Insights for the Australian Power Sector

TJ Effeney Scholar Report 2020

Full Report

The Australian Power Institute

LACHLAN MCKENNA

About the API's T.J. Effeney Award

In honour of the late Terry Effeney, one of the Australian energy industry's greatest contributors, the API created the T.J Effeney Award in collaboration with the Effeney Family, Ergon Energy & Energex (part of the Energy Queensland Group),

empowering the next generation with knowledge, connections and supporting others

This Award supports the Australian power sector's next generation to undertake a project or program of study (domestic or international) in the energy sector to further their professional career development.

The award's selection criteria are based on the values and strengths displayed by Terry Effeney during his career:
- Knowledge: how the proposal will broaden the students knowledge and skills in the energy sector
- Connections: how the proposal will increase the personal network of contacts for the student
- Supporting others: how the student plans to share the knowledge gained from the award with other students and the broader API Bursary cohort.

The TJ Effeney Award is available on a yearly basis. and only open to Australian university students who have been selected for an API Bursary Scholarship and are in their final 2 years of study of an engineering degree.

Lachlan McKenna is the second recipient of the T.J. Effeney Award, completing an international study tour to Ireland (and Australia following COVID impacts) in 2020. Lachlan's report is featured in the following pages.

Find further information at:

www.API.edu.au

The Australian Power Institute

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Abstract

The T.J. Effeney Award 2019/2020 program is detailed in the following report consisting of a six-month marine energy-focussed internship at DP Energy based in the Republic of Ireland and several other activities in areas of the Australian power sector.

Disruptive events including the emergence of COVID-19 impacted scheduled research at the Institute for Sustainable Energy Policies (ISEP) in Japan and prompted a return to Australia that enabled a diverse range of domestic activities.

The objectives, outcomes and achievements of the modified program, aligning with the aim and criteria of the award, is initially overviewed. Ideas and recommendations for sponsors and decision-makers to consider are then discussed in the final chapters.

Thank you to the Effeney Family, Energy Queensland and the API for the financial support and opportunities to share knowledge. From assisting communities impacted by flooding in Wales to discovering the many incredible projects taking shape in our industry, it was a year living Terry Effeney's values and learning much of the techno-economic challenges ahead.

Contents

Abbreviations

AEMO – Australian Energy Market Operator

API – Australian Power Institute

BESS – Battery Energy Storage System

C4NET – Centre for New Energy Technologies

COREM – Community Owned Renewable Energy Mullumbimby

EQL – Energy Queensland Limited

LCOE – Levelised cost of energy

O&M – Operations and maintenance

TSO – Transmission Service Operator

RE – Renewable Energy

RET – Renewable Energy Target

1. Outcomes and Achievements

The following outcomes were achieved:

- Learned modelling techniques and gained skills during the independent creation of a bespoke offshore wind LCOE model.
- Developed project engineering skills and a fundamental understanding of the engineering and economics over project lifecycles
- Won a startup pitch competition against five other Australian and internationally-based ideas in an event hosted by C4NET and Startupbootcamp Australia judged by representatives from AEMO, C4NET, and power sector companies.
- Expanded my professional network almost exclusively online in the onshore and offshore wind sectors, within the startup community in Australia and amongst community energy groups in the Byron Shire, NSW including Enova and COREM.
- Improved my communication of technical ideas
- Gained an understanding of supply contracts, logistics and the civil engineering, installation, and coordination of large-scale projects in challenging environments.

2. Programme Objectives

The objectives for this TJ Effeney award had to change significantly due to multiple disruptions in 2020, however, during a six-month marine energy internship at DP Energy headquartered in the Republic of Ireland, the experience offered the opportunity to achieve the following objectives:

- Develop an Inis Ealga Marine Energy Park (IEMEP) and Clarus Offshore Wind Farm feasibility reports for limited circulation – gigawatt-scale projects in the Celtic Sea and Atlantic Ocean
- Learn geographic information systems (GIS) and contribute to the constraints mapping of three offshore projects on the east, south and west coasts of Ireland
- Assess transmission capacity, constraints, and improvement works to assist with project scheduling and TSO consultations
- Conduct energy yield modelling
- Discover the innovative solutions being deployed internationally on large-scale renewable energy projects particularly in the context of harsh and dynamic marine environments
- Assist with stakeholder and community engagement to gain an understanding of the elements of a social license to operate marine energy projects
- Gain an understanding of the wider European power sector workforce and industry to learn about the interconnections between people and organisations
- Expand a network of professional contacts

Unfortunately, a placement at the Institute for Sustainable Energy Policies (ISEP) in Tokyo, Japan was not able to proceed primarily due to border restrictions and the inability for internships to be completed online. Understanding that this would likely not be possible, I set out to achieve as many of the following objectives planned in Tokyo during the internship at DP Energy and in other experiences in Australia:

- Consolidate my findings from the internship at DP Energy
- Apply a growing knowledge base of the wider industry to emerging themes applicable to Australia – renewables integration in legacy grids, grid resilience in a changing climate and technology changes in energy storage
- Compare planning frameworks and policies of Australia and other national and regional network plans
- Critically analyse the multiple dimensions of sustainability applied to large-scale energy projects in international contexts
- Learn engineering research methods and skills to apply to potential post-graduate studies

3. Overview of Activities

The original proposal involved a six-month internship in Madrid at Spanish multinational Iberdrola within their renewable energy division starting in January and concluding in June 2020. I was informed in late December 2019 this could not proceed due to new requirements for increased hiring of local students.

