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The University of Queensland Surat Deep Aquifer Appraisal Project (UQ-SDAAP)

Scoping study for material carbon abatement via carbon capture and storage

Supplementary Detailed Report

Five country survey

30 April 2019

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Disclaimer

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Contents

1. Survey

The survey utilised for this exercise is presented below.

The effect of message framing on the understanding and acceptance of low carbon technologies

Project Overview

This research project intends to advance understanding about the social challenges associated with low carbon technologies regarding their public acceptance and use. The main aim is to identify the social drivers and barriers, and the publicly perceived risks and benefits of increasing the use of low carbon technologies.

This project is funded by the Australian government under the Carbon Capture and Storage Research Development & Demonstration, the Australian Coal Association Low Emissions Technology Pty Ltd (ACALET; through the COAL21 Fund) and the University of Queensland. These organisations partnered in order to better understand climate change mitigation, and to better inform public debate and policy makers on how low carbon technologies could be a real option in Australia.

What are low carbon technologies?

- Low carbon technologies are a list of technologies which generate less carbon dioxide than all the fossil fuel power plants.
- The renewable energy sources like solar energy and wind power generate no carbon in the process of generating electricity.
- The terminology low carbon also refers to the use of fuels which produce carbon dioxide during the process of power generation, but which implement ways to lower the carbon emission into the atmosphere.

What is involved?

You are invited to participate in this study, which will take up to 25 minutes of your time. We are keen to access the views of a range of people and you do not need to be an expert in this field. We would like to encourage you to participate in the study, as your participation will contribute to building on national and international understandings about public perceptions of and preferences for low carbon energy technology options.

Do I have to be part of this program?

Completion of the study is completely voluntary and you are free to withdraw at any time without prejudice or penalty. If you wish to withdraw from the study your information will be removed from our databases.

How will my responses be recorded, used and kept?

Your responses will be collected through the Qualtrics survey platform. The research team only receives de-identified data (i.e. no personal identifying information) from Qualtrics. All data received from Qualtrics will be stored confidentially at The University of Queensland for up to five years. The results will be reported in

aggregate form only, and cannot be identified individually. Information will be used to prepare research reports and academic publications.

Data collected in this survey may be used for comparative analysis to similar data collected in China and we would also like to be able to reuse some of your responses to compare with subsequent surveys and related research we complete on international attitudes to energy technologies. It is also anticipated that we will use the results from these studies to inform the design of educational messages and other engagement activities we might undertake to further test the impact of information provision and other materials on individual attitudes.

In addition to the above use of your de-identified data for the research purposes outlined above, Qualtrics may use your aggregated and anonymised data for their own internal purposes. Qualtrics' privacy statement may be accessed at: https://www.qualtrics.com/privacy-statement/

How can I find out more about the study?

If you would like more information about this study please contact the project leader Peta Ashworth by phone (+61 7 3346 3883) or e-mail (p.ashworth@uq.edu.au).

If you would like to be notified about the availability of findings of this research, please indicate this in the field provided at the end of the survey.

Results of this study will be available on the project website: https://energy.uq.edu.au/project/surat-deep-aquifer-appraisal-project-uq-sdaap

Has this project received ethical clearance?

This study adheres to the Guidelines of the ethical review process of The University of Queensland and the National Statement on Ethical Conduct in Human Research. If you have any queries about the project please feel free to contact the Chief Investigator of the project, Professor Peta Ashworth at p.ashworth@uq.edu.au, or calling on +61 7 3346 3883. If you would like to speak to an officer of The University of Queensland not involved in the study, you may contact the UQ Ethics Coordinator on +61 7 3365 3924.

Thank you for your agreement to participate in this research.

Please tick the appropriate box:

- ❍ **Yes, I have reviewed the information above and I agree to participate in this study**
- ❍ **Sorry, I do not wish to participate in this study**

[Screening questions]

What is your gender?
(1) Male
(2) Female

What is your age (in years)?

