capability, allows Tasmania and the mainland NEM to run as a pseudo-synchronous system under a single, global or NEM wide, AGC regime for regulation FCAS, subject to inter and intra state constraints. This will allow for the creation of a single FCAS market NEM-wide, subject to existing mainland constraints. As a consequence, lowest cost available Tasmanian FCAS resources may be used post implementation of Marinus to support the mainland and vice versa.

Figure 1 Current Victoria and Tasmania transmission networks[1]



[1] AEMO, *Second Tasmanian Interconnector: Report for the Tasmanian Energy Taskforce*, January 2017, section 2.1.1, Figure 1, p. 13.

Figure 2 Conceptual Marinus routes

3. Ancillary services markets in the NEM

Ancillary services in the NEM comprise FCAS, System Restart Ancillary Services (SRAS) and Network Support Control Ancillary Services (NSCAS). In this report, we concentrate on the benefit that Marinus will bring in reducing the cost for provision of FCAS. We also discuss, qualitatively, the potential benefit that Marinus will bring to the SRAS market.

3.1 Frequency control ancillary services

NEM markets operate a dispatch cycle of 5 minutes, where generators bid to provide energy and FCAS. AEMO then dispatches the appropriate volumes required to match demand and maintain the power system frequency within its required operating limits. Bids are dispatched in lowest cost merit order[2]. This section provides an overview of the ancillary services and various providers of these services in the NEM.

AEMO manages the frequency of the power system, via the FCAS markets, to maintain the system frequency within allowable limits. Maintenance of a stable frequency is important for the maintenance of grid stability. At any instant, differences between system demand and total generation results in changes to system frequency. This gives rise to a continual need for AEMO to regulate system frequency to ensure it remains within allowable limits and rates of change. Regulation FCAS is the service provided by generators dispatched to provide frequency regulation services through automatic generator control (AGC or Secondary Frequency Control).

In addition AEMO must ensure that sufficient resources are held to manage circumstances that may result in abrupt changes in frequency such as the sudden disconnection of a large generating unit or load. Services provided for these contingencies are termed contingency FCAS, and are separated into “fast”, “delayed” and “slow” response services according to the required timeframe for response. This timeframe varies between six seconds and five minutes.

Additional active power sources available to manage unforeseen demand increase and/or generation unavailability are referred to as reserve. These comprise a variety of sources, which require different timescales to be ready to deliver these reserve services. Having a variety of sources available facilitates the determination of the optimum and efficient system performance. Participants in the FCAS markets bid into each market the day prior and are paid for their support when dispatched.

As mentioned, frequency control is provided by adjusting active power supplied to the transmission system in the NEM to match supply and demand, and or by adjusting load. Under the existing generation mix, active power provision, and hence frequency control, is supported by the mechanical inertia of synchronous generators powered by high mechanical inertia fossil-fuelled prime movers such as steam, hydroelectric, and industrial gas turbines, and slow speed reciprocating engines.

Changes in the energy mix, such as increasing variable renewable energy (VRE) generation (in particular solar and wind farms) will drive the need for additional FCAS. This increase will be required to cater for the relative variability and lower predictability of generation for these generation sources as compared to dispatchable generation. Concomitant with this change is the reduction in dispatchable synchronous

[2] The dispatch optimisation software, NEMDE (National Electricity Market Dispatch Engine) co-optimises the energy and FCAS markets to minimise the total cost of energy plus FCAS to the market.

generation powered by high mechanical inertia fossil fuelled prime movers traditionally used to provide much of the required frequency control. This will drive a requirement for alternative mechanisms to provide FCAS.

The cost of FCAS provision in the NEM was approximately $220 million in 2018. FCAS provision has exhibited a strong upward trend in costs since 2014. It is therefore important for AEMO to seek access to additional tools and services to manage system frequency so as to minimise network operating costs.

3.1.1 Contingency FCAS

In the NEM, there are six contingency FCAS markets, designed to ensure there is enough frequency response in the system to deal with a single credible contingency, which is typically the loss of a large generating unit or major industrial load.

In aggregate, market participants offering contingency services are required to perform the following tasks:

- 6 second (Raise and Lower) – arrest a rapid change in system frequency within the first six seconds of a frequency disturbance, and then provide an orderly transition to the 60 second service.
- 60 second (Raise and Lower) – stabilise the system frequency within the first sixty seconds of a frequency disturbance, and then provide an orderly transition to the 5 minute service.
- 5 minute (Raise and Lower) – Restore system frequency to its nominal 50 Hz within the first five minutes of a frequency disturbance, and to sustain response until notified by central dispatch.

The maximum amount of contingency service procured is equal to the size of the largest credible contingency minus assumed load relief. The largest credible contingency generally refers to the largest unit of generation that may fail, or the largest combination of generation capacities connected through a single point of failure (for raise services), or the largest unit of load that may disconnect (for lower services). Load relief refers to the partially self-correcting mechanism whereby loads such as motors, pumps and fans draw less power when power system frequency is lower. AEMO recently reduced the amount of assumed load relief used to calculate FCAS requirements[3], meaning that contingency FCAS volumes are likely to step up to a higher level in the future than they have been in the past under similar conditions as the reduced load relief assumption is phased in.

3.1.2 Regulation FCAS

The other frequency service is Regulation (or load matching). This service is again broken into raise and lower elements for each region. Unlike contingency services that are locally enabled/installed on sites, regulation services are managed by an AEMO signal that is updating every 4 seconds via the AGC system. In Tasmania, hydroelectric systems require an eight second AGC target to avoid interaction between primary frequency control (PFC) and AGC systems. However, for the purposes of our analysis, this nuance is not material. As the power system moves between 49.85 Hz and 50.15 Hz (the Normal Operating Frequency Band), a small adjustment of up or down (raise or lower) is sent from AEMO to enabled generators (and loads) to alter their output (demand), thereby keeping the nominal frequency at 50 Hz[4]. An important element of the regulation services is the concept of Causer Pays Payment Recovery - that is, the costs for Regulation FCAS is recovered from market participants responsible for causing the need for the service. Frequency control services act state-wide or inter-state subject to interconnector and or local constraints.

---

[3] AEMO (2019) "Changes to Contingency FCAS Volumes", August update, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Ancillary-services/Load-relief.

[4] The mainland and Tasmanian market regions are separated once time errors exceeds +/-1.5 seconds. With a single AGC this will not be necessary.

3.2 System restart ancillary services

System Restart Ancillary Services (SRAS) (also known as black start services) are contracted as a contingency arrangement for restoring supply in the event of a total or partial shutdown of the transmission network in a given state or, potentially, intra-state[5]. The recovery procedure entails starting isolated power stations that have the capability to start generating units on-site absent external electricity supply provision to power sections of the transmission network. These energised sections are then used to start, synchronise and connect generators that do not have a black start facility and to allow the energised sections to be synchronised and reconnected to each other. In this way, an interconnected transmission system is restored.

