Waiting to generate: an analysis of wind and solar project development lead-times in Australia's National Electricity Market

Zero-Carbon Energy for the Asia-Pacific ZCEAP Working Paper ZCWP07-22

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Abstract

The complexity of administrative approvals can slow down the deployment of renewable energy. Approval processes are different within and across countries, which can substantially influence start-up costs and lead-times. Very few studies estimate renewable energy development lead-times across multiple years and projects. This study investigates the determinants of lead-times for 146 onshore wind and solar projects completed in Australia between 2000 and 2020. This includes estimating the impacts of ownership, location, and requirements that differ by size of generation. In Australia, there was an improvement in lead-times. Prior to 2016, the average lead-time for solar projects was 46-85 months. This decreased to 24-40 months between 2016 and 2020. Onshore wind projects took longer to develop. Project lead-times were 54-128 months before 2005 and decreased to 30-72 months after 2011. While pre-construction lead-times decreased notably for both solar and wind, commissioning lead-times decreased for wind projects but increased for solar projects. This commissioning stage involves a re-iterative process of tests and equipment changes to meet generator performance standards. Changes in project ownership occurred often (42% of projects) but this had little impact on lead-times (increase of 5-8 months). Accurate estimates of lead-times are important for investors, project owners and policy-makers.

Keywords:
Renewable energy; lead-time; administrative approvals; transaction costs; project ownership.

JEL Classification: Q42, Q47, Q20, K32

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The Australian National University Grand Challenge: *Zero-Carbon Energy for the Asia-Pacific* transdisciplinary research project is a $10m investment between 2019 and 2023 that aims to help transform the way Australia trades with the world. It comprises five interrelated projects: Renewable Electricity Systems, Hydrogen Fuels, Energy Policy and Governance in the Asia-Pacific, Renewable Refining of Metal Ores, and Indigenous Community Engagement. The Grand Challenge's goals include developing zero-carbon export industries, creating new paradigms in benefit-sharing, and developing technologies, polices and approaches which can be applied in the Asia-Pacific and beyond.

1 Introduction

The duration and complexity of administrative approvals is one barrier that has slowed down the deployment of renewable energy in Australia and elsewhere (Byrnes et al., 2013; del Río and Unruh, 2007; Klessmann et al., 2011; Lüthi and Prässler, 2011). Recent announcements in the European Union and the United States aim to improve lead-times and foster faster deployment of renewable energy (Reuters, 2022). Project lead-times can be notable and delays have been associated with the design of administrative processes, including the permitting procedure, the number of authorities involved, and delayed grid connection (International Energy Agency, 2020; Mendonça et al., 2010). These processes are different within and across countries, which can substantially influence deployment, transaction costs, and lead-times for renewable energy projects. The duration of the administrative process has been identified as one of the most important attributes in the decision to invest in solar energy projects in a given country, which was followed by the level of the feed-in tariff (Lüthi and Wüstenhagen, 2012). Regulatory uncertainty is a major source of investment risk (Ciarreta et al., 2020). Project delays will be costly, especially when they lead to refinancing at a time with higher interest rates.

While the costs of renewable energy generation have decreased notably, understanding the practical barriers of greater deployment of renewable projects is important. Accurate project lead-time estimates are rare, but are important for an understanding of renewable energy investment environments and the complexity of approval processes. To make informed decisions, investors and project owners need to understand how long renewable projects take to be approved, built, and commissioned. Lead-times are also important for policymakers who review approval processes, implement renewables policies or set generation/emission targets.

Studies have found that risks related to uncertain project timings can have a decisive impact on investment decisions and project outcomes (Dandage et al., 2018; Elmaghraby and Herroelen, 1990). Furthermore, having access to realistic estimates for project duration can overcome barriers of perceived risk and lower upfront costs (Bock and Trück, 2011; Dandage et al., 2018). The large upfront capital investment required to develop renewables projects means that the cost of capital makes up a significant proportion of project costs (Steffen, 2020). Uncertain and excessively lengthy development durations have the potential to significantly impact a project's net present value due to an increased burden of borrowing costs and the opportunity cost of mobilised capital (Žižlavský, 2014). Without measurement and reporting, projects with long delays may capture attention and distort expected lead-times. It is likely that the best or average lead-times are relevant for most investment decisions.

To estimate average lead-times we built a comprehensive data set of all solar and onshore wind projects in Australia's National Electricity Market (NEM), which covers New South Wales, Victoria, Queensland, South Australia and Tasmania. 146 completed renewable energy projects were included in the analysis of the key factors determining lead-times, which were location and administrative requirements that differ by size of generation. Lead-times for renewable projects have improved across all regions. There was no single policy or process change associated with these improvements. Other than time-periods and being in a region with streamlined approvals, the main determinant of lead-times was whether forecasting of future generation and meeting generator performance standards were needed to establish semi-scheduled status. Non-scheduled projects are smaller and not subject to the same process. Changes in project ownership had little impact on lead-times.

While we find improvements in lead-times, more could be done to ensure that these lower lead-times are sustained in the future. There is also some evidence of longer lead-times for the projects nearing completion. Delays in project development will influence the feasibility of achieving renewable targets and need to be accounted for when setting policies/targets. Also, many economic models of renewable energy deployment ignore approval process lead-times and only incorporate construction lead-times. This is even the case when modelling regulatory uncertainty or investment planning (Kumbaroğlu et al., 2008; Ritzenhofen and Spinler, 2016). This limits the transferability of these modelling results to countries with onerous approval process and lead-times.

