Deloitte Access Economics

Emissions metrics: Australia's carbon footprint in the G20

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Executive summary

CO_2-e/GDP provides a different way of looking at Australia's emissions performance

National emissions comparisons are commonly cited on the basis of a carbon dioxide equivalent (CO_2-e) per capita metric, which has the benefit of being a simple and easy to understand scaled measure.[1]

However, this measure has some shortcomings. These shortcomings are primarily due to the fact that while emissions themselves are related to productive activity, the relationship between productive activity and population of an economy can vary based on a number of factors unrelated to the generation of emissions. If emissions are to be expressed on a per capita basis, a country's carbon emissions should, at the very least, account for imported and exported emissions.

Some of these shortcomings with the use of CO_2-e /capita can be addressed through the use of Gross Domestic Product (GDP), rather than population, as the normalising factor when making comparisons of emissions between countries.

However, CO_2-e/GDP measurement favours more developed, services-sector driven economies as opposed to developing economies, which has led us to investigate how we can identify the relationship between the structure of economies and emissions.

Ideally, countries should seek to reduce emissions while maintaining economic growth, by reducing the emissions intensity of their economies. Historically, there has been a close link between GDP and emissions, however, in some countries this link is in the early stages of decoupling.[2]

The purpose of this paper is to look at carbon emissions in a different light, to help understand the economic drivers of carbon emissions and better reflect the relationship between economic activity and carbon emissions. To this end, we have conducted econometric analysis which models the relationships between country characteristics and emissions.

Benchmarking the G20 countries

We have compared Australia's CO_2-e/GDP to other G20 countries. The G20 countries represent 66% of the global population, 85% of global GDP and 76% of global carbon emissions and therefore represent a substantial benchmark sample. The G20 countries

[1] CO_2-e is a commonly used quantity measure which describes, for a given mixture and amount of different greenhouse gases, the amount of carbon dioxide that would have the same global warming potential.

[2] In this context decoupling means that the amount of negative environmental impact per unit of economic activity is reducing. ABS, 4655.0.55.002 - Information Paper: Towards the Australian Environmental-Economic Accounts, Chapter 1 Integrated Accounts, 2013.

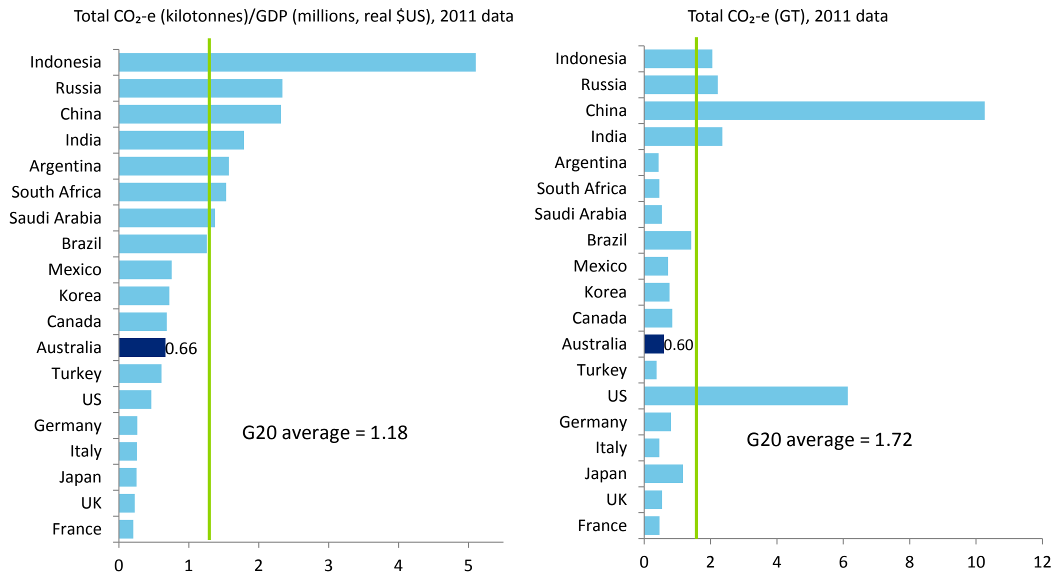
include the top five carbon emitters (China, US, India, Russia and Japan) and the large emerging and growing economies of China, Russia, India and Brazil.

Without the collective action and agreement of the G20 countries, and in particular the top five emitters, it will be difficult to achieve the necessary reductions in global emissions. At present, committed reductions from UNFCCC signatories will not deliver the reductions required to constrain warming to 2 degrees.[3]

Overview – total emissions

Australia's total equivalent carbon emissions (kilotonnes) per million dollars of GDP are below the average of the G20 countries and are similar to Canada. This result differs markedly from per capita emissions, in which Australia is often shown to be the worst performing country in the G20.

Figure 1 –Total kilotonnes of equivalent carbon emissions per million dollars of GDP (real $US) and total emissions (Gigatonnes (GT)) - where Australia sits in the G20[4]



Source: World Resources Institute data, IEA data, Deloitte analysis

Note: Includes emissions from land use and land use change and forestry

In recent years, Australia's carbon emission productivity has been improving in both absolute terms and relative to the average of the G20. From 2009 to 2010 Australia's emissions per unit of GDP fell 4.4% and a further 3.1% from 2010 to 2011.

[3] United Nations Environment Program, *The Emissions Gap Report 2013,* November 2013.

[4] In this paper we have used real GDP in $US 2005, sourced from the IEA, as we consider this represents the latest published, best measure of output in constant terms to enable comparisons. We refer to this as real $US. The IEA also presents GDP data in current $US and Purchasing Power Parity (PPA). We present all benchmarking results using GDP expressed in current $US and PPA in the Appendix.

Energy carbon emissions

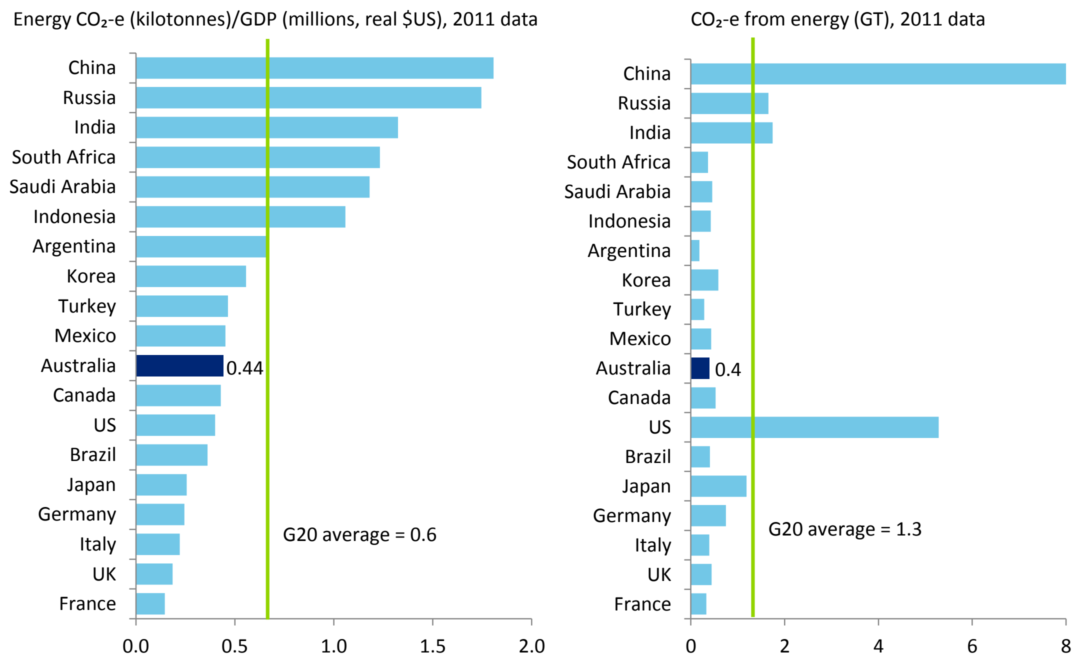
Energy is one of the most significant contributors to carbon emissions. According to the IEA, in the 43 developed and transitioning economies listed as Annex I under the UN Framework Convention on Climate Change, on average energy use accounts for 83% of carbon emissions resulting from human activity. Historically and today, the majority of the world's energy needs have been met by burning fossil fuels.[5] In 2013, 67% of Australia's emissions were from the energy sector.

