BERMUDA INTEGRATED RESOURCE PLAN 2024

STRATEGIC REVIEW

October 2024 I Rev G

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Executive Summary

A significant step forward in IRP planning

BELCo's 2023 Integrated Resource Plan Proposal represents a significant step forward in IRP planning for Bermuda. The IRP demonstrates multiple affordable portfolios that can achieve significant decarbonisation of the electricity grid, while reducing rate volatility over time. Use of a robust set of quantitative metrics provides meaningful insights into the pros and cons of different portfolios and has led to selection of what is in our view a sensible low risk strategy to improve air quality in the short-term, while building out mature renewables at scale such as offshore wind and solar photovoltaics.

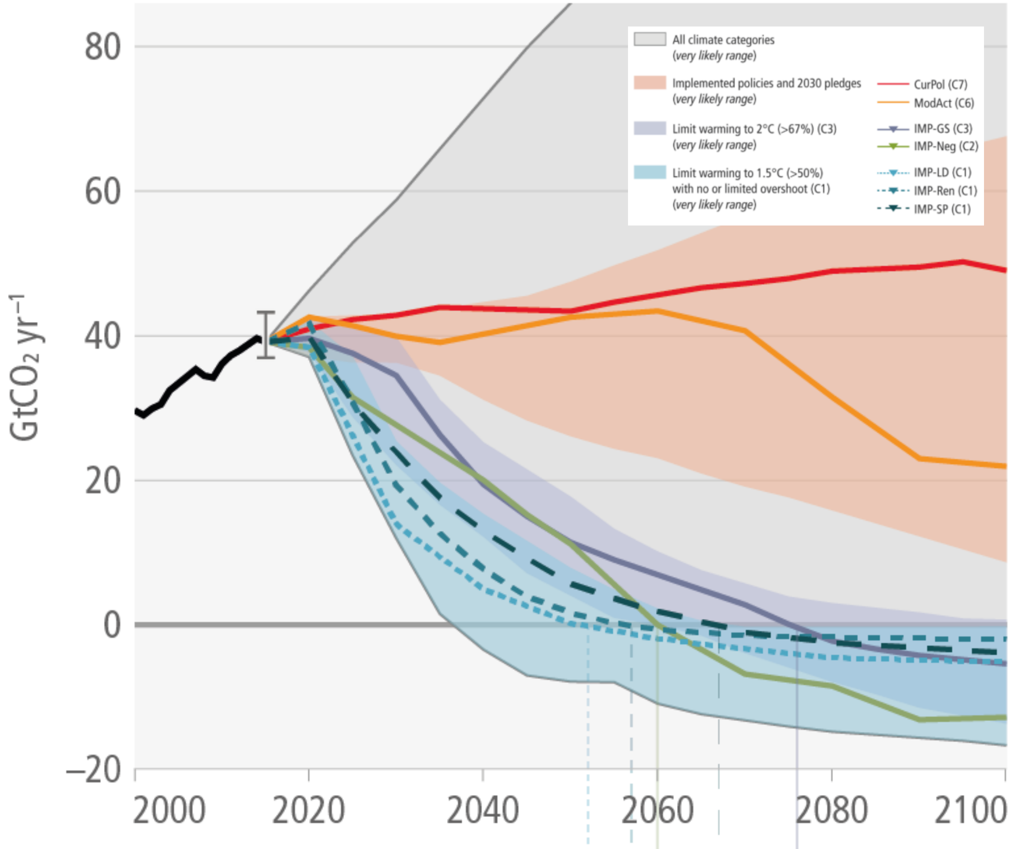
Consideration of IPCC Pathways

We do not consider portfolios that are not compliant with an IPCC C1 emission reduction pathway to meet the Electricity Act 2016 or National Electricity Sector Policy requirements for environmental sustainability. The C1 pathways are aimed at limiting warming to 1.5˚C or less and have been adopted by many small island states. Our view is that with the exception of the P1 counterfactual portfolio, all portfolios should comply with a C1 pathway over the IRP period, while preserving some optionality. This would simplify planning and reduce the strategic and reputational risk to Bermuda due to build-out of a non-1.5˚C compliant portfolio, which could result in asset stranding. Several of the portfolios considered in the IRP, including the preferred P4L portfolio, already appear to be compliant for 2030. Removing non-compliant portfolios could also lead to an increased focus on the most cost-effective way of genuinely decarbonizing the grid.

A critical point in sizing offshore wind

The current IRP may be the last one published before a decision is made on the size of an offshore wind farm for Bermuda. As the build of an offshore wind farm is likely to be a 'one-shot' project due to Bermuda's remote location and the projects very small size, it is vital that the right capacity is determined in this IRP.

BELCo hold a unique responsibility in this regard, as the only entity with the funds and technical knowledge required to carry out this exercise. While the current IRP did include a sensitivity test for offshore wind capacity, it appears a doubling and then tripling of installed capacity was applied, with a predictable outcome in terms of uneconomical levels of curtailment. Before conclusion of this round of IRP planning, we believe it is essential to run additional sensitivity testing to understand the implications of adding one or two more turbines, to build 75 or 90MW capacities. We note that, significantly, each additional turbine could provide 7.5 - 10% of Bermuda's electricity.



The IPCC modelled various emission reduction pathways in their most recent AR6 report, with the C1 pathways appearing the most practical given current limitations in negative emission technologies. These indicate a 48% reduction in carbon dioxide emissions (the main type of emissions associated with fuel combustion for power generation) from 2019 levels is required by 2030, increasing to 80% by 2040 and close to 100% by 2050. © IPCC

Executive Summary

Refinement could result in different conclusions

While we broadly agree with the majority of assumptions used in the IRP, and the methodology so far as it is explained, some appear to be excessively conservative to the disadvantage of portfolios with higher penetrations of capital intensive intermittent renewables. We think there is good potential to refine assumptions in several key areas to identify cheaper pathways to deploy mature renewables. Ultimately, this could lead to significant long-term reductions in the cost of electricity for customers.

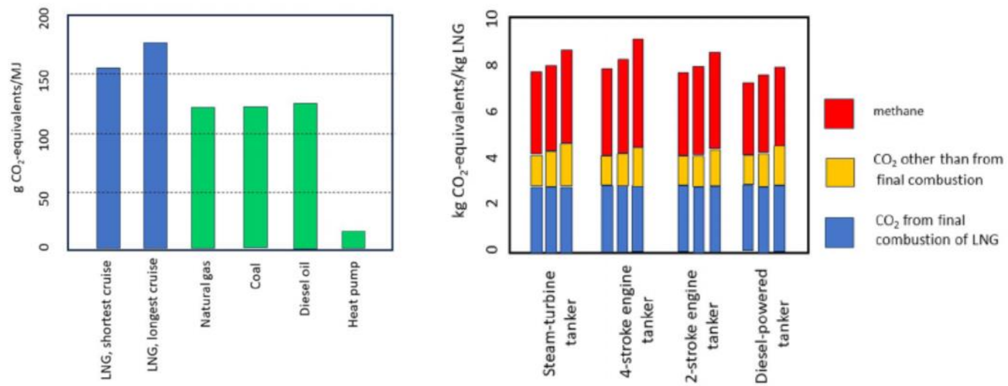
Specific examples include increased deployment of cost effective energy efficiency measures above the 5.7% assumed in the IRP, smart charging of electric vehicles, bidirectional charging of electric vehicles, further consideration of LPG for use with the gas turbines, optimization of the Tynes Bay Waste to Energy plant to increase power generation, use of biogas from anaerobic digestion of food and horticultural wastes, and greater use of large scale commercial and industrial solar, such as on car park canopies, and on industrial buildings.

A red-line is required for LNG

Our view is that the ongoing consideration of LNG is an unhelpful and costly distraction from planning a genuine decarbonisation pathway. There are multiple fundamental issues with LNG, the most important of which is the very high lifecycle emissions associated with extraction, liquefaction, transport, and regasification. A recent study published in Energy Science & Engineering calculated the lifecycle emissions from LNG sourced from the USA were higher than for coal, and that upstream emissions were often greater than emissions at the point of combustion. We therefore do not regard the IRP's use of Scope 1 emissions as a technically robust basis for quantifying emissions from LNG generation.

This issue is particularly important as the IRP itself acknowledges that portfolios with LNG are less well suited to deployment of large amounts of renewable energy, as it erodes energy sales required to pay for the investment in LNG. Another important issue with LNG is cost, where the conservative estimates for energy efficiency seem likely to underestimate the end cost per kWh that customers will need to pay to cover the large capital investment required for LNG infrastructure. Finally, we note that the RAB appears to have changed its mind on LNG since the last round of IRP planning in 2018, without a clear quantitative justification for the change, or acknowledgement of the strong level of public opposition.