I departed Australia on the 26th of December with the intention to find an alternative similar position through Iberdrola and equivalent organisations. I networked digitally as extensively as I could during January and February 2020. I reached out to the director of Metocoean Hub, an innovative meteorological-oceanographic (metocean) consultancy specialising in predictive weather software applied to the O&M of offshore wind farms and had dinner with him to discuss the industry and potential opportunities in the United Kingdom.

This on-the-ground engagement with key contacts helped in establishing a network in the region. In January, I flew to Madrid where I spoke with my contact at Iberdrola about alternative opportunities at the company. Through these conversations and subsequent applications for advertised and speculative positions, I secured an internship at DP Energy - one of Iberdrola's partner developers in Australia and the Republic of Ireland.

The position allowed for the completion of my honour's year of a Bachelor of Engineering (Sustainable Systems) with approval granted from the Australian Power Institute and the school of engineering at RMIT University in February 2020.

The placement in County Cork had a hybrid focus in technical engineering and economic evaluation of multiple offshore wind farms in Irish waters. I was also able to represent DP Energy during a collaboration on EirWind, a four-year industry-university partnership programme based at the University College Cork (UCC) with the aim to assist the local offshore wind sector gain the base of research required for development and investment.

Ultimately, I had to work from home for this position and only met one colleague in-person who picked me up from Cork International Airport on the 16th of March. Integrating into the team while organising safe accommodation during this tumultuous time was challenging, but I was able to move into a country home in South Wales for the first half of the internship. I returned to Australia in June after my father's cancer diagnosis. The internship concluded on 31 August.

Initial activities and projects involved working with DP Energy's electrical and geospatial engineers and attending presentations at UCC assisting in the writing of feasibility reports. These documents reported on constraints mapping, visual impact assessment, potential repurposing of offshore gas platforms, route-to-market opportunities and the feasibility of hydrogen production and battery storage.

A need arose for a detailed project schedule from 2020 until full energisation of the Inis Ealga Marine Energy Park and I completed extensive research gaining an understanding of the scheduling stages from development through to decommissioning. This project lead to tasks creating simplified scheduling graphics for stakeholder engagement with potential suppliers and local communities.

Upon my return to Australia, the work shifted to focus on a LCOE model. DP Energy required a model with the flexibility to apply this to all offshore wind projects and be able to integrate our own and third party energy yield and metocean models. This was the largest and most complex deliverable of the internship and was invaluable in developing skills applicable to many areas of the power sector.

After completion of the internship, I had a break for four weeks before I briefly started a full-time junior project engineering role at DP Energy for three weeks in October 2020. In late October, I concluded this position before moving to Melbourne to spend more time with my father and family. I shifted to working primarily with the Australian team in scouting areas for future developments using wind resource assessment and GIS software.

While growing my professional network beyond the company and attending events was challenging during 2020, the shift to digital events did assist in attending a larger number of informative webinars on European and Australian energy markets. These included:

- A webinar from the EUSysFlex project entitled: *Technical Shortfalls for Pan-European Power System with Higher Levels of Renewable Generation*
- DNV GL's webinar: *Floating offshore wind: Attract financing by reducing and managing risk*
- IRENA's webinar: *Second International Forum on Long-term Energy Scenarios for the Clean Energy Transition*
- The Irish Wind Energy Association's (IWEA) webinar: *AMA on wind energy*, hosted by IWEA's CEO and Head of Policy
- The launch of the UK's *Operations and Maintenance Centre of Excellence*
- UK Offshore Wind Catapult project's webinar: *A Vision for Smart O&M*
- Leosphere's (LiDAR manufacturer) webinar: *Lidar solutions and strategies for offshore wind projects*
- Australian Wind Energy 2021 pre-conference presentation and discussion: *Exploring Australia's Massive Offshore Wind Potentials*
- Blue Economy Cooperative Research Centre's webinar: *Harnessing Australia's offshore wind for a clean energy future*
- Baker McKenzie's webinar: *2020 Energy Masterclass Series - Integrating Renewables - Actioning the ISP and Renewable Energy Zones*
- Fortnightly EirWind webinars and research presentations

Although DP Energy tasks occupied the majority of my time, I found time to become involved in other power and energy-related areas of interest.

The farm in South Wales where I lived for six months appear at first to be the perfect site for a future 1 – 5 MW solar farm as my hosts had the space, a transmission line immediately beside the property, nearby industrial loads and six open gently-sloping paddocks. During my stay I learned how to conduct a solar energy yield estimate on PVSyst 7.1 and applied this to the sheep farm.

I pitched a startup idea at the Centre for New Energy Technologies (C4NET) and Startupbootcamp Australia's pitch competition on Consumer Data Rights (CDR) sponsored by AEMO. I won the competition for the pitch of *PV Buddy*, an intuitive machine learning approach to energy management with a simple customer-interfacing design. The larrikin blokey 'AI' chatbot works by identifying loads and observing customer behaviour through five and 15-minute solar inverter data. The software communicates to the average Australian consumer helping them with load shifting, explaining solutions and advertising new products to improve the performance, O&M and viability of 2.5 million rooftop solar systems in Australia.