Accordingly, in the rest of our analysis we have focused on energy carbon emissions produced by fuel combustion, which includes:

- Electricity and heat production
- Other energy industry own use
- Manufacturing industries and construction
- Transport - including road transport
- Other sectors - including residential.

In figure 2, we present data on total emissions from energy for the G20. We note that Australia's ranking is similar to the results in figure 1 for total emissions, and in line with Canada and the US.

Figure 2 –Equivalent carbon emissions from energy (kilotonnes) per million dollars of GDP (real $US) and total energy emissions (GT) - where Australia sits in the G20



Source: IEA data, Deloitte analysis

[5] BP, Energy outlook 2013, January 2014.

Carbon intensity or CO_2-e/GDP can be broken down into the key drivers of energy intensity (energy/GDP) and the carbon intensity of energy (CO_2-e/energy). Australia's energy intensity is in the lowest quartile of the G20 countries. This means that Australia uses energy efficiently to produce GDP. However, Australia's carbon emissions per unit of energy produced are high, reflecting the dominance of coal fired electricity generation. Nevertheless, this combination of low energy intensity and high carbon intensity places Australia below the G20's average CO_2-e/GDP metric.

Further, IEA data shows that over the 10 year period from 2001-11, Australia has managed to achieve moderate per capita economic growth (1.6% on average) that has outpaced its growth in total carbon emissions (1.2% on average), meaning its carbon intensity has been improving.[6]

Australia's CO_2-e/GDP is comparable to G20 countries with economies that have a similar economic structure such as Canada and the United States.

Australia performs as expected under our econometric analysis

Simple, easy to understand metrics such as CO_2-e/GDP or CO_2-e/capita do not fully capture the drivers of underlying emissions within an economy. Therefore, we have developed an econometric analysis that attempts to explain some of the drivers.

Our econometric models have tested the relative level of Australia's carbon emissions, taking into account GDP, population, urbanisation, weather, choice of energy fuel and other factors. Recognising that policy can influence the choice of energy fuel, we have evaluated emissions both with and without the choice of fuel as a parameter.

If we include fossil fuel as an explanatory variable in our model, our econometric analysis suggests that Australia's carbon emissions based on its economic characteristics are as expected – that is Australia's actual carbon emissions are close to our predictive models, ranking around the middle of the G20 countries.

If fossil fuels are removed as an explanatory variable Australia's ranking does not substantially change, moving from 10th to 11th in the G20 countries.

G20 countries' action on climate change

In February 2014, the G20 committed to developing new measures with the aim of raising the level of G20 economic output by at least 2% above the currently projected level in the next five years. The Brisbane Action Plan aims to put in place short and medium-term actions to help achieve this economic growth ambition.

Given the link between GDP and carbon emissions, policymakers should be consistent in their targets for economic growth and carbon emissions reductions.

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[6] IEA data, Deloitte analysis.

G20 members are taking action. Over the last few years many countries have either set carbon emission reduction targets for themselves and / or have emission reduction targets under the Kyoto protocol. Some examples are listed below:

- The EU leaders have recently agreed upon a greenhouse gas reduction target of at least 40% on 1990 levels by 2030, and developed a proposed policy to deliver this target which includes emissions trading, renewable energy and energy efficiency targets.[7]

- In June 2014, the Obama Administration announced its *Clean Power Plan* which is underpinned by an EPA regulatory target to reduce carbon pollution from existing US power plants by 30% from a 2005 baseline by 2030.[8] This is in addition to the US Government's commitment under the UNFCCC to an economy-wide target of a 17% reduction on 2005 levels by 2020.[9]

- At the UN Climate Summit in New York in September 2014, China announced its intention to set its total emissions peak and post-2020 targets 'as soon as possible.' China also reiterated its existing plan to cut carbon intensity by 40-45% by 2020, based on 2005 levels, and announced that its 2013 emissions intensity levels reflected a 28% reduction on 2005 levels, suggesting it is already more than halfway towards meeting its 2020 target.[10]

- Australia's 2020 target, which is part of its current Kyoto Protocol commitment, is to reduce emissions by 5% on 2000 levels. However, Australia is yet to announce a post-2020 target and this will be the subject of a review in 2015.[11]

Countries have considered the impact on GDP of adopting targets and in many cases have made higher targets conditional on other countries reducing their emissions. However, most carbon emission targets have not been set with direct reference to GDP.

A key solution to delinking carbon emissions from energy production (and GDP growth) is the development of commercially viable low emissions or zero emissions technology. While there has been some progress such as onshore wind, large scale solar generation and geothermal, there are limited examples of zero carbon generation technologies that are commercially viable without the need for subsidies or a significantly high price on carbon emissions.

Further and more substantial technological breakthroughs on several fronts will minimise the impact of carbon reductions on economic growth and living standards.

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[7] European Commission Media Release, *EU leaders agree 2030 climate and energy goals*, 24 October 2014. Available at: <http://ec.europa.eu/clima/news/articles/news_2014102401_en.htm>

[8] Barak Obama http://www.barackobama.com/climate/plan/. United States Department of State Office of the Special Envoy for Climate Change Washington, D.C. 20520, 28 January 2010

[9] UNFCCC, *Appendix I - Quantified economy-wide emissions targets for 2020*, available at: <http://unfccc.int/meetings/copenhagen_dec_2009/items/5264.php >

[10] UN Climate Summit Statements – China – New York, 23 September 2014. Available at: < http://statements.unmeetings.org/media2/4628014/china_english.pdf>

[11] Australia's Foreign Affairs minister Julie Bishop's address at the United Nations Climate Summit, September 2014.

The G20 countries might consider further encouraging research and development in energy to foster and expedite the commercialisation of new technology. This is important as the nine wealthiest countries of the G20 spent only 0.05% of GDP in 2012 on energy research and development.[12]

[12] International Energy Agency, OECD iLibrary. R&D expenditure includes R&D on Energy Efficiency, Fossil Fuels, Renewable Energy Sources, Nuclear, Hydrogen and Fuel Cells, Other Power and Storage Technologies and Other Cross-Cutting Technical Research. Data for Australia, Canada, France, Germany, Italy, Japan, Korea, United Kingdom and United States.

1 Introduction

Carbon emissions per capita (CO_2-e/capita) is commonly used as a benchmark to compare the carbon intensity of countries. Although widely used, CO_2-e/capita is a simplistic benchmarking metric, as it fails to adequately capture the complexities of the underlying drivers of carbon emissions such as the structure of a country's energy and economic systems.

The purpose of this paper is to look at carbon emissions in a different light, to help understand the economic drivers of carbon emissions and better reflect the relationship between economic activity and carbon emissions. To this end, we have conducted econometric analysis which models the relationships between country characteristics and emissions, which is presented in Section 5.

The analysis aims to build a platform for shifting the debate towards more sophisticated and explanatory metrics.

2 Carbon emission metrics

Carbon emissions are predominantly measured on the basis of the emissions generated within a country from the production of goods and services within its borders. Given that the absolute level of emissions produced by a country can vary vastly by size, carbon emission metrics are often quoted on a per capita basis for the purpose of comparisons and benchmarking.

This approach is seen to provide a reasonable 'like-for-like' comparison between the respective performance of countries in terms of contribution to global emissions. However, when carbon emissions are measured on the basis of production, metrics including population do not account for important differences between economies such as:

- Links to the global economy and the extent to which emissions are 'traded' between one country and another. Trade flows in the globalised world economy mean that a significant proportion of a country's emissions may be generated in producing goods and services that are not consumed domestically. For countries that import the majority of their emissions-intensive goods, emissions will appear relatively low because the goods consumed by their population are not contributing to national carbon emissions. However, countries such as Australia, which in 2013 derived 20% of its GDP from exports,[13] will tend to perform relatively poorly on metrics that do not account for these linkages in the global economy. This is especially so for Australia, because the goods it exports are relatively emissions intensive, although we note that imports and exports are only one driver of emission performance.

- The carbon intensity of production and the production output achieved for a given level of emissions. For example, two countries that generate the same amount of emissions and with the same population will be equivalent in terms of CO_2-e/capita, even if one of the countries produces twice as much output per tonne of CO_2-e generated and is therefore less emissions intensive.

These shortcomings are primarily due to the fact that while emissions themselves are measured on the basis of productive activity, the relationship between productive activity and population of an economy can vary based on a number of factors unrelated to the generation of emissions.