2 Lead-times across regions and the approval process in Australia

2.1 Previous estimates of lead-times for Europe, Japan and Australia

Even though there has been a lot of research on renewables and barriers to deployment, accurate estimates of lead-times are scarce. There are a range of estimates for wind project lead-times for Australia, the European Union and Japan. These range from 6 months for approval stages and more than 60 months for the full process (Table 1). Lead-times are notably different by country, local region, and time-period. In some cases, lead-times have improved (examples include Germany, France and Spain) but there are examples of lead-times getting longer due to changes in processes (e.g. Japan). Lead-times of up to seven years have been reported for onshore wind in Sweden (Lundin, 2022).

Table 1: Estimates for wind and solar project lead-times

Year	Country	Type of generation	Lead-time estimate (location: type of estimate)	Source
2009	Australia	Onshore wind	4.5-31 months (Victoria: state level approval process); 8.5-51 months (Victoria: local government level approval process); 5-7 months (New South Wales and South Australia: approval process); at least 15 months (N/A: connection to the grid)	(Parliament of Victoria, 2009)
2011			6 months (South Australia: approval time); 12-24 months (Victoria and New South Wales: approval time)	(Wood, 2012)
2008	European Union	Wind (both)	23 months (Belgium: administrative procedure); 76 months (Spain: administrative procedure); 2 months (Denmark: grid access procedure); 47 months (Portugal: grid access procedure)	(Wind Barriers, 2010)
		Offshore wind	32 months (EU: administrative procedure); 14 months (EU: grid access procedure); 32 months (EU-6: administrative procedure); 8 months (EU-6: grid access procedure)	
		Onshore wind	55 months (EU-27: administrative procedure); 26 months (EU-27: grid access procedure)	
2018	European Union	Wind (both)	12-18 months (France: construction & operation license); 12 months (France: grid access); Up to 25 months (Germany: permitting process); 60 months (The Netherlands: entire project development cycle, including permitting); 30-36 months (Spain: permitting process); 27 months (Great Britain and Northern Ireland: permitting process, excluding grid connection permit or any delays resulting from legal challenges);	(Wind Europe, 2019)
Before 2012 /up to 2014	Japan	Wind (both)	At least 60-72 months (after October 2012, implementation of Environmental Impact Assessment amendment); 36-48 months (before October 2012)	(Mizuno, 2014)

2.2 Approval process in Australia

The development process for wind and solar farms is complex and varies depending on the country. In this study, the process was separated into pre-construction stages (e.g. site selection, feasibility assessments, planning approvals, and environmental approvals), and then construction and commissioning. Lead-times for solar and wind project development are largely determined by the approval stages and the grid connection process. For Australia, our estimates show that 65%-85% of the total lead-times for wind projects were the pre-construction lead-time. For solar projects, pre-construction was 50%-83% of the total lead-time. The approvals process must be completed prior to the commencement of construction, while the grid connection process involves several stages throughout the entire development process, including throughout construction.

The approvals process varies markedly across States, with complex and difficult to navigate planning systems acting as a significant hurdle for renewable energy project development in Australia (McBean, 2017). Depending on which State the development takes place in, and which technology type is being assessed, this process may require state or local council approval (Table 2). Additionally, all developments can be subjected to federal assessment under the Environmental Protection Biodiversity Conservation Act if the development is likely to have a significant impact on a matter of national environmental significance (Queensland Government, 2020).

Grid connection challenges and associated commissioning delays are frequently cited as the primary concern of renewable energy developers in the NEM (Clean Energy Council, 2020; Parkinson, 2018). A generator must have a performance standard approved by the Australian Energy Market Operator (AEMO), and then pass commissioning tests to demonstrate that the performance standard is being met.

2.2.1 Important differences between semi-scheduled and non-scheduled generators

Non-scheduled generators are those that are “invisible” to AEMO, meaning that they are not required to participate in central dispatch. Non-scheduled generators have fewer requirements due to a lower level of technical information required for connecting to the grid. This is because they are not expected to assist in network management (AEMC, 2008; Niemann et al., 2017).

Before completion, semi-scheduled projects need to work with AEMO to test their power control requirements so that they can follow the specific dispatch targets provided by the market operator. There are additional generator performance standards to follow. The construction/commissioning stage needs careful planning, as it can often become a re-iterative process of tests and changing a range of equipment (harmonic filters, synchronous condensers, capacitor banks, etc.) until the performance standards are met. These changes can be costly. For example, a change in this process during 2018 led to a solar project needing to install a $20 million synchronous condenser prior to connecting and was expenditure after financial close (Simshauser, 2021). Large complex projects often have unintended impacts on the network and need to respond to these issues during the construction/commissioning stage.

The size requirements to be classified as non-scheduled have changed a few times, with the latest amendment to the National Electricity Rules (NER) in 2017 reducing the maximum capacity that a new generator can receive non-scheduled status from 30MW to 5MW (AEMC,2017). This means that there are likely to be lower numbers of non-scheduled projects in later periods, which is consistent with our data.

Table 2: Approvals Process for NEM States

State	Tech	Approvals Process
QLD	**Solar**	Approved by local councils.
	Wind	Approved by the State Assessment and Referral Agency, within the QLD Department of Infrastructure, Local Government and Planning.
NSW	**Solar**	The approval authority is dependent on the size of the capital investment and capacity of the proposed project. Authorities include the Local Council, Joint Regional Planning Panel, and the planning minister and Planning Assessment Commission. Projects > $30 million are deemed state significant and must undergo a more rigorous approvals process.
	Wind	
VIC	**Solar**	The Victorian Minister for Planning is responsible for issuing permits for wind farms and large-scale solar energy facilities.
	Wind	
TAS	**Solar**	Approved by local councils, although the Environment Protection Authority may undertake assessment of environment impacts of a proposal.
	Wind	
SA	**Solar**	Approved by local councils, unless the project is classified as a state significant project, whereby the Minister is responsible for deciding on the proposal.
	Wind	

Note: Adapted using the Australian Energy Infrastructure Commissioner planning and compliance guideline. Source: (Australian Energy Infrastructure Commissioner, 2020)

3 Data and Methodology

To create a dataset of lead-times for completed projects we started with the NEM generation information database published by AEMO, which has data on solar and wind projects (AEMO, 2021). We focused on completed and committed projects with an installed capacity exceeding 2MW, as our focus is on grid-scale projects that had tangible lead-times to analyse.