In which State or Territory do you live?
(1) New South Wales
(2) Victoria
(3) Queensland
(4) South Australia
(5) Western Australia
(6) Tasmania
(7) Australian Capital Territory
(8) Northern Territory

Please say which, if any, of these things have you done or not done in the last 12 months, out of concern for the environment?
(tick as many as applicable)
a) Have chosen household products that you think are better for the environment
b) Have decided for environmental reasons to reuse or recycle something rather than throw it away
c) Have tried to reduce water consumption for environmental reasons
d) None of the above

Has your household installed any of the following items over the past ten years in your current primary residence?

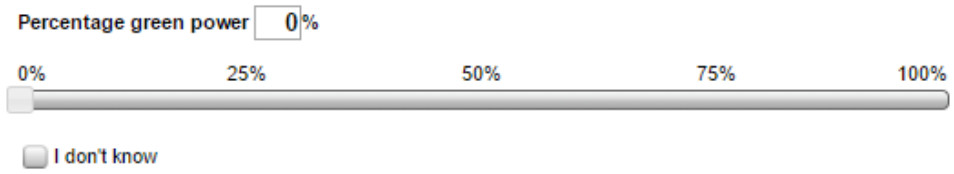
	Yes.	**No, my house was already equipped.**	**No. It is not possible or feasible to make these changes in my house.**	**No. I didn't want to spend the money.**
Top-rated energy efficient appliances (e.g. washing machines, refrigerators)				
Low-energy light bulbs (compact fluorescent, LED)				
Energy efficient windows (e.g. double or triple glazed)				
Thermal insulation of walls/roofs				
Solar panels for electricity or hot water				
Air conditioning controlled by a utilities company				

How often do you perform the following in your daily life?

	Never	Rarely	Sometimes	Frequently	Always
	1	2	3	4	5
Turn off lights when leaving a room					
Cut down on using heating/air conditioning to reduce energy consumption					
Only run full loads when using washing machines or dishwashers					
Washing clothes using cold water instead of warm/hot water					
Switch off standby mode of appliances/electronic devices (e.g. TV, computer)					
Air dry laundry instead of using a clothes dryer					
Take public transport, walk or cycle when possible to reduce the use of a car					
Drive an electric car					

Do you subscribe to GreenPower?
a. Yes
b. No
c. Don't know

(If yes) And what percentage do you subscribe to GreenPower?



Please find below a definition of the different energy technologies.
Please indicate how strongly you agree or disagree with the following options as potential ways of generating [country name's] future energy needs.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
	1	2	3	4	5	6	7
Coal - The energy of coal converted into electricity in coal-fired power stations.							
Gas or coal with carbon capture and storage (CCS) - The energy of gas or coal converted into electricity in power plants that use carbon capture and storage technologies. Carbon capture and storage technologies (CCS) capture carbon dioxide (CO2) from fossil fuel power plant exhaust and store it in underground reservoirs.							
Nuclear - The energy produced from controlled, non-explosive nuclear reactions within a nuclear power plant.							
Solar (photovoltaic) - The energy of sunlight (solar radiation) captured by solar panels (photovoltaic cells).							
Wind - The motion-based energy of wind captured by wind turbines. Wind turbines are large windmill-type structures that may be located on land or in the ocean.							

Before today, which of the following carbon dioxide mitigation methods have you heard about?

	Never heard about it	Heard about it	Know it very well
	1	2	3
Solar energy			
Wind energy			
Nuclear energy			
Energy efficiency appliances			
Hybrid engine vehicles			
Hydrogen fuel vehicles			
Biomass			
Forest carbon sink			
Carbon capture and storage (CCS)			

[Third Way video: Julio explains it all: Why we need carbon capture for climate. Run time is 02:27.]

https://www.youtube.com/watch?v=t-b0JC0PsaE

https://www.thirdway.org/video/julio-explains-it-all-why-we-need-carbon-capture-for-climate

Once you have watched the video, press 'Next' to continue

Repeat measure:
Please indicate how strongly you agree or disagree with the following options as potential ways of generating [Australia's] future energy needs.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
	1	2	3	4	5	6	7
Coal - The energy of coal converted into electricity in coal-fired power stations.							
Gas or coal with carbon capture and storage (CCS) - The energy of gas or coal converted into electricity in power plants that use carbon capture and storage technologies. Carbon capture and storage technologies (CCS) capture carbon dioxide (CO2) from fossil fuel power plant exhaust and store it in underground reservoirs.							
Nuclear - The energy produced from controlled, non-explosive nuclear reactions within a nuclear power plant.							
Solar (photovoltaic) - The energy of sunlight (solar radiation) captured by solar panels (photovoltaic cells).							
Wind - The motion-based energy of wind captured by wind turbines. Wind turbines are large windmill-type structures that may be located on land or in the ocean.							