[13] The World Bank, Exports of goods and services (% of GDP) http://data.worldbank.org/indicator/NE.EXP.GNFS.ZS>

2.1 Alternative metrics

2.1.1 Consumption-based emissions metrics

If emissions are to be expressed on a per capita basis, a country's carbon emissions should account for imported and exported emissions to reflect a true measure of carbon emissions that are caused by the consumption of the population.

Several international studies have attempted to quantify the emissions embedded in international trade to estimate a country's consumption based emissions. However, the process of doing so is complex and there is not yet an accepted methodology or standard for calculating and reporting consumption based carbon emissions.

The Australian Bureau of Statistics has made experimental estimates of Australia's consumption based carbon emissions in its information paper on the development of a set of Environmental-Economic Accounts for Australia. The ABS estimated consumption based emissions by netting off exported emissions and assuming that imported products were produced using production functions that were identical to those used for locally produced products of the same type (i.e. imported products result in the same amount of emissions that purchasing the same product domestically would). Overall, it found Australia's consumption based emissions in 2008-09 were approximately the same as the production based estimates. The ABS analysis provides valuable insights into the link between domestic economic activity and emissions, but is limited in relation to providing a foundation for making comparisons between countries due to the fact that the different emissions intensity of production in different countries is not taken into account. In particular, we note that the ABS considered that its approach may overstate imported emissions for Australia.[14]

Research by Davis and Calderia presents consumption based emissions (from energy) for 113 countries. Davis and Calderia note that 23% of global carbon emissions were traded internationally, mainly as imports from China and the developing world to consumers in the developed world.[15] According to their analysis (2004 carbon emission data sourced from the Energy Information Administration), consumption based emissions for many European countries were much higher than their emissions measured on a production basis. While the reasons for this vary between countries, it is due in large part to these economies being heavily service-based, with low emissions intensity in relation to domestic productions, while imported products and services are more likely to come from higher emitting countries. For example, the United Kingdom's consumption based emissions were 46% higher than its production based emissions, Italy's were 25% higher, France's were 43% higher and Germany's were 28% higher. Australian consumption based emissions were 2% lower that its production based emissions, while China's were 23% lower and India's were 7% lower. Overall, this research demonstrates that benchmarks based on consumption based emissions per capita are significantly different to benchmarks based on production based emissions per capita.

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[14] ABS 4655.0.55.002 - Information Paper: Towards the Australian Environmental-Economic Accounts, 2013, Chapter 5 Greenhouse Gas Emissions.

[15] Steven J. Davis and Ken Calderia, Consumption-based accounting of CO_2-e emissions, Department of Global Ecology, Carnegie Institution of Washington, Stanford, CA 94305

Multi-region input-output models (MRIO) have been used in measuring carbon emissions, incorporating consumption based measures, because they provide an appropriate framework for this type of analysis. However, many researchers have concluded that to deal with the uncertainty in MRIO modelling, improvements in data availability, quality and modelling techniques are needed.[16]

The OECD published estimates of consumption and production based emissions for member countries, using an MRIO approach.[17] Its estimates suggested that consumption based emissions in 2009 were on average 15% higher than production based emissions, and more than 40% higher in seven countries (Belgium, Switzerland, Denmark, Greece, Ireland, Italy, Norway and Sweden). For Australia, the OECD's consumption based estimate was around 10% lower than its production based estimates in the period 1995-2000, but that by 2008, Australia's consumption based estimates were around 8% higher than production based estimates. It observed that the gap between production and consumption based estimates are affected by global trade and economic activity and therefore fluctuated during the Global Financial Crisis period. We note that the OECD's methodology incorporated adjustments to deal with measurement issues, such as re-exports, unspecified partners and commodities and missing data, particularly for trade in services.

The research on measuring carbon emissions based on consumption continues, but until such time that an internationally accepted framework and methodology is adopted and implemented, production based emissions provide a better starting point for benchmarking countries on their emissions performance.

2.1.2 Use of GDP as a normalising factor

Under production based measures of emissions, some of the shortcomings with the use of CO_2-e/capita can be addressed via the use of Gross Domestic Product (GDP), rather than population, as the normalising factor when making comparisons of emissions between countries.

GDP is defined by the World Bank as the sum of gross value added by all resident producers in the economy plus any production taxes and minus any subsidies not included in the value of the products. Therefore, CO_2-e (kilotonnes)/GDP (millions, real $US) provides a measure of the emissions generated by an economy related back to the value of the goods and services produced in generating those emissions – i.e. it is a measure of carbon intensity and carbon efficiency of a country's economy. This metric explicitly recognises the relationship between emissions and productive activity, and therefore provides a starting point for understanding trade-offs between economic growth and emission reduction targets.

However, CO_2-e/GDP measurement favours more developed, services-sector driven economies as opposed to developing economies, which has led us to investigate how we can identify the relationship between the structure of economies and emissions.

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[16] Thomas Wiedmann, A review of recent multi-region input–output models used for consumption-based emission and resource accounting, Ecological Economics 69 (2009) 211–222

[17] OECD, *Carbon Dioxide Emissions Embodied in International Trade*, available at: <http://www.oecd.org/industry/ind/carbondioxideemissionsembodiedininternationaltrade.htm>

Our analysis seeks to provide further detail on the drivers of differences between countries in terms of CO_2-e/GDP, by examining:

- Emissions intensity of energy production (carbon emissions per unit of energy produced) together with how much energy is used for economic activity. This provides insights into how countries differ in the production of energy and carbon emissions, based on their energy fuel mix.

- The components of GDP, by breaking GDP down into 'service', 'industrial' and 'agricultural' sectors to determine how countries with similar GDP structures compare to one another on emissions.

Finally, we compare the emissions of G20 countries relative to a baseline that normalises differences between countries such as the structure of their economies and resource endowments.

In our analysis, we have focused on presenting carbon emissions produced by fuel combustion for energy (unless stated otherwise), which includes:

- Electricity and heat production

- Other energy industry own use

- Manufacturing industries and construction

- Transport - including road transport

- Other sectors - including residential

Energy emissions are the focus of this paper because energy is one of the most significant contributors to carbon emissions. Historically and today, the majority of the world's energy needs have been met by burning fossil fuels.[18] This has resulted in energy accounting for the greatest portion of countries' carbon emissions. In 2013, around 67% of Australia's emissions were from the energy sector.

The world's energy needs are increasing rapidly and primary energy demand is forecast to grow, by 41% between 2012 and 2035, with 95% of that growth expected to come from emerging economies such as China and India.[19]

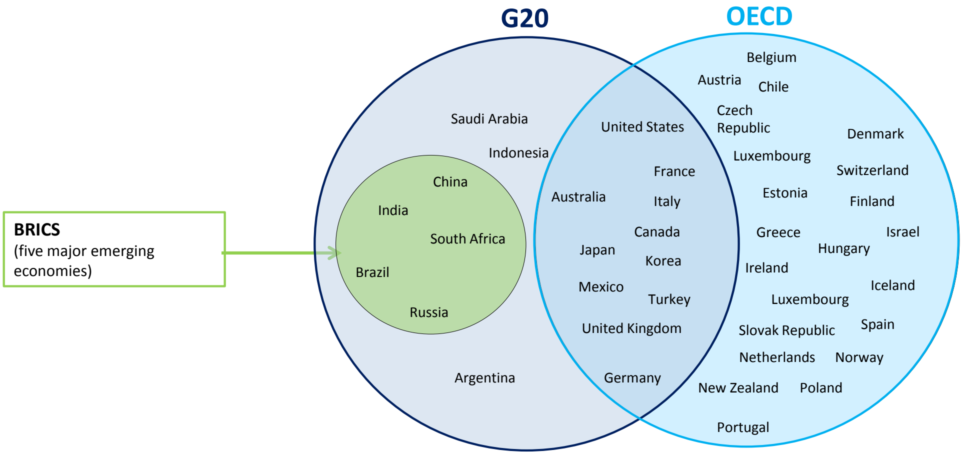
[18] BP, Energy outlook 2013, January 2014.
[19] Ibid.

3 The benchmark sample

3.1 The G20 countries

Our analysis is based on the G20 countries, which consists of the world's largest advanced and emerging economies. The G20 countries compared to the OECD countries are demonstrated in the figure below.

Figure 3 – How the G20 fits within the global context*



Source: G20 Members <https://www.g20.org/about_g20/g20_members> About the OECD <http://usoecd.usmission.gov/mission/overview.html> EA CO_2-e from fuel combustion, 2013.