While AEMO does collect data for proposed projects, this data is incomplete as providing this information is voluntary. In addition, some of these projects may have been abandoned by their owners and will never proceed. Furthermore, projects that are nearing the commitment stage are often confidential as developers can choose not to disclose project details to AEMO until the latest possible point. With this in mind, only duration estimates for projects that have proceeded past the commencement of construction were considered.

Table 3 provides detail on how the site commitment date, construction commencement date and completion date were identified. To calculate lead-times we needed to find the earliest possible baseline date that could be identified. We focused on identifying the month and year of site project commitment. As a proxy for the month and year of site commitment for each of the relevant projects, the Australian Securities Investment Corporation (ASIC) registry was utilised in order to identify when an Australian Company Number (ACN) was set up for the shell companies of the wind and solar projects (ASIC, 2022). The establishment of a shell company generally occurs early in the establishment of a potential project. However, there is some variability between developers. Due to this variability, the ACN establishment date was cross-referenced with the earliest mention of site selection from a project by project internet search. The key documents that were found included press releases, land lease contracts, and resource monitoring statements. Where a miss-match between the ACN data and a public document or announcement occurred, the earlier date was chosen. Only three projects were omitted from the study on the basis that a reliable date for site commitment could not be ascertained.

Construction start dates were sourced via internet searches (as they were often the subject of press releases). The NEMweb 5-minute interval Supervisory Control and Data Acquisition (SCADA) database allowed us to identify project completion dates, which we defined as the date when available generation first exceeded 80% of registered capacity (AEMO, 2022). When NEMweb data was not available (i.e. non-scheduled sites), project completion dates were obtained using internet searches.

Table 4 provides an overview of the data set complied and compares the quality of solar/wind resources, generation capacity, year of site commitment, year of construction, and completion year. The dataset is a cross-section of all of the projects developed across the eastern and southern parts of Australia. The only major Australian regions missing are Western Australia and the Northern Territory, which are not part of the NEM.

Ordinary Least Squares (OLS) regressions were used to determine the relationship between the three project development duration estimate categories (dependent variables) and project descriptors (via a set of dummy variables). Tables 5 and 6 provide descriptions and summary statistics for the variables included in the regressions. Equation 1 shows the specification of the regression where Y is the dependent variable, X is a vector of explanatory variables and ε is the error term. There are multiple project sites (*i*) and different time periods (*t*). β_0 is a constant and α is a vector of the estimated parameters for each explanatory variable. We do not run the regression as an unbalanced panel due to the heterogeneous nature of each project; rather it is run as a cross-sectional analysis. To allow for common developers across projects, we cluster the standard errors using the organisations that were the initial project developer at the start of the project. For the 146 projects in the regressions, there were 76 groups of initial project developers that started the project and 81 groups of corporate owners by the time of project competition. Notable variation in project ownership occurred and we included a dummy variable in the regression to capture whether the owner of the project changed. This occurred for 49% of wind projects and 35% of solar projects (as shown in Tables 5 and 6).

$$Y_{it} = \beta_0 + X_{it}\alpha + \varepsilon_{it} \quad (1)$$

Table 3: Description of Relevant Dates Collected in the Dataset

Relevant Date	Description
Site commitment date	Month/year of site commitment. Australian Company Number (ACN) establishment date, which was cross-referenced with the earliest mention of site selection via internet searches.
Construction commencement date	Month/year of construction start date. Collected from project websites, press releases and news articles.
Completion date	Month/year of "completion". First time a site has availability > 80% of nameplate capacity in NEMwatch data.

Table 4: Summary of the full dataset

Variables	Type of variable	Minimum	Median	Mean	Maximum	Count
			Wind projects			
Wind quality	Wind Speed at 150m (m/s), annual average	7	9	8	11	71
Capacity	Nameplate capacity of each site in MW	4	107	123	532	72
Site commitment year	Year	2000	2007	2007	2018	72
Construction commencement year	Year	2004	2016	2014	2020	72
Completion year	Year	2005	2017	2015	2022	72
			Solar projects			
Solar quality	Global Horizontal Exposure, annual daily average (MJ/m2)	17	19	19	22	71
Capacity	Nameplate capacity of each site in MW	2	58	76	275	74
Site commitment year	Year	2010	2016	2015	2019	74
Construction commencement year	Year	2013	2017	2017	2020	74
Completion year	Year	2014	2019	2019	2022	74