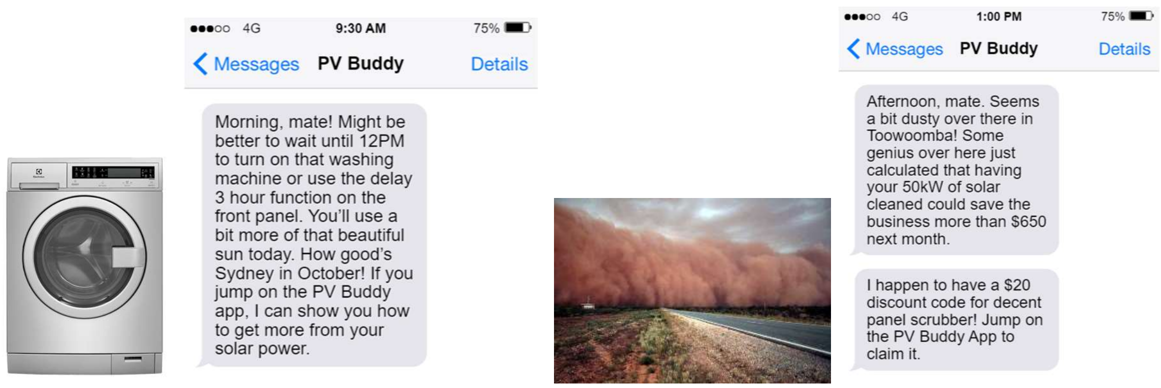


Figure 1: Examples of PV Buddy's intuitive interface and larrikin communication style - load shifting advice (left), prompting O&M activities (right)

While living in northern NSW in September and October, I assisted the not-for-profit group Community-Owned Renewable Energy Mullumbimby (COREM) with an analysis of a local primary school's energy consumption and solar PV generation. The result was a report of recommendations and behaviour changes to increase the yield of the school's 26kW rooftop solar system. I also discussed improvements to COREM's plans for the refurbishment and re-energisation of the Mullumbimby Hydro-electric Power Station Complex.

Prior to the start of the internship, Storm Dennis lashed the United Kingdom in February 2020 and caused extensive once-in-a-hundred-year flooding to my local area. Knowing that Terry Effeney emphasised safety and the need to protect communities in Queensland from the impact of natural disasters and weather events, my partner and I assisted with the collection of essential items and assembled food relief packages for those affected by the flooding.

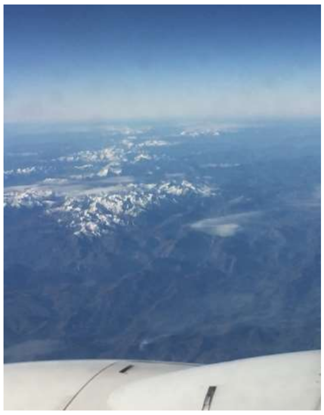
Although these types of community activities are not the stated aim of the scholarship, I do believe that the values of Terry Effeney should be reflected in these types of programme activities. The impacts of climate change are being felt in every corner of the world and its likely that any future scholarship recipients will witness extreme weather events domestically or internationally.

Other extracurricular activities completed during the year included:

- Attendance at the Six Nations rugby match between Wales and Italy at Principality Stadium in Cardiff, UK on the 1st of February
- Hiking to the summits of Table Mountain and Mount Sugar Loaf in the Brecon Beacons National Park, Wales.
- Attended the Banff Mountain Film Festival in Brecon, Wales.
- Visited the Centre for Alternative Technologies (CAT) and its Graduate School of the Environment during a trip to North Wales.

(a) Wales vs. Italy in the Six Nations rugby tournament (2nd Feb 2020)

(b) Beekeeping in South Wales



(c) Flying into Spain over the Cantabrian Mountains

(d) Visit to the Centre for Alternative Technologies in North Wales

(e) Kayaking with my father around Macleay Island, Queensland

Figure 1: Other experiences throughout the year

4. Knowledge Sharing

Between lockdowns, cancelled events, and university closures, the knowledge sharing tasks outlined in the original proposal were immensely difficult to achieve.

I am an active LinkedIn user and through involvement with the Student Association for Sustainable Systems Engineers (SASSE), I have managed to connect with most sustainable systems engineering students and alumni from RMIT University. Many of these students I have previously engaged with and encouraged to apply for the API student bursary programme. An announcement post of my receipt of the T.J. Effeney Award received more than 570 views.

A post and article entitled *Renewable Superpowers: Australia and Ireland's Opportunity* gained a similar number of views and post engagements. The post provided links to the T.J. Effeney Award and promoted the work of the API in providing opportunities for power engineering students.

While discussing the award and experience with engineers in Ireland and the United Kingdom, I also remain committed to continuing to promote the award and the work of the API in fostering up-and-coming power engineers in Australia too. Engagement activities in 2021/2022 have and will include:

- Presenting at the EQL engineering seminar on the 20th of May 2021
- Presentation to the Renewable Developments team at Entura (Hydro Tasmania) the 24th of May 2021
- Presentation (in-person or via webinar) to the API Summer School between 14th – 25th of February 202
- Presentation to the API's Bursary student community (~100 students) in late 2021, linked to promoting the next opportunity for the TJ Effeney Award to students
- A presentation to the boards of the API and Energy Queensland Group

5. Challenges and Opportunities for Future Power Sector Workforce

2020 showed that human behaviours can change rapidly in an era of constant macro-scale disruption and uncertainty. This has profound effects on the energy industry. Those entering the power sector workforce will need a similar degree of adaptability reflected in the characteristics of future networks.

As a project engineering intern, I had firsthand exposure to the current energy industry trend in Europe of massive investments in increasing large high capacity renewable energy projects. Considering the recent advancement of multi-gigawatt scale projects in Australia [1, 2] and around the world [3], the trend offers many challenges and opportunities for efficiency improvements. With scalability comes challenges to all life cycle stages of a project from community consultation to logistics to contingency to transmission. Experience with developing those innovations in a private or research setting will be invaluable to young power professionals.

However, renewable energy technology is not necessarily sustainable energy. Additional effort must be made to ensure that the energy industry does not simply shift to renewable power sources with the same traditional models. A future workforce needs critical thinking skills beyond technical understanding to improve the sociocultural and environmental outcomes of industrial-scale energy projects.