A 1.2MW solar carport located in St. Kitts at the Eastern Caribbean Central Bank, engineered to withstand a Category 5 hurricane. There could be good potential for similar structures around Bermuda. © Azimuth Energy



A range of studies indicate the lifecycle emissions from LNG are higher than the combustion only emissions assumed in the IRP and in some cases higher than oil based fuels. © Howarth

Executive Summary

Overview of the Portfolios

The adjacent graphs show the installed capacity and annual energy generated or stored, from different resources across the eleven portfolios by 2050. This does not include around 35MW of behind the meter solar. The portfolios can be split into four fuel strategies, outlined below, and these can be further subdivided into up to three strategies in terms of whether optimization was undertaken for 'economics' or emission reductions.

P1 and P2

These portfolios both use **heavy fuel oil**, with P1 acting as a counterfactual portfolio, against which others can be compared. P2F is economically optimised via build-out of offshore wind, solar, storage, and biomass. These portfolios were not selected to take forward due to high emissions and fuel price volatility.

P2N, P4N and P5N

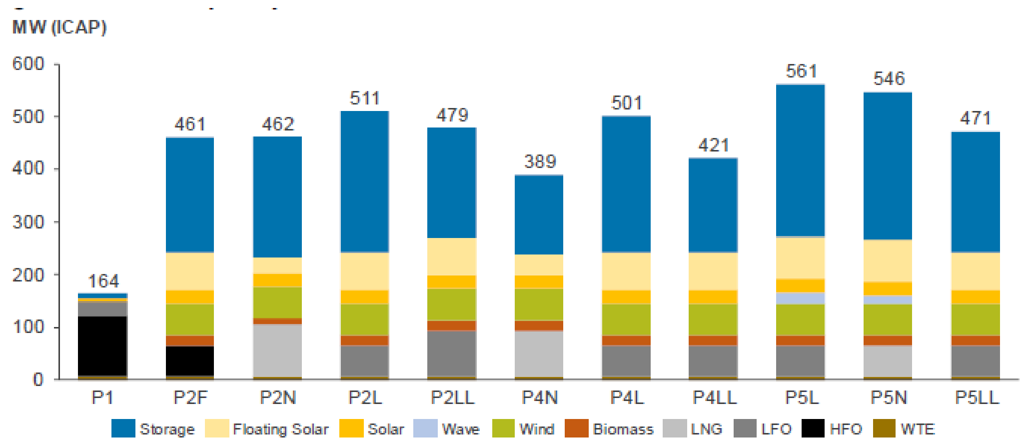
These portfolios all use **LNG** combined with a **30 year cycle** upgrade, with build-out of offshore wind, solar, storage and biomass. P2N is economically optimised, whereas P4N and P5N are designed to deliver 85% renewables by 2040 and as close as possible to net zero by 2050.

P2L, P4L and P5L

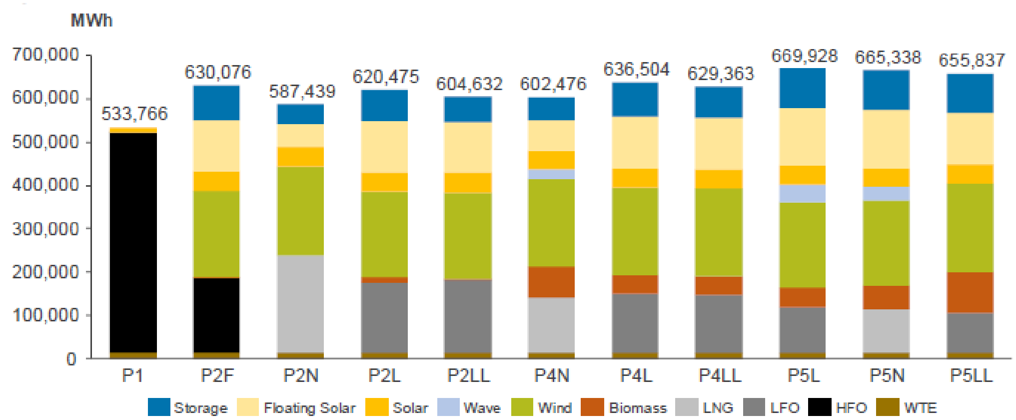
These portfolios all use **light fuel oil** with a **10 year life extension**, with build-out of offshore wind, solar, storage and biomass. P2L is economically optimised, whereas P4L and P5L are designed to deliver 85% renewables by 2040 and as close as possible to net zero by 2050. P4L was identified as BELCo's preferred portfolio.

P2LL, P4LL and P5LL

These portfolios all use **light fuel oil** with a **30 year life cycle upgrade**, with build-out of offshore wind, solar, storage and biomass. P2LL is economically optimised, whereas P4LL and P5LL are designed to deliver 85% renewables by 2040 and as close as possible to net zero by 2050. These portfolios were found to have increased costs relative to the shorter 10 year life extension option, and were therefore not preferred by BELCo.



Installed capacity of different generation and storage resources assumed in BELCo's Integrated Resource Plan by 2050. © Charles Rivers Associates



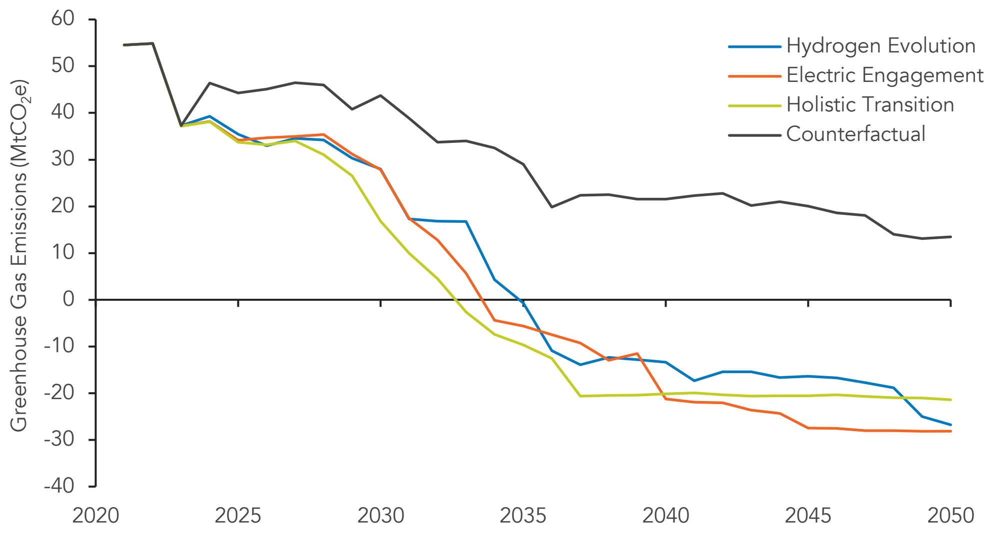
Annual energy flows for different generation and storage resources assumed in BELCo's Integrated Resource Plan by 2050. © Charles Rivers Associates

Executive Summary

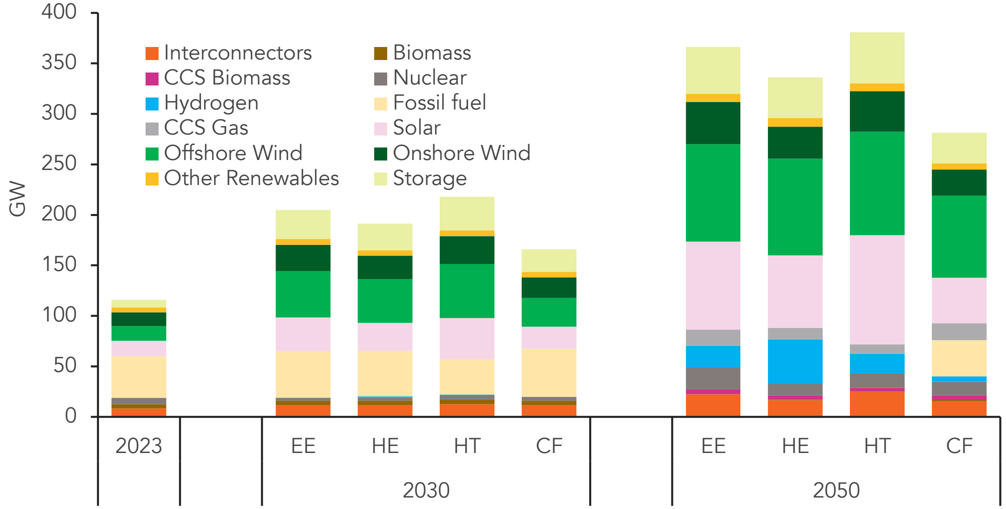
Converging on a smaller, more refined, set of portfolios