Table 5: Summary of wind project data used in regressions

Variables	Type of variable	Minimum	Median	Mean	Maximum	Count
Total project lead-time	Continuous – number of months	18	91	95.48611	196	72
Pre-construction lead-time	Continuous – number of months	9	74.5	77.30556	165	72
Building and commissioning	Continuous – number of months	5	17	18.18056	49	72
Semi-scheduled b/n 2001 to 2005	Dummy variable	0	0	0.222222	1	72
Semi-scheduled b/n 2006 to 2010	Dummy variable	0	0	0.388889	1	72
Semi-scheduled b/n 2011 to 2015	Dummy variable	0	0	0.111111	1	72
Semi-scheduled b/n 2016 to 2020	Dummy variable	0	0	0.041667	1	72
Non-scheduled b/n 2001 to 2005	Dummy variable	0	0	0.125000	1	72
Non-scheduled b/n 2006 to 2010	Dummy variable	0	0	0.055556	1	72
Non-scheduled b/n 2011 to 2015	Dummy variable	0	0	0.041667	1	72
Change in owner during project development	Dummy variable	0	0	0.486111	1	72
Queensland	Dummy variable	0	0	0.027778	1	72
South Australia	Dummy variable	0	0	0.291667	1	72
Tasmania	Dummy variable	0	0	0.041667	1	72
Victoria	Dummy variable	0	0	0.430556	1	72
New South Wales	Dummy variable	0	0	0.208333	1	72

Table 6: Summary of solar project data used in regressions

Variables	Type of variable	Minimum	Median	Mean	Maximum	Count
Total project lead-time	Continuous – number of months	9	41	43.77027	102	74
Pre-construction lead-time	Continuous – number of months	3	25	26.98649	82	74
Building and commissioning	Continuous – number of months	2	15	16.78378	53	74
Semi-scheduled b/n 2006 to 2010	Dummy variable	0	0	0.0405405	1	74
Semi-scheduled b/n 2011 to 2015	Dummy variable	0	0	0.2972973	1	74
Semi-scheduled b/n 2016 to 2020	Dummy variable	0	0	0.4594595	1	74
Non-scheduled b/n 2006 to 2010	Dummy variable	0	0	0	0	74
Non-scheduled b/n 2011 to 2015	Dummy variable	0	0	0.1486486	1	74
Change in owner during project development	Dummy variable	0	0	0.3513514	1	74
Queensland	Dummy variable	0	0	0.3918919	1	74
South Australia	Dummy variable	0	0	0.0540541	1	74
Tasmania	Dummy variable	0	0	0	0	74
Victoria	Dummy variable	0	0	0.1486486	1	74
New South Wales	Dummy variable	0	0	0.4054054	1	74

4 Results

4.1 Raw data – lead-times by time and scheduling status

The main difference in the lead-times of wind projects was whether the project started before 2011 and whether it was semi-scheduled. Before 2011, semi-scheduled wind projects took an average of 121 months to complete and this decreased to an average of 61 months between 2011 and 2020. Non-scheduled wind projects were quicker to complete, with an average of 54 months (2001-2010) and 45 months (2011-2020). Figure 1a provides averages for five-year time periods and contains dot points to show the individual estimates for all 72 wind projects.

Solar projects were quicker to complete. Between 2011 and 2020, the average lead-time was 43 months for semi-scheduled and 38 months for non-scheduled projects. Semi-scheduled projects decreased from an average of 50 months (2011-2015) to an average of 39 months (2016-2020). For non-scheduled projects, the average lead-times were 46 months (2011-2015) and 19 months (2016-2020). Figure 1b provides averages for each five-year time period and contains dot points to show the individual estimates for all 74 solar projects. These estimates do not account for differences in ownership or region, which are controlled for in the regression results.

4.2 Regression results – lead-times by all determinants (incl. region)

The regression results for wind projects confirm that semi-scheduled projects had higher lead-times, especially when comparing those before 2011 to those completed after 2015. Table 7 shows the regression results for wind projects, which are broken down into the total lead-time, pre-construction lead-time, and building and commissioning lead-time. The main determinant of lead-times was whether forecasting of future generation and meeting generator performance standards were needed to establish semi-scheduled status. Differences across regions were minor and the only region with a lower lead-time was South Australia, which is measured compared to lead-times in New South Wales (as this is the dummy variable dropped to avoid the dummy variable trap). Changes in ownership during the approvals stages had no impact. An average of 8 months was added to the lead-time estimate for the 49% of projects with changes in ownership. This was not statistically significant. Figure 2a plots a selection of the wind project regression estimates to show how the decreases in average lead-times came down over time for each approval stage and the scheduling status. Controlling for ownership and region (using the regression results) provides slightly different average estimates. For wind, the estimated project lead-times are between 54-128 months before 2005. This then decreased to 30-72 months after 2011. The regression results are those reported in the abstract and conclusion.