SRAS are procured from power stations (such as thermal, hydroelectric and pumped hydroelectric storage stations). However, HVDC interconnectors, backed by appropriate generation, are also capable (using grid forming inverters) of providing a black start capability as they have the ability to access generators in an area which is not blacked out. They therefore provide an opportunity to reduce the cost of SRAS through provision of a lower cost service. They can also enable reduced restoration times for the transmission system over starting fossil fuelled plant. Such ability for Marinus would need to be established through studies to demonstrate that Marinus, supported by Tasmanian hydroelectric power, or by Victorian generation (depending on the region blacked out) would be capable of providing this service whilst still managing the control of transmission voltages. The control of transmission voltages is a known issue when relying on long distance corridors for system restart. However, the design of the DC-AC inverter station will enable it to control the transmission voltage local to its connection point subject to appropriate isolation of sections of the transmission system in the state blacked out.

3.3 Reactive power (voltage control)

The flow of reactive power on a transmission network enables control of voltage levels and rate of change of voltage within limits. Unlike system frequency, which is typically consistent across the network, voltage control provision is a localised issue and is uniquely related to the prevailing real and reactive power supply and demand in a local area in conjunction with network impedance.

Interconnectors based on HVDC VSC-technology are designed with inherent reactive compensation plant that can be utilised to generate or absorb reactive power as required without the need for any additional equipment. There are opportunities in the NEM to utilise the reactive power capability of new HVDC interconnectors to meet the changing needs of the power system and to reduce the need to procure reactive services from other sources.

[5] This section is based on extracts from National Grid, *Benefits of Interconnectors to GB transmission system*, December 2014, sections 4 to 8

4. FCAS valuation method

This chapter outlines our method for estimating the future FCAS benefits that Marinus will provide over a period of 2027 to 2050. We have selected this period to align with market modelling timeline undertaken by TasNetworks. As previously described in Section 1, Tasmania and the mainland operate as two separate power systems, with separate FCAS markets, for much of the time. In this section, we explain the constraints that cause the separation of FCAS markets and how often they occur. We analyse the overall FCAS market size and the impact Marinus will have, in respect of service provision and cost reduction of service provision on the FCAS markets.

For each dispatch interval, AEMO's National Energy Market Dispatch Engine (NEMDE) determines a market clearing price for each of eight separate FCAS markets. This price is used to determine the payments to the FCAS providers. The payments for FCAS are then recovered from market participants.

4.1 Global and local FCAS

The NEM operates a single FCAS market whenever it is possible to source services globally (that is across the whole of the NEM), irrespective of physical location of the provider. This leads to FCAS payments that, absent constraints, are recoverable on a global basis (recovered across the entire NEM).

However, there are also occasions when local constraints bind (i.e. interconnector and transmission line operation on the flow limit, or power flow reversal limitations as with Basslink) that cause FCAS service to be procured from a local supplier. In these instances, AEMO pays for the cost to the contingency service provider for meeting the binding constraints. These payments are then recovered from market participants by local recovery mechanisms (recovery being based on the regions in which the constraint was required). Hence, in practice, FCAS charges are recorded by AEMO on a state basis. Since the costs of FCAS are sourced from market participants, it is a reasonable first order assumption that the net cost of FCAS is built in to electricity tariffs and passed on to consumers[6].

The current constraints mean that Tasmanian FCAS is locally supplied on a regular basis and is therefore unable to take advantage of lower cost fast response FCAS from other NEM regions. Similarly, the relatively lower cost of regulation service from Tasmanian hydroelectric generation plant is unavailable to the mainland. Marinus overcomes this limitation and provides an opportunity to share lower cost FCAS resources between Tasmania and the mainland.

4.2 Constraints that typically impact the exchange of FCAS between Tasmania and the mainland

This section describes the different FCAS conditions that bind in Tasmania. In some cases, local and global constraints can apply at the same time. Local constraints, in this case, refer to a set of conditions defined within the NEM Dispatch Engine (NEMDE) that restrict the procurement of FCAS to sources within the same region, due to a restriction in inter-regional power flows. Global constraints, on the other hand, refer to a set of conditions within NEMDE in which there is no restriction on the locations from which FCAS may be procured. Our valuation method therefore focuses on the following.

[6] In practice, there is usually a small surplus in a given year between the FCAS charges recovered from participants and that paid to FCAS providers.

- identifying the constraints impacting FCAS provision to and from Tasmania arising from the limitations of Basslink
- determining the costs associated with local recovery of FCAS arising from these constraints, as compared with the costs absent the constraint (i.e. with Marinus in place).

We set out the types and impact of the various constraints for FCAS provision between mainland NEM and Tasmania below:

- *Global FCAS constraints (single NEM region)*
  Binding constraint: F_I+… (global)
  Global FCAS constraints set requirements for procurement of FCAS and Tasmania can participate in the FCAS market. The amount of service enabled is determined by NEMDE identifying the lowest cost option of FCAS from Tasmania and rest of the NEM.
- *Tasmanian local requirement but with global constraints still binding*
  Binding constraints: F_T+… (Tasmanian) and F_I+… (global)
  A portion of FCAS must be procured locally due to technical limitations of Basslink. However, absent these limitations, this local Tasmanian requirement can contribute to meeting the FCAS volume requirement on a global basis. The cost of out of merit dispatch of Tasmanian FCAS leads to sub-optimal outcomes in the market and the cost for this is borne by the Tasmanian region.
- *Tasmanian local requirements but mainland constraint binding (not global)*
  Binding constraints: F_T+… (Tasmanian) and F_MAIN+… (mainland)
  In this scenario, mainland and Tasmania operate as two distinct FCAS markets. This limitation may arise when Basslink is:
  - on its maximum or minimum import or export limit
  - transitioning through its 'no-go' zone

  or, under certain conditions when Basslink could be on import but the mainland constraint is more restrictive than global.
- *Mainland constraint binding and no Tasmanian or global binding*
  Binding constraints: F_MAIN+… (mainland)
  This scenario occurs when Basslink is dispatched such that it is able to import FCAS exclusively from the mainland, with Tasmanian FCAS disabled

Binding local constraints generally results in increased costs of FCAS provision in Tasmania. The constraint conditions under each of the situations are outlined in Appendix A.

4.3 Global procurement proportions

Estimates of the numbers of annual dispatch periods where FCAS is globally procured across the NEM as a whole, as proportions of the total number of dispatch periods, are shown in Table 1. With Marinus in service we have assumed unconstrained FCAS provision between the mainland NEM and Tasmania and vice-versa. This assumption is based on Marinus being designed with a short term (up to fifteen minutes) overload capacity as advised by TasNetworks. As such, all FCAS can be provided over Marinus, even during times of maximum continuous power flows. The advantages conferred by Marinus are assumed to be 100% global provision of FCAS minus the proportions shown in Table 1 multiplied by the projected cost differences between constrained and unconstrained provision.