In summary, our view is that the final IRP would benefit from consideration of the following:

1. **A smaller set of portfolios** that comply with a suitable IPCC C1 (1.5˚C) pathway, with the exception of the P1 portfolio, which could serve as a counterfactual. LNG portfolios would be excluded as they cannot affordably deliver the required emission reductions when emissions beyond scope 1 are considered.
2. **Test key measures in this list** in at least one portfolio. This could use a similar approach to the UK's National Grid, where several of the suggestions below are combined to create one or more optimised portfolios.
3. **Test 75 to 90MW of offshore wind** in at least one portfolio, in combination with other measures in this list that could reduce the cost of integrating wind. This would represent the addition of one or two more 15MW offshore wind turbines.
4. **Test smart and bidirectional electric vehicle charging** in at least one portfolio, based on a constructing a set of assumptions for customer participation.
5. **Test greater uptake of energy efficiency** in at least one portfolio by developing an improved set of assumptions on the potential for energy efficiency.
6. **Bermuda's existing resources** could be further developed and tested in at least one portfolio, for example by upgrading Tynes Bay to generate more electricity, and using biogas from anaerobic digestion of food and horticultural wastes.
7. **Solar photovoltaics** mounted on car park canopies and industrial buildings could help to reduce future reliance on floating solar and further refine cost estimates.
8. **LPG combustion in gas turbines** could be included in at least one portfolio to further reduce emissions without the lock-in or upstream emission issues associated with LNG.
9. **Wave energy** and other pre-commercial technologies could be excluded.



Emission reduction pathways for the UK National Grid's Future Energy Scenarios. Despite having a large and diverse energy system, just four pathways are used, three of which are 1.5˚C compliant. All include a rapid phase-out of gas generation. © National Grid



Installed capacity for the National Grid's four pathways. © National Grid

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Comments on key assumptions and metrics

This section provides feedback on key assumptions and metrics used in the IRP.

Comments on IRP assumptions

The IRP generally provides good explanations of key assumptions and how they have been applied to the modelling, and our view is that for the most part these are reasonable.

The sources of some assumptions, and the specific way in which they have been used in the modelling are unclear in some cases, which makes it difficult or impossible to comment. A summary of feedback and areas of concern around assumptions used in the IRP is provided below:

Financial

- **Depreciation periods** for wind and solar are unclear but based on the short-term price increases, it seems likely that the depreciation period may be shorter than would usually be assumed by bodies such as the IEA, IRENA, or NREL. This could falsely give the impression that rates need to rise more in the short to medium-term than would be necessary with a correctly structured long-term power purchase agreement. For example, BELCo currently purchase electricity from the airport peninsula solar array at around 10C/kWh, which is below the cost of generation. Entering similar contracts should be expected to reduce prices, not increase them, accepting balancing costs also need to be taken into account as the amount of renewables increases.
- **CRA's revenue model** is described at a high level, but not in sufficient detail to fully understand how it functions. It seems there is a risk that the way this model functions may disadvantage some generation technologies over others and as a result it may not be effective in identifying the most cost effective way to invest in, and recover costs from, different generation/storage technologies.
- **Capital costs for offshore wind** of $6,300/kW are 28% higher than the $4,934 indicated by BVGA in 2022 as a result of detailed bottom-up calculations, specifically for a 60MW offshore wind farm in Bermuda, which included consultation with industry partners. We are not confident that the high-level approach adopted by Charles Rivers Associates using modified US Energy Information Administration figures is more accurate. In addition, sensitivity tests were run for even higher capital costs, but not for lower ones, despite the presence of lower cost points in detailed studies recently carried out specifically for Bermuda.
- **Capital costs for onshore solar** of $2,750/kW seem somewhat high based on sense-checking them in an LCOE calculation against the contracted power purchase price for the airport solar project. Fixed O&M costs for solar of $20/kW/year are also on the high end of what was assumed in the Bermuda Better Energy Plan.
- **Capital costs of battery storage** may have reduced significantly since the IRP calculations, with costs reported to have reduced around 40% between 2023 and 2024. Ideally, portfolios would be re-run to account for this.
- **Capital costs for LNG regasification & pipeline** are reported as $130 million in 2016. We assume this figure has been reviewed and updated for 2023, but could not find the specific figure that has been used in the IRP. This is a key assumption that should in our view be clearly stated. The unusual nature of such a small operation was identified as a key risk in the last IRP. It is not clear how this would be addressed.
- **Delivered LNG fuel costs** are provided in Figure 18. We assume these costs include regasification, UNESCO tax, and Customs Duty, but this is not specifically stated. Fuel costs are stated to be derived from 'fundamentals' and appear to be reasonable, however it would be helpful if an explanation could be provided as to why the AEO reference case has not been used, as was the case for other fuels. The IRP states that flexibility required to procure decreasing amounts of LNG is expected to come at a premium, but it is unclear if or how this has been accounted for in fuel cost forecasts.
- **Weighted Average Cost of Capital** of 8.01% was assumed, which we agree is reasonable based on comparison with IEA data, and is also close to the 7.5% assumed in BVGA's levelised cost of energy assessment for offshore wind in Bermuda.
- **Social discount rates** appear relatively high at 8%, with testing of 6%. The US EPA, and others, use rates as low as 2.5-3%. Use of a lower rate is expected to favour portfolio development with larger amounts of capital intensive renewables with lower operational costs, resulting in changes to the planned build-out of capacity.
- **Demand side management** seems to have assumed use of active systems, rather than time of use tariffs. The cost implications of these two approaches could be quite different and we recommend are considered.

Comments on IRP assumptions

Demand Forecast

- **Energy efficiency** potential appears to be very conservative at 5.7%. Although three sets of assumptions are developed (low, base and high), it is unclear how they have been used and whether they are reflected in any of the results.
- **Smart or bidirectional charging** of electric vehicles has not been assumed, but is already a core assumption in modelling carried out by other large utilities. UK National Grid use modelling from ev.energy based on real-world data for electric vehicle charging and time of use tariffs. This has the potential to significantly reduce renewable energy curtailment, and therefore cost.
- **Electric vehicle load shape modelling** assumed electric vehicles are driven 35 miles per day, which implies annual milage of 12,775 miles/year, however this doesn't align the 6,500 miles/year used elsewhere in the IRP.

Solar

- **Generic hourly production profiles** were used for solar generation, however it is unclear if this accounted for systems with different tilt angles and orientations. Use of a single tilt angle and orientation could create a 'peaky' overly idealized generation profile, which results in greater storage requirements or curtailment than a more realistic mix.
- **Solar potential** is discussed at a high level, but a more detailed explanation of which sites have been assumed to be available for ground mount solar, and how the figures for behind the meter solar have been developed would be useful.
- **The system impact study** on system limits for distributed generation will be a key resource for strategic planning among solar installers and other stakeholders. We encourage their involvement through a peer review process.
- **Residential solar water heaters** and heat pump water heaters are assumed to account for 22% of energy efficiency savings, however solar water heaters have not been cost effective on a wide scale in Bermuda for many years as costs of solar photovoltaics have reduced.
- **Grid defection** risk via solar with storage is not acknowledged in the IRP, but is a strategic risk that needs to be considered.

Other generation resources

- **LPG** is discounted as a generation option, but in our view the case against it is not convincing. On a lifecycle emissions basis, it appears to be a much better option than LNG. It also seems to be better suited for use in a portfolio with a decreasing capacity factor, as it avoids the fossil fuel lock-in associated with the infrastructure required to support LNG. We are interested in seeing it included as a fuel option for GT5 in an updated portfolio, and more detail around potential conversion or repowering options for the EPS and NPS.
- **Wave energy** is included in some portfolios, however this seems premature given that it is not considered to be a commercially mature technology.
- **Tynes Bay Waste to Energy Plant** has an output of 7.2MWe, which is very low by international standards in relation to the volume of waste combusted. It may be of value for the IRP to consider how the electricity generation efficiency could be improved. It is also unclear what emission factor has been assumed for electricity generated by Tynes Bay and would be helpful if this could be clarified.
- **Anaerobic Digestion** of food and horticultural waste could improve waste management, increase the energy content of the waste stream going into Tynes Bay, and produce a modest amount of biogas for electricity generation.
- **Battery storage** could represent an additional pivot strategy, for example due to the development of battery chemistries with significantly higher cycle life, or lower costs than current chemistries.