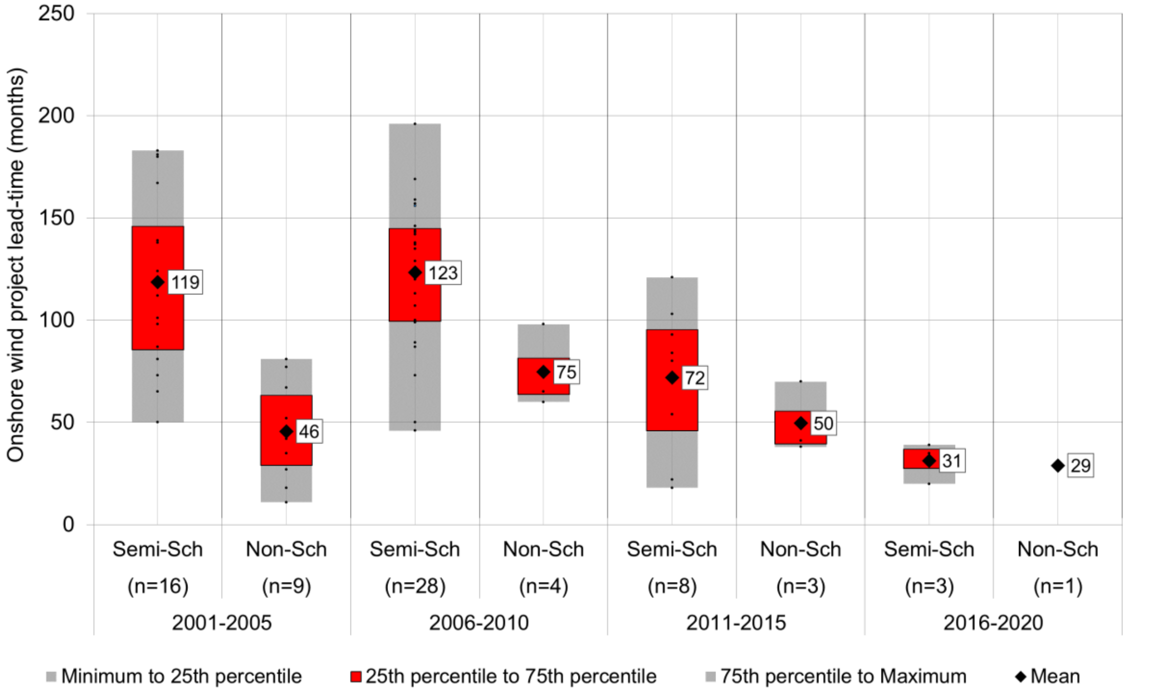
Figure 2 also shows the breakdown of total lead-times into the pre-construction, and building and commissioning phases. The majority of the decrease in lead-times was from improved pre-construction lead-times. For semi-scheduled wind projects, there was a decrease in building and commissioning lead-times from 20 to 13 months. Note that we did not plot the estimate for non-scheduled projects after 2016 as there was only one observation in the data set.

Table 8 shows the regression results for solar. The regression results for solar projects also confirms that semi-scheduled projects had higher lead-times. For solar, lead-times were also significantly lower in South Australia (compared to New South Wales). As was the case for wind projects, changes in ownership did not have a significant impact on lead-times. For solar, a change in ownership, relevant to 35% projects, added 4 months to the lead-time estimate.

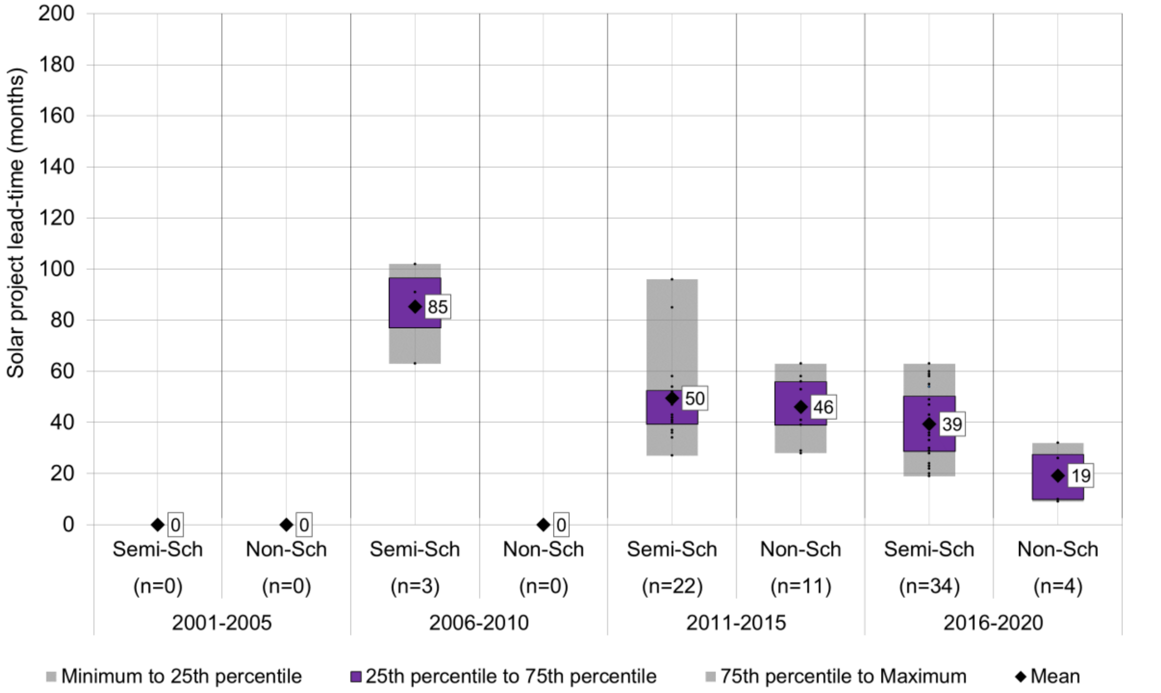
Figure 2b plots a selection of the solar project regression estimates to show how the decreases in average lead-times have decreased. Prior to 2016, the average lead-time for solar projects was 46-85 months depending on whether the project was semi-scheduled or not. This decreased to an average of 24-40 months between 2016 and 2020.

As for wind projects, the majority of the decrease in solar lead-times was from improved pre-construction lead-times. For semi-scheduled solar projects, there was an increase in building and commissioning lead-times from 14 to 20 months.