Estimation of the average time that Tasmania is able to take part in the global FCAS markets is based on analysis of binding dispatch constraints over a trailing four-year period. Analysis reveals that, for an average of 40% of the time, the Mainland and Tasmanian contingency FCAS markets are separated. Access to Tasmanian hydroelectric units could reduce the costs of regulation in NEM particularly under a single region scenario. The reduction in regulation due to improved PFC response will be counteracted, with respect to raise services, by reducing the number of thermal generators in service and increasing participation of renewable sources[7]. Since November 2018, Tasmania has not been able to participant in raise regulation due to departure of time error exceeding the threshold of 1.5 secs. Typically the markets are suspended up to 12 hours a day. Based on recent analysis, Tasmania participated in the global regulation market for approximately 10% of the time. However we have calculated benefits on the assumption that this percentage could be increased to the pre-November 2018 levels, as shown in Table 1. Overall market benefits on the assumption that global regulation percentages would remain at 10% in the absence of Marinus would triple the reported present value.

Table 1 Percentage of time mainland NEM and Tasmania FCAS is globally procured

	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG	LOWER REG
Global FCAS	65%	63%	70%	37%	46%	53%	10%-73%	10%-70%

Source: GHD and TasNetworks calculations based on NEM data (MMS data model).

4.4 Impact of FCAS on NEM participants and electricity consumers

The costs of procuring FCAS (payments to providers) are primarily recovered from generators and customers in relevant requirement regions, generally in proportion to their energy consumption for contingency services and (in the case of regulation services) their Market Participant Factors (MPF) for regulation services. This cost recovery mechanism attributes causation to large individual market participants based on deviations from a linear path to reach their dispatch targets or, in the case of variable renewable generation, predicted output. As explained in section 3.1.2, this cost is recovered from market participant responsible for causing it.

4.5 The economic impact of Marinus on FCAS markets

Basslink, has limited maximum power transfer capacity and is unable to operate at a power flow between 50 MW of import and export (the 'no-go' zone). It also requires a period with no power transfer before it can change the direction of its power flow. Marinus will address all of these deficiencies and provide sufficient additional transfer capacity as well as improved controls, such that whenever Marinus is in service there will be sufficient capacity to provide FCAS in either direction.

As Marinus will support bi-directional FCAS provision on a global basis, our analysis demonstrates that, at some times and for some services:

- The mainland will benefit from access to lower cost Tasmanian services (slow response and regulation services)
- Tasmania will benefit from access to lower cost mainland services (fast response services)

[7] We also note that all registered generators, subject to energy source limitations are mandated to provide primary frequency response. This means that VRE generators will tend to provide lower service, raise will tend to come from thermal generators backed-off, but still operating above minimum stable operating conditions to accommodate renewables until such time as a unit is turned off or retired.

- The duplicated volume of FCAS required when they are provided both locally in Tasmania and simultaneously on the mainland will be eliminated.

All of the above expectations will entail real cost savings to market participants, and hence provide a real opportunity to lower the sum of producer and consumer surplus. The quantification of these benefits is described in Section 5.

A possible additional benefit of Marinus – which is not quantified - is that it would increase the number of potential providers for additional dispatch intervals and therefore improve the competitiveness of FCAS markets. This will reduce the difference between FCAS charges and marginal cost. The frequency of occasions when the costs of FCAS rises above $5,000/MWh, e.g. due to a constraint requiring local FCAS provision, are testament to the possibility that FCAS markets are not perfectly competitive.

4.6 Sources of historical FCAS data

Our analysis to understand local constraints was conducted on a five-minute dispatch interval resolution but our modelling approach uses yearly aggregates of cost and volumes to determine representative average prices, where cost (in dollars) is equal to volume (in MWh) multiplied by average price (in dollars per MWh). This has enabled us to identify long-term patterns and relationships in the data. This approach is adopted since localised constraints are likely to be resolved with the commissioning of Marinus. Global procurement of FCAS from a number of competing suppliers should ensure, *ceteris paribus*, that the markets are competitive. This means that the average prices that we calculate, while they do not exist in practice, closely reflect the economic cost of FCAS supply over a period. The basis of the data used to project our base case (no Marinus) and likely reduction in FCAS costs in the NEM from the introduction of Marinus is set out below.

4.6.1 Costs of FCAS

Table 2 and Table 3 below show the total costs of each service for mainland regions as a whole and for Tasmania, for each year since 2012. These data are derived from AEMO's published historical summaries of ancillary service payments[8]. Each annual summary details the annual cost of each type of frequency control service for each NEM region for each trading week of the year. The value for 2019 is annualised, based on first 40 weeks of settlement.

Table 2 Total mainland FCAS costs ($ million)

Year	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG	LOWER REG	TOTAL COST
2012	3.89	3.21	5.61	0.23	1.73	0.98	2.78	1.46	19.89
2013	3.33	2.14	4.03	0.66	2.64	0.55	1.77	0.84	15.97
2014	4.04	2.81	6.02	0.54	0.64	1.52	2.67	1.36	19.61
2015	4.10	3.65	6.60	2.79	2.12	2.45	16.13	14.84	52.68
2016	17.79	10.33	11.73	0.22	0.31	1.32	36.09	27.41	105.20
2017	36.90	16.83	31.21	0.40	0.31	0.59	49.55	41.71	177.51
2018	38.64	28.27	61.92	2.75	3.49	1.58	41.25	13.50	191.40
2019*	17.79	18.51	11.38	1.93	2.23	0.88	82.67	26.23	161.61

Source: AEMO Ancillary Services Payments Summaries (various).

** Annualised value but based on 40 weeks of settlement data*

[8] AEMO, Ancillary Services Payments and Recovery webpage, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Data/Ancillary-Services/Ancillary-Services-Payments-and-Recovery, one file for each calendar year.

Mainland FCAS costs have increased materially since 2014, particularly for contingency raise and regulation raise (and to a lesser degree contingency lower) services. Tasmanian costs have also generally increased, with 6 second raise services disproportionately affected. Whilst it may be expected that the increase in variable renewable energy generation results in an increase in demand for FCAS and hence increase in costs, there are also limited incidents of very high prices that occur when local constraints are binding. In such cases, incumbent local service providers are immune from competition from lower cost providers outside their region.

Table 3 Tasmanian FCAS costs ($ million)

Year	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG	LOWER REG	TOTAL COST
2012	1.84	0.45	0.70	0.56	0.14	0.35	0.38	0.26	4.69
2013	1.04	0.35	0.38	2.71	0.16	0.22	0.32	1.66	6.84
2014	3.30	0.50	0.57	3.72	0.13	0.37	0.56	1.57	10.73
2015	4.40	0.70	0.50	3.21	0.05	0.14	1.25	0.29	10.54
2016	5.88	1.14	0.81	2.19	0.13	0.12	2.72	1.27	14.24
2017	16.16	3.72	4.06	0.00	0.01	0.07	8.04	4.11	36.17
2018	11.38	2.85	3.49	0.48	0.05	0.10	4.05	2.69	25.09
2019*	13.69	4.10	1.86	0.06	0.04	0.08	5.49	4.77	30.09

Source: AEMO Ancillary Services Payments Summaries (various).