The geographically dispersed nature of renewable generators will expose communities, with little to no knowledge of our sector, to the enormous potential of their local high-value renewable resources. There is a substantial risk of those who live closest to these new generators in remote areas being left behind by the potential economic benefits similar to many indigenous communities near mineral resources in Western Australia. Sharing and distributing our renewable resource wealth not just through regional jobs but through new models of community ownership these assets is an opportunity for regional empowerment, energy democratisation and long-term economic equitability. Wind and sun energy are not finite resources. If projects are setup correctly, repowering sites could lead to true long-term sustainability.

In Australia, this issue is most stark in native title disputes. Indigenous communities in all states and territories, excluding the Northern Territory, do not currently have absolute rights to negotiate with developers of renewable energy projects [4]. Extractive mining companies have won 126 of 129 challenges at the Australian National Native Title Tribunal [4]. This is a challenge for the sector and the workforce as generators and the transmission system become more geographically distributed around Australia.

In the Republic of Ireland, the renewable energy support scheme (RESS) is the auctioning process for generators to receive contracts towards a 70% 2030 national RET. It mandates that all submissions must factor in a contribution of €2/MWh (AU$3.15/MWh) to a local community benefit fund with the aim to guarantee a share of the economic benefits [5]. With the Government of Ireland highlighting the potential for a national grid with more than 600% renewable energy capacity, the potential economic benefits to local communities are enormous. Fostering greater local workforce participation through these funds in areas clustered with renewable projects will engage a more dispersed regional workforce.

6. Advise for People Starting out in their Careers

The power system has been and will continue to be in a state where the only constant is change. For those starting out in their careers and trying to understand even a small part of this highly complex system, reading analysis by experts is a valuable way of getting your head around the whole industry. Organisations such as AEMO, Deloitte, Bloomberg New Energy Finance, and software company WattClarity.com.au frequently publish reports and articles that help to explain key areas and changes. These are just some of the many sources of information that can help those starting out in their careers find insights into their own specific or broad areas of interest. These may also lead to the discovery of potential employers or job opportunities.

Working as a part-time solar designer in my penultimate year was invaluable. More than two million individual systems producing up to 10GW instantaneously and profiting from the revenue is unique in the history of our sector and it could account for 22% of Australia’s total energy demand by 2040 [6]. With plenty of future growth expected, those starting out in their careers would gain a significant insight from early exposure or understanding of the small to medium-scale rooftop solar sector. There is a lot of part-time work available for solar PV designers where it is installed. Small and medium-scale solar design positions require only an elementary understanding of electrical circuits and a 60-hour design qualification with accreditation from Clean Energy Council (CEC).

Many power sector startups require engineers, technicians, and others in the power sector to help establish their expertise and commercial success. Networking with founders and others in the power startup community could provide opportunities for newcomers. Support for business ideas as well as potential connections to employment in innovative companies is available through organisations such as EnergyLab, Startupbootcamp, state government startup support organisations and startup programmes at universities around the country.

7. Suggestions, recommendations and 'ideas to consider' for senior managers and decision-makers

Human behaviour change and larger lessons from 2020 brought new bold ideas and ways of living and working. I reflected on these and researched a few keen areas of interest. The following are suggestions and ideas to consider.

Energy independence and grid defection

Support for local energy independence as well as grid defection could be a rising phenomenon in the suburbs and industrial parks of Australia. With sprawling urban areas containing the vast majority of Australia's population, there is more potential rooftop generation than what is required to meet current demand including small footprint multi-terra watt-hour users. Coordination of cheap grid-forming inverters and battery energy storage is increasingly looking likely to dominate as the largest combined generator. The primary disruptive force of emerging prosumers are not driven by commercial gain but rather energy independence. In fact, many are more motivated to reduce their consumption to match the solar system capacity they have. With the addition of battery energy storage and vehicle-to-grid, fundamentally, this removes almost every current revenue source of the established industry. By supporting grid defection, however, a more robust network of islands may emerge which are isolated from the disruptions of higher intensity natural disasters and potential energy insecurity from extreme or 'black swan' events. Public knowledge of the physics of our sector may also increase as individuals seek ways to become energy independent.

Planning for offshore wind in Australia

Offshore wind is rapidly approaching price parity with onshore mostly due to the utilisation of more abundant resources, greater scale, and higher capacity wind turbine generators. The emerging industry ambition is for the deployment of 20MW offshore wind turbines standing more than 200 metres high from base to hub. Coupled with floating platforms operating in far deeper waters, many technical and economic improvements will occur in the coming years.

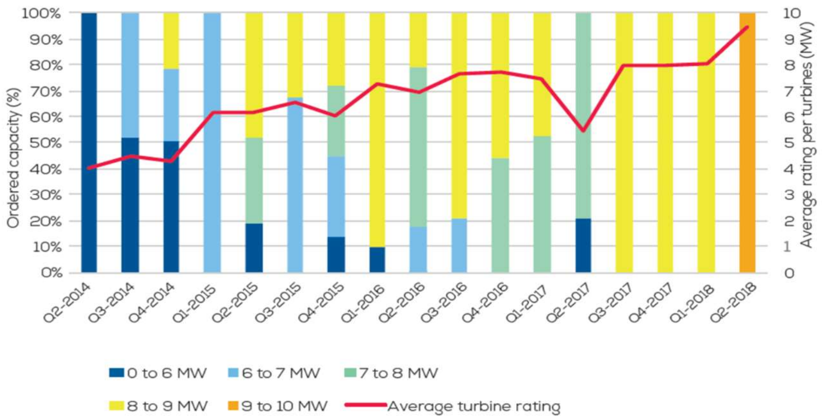


Figure 2: Capacity rating and average rating of the proportions of offshore wind turbine generators ordered in Europe per quarter (2014 – 2018). Source [8]

Increasingly, major oil and gas multinationals are investing in offshore wind projects [7] due to their offshore expertise and need for scalable transition. The area is emerging as an area of bipartisan political support domestically with many of the covenantal anti-wind energy arguments eliminated – higher capacity factors (reliability), visual impact, employment numbers in single projects, etc.