Figure 1: Lead-times of solar and onshore wind projects (raw data)

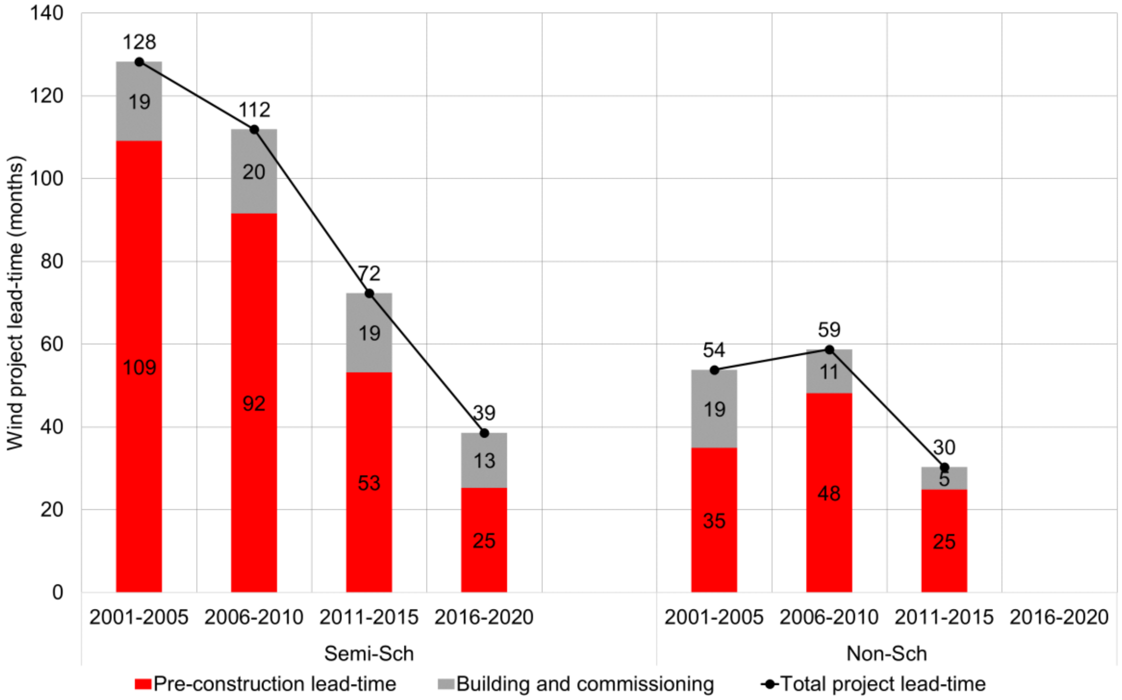


a) Total lead-time for wind projects by time period and scheduling (Sch) status

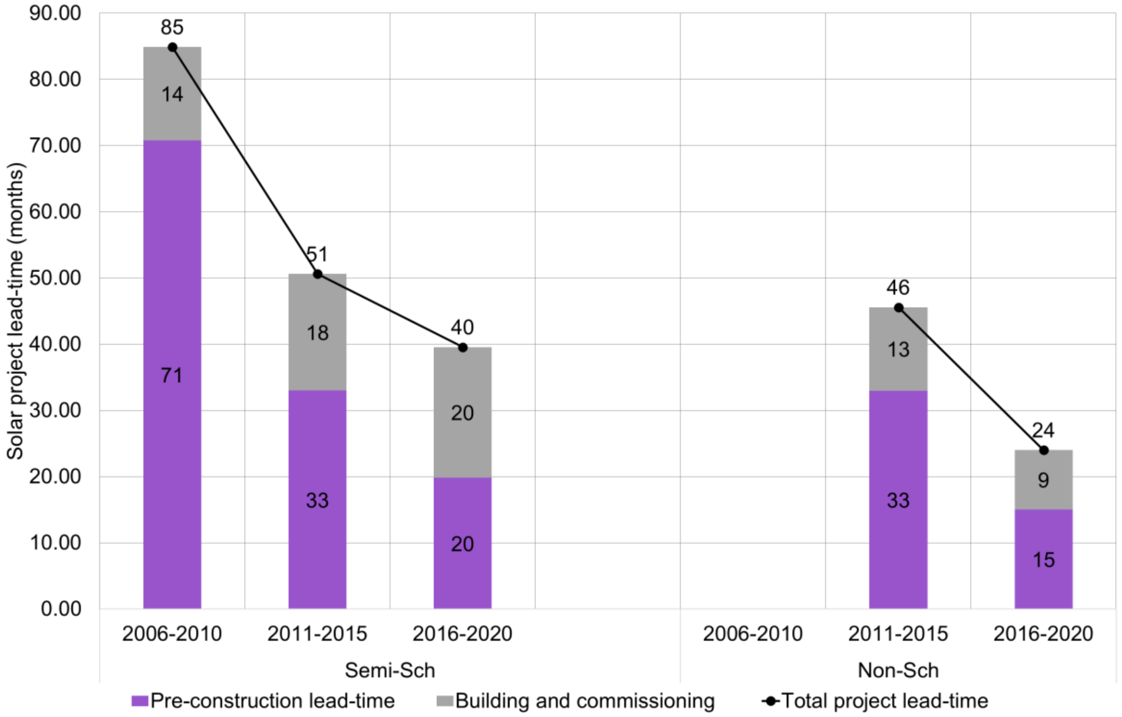


b) Total lead-time for solar projects by time period and scheduling (Sch) status

Figure 2: Lead-times of solar and onshore wind projects (regressions)



a) Lead-time for wind projects by time period, phase, and scheduling (Sch) status



b) Lead-time for solar projects by time period, phase, and scheduling (Sch) status