When you think about carbon capture and storage (CCS), what first comes to mind?
a. The advantages of CCS as a carbon reduction option outweigh the risks it poses
b. The risks of CCS as a carbon reduction option outweigh its advantages
c. Neither
d. Don't know

Please indicate how strongly you agree or disagree with the following statements about the potential risks of CCS technologies.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
	1	2	3	4	5	6	7
The technologies are still in the developmental stage and demonstration phase and are relatively immature.							
Science is able to assess the consequences of CO2 storage in the subsurface sufficiently well.							
CO2 capture, transport and storage will lead to other accidents.							
CO2 leakage would cause ecological damage.							
CO2 leakage from transportation and storage could threaten human health.							
Geological storage of CO2 can cause earthquakes and other natural disasters.							

Please indicate how strongly you agree or disagree with the following statements about the potential benefits of CCS technologies.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
	1	2	3	4	5	6	7
CCS technologies are an effective means of climate mitigation.							
CCS can reduce CO2 emissions.							
CCS is an important bridge in Australia's transition to a low-carbon economy.							
CCS projects will provide more jobs for the community.							
CCS technologies can benefit environmental protection.							

How beneficial do you think CCS is. . .

	Not at all beneficial	Somewhat beneficial	Very beneficial
	1	2	3
For you personally?			
For Australian society?			
For future generations?			

To what extent do you trust information about (the risks and benefits, and the pros and cons of) CCS if it were to come from the following sources?

	Not at all	Very little trust	Neutral	Somewhat trust	Trust a lot
	1	2	3	4	5
Local government/councils/authorities					
Ministries or departments in the state government					
Ministries or departments in the federal government					
Energy companies that operate carbon capture and storage sites					
Non-government organisations					
University researchers					
Other publicly funded research agencies e.g. CSIRO					

To what extent do you trust the following institutions to monitor the safe operation of CCS sites?

	Not at all	Very little trust	Neutral	Somewhat trust	Trust a lot
	1	2	3	4	5
Local government/councils/authorities					
Ministries or departments in the state government					
Ministries or departments in the federal government					
Energy companies that operate carbon capture and storage sites					
A neutral and technically qualified third-party monitor					

Please indicate how strongly you agree or disagree with the following statements.

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
	1	2	3	4	5	6	7
I support Australia's large-scale development of CCS.							
It is necessary for Australia's coal-fired and gas-fired power stations to install carbon capture equipment, or for newly constructed power plants to carryout reserve installations.							
Public finances should be used to support CCS.							
The government should formulate CCS-related laws, regulations and standards.							
I'm a strong proponent of CCS-related public awareness and training.							

How legitimate do you think the information provided is:

	Not at all legitimate		Not sure		Definitely legitimate
	1	2	3	4	5
In this video?					
In this CCS factsheet?					
In this power plant comparison?					

We are interested in how effective you found the information presented. In doing so, please view the information in an even-handed way, putting aside any concerns about the source.

	Definitely NOT effective			Not sure			Definitely effective
	1	2	3	4	5	6	7
In this video?							
In this CCS factsheet?							
In this power plant comparison?							

Do you trust the information presented:

	Not at all	Very little trust	Neutral	Somewhat trust	Trust a lot
	1	2	3	4	5
In this video?					
In this CCS factsheet?					
In this power plant comparison?					