** Annualised value but based on 40 weeks of settlement data*

4.6.2 Volumes of FCAS

Table 4 Average Mainland FCAS enablement (MW)

Year	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG	LOWER REG
2016	386	391	477	132	233	305	162	146
2017	371	374	491	61	112	221	137	126
2018	418	424	478	82	169	275	183	140
2019*	383	388	402	75	156	216	231	187

Source: AEMO Ancillary Services Payments Summaries (various).

** Based on 40 weeks of settlement.*

Table 5 Average Tasmanian FCAS enablement (MW)

Year	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG	LOWER REG
2016	38	62	26	63	79	62	31	39
2017	57	81	61	9	21	51	35	25
2018	32	57	32	23	51	62	24	35
2019*	39	82	32	17	32	43	32	33

Source: AEMO Ancillary Services Payments Summaries (various).

** Based on 40 weeks of settlement.*

Historical FCAS volumes are derived from half-hour trading interval data for the calendar years 2016 to 2019[9]. The data include the combined mainland regions and Tasmania. Historical volumes for individual mainland regions are allocated to each of the four regions in proportion to respective energy consumption. The volume is represented as average FCAS enablement. In practice the volume of FCAS enablement changes

There are no consistent patterns across the categories of mainland or Tasmanian FCAS volumes since 2016. This is with the exception of mainland regulation raise and lower volumes and six seconds lower services in Tasmania that have increased significantly in the last two years. Meanwhile, Tasmanian volumes of five minute raise and lower, and raise six seconds services have fallen since 2017

4.6.3 Volume weighted average FCAS prices

We have constructed historical average prices in $/MWh by dividing total cost by total volume. This represents a volume weighted FCAS price per service for the purpose of modelling aggregate FCAS outcomes in the future. As such, these prices are not necessarily comparable with prices that may be observed in the FCAS markets for any dispatch period. The volume weighted price is a more representative measure since time weighted price does not accurately reflect market costs particularly for lower contingency services which typically settle on a 30 minute basis for less than a couple of cents per MWh. When spikes in market prices occur for these markets, under a time weighted approach this spike might be diluted whereas costs incurred by market participants are accurately reflected in the volume weighted price.

Table 6 Volume weighted Mainland prices ($/MWh)

Year	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG	LOWER REG
2016	5.25	3.01	2.80	0.19	0.15	0.49	25.31	21.39
2017	11.35	5.14	7.26	0.75	0.32	0.30	41.19	37.87
2018	10.55	7.62	14.79	3.84	2.35	0.66	25.75	10.97
2019*	4.07	4.18	2.48	2.24	1.25	0.36	31.38	12.29

Source: GHD calculations.

** Based on 40 weeks of settlement.*

Table 7 Volume weighted Tasmanian prices ($/MWh)

Year	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG	LOWER REG
2016	17.60	2.10	3.63	3.96	0.19	0.21	10.04	3.66
2017	32.53	5.21	7.61	0.03	0.03	0.16	26.21	19.01
2018	40.84	5.75	12.26	2.36	0.11	0.18	19.29	8.76
2019*	30.92	4.38	5.15	0.29	0.12	0.16	14.99	12.80

Source: GHD calculations.

** Based on 40 weeks of settlement.*

Given the relative stability of prices in recent years it is our expectation that the average yearly price derivation provides a reasonable estimate of underlying costs of supply for each service in each region. Our benefits estimation uses historical data from 2016 to 2019 as representative of long run underlying costs, given current technologies.

[9] Available as separate files for each trading interval on the AEMO website, extracted using NEO and provided to us by TasNetworks. 2019 is incomplete, but is free of periods of extreme high prices, and therefore we believe it is reasonably representative of an average year. While data were made available for part of 2015, it was not unlikely to be representative of the year as a whole and so was discarded.

5. Estimated benefits projections

5.1 Inputs and assumptions

Projected costs for each respective service are calculated as the respective volume times the annual average price. Both volumes and prices are expected to change when Marinus is implemented. Annual benefits are equal to costs in the absence of Marinus being implemented minus costs with Marinus implemented. Marinus is planned to be in operation in financial year 2027-28. However, if commissioning of Marinus is advanced or delayed, ancillary services benefits will begin accruing from whenever the interconnector is commissioned. Costs savings are estimated on this basis and compared to costs calculated for a no Marinus base case.

5.1.1 Contingency FCAS providers

Contingency raise services are traditionally provided by increasing the power output of generating units that are in operation or by starting a fast start generator or through load shedding. Contingency lower services are traditionally provided by backing off an operating generator. However, alternative technologies, such as battery energy storage systems, may increasingly provide contingency services in the future, potentially at lower cost than now. Given the low marginal operating costs and relatively fast response of hydro-electric plant, Tasmania is well placed to provide low cost frequency raise and lower regulation and contingency services.

5.1.2 6 second raise and lower

The volumes of 6 second services are likely to increase over time depending upon the trend of largest contingency in NEM. While the period of peak generation from thermal generators is likely to reduce with retirement of thermal generators, increasing large scale of wind and solar farm could increase the size of the largest contingency[10]. However, it is unlikely that Tasmanian hydroelectric will provide the benefits of 6 seconds raise or lower services to the mainland.

Hydroelectric generation is not well suited to provide this 6 second raise or lower service, due to the time taken to change the output from a hydroelectric generator arising from the time delays in changing the water flow rate. This delay is due to pressure reduction when opening guide vanes at the entry to the turbines. Hydroelectric dominated systems generally have wider frequency bands and relatively small generator contingency sizes than coal-fired generation plant. Whilst hydroelectric turbine/generator sets are heavy machines, inertia is not high, *per se*, but they have a 2.5 to 3.5 second response time due their relatively slow speed.

The combination of the delay in change in water flow, coupled with the inertia of the turbines means that they are unable to compete in the six-second FCAS regulation markets. Following the introduction of *the Ramp Rates, Market Ancillary Service Offers and Dispatch Inflexibility* Rule change implemented in NER version 27 commencing 31 March 2009, wider frequency control band limits arising from this Rule change mean that more of the contingency 6 second response is met by load relief. One of the existing benefits of Basslink is the ability to provide more 6 second raise into Tasmania from the mainland. A Basslink contingency is managed through a system protection scheme which trips load under import conditions if Basslink trips.

[10] Traditionally, this related to the largest single generating unit on the system. More recently it has also related to the largest combination of distributed generation connected through a transmission line representing a single point of failure for export of power from that combination of distributed generation.

5.1.3 60 second raise/lower and 5 minute raise/lower

As mentioned previously, the volume of other raise and lower contingency services will increase with reduction in load relief factor. With advancement in technology we anticipate the load relief factor will continue to reduce into the future. However, for the purpose of this analysis, we have assumed the volume of contingency services will remain unchanged. This is largely to balance the forecasted reduction in load relief factor with likely fall in contingency requirement as generation from thermal generators reduce with greater wind and solar energy penetration. Hydroelectric generation is well suited to provide these services. The relatively low short run operating costs of Tasmanian hydro make it likely that increased interconnection capacity with the mainland will lead to lowering of mainland costs for the services. Over time as the coal plant retires, other technology is likely to provide these services. The most likely replacement technology is battery energy storage systems, which is projected to reduce the costs of providing the service[11].