* The analysis in this paper does not include the European Union, although the major European countries are separately included in the G20 countries.

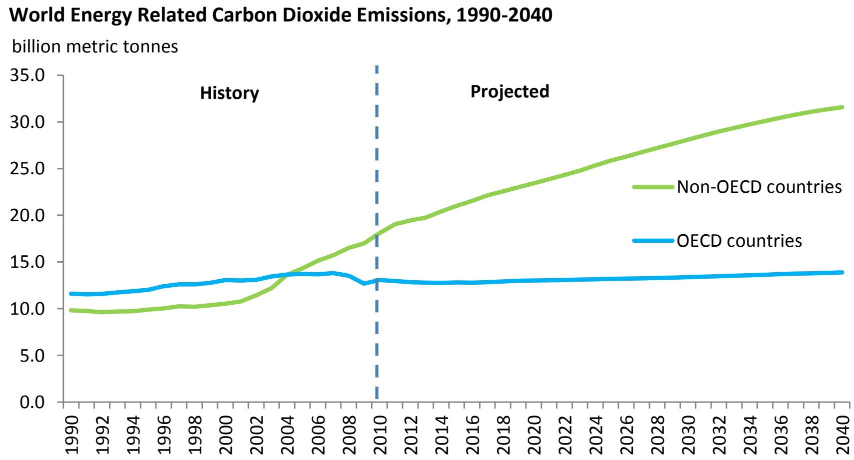
We have selected G20 rather than OECD countries because the G20's membership represents 66% of the global population, 85% of global GDP and 76% of carbon emissions. By comparison, the OECD countries represent a significantly lower share of global population (18%), global GDP (51%) and carbon emissions (39%).[20]

The G20 also covers diverse economies, which allows us to examine how different stages of economic advancement influence carbon emissions. A number of high carbon emitting countries such as China and India are not included in the OECD.

[20] Population and GDP are from 2010, carbon emissions from 2013. OECD iLibrary, OECD Factbook 2013: Economic, Environmental and Social Statistics. OECD, Perspectives on global development <http://www.oecd.org/dev/pgd/economydevelopingcountriessettoaccountfornearly60ofworldgdpby2030accordingtonewestimates.htm> EIA, International Energy Outlook 2014.

Figure 4 demonstrates that non-OECD countries are expected to account for the majority of future carbon emissions.

Figure 4 – G20 and OECD carbon emissions comparison



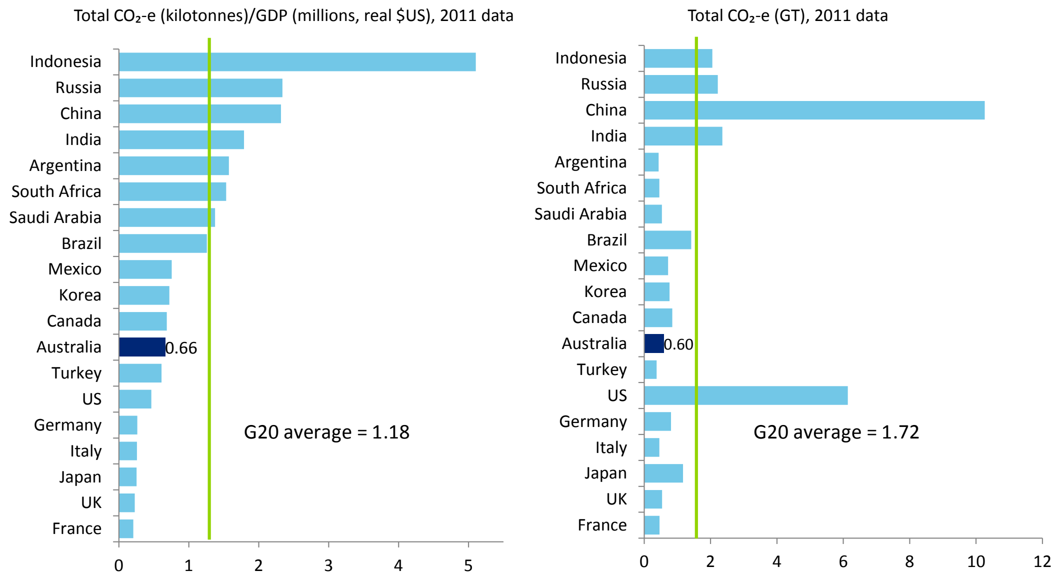
Source, International Energy Outlook, 2013

4 How does Australia compare to the G20?

4.1 GDP and total carbon emission benchmarks

In this section we examine total CO_2-e (kilotonnes) /GDP (millions, real $US) to present an overview of how Australia compares internationally on this metric. This provides an indication of Australia's carbon 'productivity' compared to other G20 countries. In other words, it demonstrates how much economic output Australia achieves for each unit of carbon emissions. This is presented, along with each country's total emissions (including land use and land use change and forestry) in the figure below.

Figure 5 – Total kilotonnes of equivalent carbon emissions per million dollars of GDP (real $US) and total emissions (GT) - where Australia sits in the G20



Source: World Resources Institute data, IEA data, Deloitte analysis

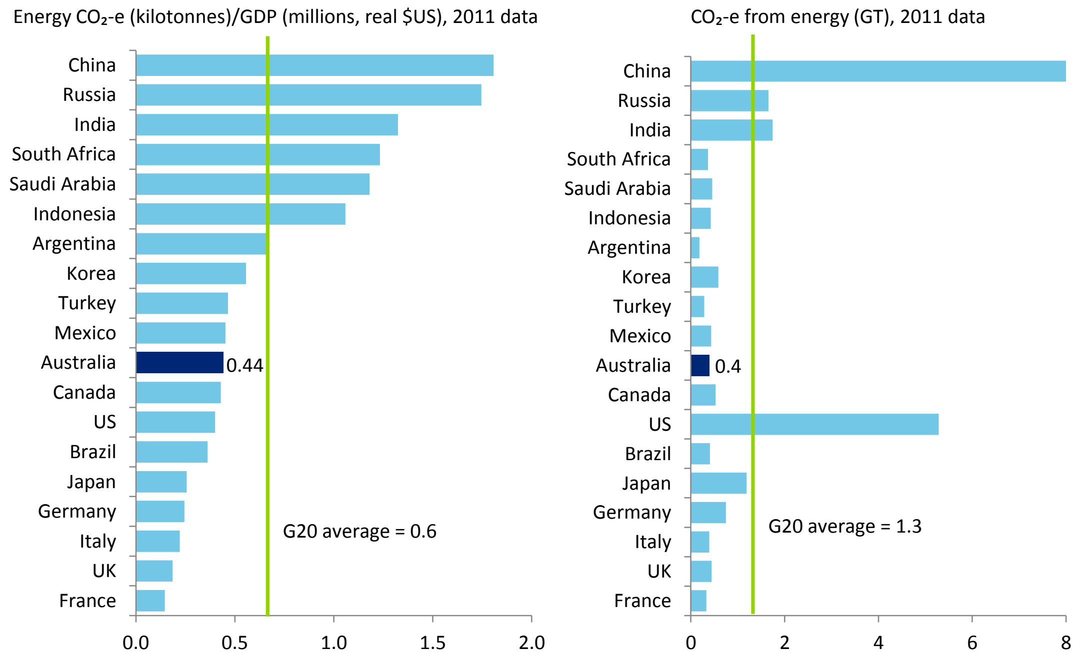
Note: Includes emissions from land use and land use change and forestry

Australia's total carbon emissions per unit of GDP are well below the average of the G20 countries and are similar to Canada. This result differs markedly from per capita emissions, in which Australia is often shown to be the worst performing country. The right hand side of the chart also highlights that Australia's emissions are relatively small at 1.8% of total G20 emissions.

4.2 Energy carbon emission benchmarks

Similar to the analysis above, we have compared Australia's energy carbon emissions per unit of GDP to the average of the G20, however, in this case the emissions used are those related to energy from fuel combustion. This, along with each country's total energy emissions is shown in the figure below.