Please provide your thoughts and reactions to the video and the information provided.
[Open response]

What would be your preferred format/s for information, including educational, about CCS? (e.g. media articles, research articles, videos, workshops, community education seminars)
[Open response]

Is there anything else you would like to add about the information on CCS you've been presented with today?
[Open response]

Do you believe global warming is happening now or will happen in the next 30 years?
a) Yes, it is already happening.
b) It will start happening within the next 30 years
c) No, it is not happening and won't
d) I do not know/ I am not sure

Demographic questions

What is the highest level of education you have completed? (If still studying check for highest achieved so far)

a) Up to and including Year 10 (junior secondary)
b) Year 12 or equivalent (senior secondary)
c) Certificate/Diploma/Advanced Diploma/TAFE
d) Bachelor degree (including Honours)
e) Graduate diploma/Graduate certificate
f) Postgraduate degree
Other (please specify)

Which term below best describes you?
a) Employed

b) Self employed
c) Unemployed
d) Retired/pension recipient (including disability)
e) Home duties
f) Student
Other (please specify)

To what extent is your job associated with the Coal and/ or Gas Industry?

What is your household's total income per year (before tax)?
a) Less than $25,000
b) $25,000 - $49,999
c) $50,000 - $74,999
d) $75,000 - $99,999
e) $100,000 - $124,999
f) $125,000 - $174,999
g) $175,000 - $199,999
h) $200,000 - $299,999
i) $300,000+
j) Prefer not to answer

In which country were you born?
(1) Australia
(2) Other (please specify)

Are you eligible to vote in Australian elections?
(1) Yes
(2) No
(3) Unsure
(4) N/A

With which of the following parties do you identify with the most?
a) Liberal
b) National
c) Labor
d) Greens
e) One Nation
f) Independent
g) None
Other (please specify)

A summary of the findings will be made available to participants on the completion of the project. Would you like the summary to be emailed to you? Please tick the appropriate box.
a) Yes
b) No

3. CCS fact sheet

What is Carbon Capture and Storage?

Carbon capture and storage (CCS), sometimes called carbon capture and sequestration, refers to the separation of carbon dioxide (CO_2) emitted while producing power or making steel, cement or fertiliser, its transportation and permanent storage deep underground. The process prevents large amounts of CO_2 from being released into the atmosphere [1] [2] [3].

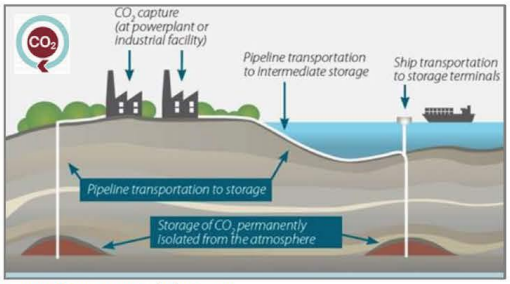
How does CCS work?

Capture: CO_2 is separated from other gases produced at large industrial process facilities such as coal and natural gas power plants, oil refineries, iron and steel mills, and cement plants.

Transport: CO_2 is then compressed (turned into a liquid form) and transported via pipelines, trucks or ships to a suitable site for geological storage. Pipelines have been carrying CO_2 for over 40 years and over 5,000 km of CO_2 pipelines exist in the US alone.

Storage: The compressed CO_2 is pumped deep underground into one of two types of CO_2 storage reservoir:

- Deep saline aquifers, which are found between 700 and 3000m underground
- Depleted oil and gas fields, found as deep as 5000m below the earth's surface



www.zeroemissionsplatform.eu

Storage sites are carefully selected and monitored at every step and after injection is completed. By storing CO_2 underground, we are replicating a natural process that has trapped CO_2, oil and gas for millions of years. Both oil and gas fields and deep saline aquifers have the same key geological features required for CO_2 storage: a layer of porous rock to absorb the liquid CO_2 and an impermeable layer of cap rock which seals the porous layer underneath, trapping the CO_2. [1]

Why do we need CCS?

The fossil fuels - coal, oil and natural gas - supply around 80% of the world's energy needs. This level has remained stable for over 30 years despite the strong growth in renewable energy. The International Energy Agency (IEA) predicts that fossil fuels will continue to be our principle source of energy around the world for many years to come, especially as the demand for energy is increasing [4] [5]. However, they are also a major source of atmospheric CO_2 emissions contributing to global warming.