5.1.4 Regulation raise and lower providers

Selected generators are dispatched to provide regulation services. AEMO's AGC monitors slower changes to the system frequency as well as time error. Based on these signals, the AGC calculates Area Control Error (ACE). The processed ACE signal is converted to control signals sent to generators dispatched to provide frequency regulation services. An increasing future proportion of variable renewable energy non-synchronous generation and reduction in high inertia, synchronous generation in the power system is likely to result in greater amounts of regulation services being required, potentially from a falling number of providers as fossil fuel plant is retired.

The volumes of regulation services may increase over time as the variability increases and reduction in predictability of the generation fleet occurs with increasing levels of VRE generation capacity. However, mandatory PFC will improve quality of the frequency regulation services. This service is traditionally provided by thermal units and hydroelectric generators. Over time as the coal plant retires, hydro generation is well suited to provide this service. Technologies, other than fossil fuel generators that can provide increased levels of regulation service are pumped hydroelectric, and battery/inverter energy storage systems.

5.2 FCAS volumes

We have projected annual volumes from the historical data for the last four years as follows. For each type of service for each region the initial future year (2020) is the 50th percentile of the previous four years. Absent Marinus, all contingency services are projected to remain constant, while regulation raise and lower are projected to grow by one per cent per annum. In the with the Marinus case, from the year of implementation, mainland volumes reduce by the amount of increased global services provided by Tasmania.

The forecast volumes for most contingency services may be understated since the approach to volume projection is based on the 50th percentile of the last four years. The contingency requirements have increased and are forecast to increase further due to AEMO assumed load relief reduction. Estimated contingency volume for Raise 6 and 60 were approximately 450 MW for mainland in November 2019[12] with a load relief factor of 1%. The contingency requirement is expected to increase by a further 50 MW once load relief factor is reduced to 0.5%. In contrast, forecast volumes used in our analysis are materially lower than actual 2018 and 2019 volumes. Table 8 and Table 9 demonstrate that in most cases the procedure used to project FCAS volumes results in relatively low levels and growth over time, compared with the most recent

[11] Expert interviews, BNEF, SNE research, Navigant Avicenne Energy, Bernstein, McKinsey Battery cost model, 2017

[12] AEMO, Review of load relief November 2019 update, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Ancillary-services/Load-relief.

observations. As mentioned above, the increase in variable renewable energy generation, coupled with the closure of fossil fuelled synchronous generation backed by mechanical inertia is likely to result in an increase in demand for FCAS.

Table 8 Actual and projected average mainland FCAS volume (MW)

Year	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG*	LOWER REG*
2016	386	391	477	132	233	305	162	146
2017	371	374	491	61	112	221	137	126
2018	418	424	478	82	169	275	183	140
2019**	383	388	402	75	156	216	231	187
No Marinus forecast	381	378	461	68	141	238	167	138
With Marinus forecast	369	356	452	63	123	216	170	137

Source: AEMO Ancillary Services Payments Summaries (various).

** Regulation volumes are predicted to grow as the proportion of variable generation technology increases in the NEM.*

*** Based on 40 weeks of settlement.*

Table 9 Actual and projected average Tasmanian FCAS volume (MW)

Year	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG*	LOWER REG*
2016	38	62	26	63	79	62	31	39
2017	57	81	61	9	21	51	35	25
2018	32	57	32	23	51	62	24	35
2019**	39	82	32	17	32	43	32	33
No Marinus forecast	38	72	32	20	41	57	31	34
With Marinus forecast	With Tasmania part of a global, NEM-wide FCAS market - local enablement is undefined							

Source: AEMO Ancillary Services Payments Summaries (various).

** Regulation volumes are predicted to grow as the proportion of variable generation technology increases in the NEM.*

*** Based on 40 weeks of settlement.*

5.3 Volume weighted average prices

The FCAS price per service is published for each dispatch interval. However, using time weighted average price does not accurately represent the value of the service. Instead, our analysis is based on a volume weighted price that takes into account total cost of the service in a year and divides it by the total volume enabled. This approach accurately represents the average price paid by the service on the mainland and Tasmania.

Local market separation by global constraints has, in the past, reduced competition, giving rise to higher prices since services that have to be procured locally under constraint conditions are typically higher costs than those procured globally. Our use of an average price measure demonstrates considerably less explicit instances of market behaviour than would a detailed analysis at a five-minute dispatch interval level analysis. For instance, the current aggregation of cost approach assumes costs of localised constraints are shared across the regions whereas they are likely to be recovered from within the region. Our analysis assumes that market participants would resolve these localised constraints, similar to Marinus resolving constraints associated with Basslink, and the long term price forecasts would trend towards the forecast prices.

Average prices are fixed in real terms at the medium values observed for each service in the most recent four years. They reasonably reflect the long term average workings of the competitive FCAS markets and so in a no Marinus scenario are likely to correspond to the average of underlying short run marginal procurement costs applicable in all dispatch periods in the year, for each type of procurement in each region. In a with Marinus scenario, contribution of cost effective Tasmanian FCAS will put downward pressure on the mainland price while Tasmania will also be able to utilise cost effective services from the mainland.

Underlying costs for each type of FCAS in each of Tasmania and the mainland NEM are derived from the last four years' of cost and average enablement volumes data, projected forward. The FCAS impact of the implementation of Marinus is modelled by choosing the lowest cost service from wherever it exists, either in Tasmania or the mainland. Thus if the lowest cost service exists in the mainland, Tasmania benefits, and vice versa. This assumes the continuing provision of the various services by existing technologies. However, we have allowed for the introduction of lower cost storage to provide FCAS, such as batteries or pumped hydroelectricity, by halving the costs of contingency provision after 2034/35.

Table 10 and Table 11 below demonstrate that in most cases the procedure used to project FCAS prices results in plausible levels over time, compared with the most recent observations.

Table 10 Volume weighted Mainland prices ($/MWh)

Year	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG	LOWER REG
2016	5.25	3.01	2.80	0.19	0.15	0.49	25.31	21.39
2017	11.35	5.14	7.26	0.75	0.32	0.30	41.19	37.87
2018	10.55	7.62	14.79	3.84	2.35	0.66	25.75	10.97
2019*	4.07	4.18	2.48	2.24	1.25	0.36	31.38	12.29
No Marinus	7.93	5.29	5.25	1.84	0.97	0.48	33.33	18.70
With Marinus to 2035	7.90	4.66	5.03	1.65	0.69	0.46	32.33	18.49
With Marinus 2036 and beyond	3.95	2.33	2.51	0.82	0.35	0.23	32.33	18.49

Source: GHD calculations.