Table 7: Regression results for wind project – lead-times in months

Variables	Total project lead-time	Pre-construction lead-time	Building and commissioning
Semi-scheduled b/n 2001 to 2005	121.30***	107.70***	13.60***
	(11.11)	(11.09)	(3.20)
Semi-scheduled b/n 2006 to 2010	104.92***	90.23***	14.69***
	(9.27)	(8.84)	(3.24)
Semi-scheduled b/n 2011 to 2015	65.36***	51.82***	13.55***
	(12.13)	(9.13)	(4.79)
Semi-scheduled b/n 2016 to 2020	31.65**	23.93*	7.72**
	(14.31)	(12.74)	(2.91)
Non-scheduled b/n 2001 to 2005	46.87***	33.52***	13.35***
	(9.63)	(8.68)	(3.36)
Non-scheduled b/n 2006 to 2010	51.77***	46.80***	4.96*
	(10.77)	(9.11)	(2.87)
Non-scheduled b/n 2011 to 2015	23.34**	23.47**	-0.13
	(9.16)	(10.11)	(1.61)
Change in owner during project development	8.02	5.41	2.62
	(8.81)	(8.15)	(2.05)
Queensland	6.56	7.64	-1.09
	(23.29)	(23.02)	(2.09)
South Australia	-25.99**	-22.02*	-3.97
	(12.38)	(11.53)	(2.60)
Tasmania	-2.07	-4.41	2.34
	(16.16)	(14.02)	(2.99)
Victoria	13.97	14.17	-0.20
	(11.95)	(11.27)	(2.70)
Constant	7.01	1.42	5.59
	(11.55)	(10.37)	(3.89)
Observations	72	72	72
R-squared	0.58	0.58	0.24

Robust standard errors in parentheses, statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 8: Regression results for solar project – lead-times in months

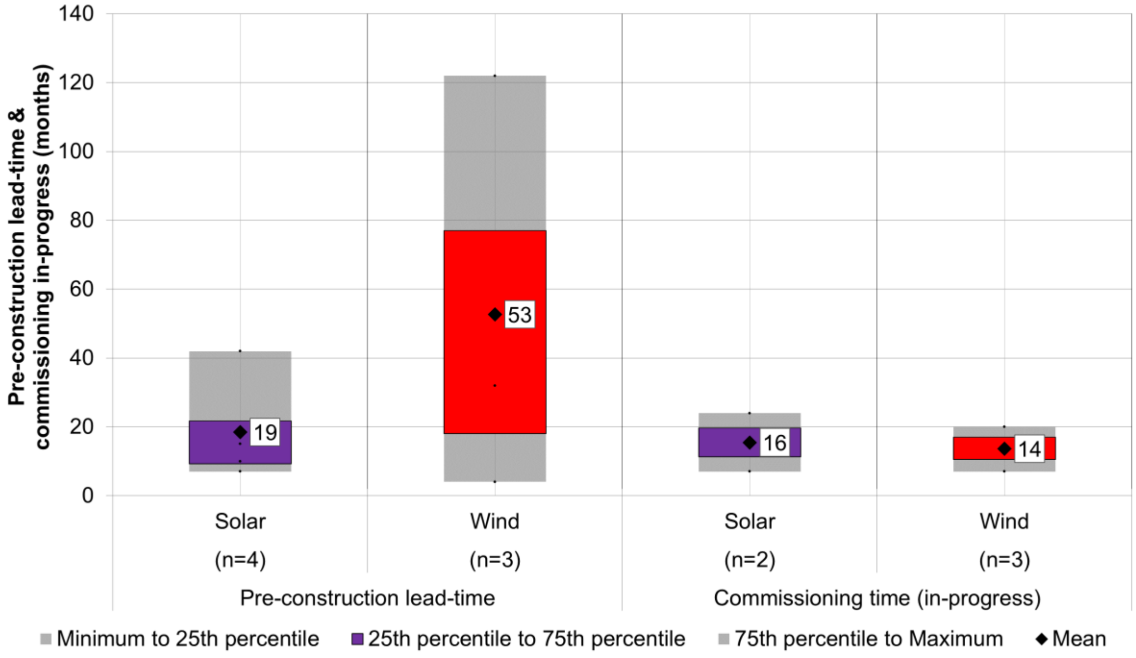
Variables	Total project lead-time	Pre-construction lead-time	Building and commissioning
Semi-scheduled b/n 2006 to 2010	60.90***	55.74***	5.16*
	(11.79)	(9.83)	(2.81)
Semi-scheduled b/n 2011 to 2015	26.59***	17.95***	8.64***
	(5.38)	(3.44)	(2.87)
Semi-scheduled b/n 2016 to 2020	15.56***	4.78	10.78***
	(5.11)	(3.59)	(2.53)
Non-scheduled b/n 2006 to 2010			
Non-scheduled b/n 2011 to 2015	21.58***	17.94***	3.64
	(6.33)	(5.57)	(2.84)
Change in owner during project development	4.04	5.54*	-1.51
	(3.86)	(3.00)	(1.84)
Queensland	-2.81	-4.94	2.13
	(4.25)	(3.92)	(1.96)
South Australia	-14.72***	-8.96**	-5.76***
	(3.77)	(3.62)	(1.61)
Tasmania			
Victoria	-3.42	-0.40	-3.02
	(4.75)	(3.43)	(2.55)
Constant	24.03***	15.06***	8.97***
	(5.80)	(4.50)	(2.73)
Observations	74	74	74
R-squared	0.44	0.57	0.18

Robust standard errors in parentheses, statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

4.3 Projects nearing completion

The previous analysis of the raw data and the regressions focused on the 146 projects that were completed by the time of analysis. However, we also assessed the pre-construction lead-times of solar and onshore wind projects nearing completion. These are the projects that have started construction, but have not been fully built or commissioned. Figure 3 provides the pre-construction lead-times for 7 semi-scheduled solar and wind projects. The 2020-2022 period involved notable disruption, which may have impacted these lead-times. The average pre-construction lead-time for solar projects nearing completion was 19 months. Two wind projects had a pre-construction lead-time below 32 months, but the average lead-time was inflated to 53 months due to a project that took 122 months. Projects that have not completed construction have not been assessed in this analysis as it is unclear whether they are on-hold or actively going through the approval process. We also provide the (in-progress) commissioning times for 5 semi-scheduled solar and onshore wind projects nearing completion (Figure 3). These projects have dispatched electricity to the grid, but are completing the commissioning process. For these in-progress commissioning times, we use the difference between the first electricity dispatched and the time of analysis (October 2022).