There are currently 25GW of offshore projects under development in Australia concentrated in shallower waters close to higher capacity transmission infrastructure (e.g. Geraldton WA, Gippsland VIC, Portland VIC, Newcastle NSW), although many of these are at least 10 years from energisation.

Demand Growth and Exponentials

Sustainability and high level systems analysis are also areas of interest of mine. At the end of a presentation to EQL's monthly engineering development seminar on the 20th of May 2021, I worked through an exercise in exponential extrapolation originally outlined in a book (*Energy and Human Ambitions on a Finite Planet*) by physicist Dr Tom Murphy from the University of California [9]. I believe it is a relatively simple, quick (10-minute) and significant exercise in demonstrating the largest single problem for our industry.

As detailed in the problem by Dr Murphy, the growth in the energy production rate (power) of the United States is exceedingly similar to the global energy production rate over the last approximately 400 years. This is consistent with a 2 – 3% annual growth rate and, noting wars and economic depressions, shows a clear exponential relationship over the long-term.

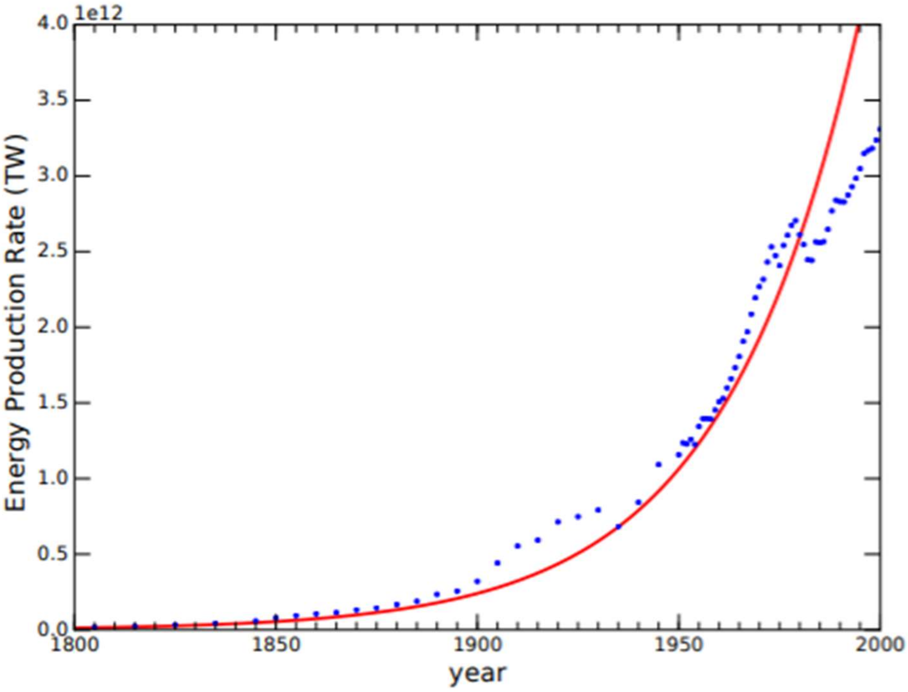


Figure 3: Instantaneous energy production rate (TW) in the United States averaged per year between 1800 and 2000 (blue) and an exponential curve broadly covering the trend. Source [9]

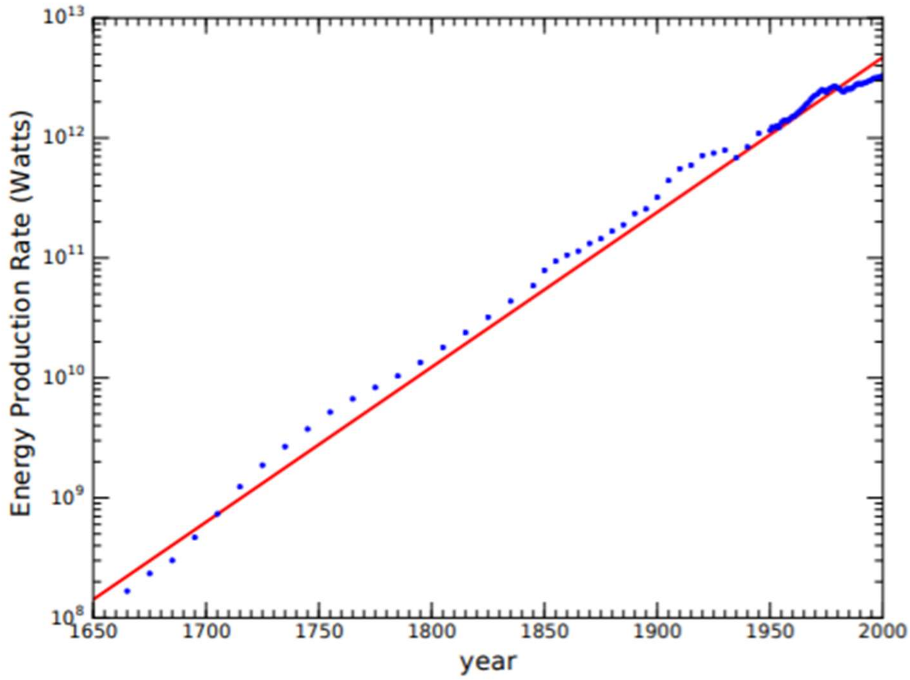


Figure 4: Energy production rate (TW) of the United States between 1650 and 2000 and an exponential line of a 2.9% growth rate on a logarithmic chart. Source [9]