Figure 6 – Equivalent carbon emissions from energy (kilotonnes) per million dollars of GDP (real $US) and total energy emissions (GT) - where Australia sits internationally

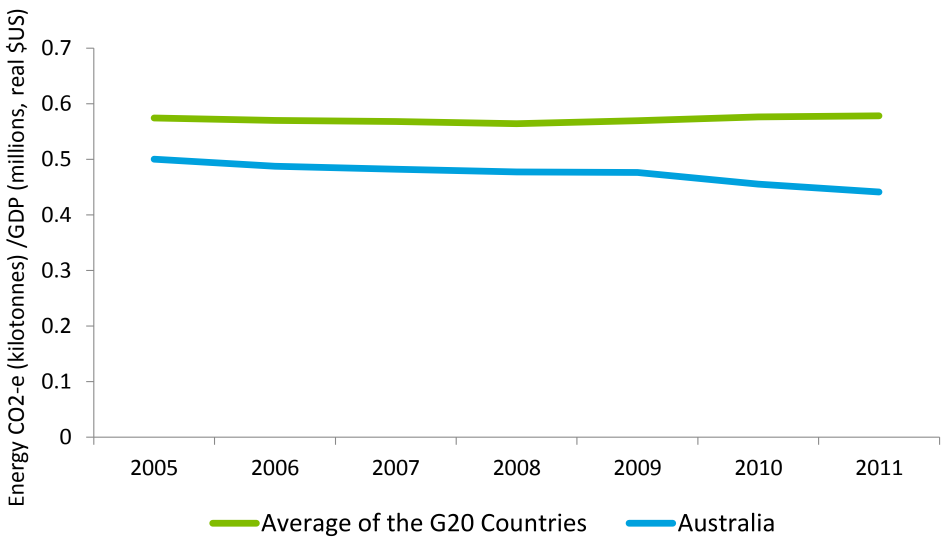


Source: IEA data, Deloitte analysis

The left hand side of figure 6 shows that Australia's carbon emissions per unit of GDP is below the average of the G20 countries and is similar to Canada and the US. The right hand side demonstrates that Australia's total energy carbon emissions are relatively small compared to other G20 countries.

In the figure below we have also compared Australia's energy carbon emissions per unit of GDP to the average of the G20 over seven years to 2011. The figure below demonstrates how the G20 countries' energy carbon emissions per unit of GDP have been changing over time.

Figure 7 – Energy carbon emissions per unit of GDP over time

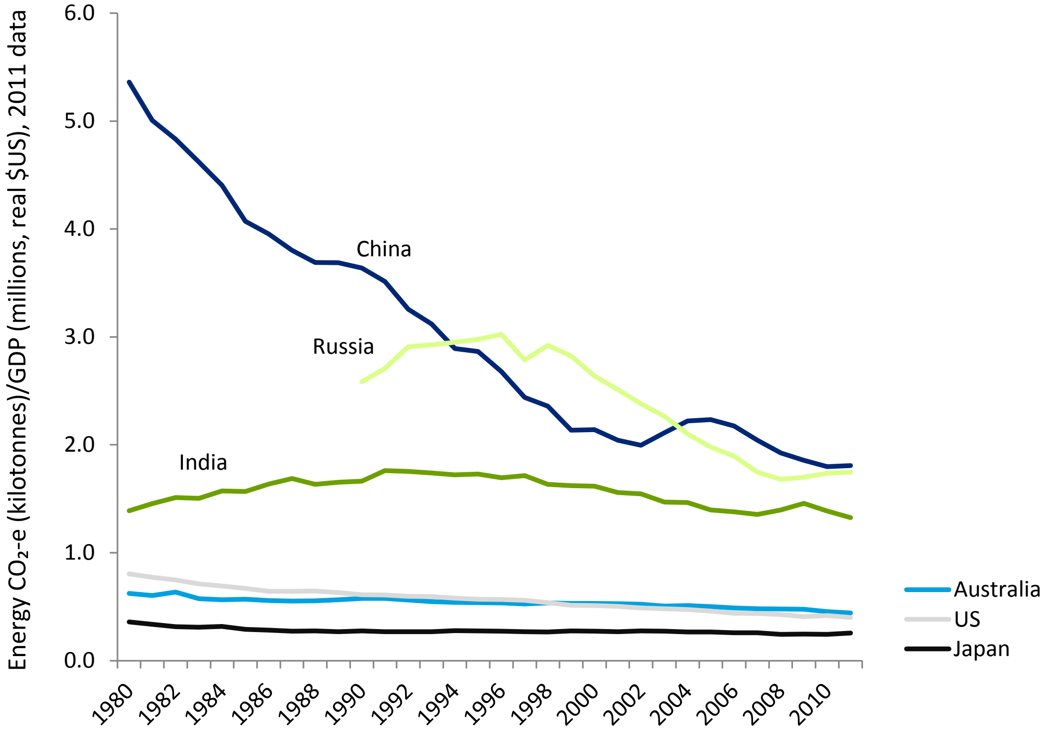


Source: IEA data, Deloitte analysis

The results in figure 7 demonstrate that Australia's carbon emissions productivity has been improving in both absolute terms and relative to the average of the G20. From 2009 to 2010 Australia's emission per unit of GDP fell 4.4% and a further 3.1% from 2010 to 2011.

Figure 8 compares Australia's carbon emissions productivity to the top five carbon emitters in the G20.

Figure 8 – Energy carbon emissions per unit of GDP over time – top five carbon emitters and Australia



China, the largest carbon emitter has achieved significant improvements in its carbon intensity (as measured by CO_2-e/GDP) over the 20 year period. In September 2014 at the UN Climate Summit, China announced that in 2013 its carbon intensity was down by 28.5% from the 2005 level.[21] However, China's emission intensity has been relatively flat over the last five years.

Russia has also made significant improvements – but like China its emissions intensity has shown little improvement over the last five years.

India unlike China and other developing economies has shown only marginal improvements over the last 20 years.

It is expected that the developing economies will improve their emissions intensity as they transition to more service based economies and economic growth enables the adoption of less carbon intensive and more energy efficient technologies. China and Russia have followed this transition to a less carbon intensive economy.

The developed economies of the US and Japan have achieved marginal improvements over the 20 year period. Australia's performance is in line with the US and Japan.

The drivers of Australia's performance are examined in the following sections.

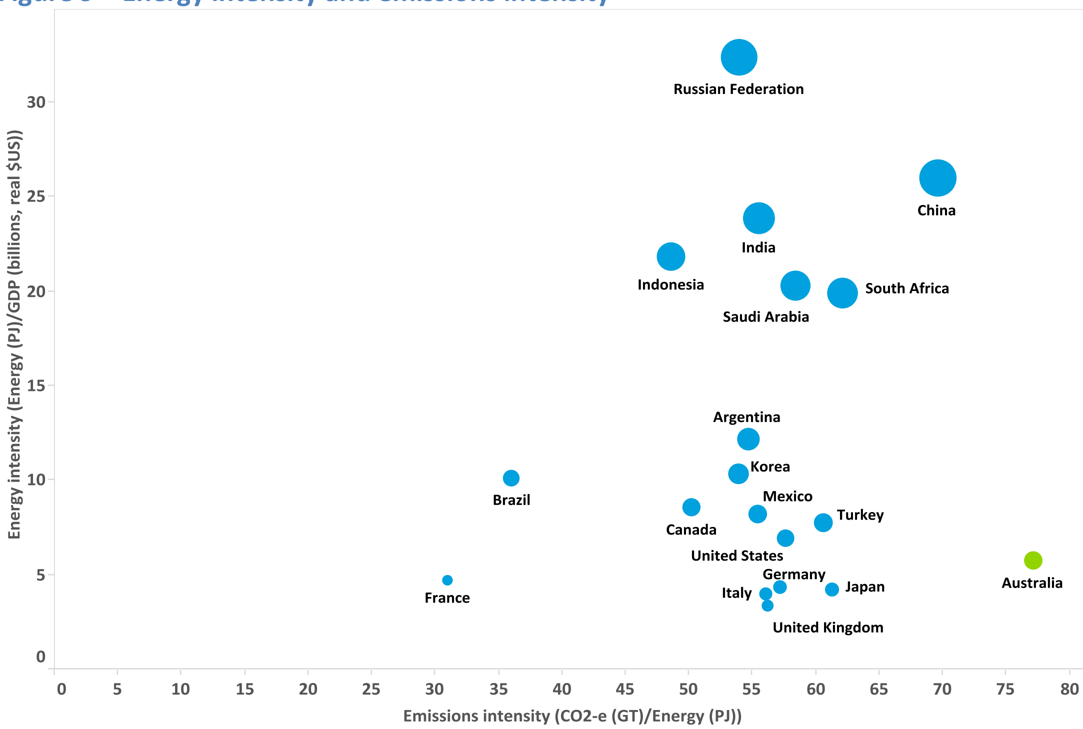
[21] Address by H.E. Zhang Gaoli Special Envoy of President Xi Jinping and Vice Premier of the State Council of China at the UN Climate Summit, Build Consensus and Implement Actions For a Cooperative and Win-Win Global Climate Governance System, 3 September 2014.