Comments on IRP scorecard metrics

The IRP uses a set of twelve performance indicators to score portfolios against six objectives. Positively, all but one indicators are quantitative and therefore provide a reasonable technical basis for comparison. Our view is that using such a large number of indicators risks overcomplicating an IRP that in simple terms needs to figure out the cheapest way of reliably decarbonizing the electricity grid. Comments on specific indicators are provided below:

- Economic cost to consumer using social discount rates could be excluded if all portfolios were required to meet an IPCC 1.5˚C aligned pathway.
- Financial cost to consumer is a key indicator that we support being retained. It uses a 20 year NPV, which appears to be a serious methodological issue as it will significantly underestimate the NPV of solar, which has warranted lifetimes of 25-40 years, and offshore wind, which has a typical design life of 32 years.
- Cost certainty indicator is reported as the difference in 20 year averages of NPVRR for high and low scenarios. While this also seems useful, the change over time is not reported, and this presumably improves over time for portfolios with more renewables.
- Carbon emissions are assessed using scope 1 emissions. We regard this as a serious methodological issue for a strategic plan that seeks to deliver genuine emission reductions, given the significant out-of-scope emissions.
- Renewable energy indicators appear to be unnecessary and we found inclusion of BTM solar as a reduction in load rather than reported as renewable energy generation confusing.
- Dispatchable capacity is of technical interest, but appears to be unnecessary considering that all portfolios achieved the required 1 day in 10 year loss of load expectation.
- Technology concentration using the Herfindahl-Hirschman Index is potentially overly simplistic as it does not account for variations in capacity factor, and some technologies such as energy storage, demand side management, or behind the meter solar.
- Curtailment is of technical interest, but appears to be unnecessary as this will already be factored into the financial cost to consumer.
- Land Use of 70-73 acres was assumed, compared to 60-70 available. This could be applied as a constraint, rather than reported as an indicator.
- Execution Risk while this uses a qualitative and therefore subjective scale, we agree with the assessed levels of risk. The IRP does appear to under-represent levels of support for decarbonizing Bermuda's electricity systems, stating that there is 'some' level of support. The Department of Energy's public opinion survey, and the overwhelming response to the last IRP consultation have consistently demonstrated the majority of respondents support appropriate deployment of renewable energy technologies.

Objective	Performance Indicator
Customer Affordability	Economic Cost to Customer
	Financial Cost to Customer
	Rate Growth
Rate Stability	Cost Certainty
	Cost Risk
Environmental Stewardship	Renewable Energy Targets
	Carbon Reduction
Resource Adequacy	Dispatchable Capacity
Resource Diversity	Technology Concentration
Supplemental	Minimise Renewable Curtailment
	Minimise Land Use
	Execution Risk

Performance indicators used to assess portfolio performance against objectives in the IRP's scorecard. © Charles Rivers Associates

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Technical Feedback

This section provides more specific technical feedback on aspects of the IRP.

Energy efficiency has much greater potential

Allowance for reduction in energy demand due to energy efficiency in the IRP appears to be low at just 5.7%. For comparison, the 2018 Bermuda Better Energy Plan, which included detailed sectoral-level analysis, concluded that relative to levels in 2017, there was potential for a 32% reduction in net generation requirements by 2050. Comparison of Better Energy Plan forecasts with recorded energy sales by BELCo indicates they were reasonable, and in fact conservative. For example, the Better Energy Plan forecast net generation of 639GWh in 2022, the IRP reported just 585GWh.

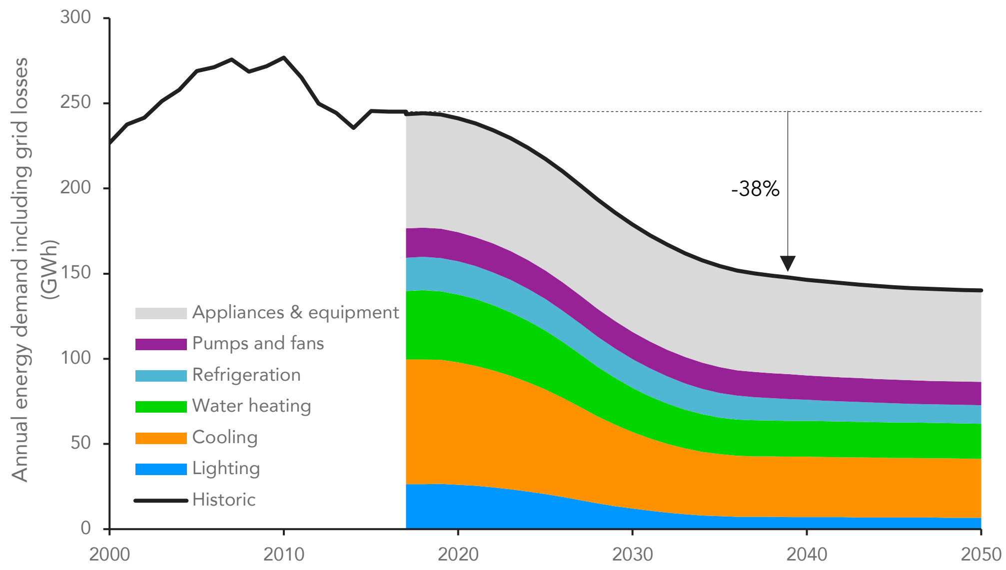
The Better Energy Plan goes on to forecast reductions in net generation required to 541 GWh by 2030, 464 GWh by 2040 and 453 GWh by 2050, including additional demand from electric vehicles, but not including behind the meter solar. These broadly align with the IRP's low scenario for energy use, which reduces to 465 GWh by 2050. Further evidence to support significantly higher rates of energy efficiency include:

1. Comparison with EU historic and modelled future data on the energy use of residential appliances. This shows the practical limits on efficiency being reached in the EU within the next decade and therefore provides confidence in the level of savings a mature market will deliver.
2. Case studies of energy audits and retrofits in commercial buildings in Bermuda, included in the Better Energy Plan, which demonstrated potential for 26% – 40% reductions in energy use.
3. The IRP identified that the LCOEs of energy efficiency measures had 'significantly lower' costs than supply side resources.

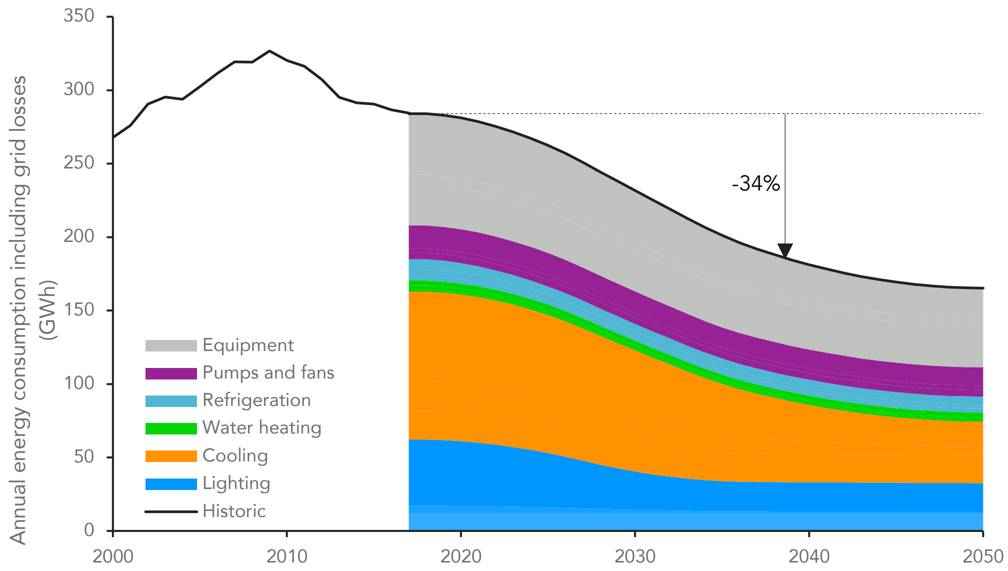
Given that the IRP acknowledges that greater levels of energy efficiency will increase costs to customers for portfolios with LNG, we believe revision of the forecast potential for energy efficiency is necessary to provide a more realistic comparison between portfolios.