To reduce levels of CO_2 in the atmosphere, we need a broad portfolio of solutions, including CCS, energy efficiency, using less carbon-intensive fuels, natural carbon sinks (vegetation), and harnessing renewable energy from the wind, earth, sun and tides. CCS can reduce CO_2 emissions from fossil fuel-burning power stations, whether gas or coal-fired, by as much as 90%. CCS is currently the only technology that will enable us to significantly decrease CO_2 emissions from industrial sources while we transition to more efficient and low carbon alternatives [1] [6].

Is CCS commercially viable?

CCS is a maturing technology that so far has been demonstrated in laboratories, pilot plants and at real world power and industrial plants. Since 1972, more than 200 million tonnes of CO_2 has been captured and injected deep underground. By 2018, globally there were 43 large-scale facilities – 18 in commercial operation, 5 under construction and 20 in various stages of development. To keep the temperature increase below 2° C (Paris Agreement target), the world is forecast to need 2500 CCS facilities operating in 2040 [7]. The cost of CCS is expected to substantially decrease through further advances in technology and efficiency, and as it is proven on a commercial scale, as has happened with renewables such as solar and wind power [8].

Is CCS safe?

There are a number of large-scale CCS projects that have demonstrated the viability and safety of the technology. A rigorous monitoring process begins at the reservoir selection stage and continues as long as required. The rock formations will be tested ahead of time to make sure the CO_2 will stay trapped. The well, cap rock and adjacent rock formations are continuously monitored for changes in pressure and CO_2 concentration levels [1].

What about leaks?

There can never be an absolute guarantee that CO_2 will not leak, but CO_2 will be stored at locations where the risk of leakage is very low. Monitoring instruments and procedures will be required. Companies with decades of experience in CCS already have detailed programmes to ensure that a leak is detected and swiftly stopped to return the site to a safe state. At present without CCS, 100% of the CO_2 produced at power plants and industrial facilities is directly emitted into the atmosphere [1] [8].

Will CCS increase the likelihood of seismic activity?

A detailed survey takes place to identify any potential geological structural weaknesses, and if any are discovered the site will not be selected. In areas where some natural seismic activity is already taking place, scientists can ensure that the pressure on the CO_2 does not exceed the strength of the rock. CO_2 storage has even proved to be robust in volcanic areas. In 2004, a storage site in Japan endured a 6.8 magnitude earthquake with no damage to its boreholes and no CO_2 leakage. Naturally occurring CO_2 has remained undisturbed underground for millions of years – despite thousands of earthquakes [1].

References

[1] Zero Emissions Platform (ZEP), "Answering your questions on CCS," European Technology Platform for Zero Emission Fossil Fuel Power Plants, [Online]. Available: http://www.zeroemissionsplatform.eu/faq.html. [Accessed 16 November 2018].

[2] CO2CRC, "What is carbon capture and storage?," March 2012. [Online]. Available: http://www.co2crc.com.au/wp-content/uploads/2016/04/What-is_CCS.pdf. [Accessed 13 November 2018].

[3] C. Ginn, "Carbon capture and storage explained: with chocolate," Commonwealth Scientific and Industrial Research Organisation (CSIRO), 23 February 2017. [Online]. Available: https://blog.csiro.au/carbon-capture-and-storage-explained-with-chocolate/. [Accessed 16 January 2019].

[4] International Energy Agency (IEA), "Global energy & CO2 status report 2017," OECD/IEA, Paris, 2018.

[5] International Energy Agency (IEA), "World Energy Outlook 2018," OECD/IEA, Paris, 2018.

[6] International Energy Agency (IEA), "20 years of carbon capture and storage: Accelerating future deployment," OECD/IEA, Paris, 2016.

[7] Global CCS Institute, "The global status of CCS: 2017," Global CCS Institute, Australia, 2017.