4.2.1 The drivers of carbon emissions per GDP

The energy intensity of the economy (energy (Petajoules (PJ))/GDP (millions)) and the emissions intensity of energy (CO_2-e/energy) are the two main drivers of carbon emissions per GDP. Energy intensity is a measure of how much energy a country uses to produce a unit of GDP. The emissions intensity of energy measures how much carbon is released for each unit of energy produced.

These measures are shown in the figure below. The size of each bubble in the figure below represents the country's carbon emissions per unit of GDP (also presented in Figure 6 above).

Figure 9 – Energy intensity and emissions intensity



Source: IEA data, Deloitte analysis

Figure 9 highlights that while Australia's CO2-e (GT)/energy (PJ) is relatively high, its low energy intensity (energy/GDP) means Australia's CO2-e/GDP is lower than the G20 average.

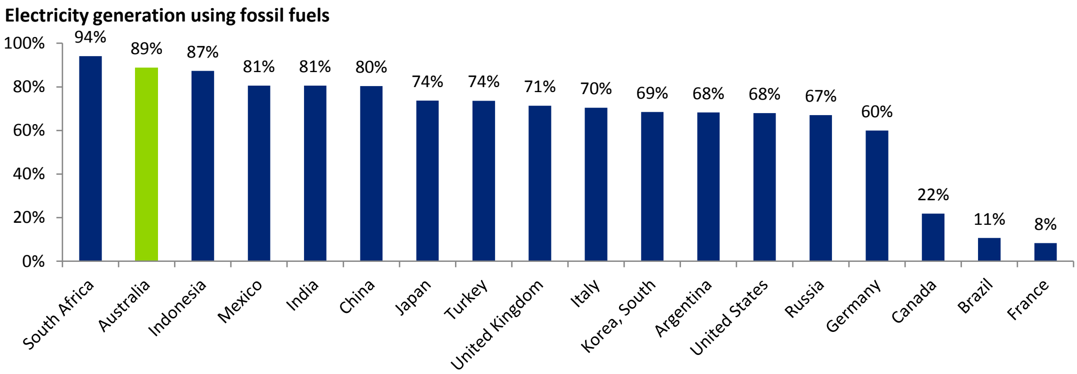
Australia's emissions intensity of energy can largely be explained by the dominance of coal fired electricity generation. Australia has an abundance of coal, with around 9% of the world's economically recoverable black coal, predominantly located in Queensland and New South Wales.[22] Australia ranks fourth in terms of world coal reserves behind USA, Russia and China.[23]

Similarly, Australia has about 23% of the world's brown coal economic resources (predominantly in Victoria) and ranks first in terms of world reserves.[24] At 2012 production levels, accessible brown coal will support 510 years of production.[25]

[22] Australian Government; Department of Industry, Geoscience Australia, BREE, Australian Energy Resource Assessment, 2014.
[23] Ibid.
[24] Australian Government; Geoscience Australia, <http://www.australianminesatlas.gov.au/education/fact_sheets/coal.html>
[25] Department of Industry, Geoscience Australia, BREE, Australian Energy Resource Assessment, 2014.

The figure below demonstrates the percentage of electricity generated from fossil fuels.

Figure 10 – Electricity produced from fossil fuels, 2011



Source: IEA data, Deloitte analysis

The extent of Australia's coal resources has provided it with a comparative advantage in terms of being able to generate cheap and reliable energy. Australia relies more heavily on fossil fuels than most of the G20 countries. In 2011 (which is the latest data available from the IEA), fossil fuels accounted for 89% of Australia's electricity generation, with coal-fired power stations located in every mainland state.[26]

In the years since 2011, fossil fuels have continued to dominate Australia's fuel mix, however, its reliance on them has been declining gradually. In 2012-13, Australia's dependence on fossil fuels for electricity generation fell to 87%.[27] However, coal continues to be the major fuel source for electricity generation and comprises of around 64% of the fuel mix, although this is down from 77% in 2003–04. In contrast, gas fired generation has increased, accounting for around 20% of electricity production, or double its 2004-05 share.[28]

Australia's renewable energy sector is also increasing. By the end of 2013, about 1.25 million small scale solar systems were installed accounting for 1.62% of Australia's total electricity.[29]

Canada, Brazil and France rely less on fossil fuels than the rest of the G20. Electricity generation in Brazil relies heavily on hydropower, accounting for 81% of its total electricity generation in 2011.[30] Similarly, Canada's main source of electricity is hydropower,[31] while the main source of electricity generation in France is nuclear power, accounting for 83% of its total generation in 2012. France also produces a significant amount of electricity from renewable resources and after Germany; France is the second-largest producer of biofuels in Europe.[32]

China, the world's largest carbon emitter, used coal to produce 69% of its energy needs in 2011. Oil was the second-largest source, accounting for 18% of energy generated. Other, cleaner fuel sources used in China include hydropower (6%), natural gas (4%), nuclear

[26] Ibid.
[27] BREE 2014 Australian Energy Update July 2014; data file.
[28] Ibid.
[29] Clean Energy Council website, available at: <https://www.cleanenergycouncil.org.au/technologies/solar-pv.html >
[30] IEA statistics, CO2 emissions highlights, 2013 edition.
[31] US Energy Information Administration, Canada <http://www.eia.gov/countries/country-data.cfm?fips=ca>
[32] US Energy Information Administration, France <http://www.eia.gov/countries/country-data.cfm?fips=fr>

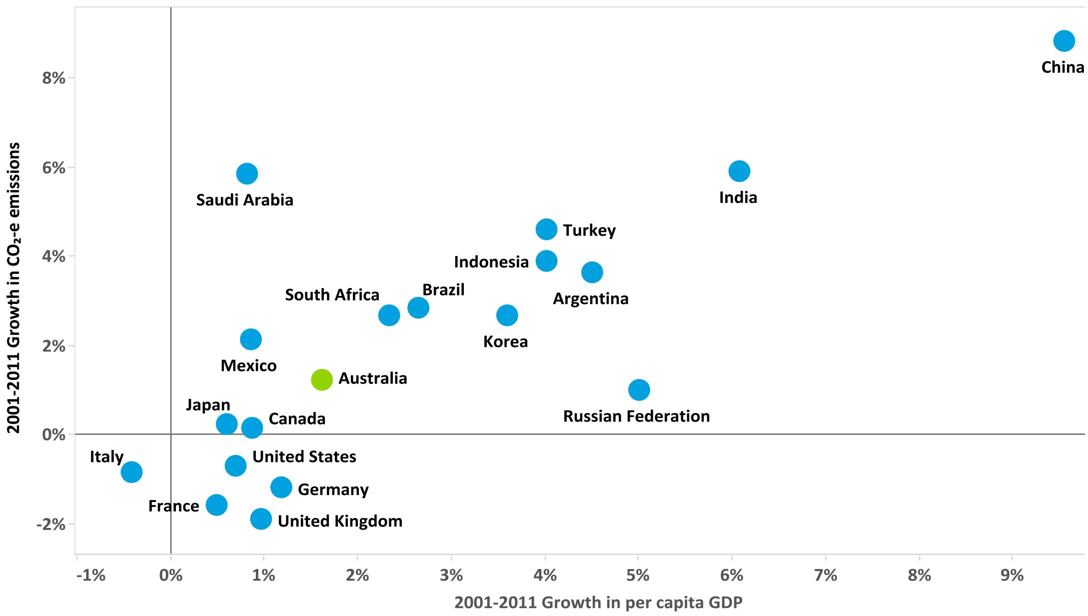
power (nearly 1%), and other renewables (1%). According to the US Energy Information Administration, the Chinese government plans to cap its coal use to below 65% of total primary energy consumption by 2017 in an effort to reduce air pollution. Further, the Chinese government has set a target to raise non-fossil fuel energy consumption to 15% of its national energy production by 2020.[33]

4.2.2 Energy carbon emissions and growth in GDP per capita

Examining growth in emissions and GDP per capita over the last decade highlights that countries which have managed to substantially increase their GDP per capita have also substantially increased carbon emissions. This finding lends further evidence to our suggestion that international comparisons of carbon emissions should recognise the interrelationship between emissions and economic growth.