Recommendations for the IRP

- Model at least one portfolio with a ~30% reduction in energy demand by 2050, due to energy efficiency.
- Consider establishing an energy efficiency taskforce to work with government to establish minimum efficiency product standards.



Forecast reduction in residential energy demand due to energy efficiency. © Etude



Forecast reduction in commercial energy demand due to energy efficiency. © Etude

Technical Feedback | Electric vehicle charging

Smart charging and bidirectional charging

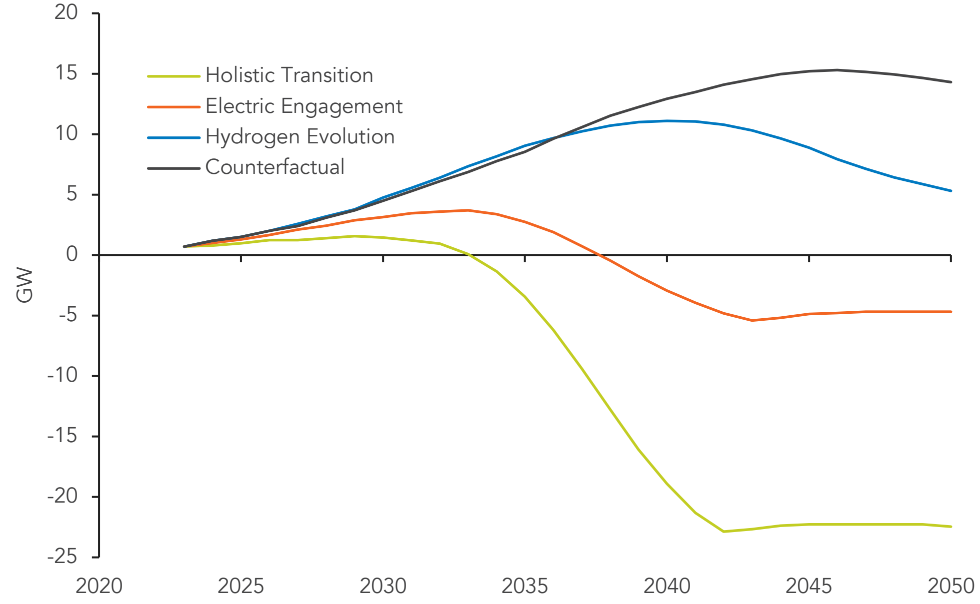
While we agree with the overall allowances for electric vehicle energy demand, in our view there are three significant issues with the way electric vehicles have been modelled, which could invalidate the current results:

1. Peak load forecasts do not account for the effect of smart and bidirectional charging.
2. Energy consumption profiles are generated using 'dumb' rather than 'smart' charging. Experience in jurisdictions that are in more advanced stages of their energy transitions shows that smart charging of electric vehicles is an important strategy to minimize the cost of integrating intermittent renewables.
3. Energy modelling does not assume use of bidirectional charging. An increasing number of new electric vehicles are being fitted with this, with manufacturer warranty coverage, and it is likely to become standard practice by the mid-late planning period in the IRP.

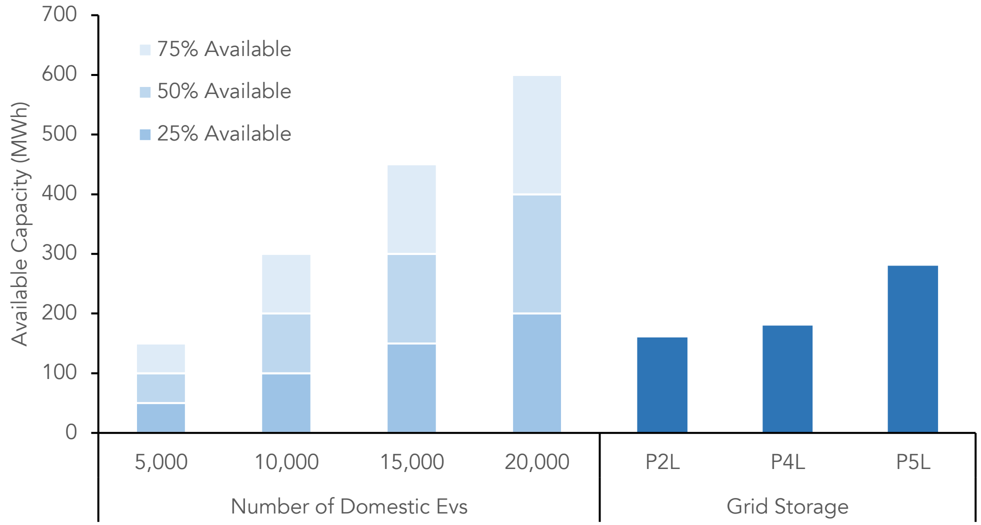
The adjacent upper graph shows the potential impact of electric vehicle charging on the UK National Grid, based on varying rates of electric vehicle deployment and customer uptake in smart and bidirectional charging. While all scenarios assume some use of both technologies, the most ambitious assumes this reduces peak demand by 32GW, a significant proportion of the forecast system peak demand of 109GW in the same scenario.

A similar level of engagement in Bermuda could alter peak system demand by around 28MW and potentially match or even exceed planned capacity of utility-scale battery storage (see adjacent graph). This would reduce curtailment of renewables and could displace the need for some grid-scale battery storage. This could be expected to reduce the cost of portfolios with large proportions of intermittent renewables by enabling more offshore wind and solar to be integrated for lower cost, therefore making them even more competitive compared to LNG.

Charles Rivers Associates' recommend direct load control of electric vehicle charging for future consideration, however we are unaware this being commonly used in the UK or EU, where market based mechanisms such as time-of-use tariffs have been sufficient to drive high levels of customer engagement. We assume this would be cheaper to implement than requiring installation of additional hardware for direct load control.



Peak demand from road transport with smart and bidirectional charging. © National Grid



Available battery capacity for different numbers of electric vehicles and different levels of availability for smart charge/discharge events, compared to proposed utility scale battery storage for three IRP portfolios. Assumes 40kWh usable capacity per vehicle. © Etude

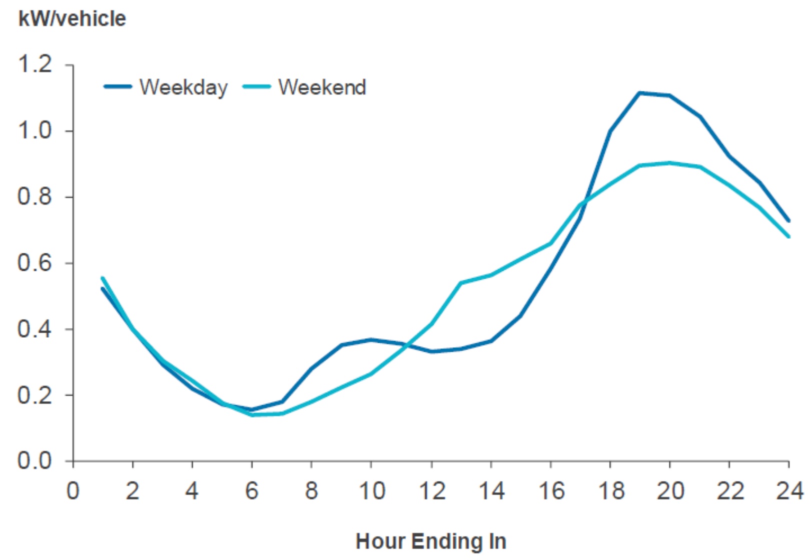
National Grid's approach to modelling smart charging

The upper adjacent graph shows the electric vehicle load profiles assumed in the IRP, while the lower graph shows the profiles assumed by the UK National Grid. The unmanaged (blue) profiles are similar in both magnitude of load and timing of load over a 24 hour period.