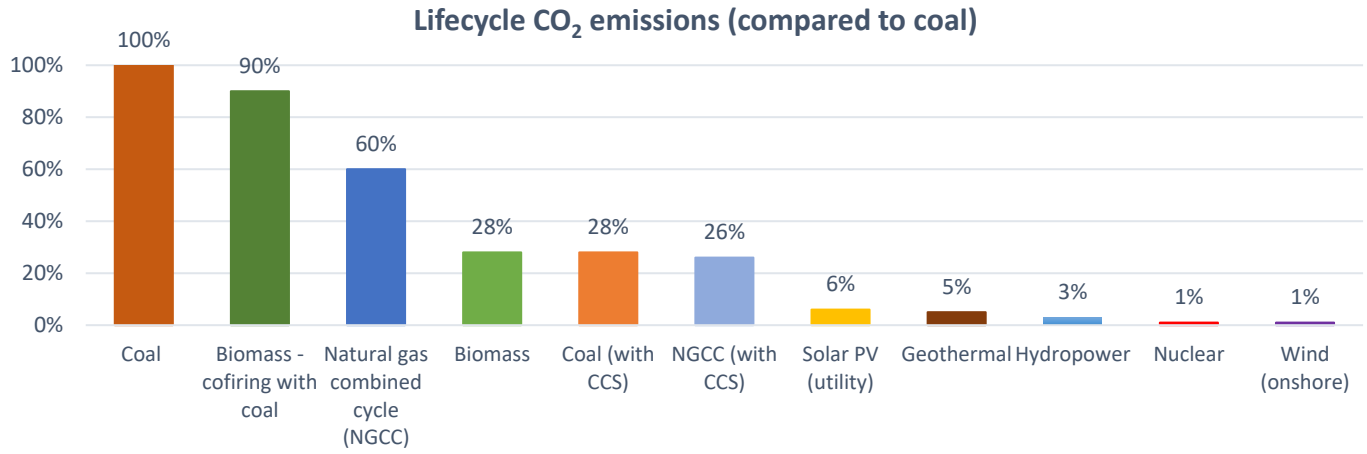
[8] The Bellona Foundation, "FAQ about CCS," [Online]. Available: http://bellona.org/about-ccs/faq-about-ccs. [Accessed 14 November 2018].

4. Power plant comparison

Electricity generation increased by 3.1%, or 780 TWh (terrawatt hours), worldwide in 2017 as electricity demand rose faster than overall global energy demand growth[i]. At the same time, CO_2 emissions increased by 1.6% in 2017[ii].

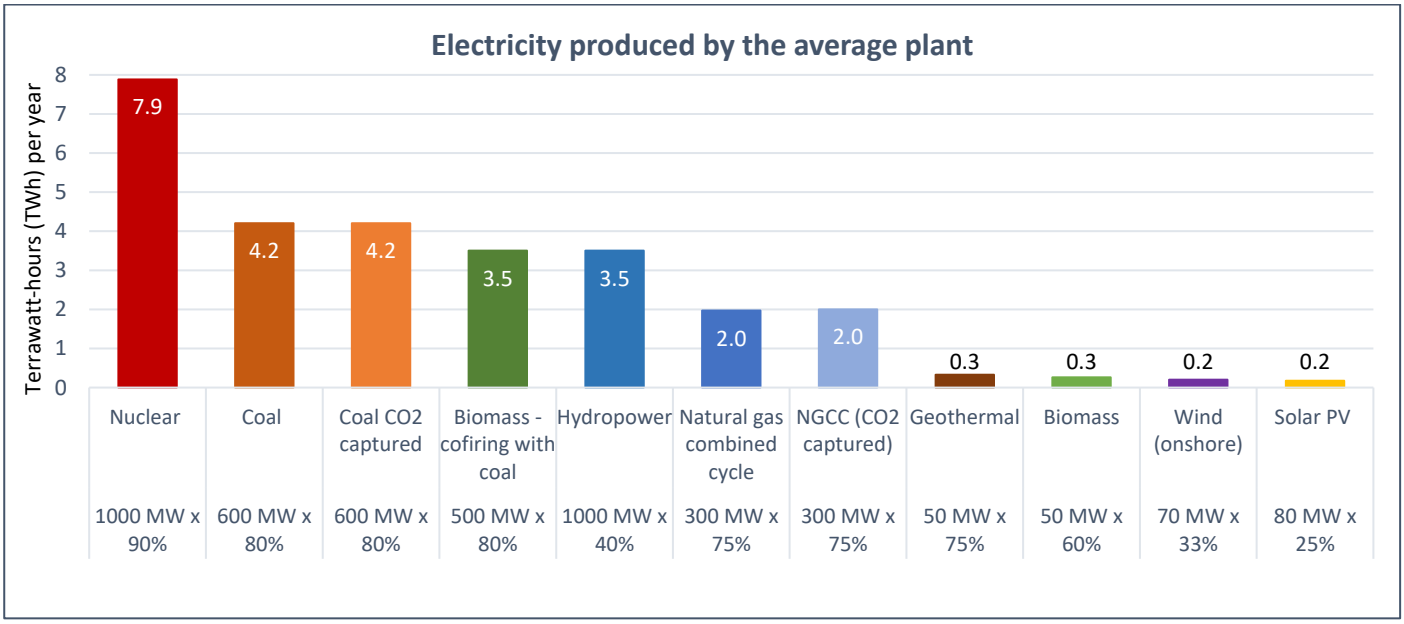
4.1 Building plants that collectively release less CO_2