Figure 3: Pre-construction lead-times and commissioning times (in-progress) of semi-scheduled solar and onshore wind projects nearing completion



5 Policy implications

A range of policies and processes that reduce lead-times have been identified (Klessmann et al., 2011), but only a few of these policies have been used in Australia (Table 9). Up until now, only one region has established a planning permit and development approval ‘one stop shop’ (i.e. Victoria). Organisations with a maximum response times are rare, we only found one example of this in Australia (i.e. New South Wales). While there are some differences in lead-times between regions, we were unable to find evidence of a policy or process that explains the decreases in lead-times over time and between states. South Australia had lower lead-times, which occurred for both wind and solar. These lower lead-times are likely to be related to streamlined approval processes, which were mentioned in the State’s low carbon investment plan (South Australian Department of State Development, 2015). 2014-15 was a time of great uncertainty for the renewables industry in Australia, but South Australia remained a good option for renewable projects.

Table 9: Implementation of policies across Australian regions

Type of issue or barrier	Options for policy response	Examples of policy implemented in Australia
Administrative procedures (high number of authorities involved, lack of coordination among authorities, lack of transparent procedures, long lead-times, high costs for applicants etc.)	“One-stop shop” approach for applications	DELWP in Victoria has established a planning permit and development approval “one-stop shop”.
	Maximum response times for authorities	In NSW there is a preliminary environmental assessment response time.
	Clear guidelines and capacity building for civil servants	No examples found.
	Limiting administrative requirements to the relevant elements	No examples found.
	Simplified procedures for small plants	As discussed, AEMO has different procedures for semi-scheduled and non-scheduled projects.
Renewable Energy Zones (REZs) not or insufficiently considered in spatial planning	Improved spatial planning rules to account for REZs	Have been proposed and some are starting approval process. However, REZs were not operating during the time of our analysis.
	Definition of REZs priority areas	
	Participation and/or compensation options for local communities	

Note: example barriers and policy responses were sourced from (Klessmann et al., 2011).

6 Conclusions

Accurate renewable energy project lead-time estimates are rare. This is surprising, as lead-times are often discussed and are required to make informed decisions about the start-up costs of renewable energy projects. Investors, project owners and policy-makers need to understand contemporary renewable project lead-times. Delays can be costly for investors and project owners, especially when refinancing occurs at a time with higher interest rates. Policymakers should regularly review lead-times to identify bottlenecks of concern in the project approval process and assess the feasibility of near-term renewables policies or targets.

We analysed 146 Australian renewable projects to assess how long it takes for wind and solar projects to be approved, built, and commissioned. Prior to 2015, the average lead-time for solar projects was 46-85 months. This decreased to 24-40 months between 2016 and 2020. Onshore wind projects took longer to develop. Project lead-times were 54-128 months before 2005 and decreased to 30-72 months after 2011. These decreases were mainly driven by improved pre-construction lead-times. Semi-scheduled wind and solar projects, which are subject to more testing and assessments, had higher lead-times. For semi-scheduled wind projects, there was a decrease in building and commissioning lead-times from 20 to 13 months. For semi-scheduled solar projects, there was an increase in building and commissioning lead-times from 14 to 20 months. Changes in ownership occurred 42% of the time, but had little impact with only 5 to 8 months added to the lead-time estimates.

Projects that have not completed construction were not assessed in this analysis as it is unclear whether they are on-hold or actively going through the approval process. However, we did estimate the pre-construction lead-times of solar and onshore wind projects that have started construction, but have not been fully built or commissioned. The average pre-construction lead-times for solar projects nearing completion was 19 months and 53 months for wind projects (with most wind projects below 32 months). For those projects that have dispatched electricity to the grid but are still completing the commissioning process, the (in-progress) commissioning times are currently an average of 14 to 16 months.

The 2014 review of the Renewable Energy Certificates scheme caused great uncertainty about the future of these tradable certificates. This included concerns that the Federal Government would reduce or scrap the renewable energy target (Taylor, 2014). Regulatory uncertainty is a major source of investment risk and can delay projects (Ciarreta et al., 2020).

We also reviewed example policy responses that overcome administrative barriers for fast approvals. These are not consistently applied across Australian regions and do not explain the improvements in lead-times. Only one region stood out; South Australia has lead the way with the deployment of renewables and streamlined approvals. We estimated that average lead-times for South Australian projects were 15-26 months shorter than the other States.

Accurate lead-times are important for an understanding of the contemporary renewable investment environment and the efficiency of approval processes. Delays in project development will influence the feasibility of achieving renewable targets and need to be accounted for when designing policies. These real-world delays should also have consequences for the modelling of emission reductions over time. Delayed technological deployment can impact the feasibility of achieving emission transition pathways (Eom et al., 2015; Iyer et al., 2015). Previous studies of regulatory uncertainty and investment planning for renewable energy have only considered construction lead-times, not administrative lead-times (Kumbaroğlu et al., 2008; Ritzenhofen and Spinler, 2016).

Some regions or countries may find it hard to kick-start a shift to renewable energy if lead-times are too long. Without measurement and reporting of lead-times, stakeholders will speculate about lead-times and the duration of administrative processes. This is an important issue, as the time taken for administrative approvals has been identified as one of the factors that impacts investment decisions and the location of renewable energy projects between countries (Lüthi and Wüstenhagen, 2012).

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