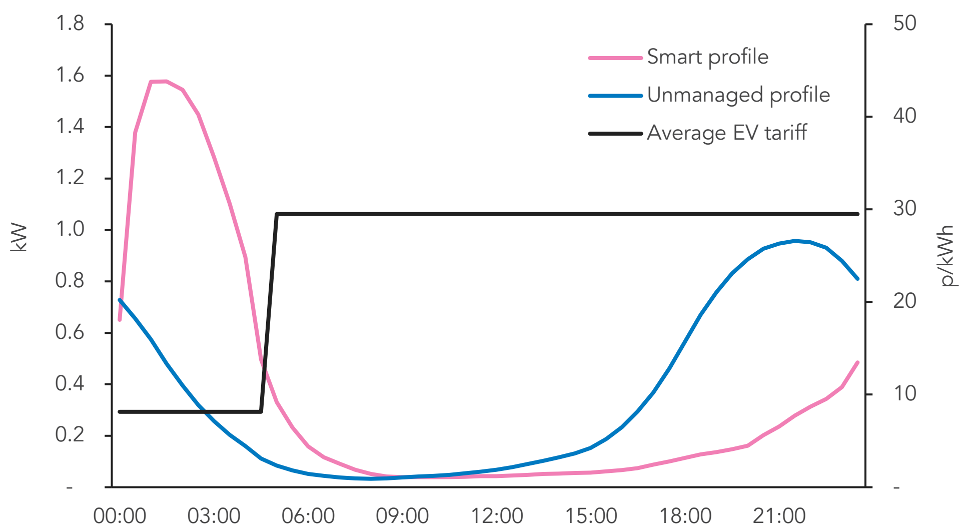
The smart profiles assumed in the National Grid modelling have been developed in conjunction with ev.energy, who we understand develop profiles based on models that combine their data on time of use pricing with charging behaviours. This produces realistic charging profiles for use in energy scenario planning.

What about battery degradation?

Degradation rates of modern electric vehicle batteries are very low, while reliability is very high, so battery degradation from mild to moderate use of bidirectional charging seems unlikely to be a significant concern. Unique aspects of Bermuda that further contribute toward this include low driving speeds and small annual distances driven, both of which can be expected to further reduce degradation. These may to some extent be offset by relatively high operating temperatures.



EV load shapes assumed in BELCo's Integrated Resource Plan, based on U.S. Department of Energy Alternative Fuel Data Centre model for Kahului. © Charles Rivers Associates



EV load shapes assumed in UK National Grid Future Energy Scenarios. © National Grid

Recommendations for the IRP

- Model at least one portfolio with smart charging
- Model at least one portfolio with bidirectional charging
- Quantify potential reduction in cost from smart and bidirectional charging, and whether it would allow for cost-effective integration of more offshore wind and solar.

Tynes Bay Waste to Energy

The incinerator at Tynes Bay burns around 70,000 tonnes of municipal solid waste a year to generate around 7.3MW of electricity. This implies a net generation efficiency of around 7.4%.

Increasing this to the average of 18% that was achieved across 97 European plants reported by Reimann (2006) would increase this to around 18 MW, while meeting a best-practice level of 30% could increase it closer to 30MW. Over the long-term, emissions from waste combustion will need to reduce via reductions to waste volumes, or carbon capture and storage, if it becomes commercially viable.

Anaerobic Digestion of Food and Horticultural Waste

Diversion of food waste from the municipal waste stream would increase the energy content of waste burned at Tynes Bay. Instead, food waste could be processed via anaerobic digestion, which would create biogas that could be used to generate electricity. It may be possible to co-digest this with some horticultural waste to increase yields of biogas. While the overall amount of electricity generated is likely to be modest, it could be dispatchable and would also help to modernise the approach to waste management.

More solar on car parks and industrial buildings

We believe there could be a reasonable additional potential for solar photovoltaic systems installed on car park canopies and industrial buildings. This could reduce reliance on less proven, and costly, floating solar.

Recommendations for the IRP

- Investigate feasibility of increasing generation from Tynes Bay
- Investigate feasibility of biogas resource
- Consider potential for solar on car parks and industrial buildings

Modern Waste to Energy facilities can achieve higher electrical generation efficiencies than Tynes Bay. © Yorkshirelive

Typical anaerobic digestion facility. Biogas can be produced from waste and used to generate electricity. © Renewable Energy Association

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Views on Ricardo IRP Assessment Report

This section provides a summary of our views on Ricardo's IRP Assessment Report.

Ricardo IRP Assessment Report

Overview

The RAB commissioned Ricardo Energy and Environment to review BELCo's IRP, establish an alternative set of performance indicators, and use these to select a preferred portfolio in an IRP Assessment Report (the report).

Having reviewed the report, we note that a variety of key assumptions and indicators have been varied in a way that generally benefits portfolios with a higher proportion of LNG, at the expense of portfolios with a higher proportion of renewable energy. In most cases this appears to have been done without a clear explanation or justification, which in our view undermines the credibility of the analysis and the report's conclusions.

While some assumptions are discussed, a full set that allows duplication of even basic LCOE calculations is not provided. This is disappointing given the examples set by the Bermuda Better Energy Plan and BELCo's IRP, both of which attempted to provide sufficient information to enable duplication of their fundamental calculations.

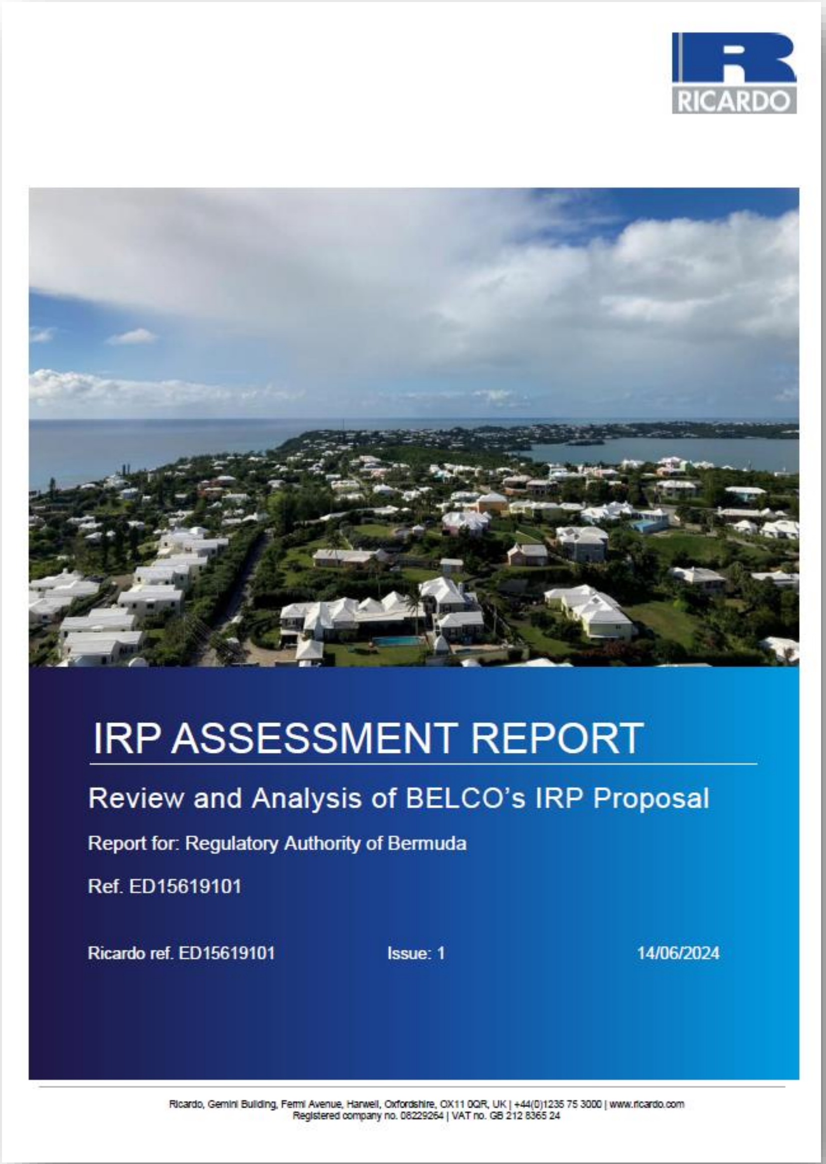
In simple terms, anyone could carry out a similar exercise using a different set of assumptions and indicators, which were designed to favour renewable energy rather than LNG, and conclude that a portfolio without LNG and with more renewable energy is the optimal least-cost choice.

Given the strategic importance of the IRP to Bermuda, we do not regard the IRP Assessment Report to provide a sufficient evidence base upon which to based decisions regarding Bermuda's future generation mix.

BELCo's IRP is a solid foundation

In our view, the assumptions and indicators used in BELCo's original IRP were more reasonable, balanced, and evidenced. We therefore view the conclusions of their work as a more reliable foundation from which to build the final IRP, than the conclusions of the IRP Assessment Report.

However, we have also identified a range of realistic opportunities to reduce the cost of portfolios with large amounts of offshore wind and solar. The approaches we have proposed are mainstream solutions being used every day by more advanced utilities around the world. We believe that additional portfolios containing these measures should be developed and modelled in order to identify the least cost pathway to decarbonise Bermuda's electricity supply in the final IRP.