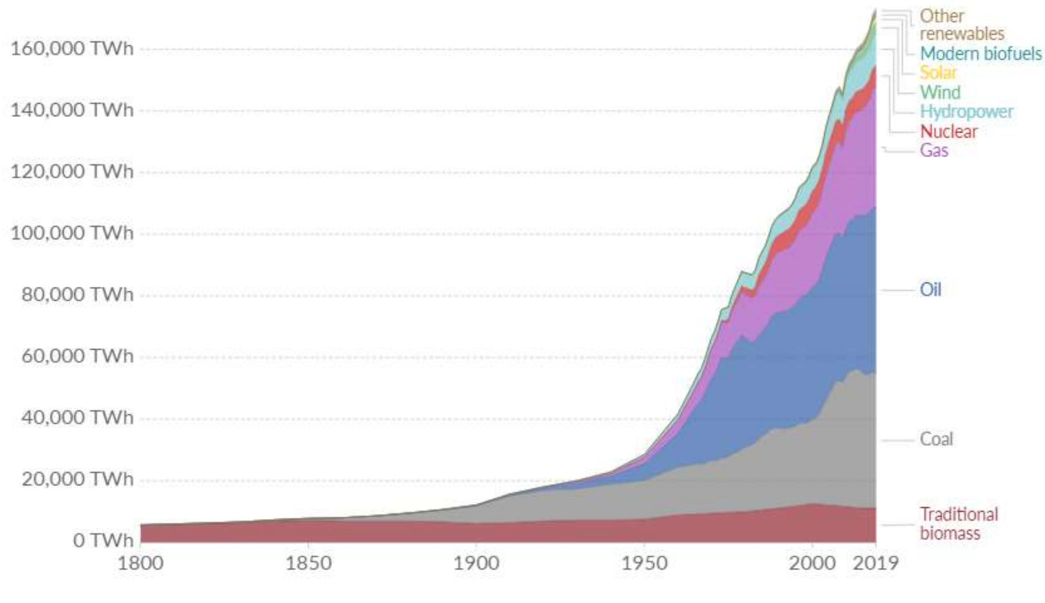


Figure 5: Global direct primary energy consumption (TWh) and source between 1800 and 2019. Source [10]

Trending forward of exponential relationships can quickly become a shocking and often impractical exercise, but the one outlined here is relatively simple. This worked exercise, at a high level, aims to show the impossible continuation and limits of exponential growth in energy production and consumption.

Current global energy production (in terra watts) in 2021 is approximately:

$$18 \times 10^{12}\, TW$$

As clearly seen in Figure 4, the United States was producing energy at a rate approximately 16% of this global rate in the year 2000 (~ 3 X 10^{12} TW).

A conservative annual growth rate for global energy production is 2.3 % over the last 400 years. It is actually slightly higher, but this conveniently results in an increase of a factor of 10 every 100 years. That is:

$$E \times (1 + r)^{y}$$

E = Energy production rate (TW)
r = percentage change in energy production rate
y = number of years

$$E_{100\, years} = E \times 1.023^{100} \cong E \times 10$$

$$1.023^{100} \cong 10$$

The sun deposits about 1000 W/m^2 across the earth's surface. Ignoring clouds and taking the earth as a perfect sphere, the **projected area** of the sun's rays are:

$$R_{earth} \cong 6400\, km\ or\ 6{,}400{,}000\, metres$$

$$Area_{projected,earth} = \pi R^2 = 1.287 \times 10^{14}\, square\ metres$$

Therefore, for an irradiance of 1000W/m^2, the projected area above and accounting for only the earth's land surface (assumed a quarter of the earth, actual is 29.2%), the total power of the sun reaching the earth's surface at any one time is:

$$Area_{earth} \times 1000\, W/m^2 \times 0.25 = 30 \times 10^{15}\, Watts$$

The first question of this exercise is; **how long would it take, if we covered the earth's entire land surface in solar modules with today's 20% efficiency, for our current energy production rate (18 X 10^{12} W = 18 TW) to reach this limit?**

Covering this area in present day solar modules would equate to a potential power production figure approximately 300 times greater than 18 TW:

$$30 \times 10^{15} \times 0.20 = 6 \times 10^{15}\, Watts$$

At 2.3% per annum growth, after one century our energy production rate is 10 times higher and after two centuries it is 100 times higher. Therefore:

$$18 \times 10^{12} \times 1.023^{250} = \sim 6 \times 10^{15}\, Watts$$

After 250 years, our global energy production has reached the point where we would require earth's entire land surface to be covered in present day solar modules. For context, Thomas Newcomen invented the first commercially viable steam engine that kick started the industrial revolution in 1711, 310 years ago. As a side note, the purpose of this steam engine was to pump water out of flooded English coalmines.