To analyse this relationship, we have used a 10 year average from 2001-11 of the GDP growth per capita and carbon emissions growth, presented in the figure below.

Figure 11 – Growth in GDP per capita versus growth in energy carbon emissions – 10 year average: 2001-11



Source: IEA data, Deloitte analysis

Australia has managed to achieve moderate per capita economic growth (1.6%) which has outpaced its total growth in carbon emissions (1.2%).[34] This means that Australia is improving the carbon efficiency of its economic growth.

We note that the US and European economies have been impacted by the global financial crisis, which is reflected in their GDP per capita growth rates and growth in emissions.

[33] US Energy Information Administration <http://www.eia.gov/countries/cab.cfm?fips=ch>

[34] IEA data, Deloitte analysis.

4.3 Sectoral analysis

In the following sections we compare Australia's carbon emissions to that of other countries with similar economic structures. To do this, we have separately identified GDP associated with the services, industrial, and agriculture sectors as a proportion of overall GDP. More specifically, we have examined each country's overall carbon emissions from energy against the proportion of GDP derived from each sector.

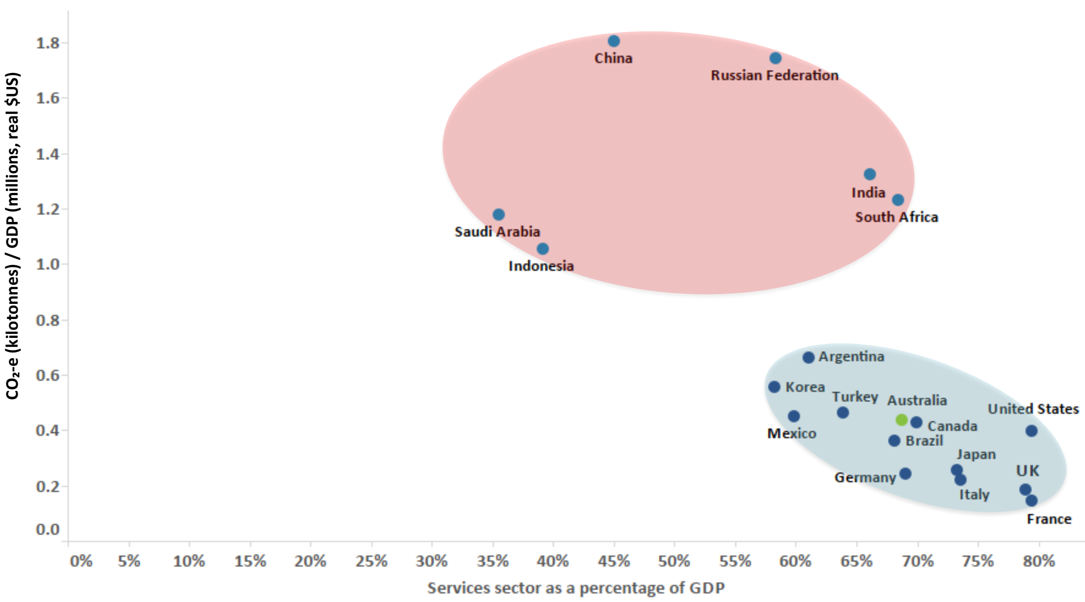
We have not examined how much carbon emissions are derived from each sector of the economy. Therefore the following analysis can be used to examine how Australia's energy emission compare to countries with a similar make-up of GDP, but not the carbon emissions performance of each sector of the economy.

4.3.1 GDP and energy carbon emission benchmarks—services sector

The majority of Australia's GDP (69% in 2011) is derived from the services sector.

In figure 12 we present each G20 country's carbon emissions per unit of GDP against the percentage of GDP derived from services.

Figure 12 – Energy carbon emissions per unit of GDP against percentage of GDP derived from services



Source: IEA data, Deloitte analysis

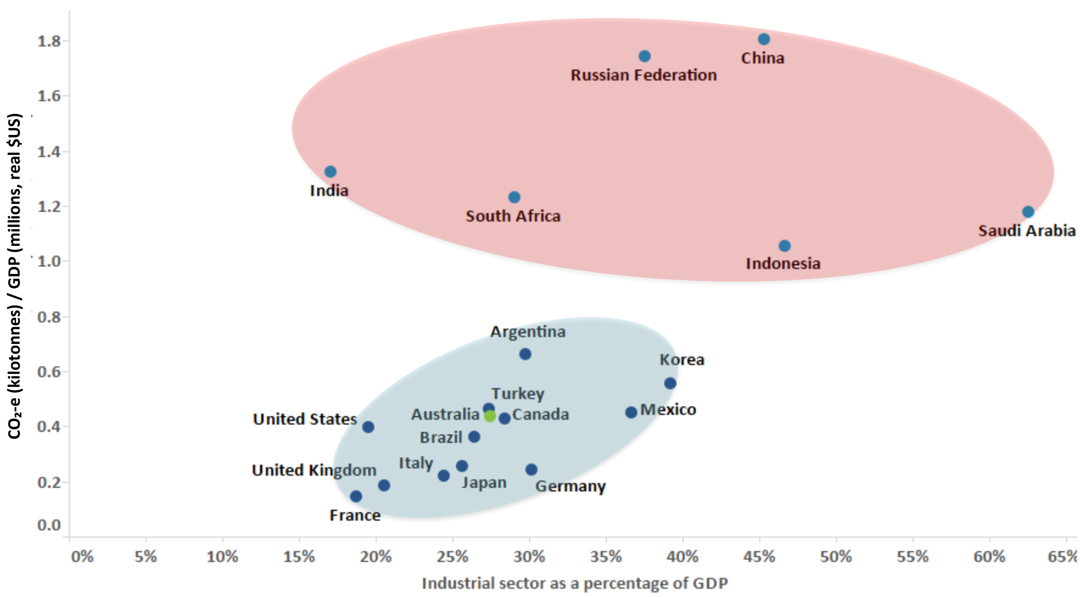
In figure 12 we have grouped the G20 countries into two broad clusters. The blue cluster consists of countries with a relatively large services sector and is typically developed economies with the exception of Brazil, Argentina and Mexico. Brazil's low emissions intensity of energy (see section 4.2.1) means its emissions given the size of its services sector are similar to more developed countries. Argentina has a relatively low energy intensity compared to other emerging countries meaning it also has similar emissions characteristics as more developed countries.

Australia is within the cluster of countries where the services sector represents a high proportion of GDP.

4.3.2 GDP and energy carbon emission benchmarks—industrial sector

As with most other more developed countries, Australia's industrial sector reflects a moderate proportion of GDP (27% of total GDP in 2011), as compared to its services sector. In general, we would expect countries with proportionally large industrial sectors to have higher energy requirements (and carbon emissions) than countries with proportionally large services sectors.

Figure 13 – Energy carbon emissions per unit of GDP against percentage of GDP derived from the industrial sector



Source: IEA data, Deloitte analysis

As with the previous analysis we observe that there is a cluster of developed economies, in which Australia sits.