Releasing CO_2 into the air contributes to climate change. The less CO_2 released by a power plant, the less it contributes to climate change. This graph compares the CO_2 emissions of each power plant type through its lifecycle, including producing the raw materials and building the plant[iiiiv]. The size of each bar shows the percent of CO_2 released by a power plant type compared with that from a coal plant (in which the CO_2 is released to the air). The CO_2 from the coal plant is shown as 100%. If a power plant type pollutes less than this coal plant, the graph will show a percentage that is less than 100%. So, the smaller the percentage, the less CO_2 put out by that plant. Overall, shorter bars on the graph are better than longer ones.



4.2 Building enough power plants to make 75 TWh of additional electricity each year

All power plants have advantages and disadvantages. No plant can run all the time – they need maintenance. Renewable technologies such as solar and wind don't directly emit CO_2 but can only work when it is sunny or windy, and use large areas of land. Nuclear produces large amounts of energy reliably but there are long-term waste considerations. Coal and gas also produce energy reliably but emit large amounts of CO_2[v]. The graph below shows the average amount of electricity each type of power plant in the US makes in one year[vi]. For instance, an average size natural gas plant (300 MW) operating 75% of the year makes 10 times as much electricity as an average size wind farm (70 MW - about 25 turbines) operating 33% of the year. So, we would need to build 10 wind farms to make the same amount of electricity as 1 natural gas plant. To make an extra 75 TWh of electricity each year, we would have to build 9 new nuclear power plants, 37 new natural gas plants, or 375 solar or wind farms.



Adapted from the Centre for Climate and Energy Decision Making (CEDM) factsheet: 'Power Plant Comparison: Reach the Goals' (2010). More information about the factsheet and CEDM projects is available at: https://cedmcenter.org/tools-for-cedm/informing-the-public-about-low-carbon-technologies/

5. References

[1] International Energy Agency (IEA). (2018). Global energy & CO_2 status report 2017. OECD/IEA: Paris.

[1] IEA. (2018). Carbon emissions from advanced economies set to rise in 2018 for first time in five years, reversing a declining trend, IEA Newsroom, 4 December. Retrieved 06 February 2019: https://www.iea.org/newsroom/news/2018/december/carbon-emissions-from-advanced-economies-set-to-rise-in-2018-for-first-time-in-fi.html

[1] Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, (2014). Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate

Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate

Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P.

Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[1] Lifecycle analysis of coal and gas (with CCS): Hertwich, E., T. Gibon, E. Bouman, A. Arvesen, S. Suh, G. Heath, J. Bergesen, A. Ramirez, M. Vega, and L. Shi. (2015). Integrated life-cycle assessment of electricity-supply scenarios confirms global environmental benefit of low-carbon technologies, *PNAS*, *112*(20): 6277-6282.

[1] Electric Power Research Institute (EPRI). (2016). Generation Technology Reference Card. March 2016. Available at: www.epri.com/refcard

[1] The average size of each type of power plant (nameplate capacity, in MW) and the average running time (capacity factor) have been calculated using US Energy Administration statistics: EIA-923; EIA-860; and Electric Power Monthly Tables 6.7a & 6.7b.

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