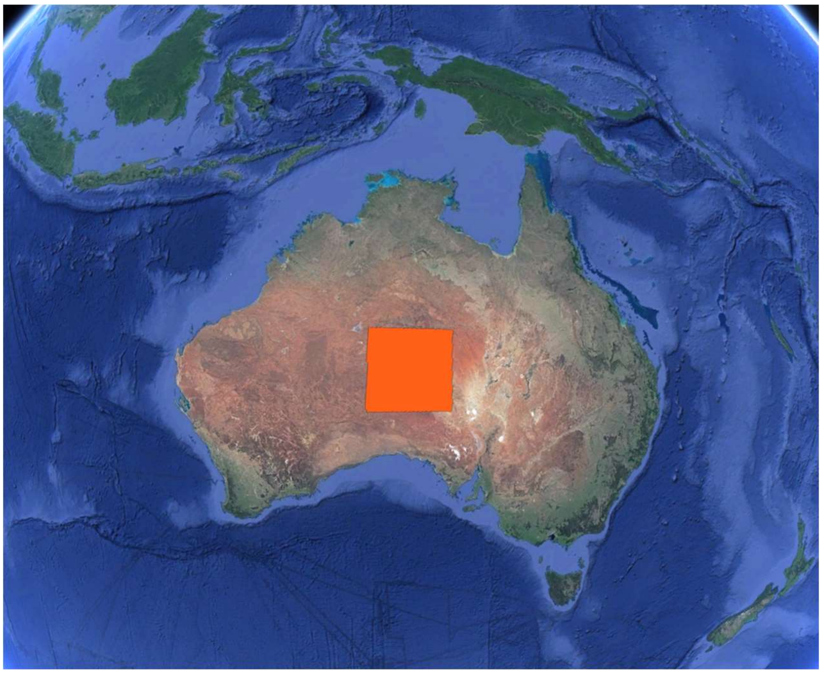


Figure 6: Required area of 20% efficient solar modules to meet current (2021) global power consumption (~430,000km^2), an area approximately one-third the size of Queensland.

Returning to the problem; if we add **floating solar modules on oceans, seas and lakes** as well as dramatically **increase module efficiency to 100%,** this limit could be stretched further. Under these conditions, there is the potential to capture over the whole surface of the earth:

$$\sim 130 \times 10^{15}\, Watts$$

This is 7,000 times greater than the 18 TW of current power production. **How long before global energy production rate reaches the power output of covering the entire earth in 100% efficient solar modules?**

Using the equation originally stated above and logarithmically solving for the number of years yields:

$$18 \times 10^{12} \times 1.023^{390} = \sim 130 \times 10^{15}\, Watts$$

Just 390 years to reach this limit, remembering that a growth rate of 2.3% results in a factor of 10 increase every century, so an increase of 10,000 is 10^4 or four centuries.

If the exercise is not absurd enough, it goes on to consider the consumption of the entire sun. The earth's projected area is tiny compared with the area of the sun and by surrounding the sun in a Dyson sphere of solar modules capturing every watt of radiation, there is the potential to harness:

$$Current\ power\ output\ of\ the\ sun = \sim 4 \times 10^{26}\, Watt$$

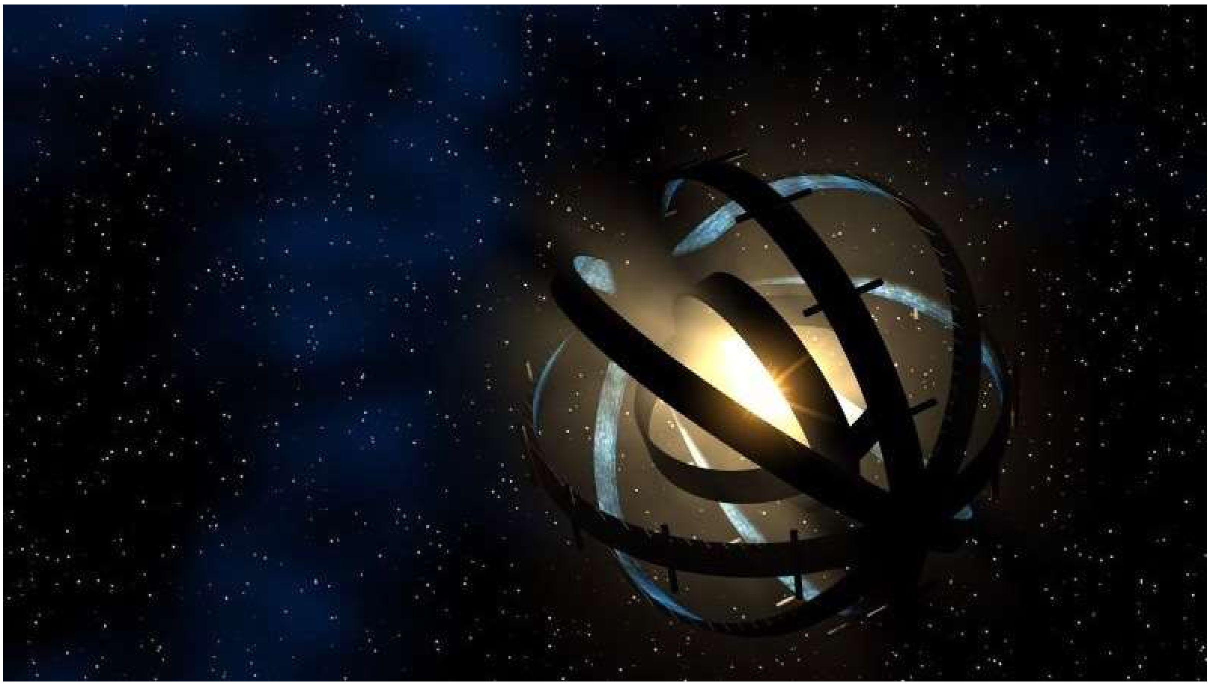


Figure 7: Artistic impression of a partial Dyson sphere**.** Source [11]

With a factor of 10 increase every century, it would take less than 1400 years to reach this particular limit:

$$18 \times 10^{12} \times 1.023^{1400} = \sim 12 \times 10^{26}\, Watts$$

Table 1: Years until energy limits at 2.3% growth rate by utilisation source. Source [9]

Utilising	Years until
Solar, land, 20% efficiency	250
Solar, all of earth, 100% efficiency	390
Entire sun (Dyson sphere)	1,400
Entire galaxy (Dyson spheres)	2,500
Light in Universe (Dyson spheres)	3,600
Mass in visible Universe	5,000

The exercise is ridiculous but the proposition is concerning. The final image I left the group of EQL engineers with was an artistic impression of the Sun Cable project, a 10GW solar and 30GWh BESS project in the Northern Territory with plans to export a fifth of Singapore's energy needs across a 4,500km transmission line.