** Based on 40 weeks of settlement. Does not capture load relief adjustment and seasonal factors.*

Table 11 Volume weighted Tasmanian prices ($/MWh)

Year	RAISE 6 SEC	RAISE 60 SEC	RAISE 5 MIN	LOWER 6 SEC	LOWER 60 SEC	LOWER 5 MIN	RAISE REG	LOWER REG
2016	17.60	2.10	3.63	3.96	0.19	0.21	10.04	3.66
2017	32.53	5.21	7.61	0.03	0.03	0.16	26.21	19.01
2018	40.84	5.75	12.26	2.36	0.11	0.18	19.29	8.76
2019*	30.92	4.38	5.15	0.29	0.12	0.16	14.99	12.80
No Marinus	31.72	4.79	6.38	1.33	0.12	0.17	17.14	10.78
With Marinus to 2035	7.90	4.66	5.03	1.33	0.12	0.17	17.14	10.78
With Marinus 2036 and beyond	3.95	2.33	2.51	0.66	0.06	0.08	17.14	10.78

Source: GHD calculations.

** Based on 40 weeks of settlement. Does not capture load relief adjustment and seasonal factors.*

Our approach does not encompass the possibility that an increase in competition, as a result of Tasmania entering some mainland FCAS markets, is likely to result in fewer dispatch intervals in which market power is able to be used to extract high prices. We have allowed for only a small increase in volumes but no increase in average prices when considering raise and lower regulation whose costs have been historically increasing.

The appearance of lower contingency price in 2019 is due to not including the higher contingency costs associated with last couple of months of the year. Additionally, prices do not reflect the increased contingency requirement with reduction in load relief factor. AEMO's findings indicate that contingency FCAS prices could increase by 150% after the load relief factor change.

We have allowed for the future impact of wide scale use of battery storage for contingency FCAS by halving contingency FCAS prices from 2036 onwards. Hence, as mentioned, our method of utilising the minimum of the 50th percentile of average prices from each region as an estimate for underlying costs estimate for the future is a conservative assumption based on underlying costs.

5.4 Calculation results

Our estimate of projected benefits include up to $8.0 million a year for mainland regions and up to $3.5 million a year in real savings for Tasmania. This results in a minimum present value of benefits of $148 million for the period from commissioning of Marinus Link to 2048/49. This value is calculated using a real, pre-tax discount rate of 5.9 per cent, and assumes that the proportion of global regulation enablement would be more than 70% - a higher level than recently observed (refer to Table 1). Alternatively, on the assumption that global regulation enablement occurs only 10% of the time in the absence of Marinus, the present value of benefits, *ceteris paribus*, would be $474 million.

5.4.1 Basis of calculation

The estimation of benefits reflects the future projections of volumes and prices, which in turn are grounded in historical average FCAS market outcomes and the intended design and implementation of Marinus. We demonstrate the benefits yielded by Marinus by replacing high cost FCAS provision both on the mainland and Tasmania. We have assumed there will be no growth in contingency volumes and that there will be reductions in underlying costs, based on changes in the technology of the service provision (reflecting emerging FCAS provision using batteries and pumped hydroelectric energy storage). We have also assumed that additional growth in regulation volumes will be met using the cheapest available technology at existing underlying costs.

Benefits are calculated for each mainland and Tasmanian service, as FCAS costs with Marinus in service by 2025-26, minus ongoing costs if Marinus is never implemented. Benefits are expressed as a discounted stream of payments from 2019-20 to 2049-50, with a (real, pre-tax) discount rate of 5.9 per cent.

5.4.2 Projected costs with and without Marinus

Table 12 shows the ongoing projected costs for each of the combined mainland regions and Tasmanian, for a base case without Marinus and for the project case in which Marinus Link is in operation as planned. The cost differences between the Marinus and no Marinus case represent the market benefits, as summarised in the following Table 13.

Advancing the commissioning date of Marinus will lead to additional benefits whereas delaying the implementation of the project will result in fewer benefits.

The precise PVs are dependent on the commissioning date of Marinus and the discount rate, as well as our assumptions about the increased rate of access to global, rather than local, FCAS and projected future FCAS volumes and average prices. For the reasons set out earlier, we consider that our assumptions are relatively conservative and hence the calculated benefits may err on the low side.

Table 12 Calculation of minimum FCAS cost savings for Marinus ($ million)

	COST WITHOUT MARINUS		COST WITH MARINUS		COST SAVINGS (Without Marinus – with Marinus)		
	Mainland $M	Tasmania $M	Mainland $M	Tasmania $M	Mainland $M	Tasmania $M	Total $M
2018/19	161.6	30.1	161.6	30.1	0.0	0.0	0.0
2019/20	140.2	23.8	140.2	23.8	0.0	0.0	0.0
2020/21	140.6	23.8	140.6	23.8	0.0	0.0	0.0
2021/22	141.3	23.9	141.3	23.9	0.0	0.0	0.0
2022/23	142.0	24.0	142.0	24.0	0.0	0.0	0.0
2023/24	143.1	24.1	143.1	24.1	0.0	0.0	0.0
2024/25	143.5	24.1	143.5	24.1	0.0	0.0	0.0
2025/26	144.2	24.2	132.8	15.1	11.4	9.2	20.6
2026/27	145.0	24.3	133.5	15.1	11.5	9.2	20.6
2027/28	146.2	24.5	134.6	15.3	11.5	9.2	20.8
2028/29	146.5	24.5	135.0	15.3	11.6	9.2	20.8
2029/30	147.3	24.6	135.7	15.4	11.6	9.2	20.8
2030/31	148.1	24.7	136.4	15.5	11.7	9.2	20.9
2031/32	149.3	24.8	137.5	15.6	11.8	9.2	21.0
2032/33	149.7	24.8	137.9	15.6	11.8	9.2	21.0
2033/34	150.5	24.9	138.7	15.7	11.9	9.2	21.1
2034/35	151.3	25.0	139.4	15.8	11.9	9.2	21.1
2035/36	118.3	13.5	109.3	12.4	9.0	1.1	10.1
2036/37	118.8	13.6	109.7	12.5	9.0	1.1	10.1
2037/38	119.6	13.7	110.5	12.6	9.1	1.1	10.2
2038/39	120.5	13.7	111.3	12.6	9.2	1.1	10.3
2039/40	121.7	13.9	112.4	12.8	9.2	1.1	10.4
2040/41	122.2	13.9	112.9	12.8	9.3	1.1	10.4
2041/42	123.1	14.0	113.7	12.9	9.3	1.1	10.5
2042/43	124.0	14.1	114.6	13.0	9.4	1.1	10.5
2043/44	125.2	14.3	115.7	13.1	9.5	1.1	10.6
2044/45	125.8	14.3	116.2	13.2	9.5	1.1	10.7
2045/46	126.7	14.4	117.1	13.3	9.6	1.1	10.7
2046/47	127.6	14.5	117.9	13.4	9.7	1.1	10.8
2047/48	128.9	14.7	119.1	13.5	9.8	1.2	10.9
2048/49	129.5	14.7	119.7	13.6	9.8	1.2	11.0
Average 2018/19 to 2048/49	136.2	19.9	128.2	16.4	8.0	3.5	11.5
Present Value (PV) at 5.9% real, pre-tax	**2,092.7**	**329.6**	**1,996.8**	**277.1**	**95.9**	**52.4**	**148.3**

Source: GHD calculations, based on the earliest possible implementation of Marinus (actual implementation is expected to be 2027/28).