RICARDO

IRP ASSESSMENT REPORT

Review and Analysis of BELCO's IRP Proposal

Report for: Regulatory Authority of Bermuda

Ref. ED15619101

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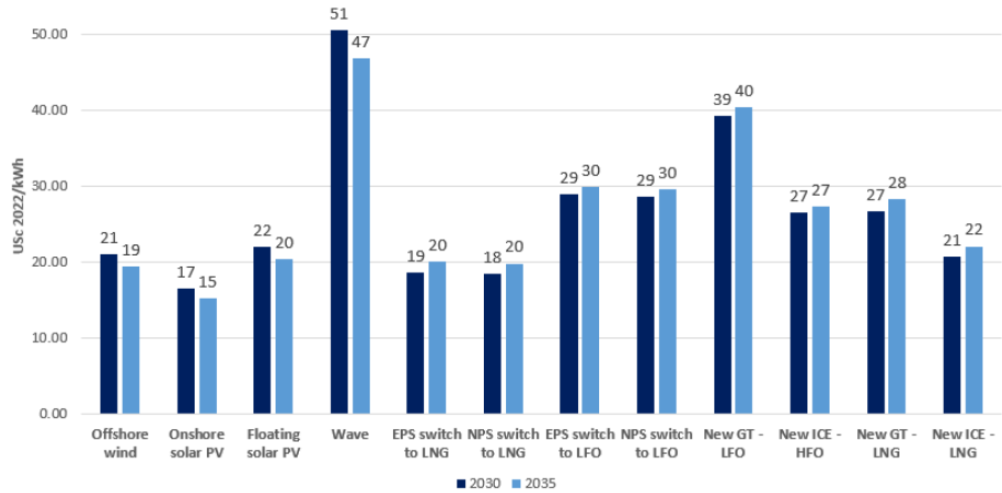
Ricardo, Gemini Building, Fermi Avenue, Harwell, Oxfordshire, OX11 0QR, UK | +44(0)1235 75 3000 | www.ricardo.com
Registered company no. 08229264 | VAT no. GB 212 8365 24

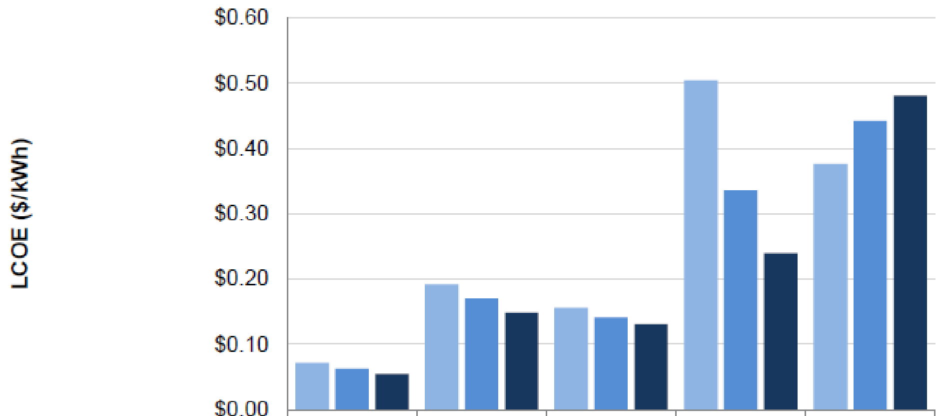
Ricardo Energy and Environment were commissioned by the RAB to provide a review and analysis of BELCo's IRP proposal. © Ricardo.

Comments on assumptions

- The LCOE's indicated in the report are higher than those in BELCo's IRP. This appears to be due to the use of a 10% discount rate, which increases the cost for offshore wind and solar. No justification is provided for the higher discount rate. Reasons why we do not believe this is a sensible assumption include BELCo's cost of debt being around 8%, BVG Associates specifically recommending a 7.5% rate when calculating the LCOE for offshore wind in Bermuda, and local banks offering both mortgages and green loans for solar at 6.5% - 6.75%.
- The report indicates that BELCo selected their preferred scenario on the basis of a 'qualitative' assessment. We do not agree with this, as the majority of BELCo's performance indicators are clearly quantitative.
- We have low confidence in the LCOE figures calculated by the report as the assumptions used to calculate them are not provided. Spot checks indicate the figures for offshore wind appear to be high and use of a single figure for onshore solar may be overly simplistic given significant differences in cost between different types of system. LNG figures will depend heavily on infrastructure costs, which are not provided.
- Energy demand is forecast to increase to 650 GWh by 2050, however no explanation is provided as to why this is justified despite reductions in demand having occurred over the past decade, and forecast potential for cost-effective energy efficiency measures that could reduce demand closer to 453 GWh by 2050. This assumption is expected to benefit LNG.
- Demand for electric vehicles is forecast to reach 100 GWh by 2050, about 2.5 times the figure used in BELCo's IRP. We have carried out detailed modelling of potential demand from electric vehicles using Transport Control Department data on the number of different vehicles and their annual mileages. This resulted in a similar number to BELCo's IRP, therefore we have low confidence in the report's assumption.
- Heavy and light fuel oil prices are assumed to be 7% and 16% higher than in BELCo's IRP over the 2025-2050 period, however no explanation is provided as to why the higher prices are justified. BELCo's IRP assumed a return from current prices to the US Energy Information Administration's AEO Reference Case, which we felt was a reasonable assumption. We therefore have low confidence in the prices used in the report's calculations.



Levelised costs of energy calculated in the IRP Assessment Report were generally higher for renewables and lower for LNG than those calculated in BELCo's IRP and the Bermuda Better Energy Plan. A set of assumptions that is favourable to LNG appear to have been used. © Ricardo.



	Solar	Floating Solar	Wind	Wave	Biomass
2030 LCOE in Bermuda	0.072	0.192	0.156	0.504	0.376
2040 LCOE in Bermuda	0.063	0.17	0.141	0.336	0.442
2050 LCOE in Bermuda	0.055	0.149	0.131	0.24	0.481

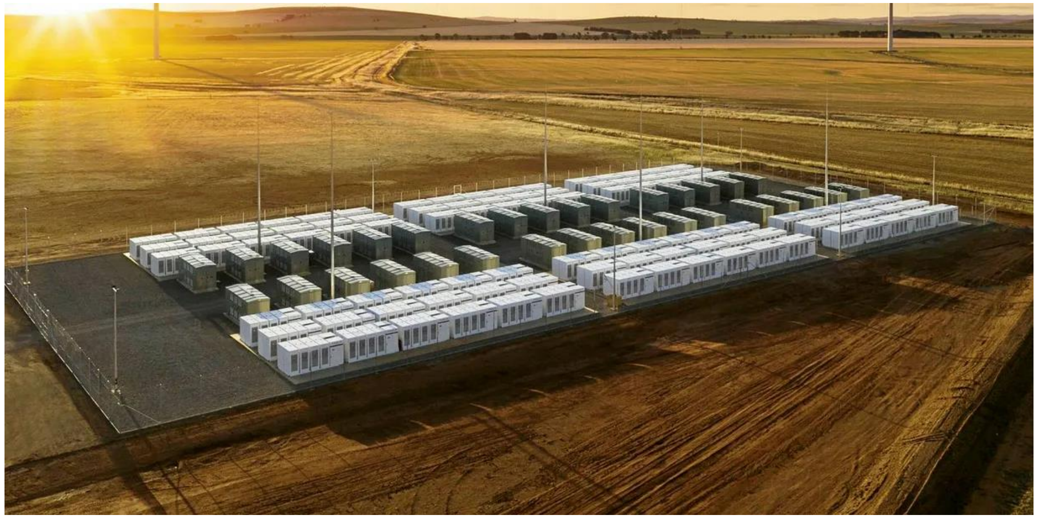
Levelised costs of energy calculated by Charles Rivers Associates in BELCo's IRP © Charles Rivers Associates

Comments on assumptions

- Capital costs for offshore wind are 15% lower in the report than in BELCo's IRP, while onshore solar costs are 12% higher, and battery costs are 'higher' by an unspecified amount. We agree the lower cost for offshore wind is appropriate, as BVG Associates have indicated that capital costs for a project in Bermuda would likely be 28% lower than assumed in BELCo's IRP. Battery storage costs are reported to have fallen 40% between 2023 and 2024, therefore use of higher storage costs than BELCo's IRP is expected to produce less reliable results.
- Technology deployment caps were varied from BELCO, with offshore wind increased to 120MW, which we agree with. Floating solar was reduced to 25MW, which we do not have a strong view on, though we think the analysis may have used very conservative allowances for the amount of solar that can be mounted on the ground, buildings, and parking structures. Battery storage was capped at 200 GWh due to land restrictions, which we think is excessively conservative given that experts we have spoken with advise this would require just 8-10 acres with current technology, not accounting for expected future improvements.