While a Dyson sphere seems like science fiction, the Sun cable project alongside the gigawatt floating wind farms to be constructed in the North Sea of Europe in the coming decades would likely also seem like science fiction to Thomas Newcomen 310 years ago or even someone starting their career in this sector 30 years ago.

Figure 8: Artistic render of the Sun Cable project with an operating start date of 2027**.** Source [12]

This of course leads to geopolitical questions and commentary on population, wealth, poverty and standards of living. However, this only confuses the conversation and makes it easy to forget that there are real boundaries to our collective addiction to growth. The additional energy consumption in almost every country in the world including Australia seems modest from year to year.

The last boom in energy consumption, which we are still arguably in, was due to the availability of cheap and abundant fossil fuels. The rise of even cheaper and more abundant renewable energy could lead to the acceleration of this trend. In Tasmania, the state government have legislated a 200 % renewable energy capacity by 2040 and in Ireland they are targeting 600 % by 2050. These targets emerging of far expanded electrical generation throughout the world highlight this point.

Decision makers working with experts will need to form the ethical, practical and multilateral solutions required for this problem. It will be up to our industry, engineers and scientists, likely at some point this century, to specify a practical global limit to energy consumption and production. A strategy of energy 'degrowth' is increasingly being openly discussed among sustainability-focussed engineers, particularly those entering sectors focussing on solutions to climate change. Degrowth could become one of many pillars of the overarching strategy of our modern globalised energy system.

8. Suggestions and feedback for improving the scholarship

A conversation with Mike Griffin in November 2019 offered a lot of insight into the life and values of Terry Effeney. Hearing about Terry's commitment to and leadership in the industry and to staff and local Queensland communities was inspiring and offered a greater insight into the kind of principles that I thought important to reflect during the year.

I believe that part of the selection criteria should be a discussion on how the student has already or plans to demonstrate Terry's principles and community leadership. Dissemination activities certainly provide opportunities to encourage participation in the power sector and assist our emerging workforce, however, going beyond our industry and engaging with the wider community in other ways could also be a highly beneficial part of the award.

Over a three-week period in February 2020, I was living in an area of South Wales that was one of the hardest impacted during a one-in-a-hundred-year flooding event with tens of thousands of homes without power and hundreds of homes submerged. Having read tributes and articles about Terry and his work within the Energy Queensland Group focussing on community preparation and support prior to extreme weather events, my partner and I wanted to help those impacted. We worked with the town church to prepare food and essential item packages and cleaned up debris and flood-affected local areas. Communities are currently experiencing the early stages of a deteriorating climate that are more extreme and frequent. There are of course other areas that future recipients could lend support to their communities – the economic hardships and pandemic demonstrate this too.

9. Ideas for maximising the value of the TJ Effeney Award for all stakeholders

I second the suggestions of the T.J. Effeney Award 2018 recipient Jack Bryant in their final report:

- The API leveraging professional networks at CIGRE and other organisations to connect with students could assist in developing a more comprehensive programme or professional network during the programme.
- Regular communications between API and the award recipient about any updates, additional activities, or further knowledge sharing opportunities.
- A standard set of knowledge sharing activities available on the award description page of the API website for award applicants to understand what will be required of them before applying.

Furthermore, I believe a continuation of the degree of flexibility that I experienced would be greatly appreciated for future recipients as well. Even prior to the pandemic being declared in March, the internship at Iberdrola in Spain was not available. Having had international experiences in university before, I understood that these kinds of disruptions can happen frequently, however, not all students have experienced this. It was very much appreciated and very encouraging to hear from David Pointing that sponsors were flexible and, following several weeks of networking, job applications, and interviews, that my modified proposal had been approved.

10. Suggestions to increase support for students

Counteroffer Professional Development Experiences to T.J. Effeney Award Submissions

Our industry is more difficult to navigate for university students than ever before. There are a lot of opportunities in transforming power sector for T.J. Effeney Award proposals, but there is a high degree of macro-level uncertainty in Australia and internationally. The international proposals of Jack Bryant in 2018 and my own in 2019 would be far more challenging in 2021 and later years.

Supporting regional and urban-based students to move for professional development in rural areas where much of the new and exciting projects are taking shape would be very valuable. Support to relocate to major conferences in cities would also be valuable.

Barriers for any proposal will continue to be a challenge and this is where the API and its large Australian network of organisations could be leaned upon.

As proposals outline applicants' motivation, skills and, potentially, demonstration of Terry Effeney's values, applicants could be matched with partner organisations if ambitious proposals face challenges. The API and EQL could reach out to organisations in their network undertaking exciting projects that align with the experience and interests of shortlisted applicants.

Secondary Options for Future Proposals

Furthermore, for T.J. Effeney Award proposals in 2021 and into the future, it may also be beneficial to allow for a second option (Plan B) within proposals.

A secondary option to suggest could be 6 – 12-month extension of the Summer internships that industry partners offer to API Bursary recipients or a capstone projects with financial support.

Group Proposals

For further innovation in the award as well as harnessing the continuously growing network of API bursary students, dual proposals could be encouraged. The generous funding, small pool of applicants, and potential for more domestic and regional-focussed proposals could allow for two or more students to utilise the funding for exciting professional development experiences in a pair or group. Whether this is an experience undertaken at the same time or on a rotation these types of applications should be entirely up to students to organise amongst themselves but suggested as an option. A shared experience could have a greater positive impact on the students and wider community.

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