Table 13 Minimum estimated FCAS benefits of Marinus, PV $ million

	Mainland benefits	**Tasmanian benefits**	**Whole of NEM benefits**
Present value of benefits (5.9% real, pre-tax discount rate over 30 years)	95.9	52.4	148.3

Source: GHD calculations.

5.5 SRAS

The existing framework in the NEM for the System Restart Standard and the associated SRAS Guidelines (Section 3.2) is compliant with the stated functions of the AEMC Reliability Panel in relation to system restart. In particular, clause 8.8.3(aa)(5) requires the System Restart Standard to "*… specify that a system restart ancillary service can only be acquired by AEMO under a system restart ancillary services agreement for one electrical sub-network at any one time*"[13]

The System Restart Standard has defined Tasmania as an electrical sub-network, and as such SRAS can only be provided by restart service providers within Tasmania. The standard specifically states that Basslink cannot be used for restart services. We consider that, with the current System Restart Standard and the existing defined electrical sub-networks, there is no potential for any SRAS costs savings as a result of commissioning Marinus, absent a change to the System Restart Standard. The only current opportunity for reduction in SRAS in Tasmania is through direct negotiation with Hydro Tasmania.

However, if there were changes in the system restart framework, there may be potential for reduction in SRAS in Tasmania, as a combined electrical sub-network including generation in both Victoria and Tasmania. Taking into account retirement of brown coal fired plant in the Latrobe Valley, Marinus would introduce competition where currently none exists. Given that changes would be related to negotiated service costs, it is not possible to quantify any potential savings. However, access of mainland regions to power from Tasmania via a grid forming VSC HVDC link (and vice versa) creates a possible future option for eliminating the need for black start units in Tasmania and Victoria. Assuming that a future blackout is contained to a single region on the mainland, then a live island would be capable to energise the rest of the network and some load in the black system, following which normal start procedures for generators could be applied.

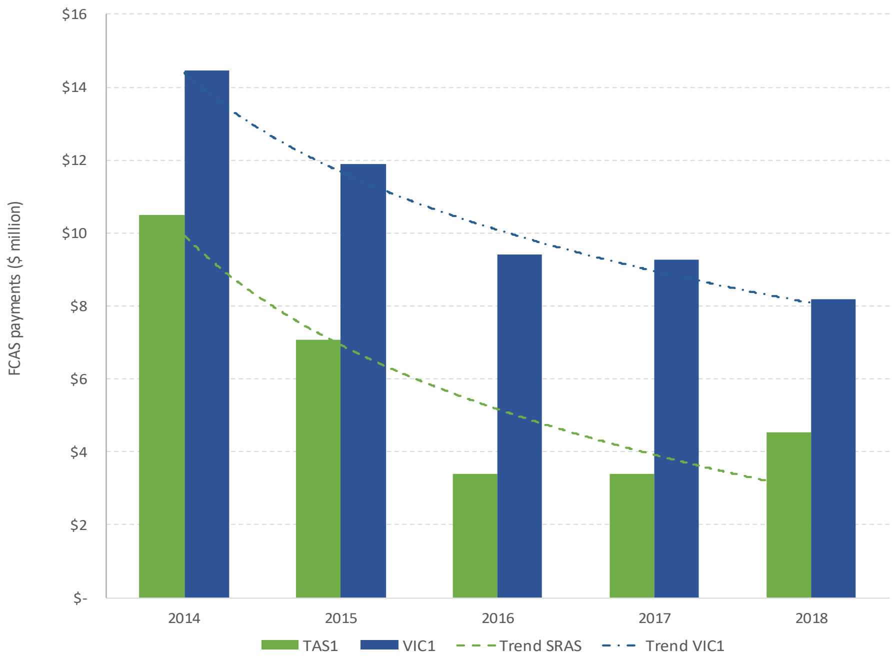
5.5.1 Historic TAS1 trend in SRAS

Figure 3 shows the historic trend in SRAS costs in the Tasmanian and Victorian regions between 2014 and 2018, highlighting a generally downward movement year-on-year. This is consistent with the overall trend for SRAS across the NEM as shown in Figure 4.

We consider that the lower SRAS costs since 2015 are related to AEMO making a conscious effort to procure from a larger number of restart services, and increased flexibility in the procurement process following determination of the System Restart Ancillary Services Rule Change in April 2015.

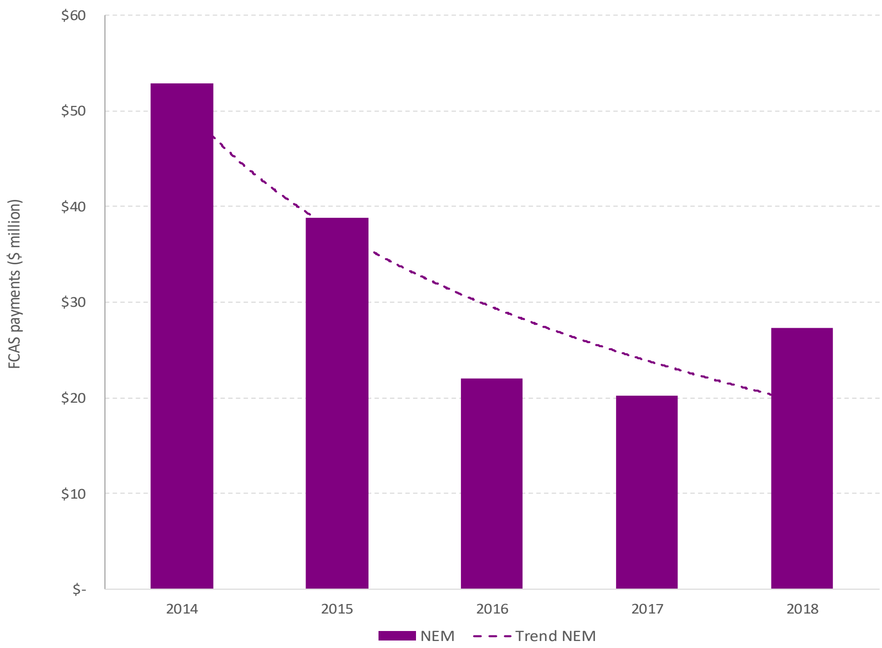
[13] National Electricity Rules, *Chapter 8 Administrative Functions*, version 124, 12 August 2019, pp. 1125-1131

Figure 3 Annual SRAS costs for Tasmania and Victoria 2014-18



Source: AEMO market data.

Figure 4 Annual SRAS costs for NEM 2014-18



Source: AEMO market data.

6. Conclusions

As well as providing additional interconnection capacity between Tasmania and the mainland NEM, Marinus will allow the entire NEM to use a single AGC and promote global procurement of FCAS and access to the lowest cost services by:

- Overcoming locational constraints to Tasmania being active in the mainland FCAS market and vice-versa
- Eliminating local FCAS requirements in Tasmania
- Allowing Tasmania to fully participate in the mainland market, creating a NEM wide, extended global FCAS market
- Increasing competition in the provision of FCAS in both Tasmania and the mainland, particularly during times of global (i.e. mainland interstate interconnector) constraints.