Comments on scenarios

- Three of the scenarios (LNG_Switch, No Fuel_Switch, LFO_Switch) do not appear capable of meeting an IPCC C1 (1.5˚C) emission reduction pathway. Our view is that these should be excluded as they represent a strategic risk to Bermuda by locking-in fossil fuel generation that effectively blocks decarbonisation of the electricity sector during a crucial decade when the world's energy supplies are switching to renewables.
- Three of the scenarios assume a switch to LNG. We do not agree this is a sensible strategic option for Bermuda given the considerable capital cost and multiple peer reviewed studies that indicate that lifecycle emissions are likely to be higher relative to continuing to use fuel oil. BELCo's preferred option of switching to light fuel oil and then steadily replacing this with renewables offers more flexibility and lower strategic risk in an environment where the costs and capabilities of renewables and battery storage continue to steadily improve.



Hornsdale Power Reserve in Australia has a capacity of 200MWh in a relatively compact footprint. © Recharge

The main battery bank in the North West corner of Hornsdale Power Reserve in Australia measures 55m x 118m, equivalent to just 1.6 Acres. Developed parts of the site occupy under 8 acres. © Google Maps

Comments on performance indicators

A general comment on the performance indicators is that the weighting is in our opinion arbitrary, and critically, does not appear to be aligned with the Electricity Act and National Fuel Sector Policy requirements to develop an environmentally sustainable energy supply. In our view a portfolio could only be considered to be 'environmentally sustainable' if it meets an IPCC 1.5˚C decarbonisation pathway. More specific comments on the indicators are provided below:

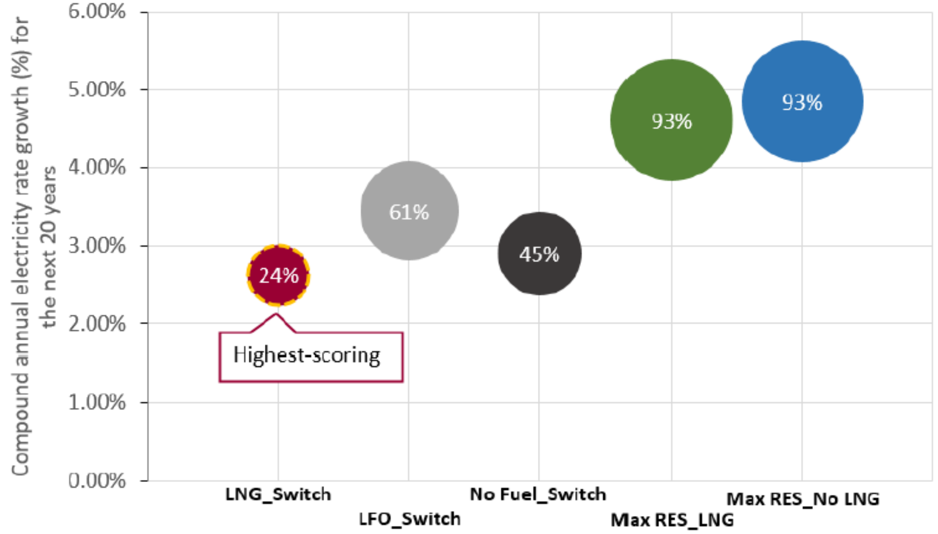
- Compound annual growth rate over 20 years is a key indicator that we support being retained, with consideration given to whether it is an appropriate period given typical design lifetimes of 25-40 years for solar photovoltaic arrays, and 32 years for offshore wind turbines.
- Carbon emissions are assessed using scope 1 emissions. We regard this as a serious methodological issue for a strategic plan that seeks to deliver genuine emission reductions, given the significant out-of-scope emissions. We support use of lifecycle carbon emissions as the primary metric.
- Renewable energy indicators appear to be unnecessary given the carbon emissions indicator.
- Dispatchable capacity is of technical interest, but appears to be unnecessary assuming that all portfolios achieved the required 1 day in 10 year loss of load expectation. This is implied in the 0% weighting.
- Resource diversity in 2050 may be of technical interest, but seems to be unnecessary. This is implied in the 0% weighting. It may also be overly simplistic as deploying an appropriate combination of complementary technologies seems to be more important than simply maximizing the number of technologies.
- Operational risk appears to be a sensible indicator, however we are unsure how it was calculated or why it was assigned a 0% weighting. A footnote implies it is, at least in part, dur to a perceived need to operate engines under suboptimal conditions in conditions with greater amounts of intermittent renewable energy. However, this was not a risk identified by BELCo, who appear to have adopted technical solutions to mitigate this risk, such as using battery storage to control engine ramp rates.

KPI	Weight (%)
Compound annual electricity rate growth for the next 20 years (%)	70%
Carbon emission reduction in 2050, relative to 2025 (%)	10%
Renewable energy generation of total energy requirements (including self-consumption) in 2050 (%)	20%
Dispatchable capacity of total installed capacity in 2050 (%)	0%
Resource diversity in 2050	0%
Operational risks[8]	0%
Total	**100%**

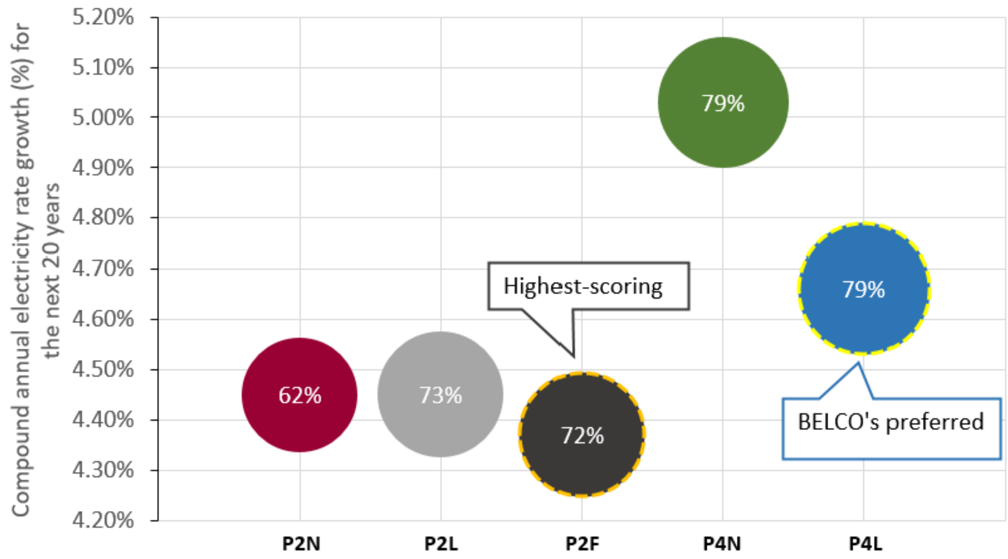
Weighting assigned to key performance indicators used in the IRP Assessment Report. © Ricardo.

Comments on Results

- We were unsurprised that the LNG_Switch scenario was preferred based on the set of assumptions, indicators, and weightings used in the analysis. However, we do not consider this finding to be reliable and are confident that re-running the analysis with a more developed and realistic set of assumptions would identify lower cost portfolio options that retain light fuel oil while deploying large amounts of offshore wind, solar, and battery storage.
- The compound annual growth rate of 2.6% for the LNG_Switch scenario is much lower than the value calculated in BELCo's IRP, however the reasons for this are unclear as the report claims similar LNG fuel price assumptions were used. This implies that capital costs for engine conversions and the regasification terminal may have been reduced. These are important assumptions that should be provided if the analysis is to be considered credible.
- A 31% reduction in emissions cannot occur in the LNG_Swtich scenario if lifecycle emissions are included. In any case, even a 31% reduction would not be compliant with an IPCC C1 1.5˚C pathway, and could not therefore be considered 'environmentally sustainable' for the purposes of the Electricity Act or National Fuel Sector Policy.



Compound annual electricity growth rates calculated in the IRP Assessment Report using an undeclared set of assumptions. It is unclear if these are directly comparable with the values in BELCo's IRP © Ricardo.



Compound annual electricity growth rates calculated in BELCo's IRP using a declared set of assumptions, with potential for further optimisation to reduce the cost of portfolios with higher percentages of intermittent renewables. © Ricardo.