We estimate conservatively that Marinus will reduce the cost of provision of FCAS to the combined mainland and Tasmania regions by at least $17 million a year over the economic life of the project. This is equivalent to a present value of $148 million cost reduction in 2019/20 dollars, based on a real, pre-tax discount rate of 5.9 per cent. At a lower level of global regulation enablement the present value of benefits could be up to $474 million.

In addition to the potential to reduce frequency control costs across the NEM, we consider that the access of mainland regions to power from Tasmania via a grid forming VSC HVDC link (and vice versa) creates a possible future option for eliminating the need for black start units in Tasmania and Victoria, thus reducing the costs of procuring SRAS. Also potential rationalisation of AGC control can produce additional savings (single area control, centrally sourced regulation, common time control). We have not attached a monetary value to these potential benefits.

Appendix A – FCAS constraint overview

List of global FCAS constraints used for various FCAS markets (single NEM region):

F_I+NIL_MG_R5
F_I+NIL_RREG
F_I+NIL_MG_R5_PPN2
F_I+NIL_MG_R6
F_I+NIL_MG_R6_PPN2
F_I+NIL_MG_R60
F_I+NIL_MG_R60_PPN2
F_I+NIL_APD_TL_L5
F_I+NIL_APD_TL_L60
F_I+NIL_DYN_RREG

Tasmanian FCAS constraints 'Basslink unable to transfer FCAS'

F_T+NIL_MG_RECL_R5
F_T+RREG_0050
F_T+NIL_WF_TG_R5
F_T+NIL_MG_R5
F_T+FASH_N-2_TG_R5
F_T+NIL_BB_TG_R5
F_T+FARE_N-2_TG_R5
F_T+CSGO_TG_R5
F_T+GO_A752_TG_R5
F_T+GO_C752_TG_R5
F_T+FASH1_2C_TG_R5
F_T+BB_N-2_TG_R5
F_T+NIL_MG_R6
F_T+NIL_MG_RECL_R6
F_T+NIL_WF_TG_R6
F_T+FASH_N-_TG_R6_1
F_T+NIL_BB_TG_R6
F_T+FASH_N-2_TG_R6
F_T+FARE_N-2_TG_R6
F_T+CSGO_TG_R6
F_T+FARE_N-_TG_R6_1
F_T+CSGO_TG_R6_1
F_T+FARE_N-_TG_R6_2
F_T+GO_A752_TG_R6
F_T+GO_C752_TG_R6
F_T+FASH_N-_TG_R6_4
F_T+FASH_N-_TG_R6_2
F_T+BB_N-2_TG_R6_1
F_T+FASH1_2C_TG_R6
F_T+NIL_MG_R60
F_T+NIL_MG_RECL_R60
F_T+NIL_WF_TG_R60
F_T+FASH_N-2_TG_R60

F_T+NIL_BB_TG_R60
F_T+FARE_N-2_TG_R60
F_T+CSGO_TG_R60
F_T+GO_A752_TG_R60
F_T+GO_C752_TG_R60
F_T+BB_N-2_TG_R60
F_T+FASH1_2C_TG_R60
F_T+NIL_MG_RECL_R5
F_T+LREG_0050
F_T+NIL_ML_L5
F_T+COGT_TL_L5
F_T+NIL_TL_L5
F_T+CO_752_TL_L5
F_T+NIL_TL_L5_DS
F_T+NIL_ML_L6
F_T+COGT_TL_L6
F_T+NIL_TL_L6
F_T+CO_752_TL_L6
F_T+NIL_TL_L6_DS
F_T+NIL_ML_L60
F_T+COGT_TL_L60
F_T+NIL_TL_L60
F_T+CO_752_TL_L60
F_T+NIL_TL_L60_DS

Mainland FCAS constraints 'Basslink unable to transfer FCAS'

F_MAIN+NIL_DYN_RREG

F_MAIN+NIL_MG_R5

F_MAIN+DD_N-2_MG_R5

F_MAIN+LD_N-2_TG_R5

F_MAIN+LD_N-2_MG_R5

F_MAIN+RREG_0350

F_MAIN+RREG_0300

F_MAIN+TG_R5_1200

F_MAIN+NIL_RREG

F_MAIN+TASCAP_RREG

F_MAIN+NIL_MG_R5_PP

F_MAIN+RREG_0180

F_MAIN+RREG_0200

F_MAIN+RREG_0220

F_MAIN+NIL_MG_R6

F_MAIN+DD_N-2_MG_R6

F_MAIN+LD_N-2_MG_R6

F_MAIN+TG_R6_1200

F_MAIN+NIL_MG_R6_PP

F_MAIN+NIL_MG_R60

F_MAIN+DD_N-2_MG_R60

F_MAIN+LD_N-2_TG_R60

F_MAIN+LD_N-2_MG_R60

F_MAIN+TG_R60_1200

F_MAIN+NIL_MG_R60_PP

F_MAIN+NIL_MG_R5

F_MAIN+DD_N-2_MG_R5

F_MAIN+LD_N-2_TG_R5

F_MAIN+LD_N-2_MG_R5

F_MAIN+TG_R5_1200

F_MAIN+NIL_MG_R5_PP

F_MAIN+APD_TL_L5

F_MAIN+NIL_DYN_LREG

F_MAIN+ML_L5_0400

F_MAIN+ML_L5_APD

F_MAIN+LREG_0120

F_MAIN+LREG_0400

F_MAIN+TASCAP_LREG

F_MAIN+LREG_0150

F_MAIN+WIP_N-2_ML_L5

F_MAIN+LREG_0170

F_MAIN+LREG_0190

F_MAIN+LREG_0210

F_MAIN+ML_L6_0400

F_MAIN+ML_L6_APD

F_MAIN+WIP_N-2_ML_L6

F_MAIN+APD_TL_L60

F_MAIN+ML_L60_0400

F_MAIN+ML_L60_APD

F_MAIN+WIP_N-2_MLL60

F_MAIN+APD_TL_L5

F_MAIN+ML_L5_0400

F_MAIN+ML_L5_APD

F_MAIN+WIP_N-2_ML_L5

GHD
Advisory

Level 9 145 Ann Street Brisbane QLD 4000 Australia GPO Box 668 Brisbane QLD 4001 Australia

61 7 3316 3000
advisory@ghd.com

G:\91\12509751\Deliverables\Final\Final\GHD Report 12509751 Project Marinus FCAS and SRAS market benefits Final.docx

Rev.No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Final 01	Richard Hickling,	Stephen Hinchliffe				21/11/2019
Final 02	Richard Hickling,	Stephen Hinchliffe		David Bones		26/11/2019
Final 03	Richard Hickling	Stephen Hinchliffe		David Bones		2/12/2019
Final 05	Richard Hickling	Stephen Hinchliffe		David Bones		4/12/2019

GHD Advisory