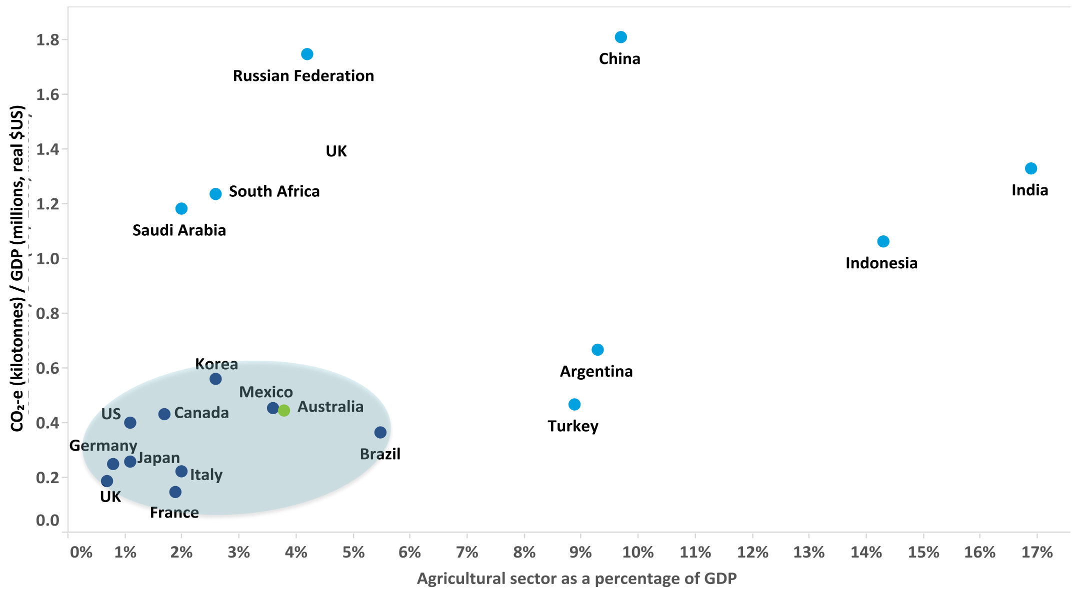
Figure 13 suggests that countries with low carbon emissions per unit of GDP typically generate a moderate proportion of their GDP from their industrial sectors. Indonesia and Saudi Arabia, while emitting more emissions than most of the more developed economies, have a relatively high proportion of GDP from the industrial sector.

Australia is within the cluster of countries where the industrial sector represents a moderate proportion of GDP.

4.3.3 GDP and energy carbon emission benchmarks—agriculture sector

Agriculture accounts for a small proportion of Australia's GDP (4% in 2011). Compared to the other more developed countries in the G20, however, this proportion is relatively large. In the figure below we present countries' carbon emissions per unit of GDP against the percentage of its GDP derived from the agriculture sector.

Figure 14 – Energy carbon emissions per unit of GDP against percentage of GDP derived from agriculture



Source: IEA data, Deloitte analysis

Figure 14 shows that, in general, countries with low CO_2-e/GDP derive a low proportion of their GDP from agriculture. Turkey and Argentina, however, derive a moderate proportion of GDP from agriculture and also have a reasonably low level of emissions per unit of GDP.

Australia is within the cluster of countries where the agriculture sector reflects a small proportion of GDP. Australia's agriculture and emissions characteristics are similar to many of the more developed G20 countries. When compared to the G20 more broadly, Australia produces fewer emissions per unit of GDP in total than Russia which also derives a similar percentage of GDP from the agriculture sector.

We note that, consistent with the analysis in this report, the emissions considered are only those derived from the energy sector and therefore do not include, for example, methane directly resulting from agricultural activities.[35]

[35] This analysis examines how Australia's energy emissions compare to countries with a similar make-up of GDP, but not to examine the emissions performance of the agricultural sector.

4.4 The role of technology

A key solution to delinking carbon emissions from energy production (and GDP growth) is the development of low emissions or zero emissions technology. While there has been some progress such as onshore wind, large scale solar generation and geothermal, there are limited examples of zero carbon generation technologies that are economically viable without the need for subsidies or a significantly high price on carbon emissions. Despite this, global clean energy investment has quadrupled over the past decade and in 2011 peaked at $279 billion.[36]

Increasingly, the private sector is leading the drive for technological breakthroughs to transition to low carbon economies:

- Tesla Motors is on the path to mass produce competitively priced electric vehicles in the near future. If successful, this could result in a substantial reduction in emissions from passenger vehicles.

- Khosla Ventures has invested in a portfolio of new energy technologies, including energy storage (Ambri, QuantumScape, Seeo), carbon capture (Calera), and solar (Cogenra Solar, Stion).

- Large scale carbon capture and store (CCS) projects are being commissioned, with the Boundary Dam Integrated Carbon Capture and Sequestration Demonstration Project in Canada (CO_2-e capture capacity of 1 Mtpa) commencing operations in October 2014. The new 582 MW power plant at the Kemper County Energy Facility in Mississippi, with carbon capture of 3 Mtpa is expected to commence in 2015. The Petra Nova Carbon Capture Project in Texas entered construction in July 2014 with carbon capture capacity of 1.4 Mtpa.[37]

- Bill Gates has established TerraPower, a nuclear energy technology company that could play a key role in addressing the imperative to move to low-carbon or zero-carbon energy. TerraPower aims to develop a scalable, sustainable, environmentally friendly, and cost-competitive energy source that would allow all nations to quicken their pace of economic development and reduce poverty.

Further and more substantial technological breakthroughs on several fronts will minimise the impact of carbon reduction on economic growth and living standards. The G20 countries might consider further encouraging research and development in energy to foster and expedite the commercialisation of new technology. This is important as the nine wealthiest countries of the G20 spend only 0.05% of GDP in 2012 on energy research and development.[38] Incentives for investment in low emissions technology can be generated by putting a price on carbon emissions.

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[36] Bloomberg New Energy Finance, 'Global Trends in Renewable Energy Investment 2013.'

[37] Global CCS Institute. We note that CCS is partially subsidised by governments.

[38] International Energy Agency, OECD iLibrary. R&D expenditure includes R&D on Energy Efficiency, Fossil Fuels, Renewable Energy Sources, Nuclear, Hydrogen and Fuel Cells, Other Power and Storage Technologies and Other Cross-Cutting Technical Research. Data for Australia, Canada, France, Germany, Italy, Japan, Korea, United Kingdom and United States.

As these technological breakthroughs occur, there needs to be cooperation and collaboration between countries so that the benefits are realised in developing, as well as developed countries. According to the World Bank, in 2011 around 22% of the world's population did not have access to electricity, almost all of whom live in developing countries.[39] As more people gain access to electricity, it is important that this is provided via economically viable and clean methods so as not to entrench past practices.

[39] World Bank, Access to electricity (% of population) <http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS/countries?display=graph>. The World Bank, Energy; the facts.

5 Comparative analysis

The purpose of this section is to use econometrics to test whether, given the relationships between emissions and certain variables including GDP, population and use of fossil fuels, Australia's historical emissions are in line with expectations.

To achieve this, we compiled data for up to 170 countries over a period of up to eleven years (2001-2011).[40] We applied three different statistical methodologies to examine the robustness of the results, and also averaged the results across the methodologies.

The most prominent result of this exercise is that Australia is consistently a little above the median of the G20 countries, regardless of the method used.

5.1 Methodologies

The basic models relate the CO_2-e emissions of each country to variables describing the size and composition of the country and its economic activity. The variables are motivated by the discussion in the previous section and include GDP, population, use of fossil fuels and the composition of output by sector.

We note that, while we consider these factors are likely to encompass the majority of the reasons for a country's emissions, there will be other factors which are not incorporated. This means that the rankings presented cannot definitively explain emissions performance but provide a guide as to some of the relative drivers of emissions.

The model parameters are given in Appendix A.

Broadly, the methodologies applied were:

1. Fixed baseline emissions measure
    a. Econometrically estimate a model relating CO_2-e emissions to the variables describing the size and composition of the country and its economic activity
    b. Parameters in the model give, for each country, the amount by which emissions vary from the average of the countries (given the characteristics of the countries). Because the model is explaining emissions, a country with a large value of the parameter ranks poorly.
2. Emissions frontier measure
    a. Return to the central question of how efficiently countries generate GDP, where efficiency is defined in terms of emissions of CO_2-e. For given GDP, lower emissions means higher efficiency

[40] Missing data meant that the estimation samples typically included less than 170 countries and less than the full eleven years.

b. The countries that are most efficient (have the highest ratios of GDP to CO_2-e, corresponding to the lowest values of CO_2-e / GDP) are considered to be close to a 'frontier'

c. Measure all countries relative to that frontier. Countries further from the frontier generate less GDP per CO_2-e or more CO_2-e per unit of GDP, and rank poorly.

3. Economic frontier measure

a. Continuing with the central question, use the frontier method to ask how efficiently countries produce GDP (per capita) based on their energy use, and other economic and demographic variables

b. A country that 'generates' GDP inefficiently is probably emitting more CO_2-e than would be the case if it generated GDP efficiently. Use the relationship between CO_2-e emissions and GDP to estimate the 'wasted' CO_2-e emissions. A country with more 'wasted' CO_2-e emissions ranks poorly.

Not surprisingly, countries' scores vary across the three methodologies. We also show an average ranking.

5.2 Fixed baseline emissions measure

The econometric model relates annual CO_2-e emissions of 125 countries over the period 2001-2011 to variables describing the size and composition of each country and its economic activity.[41] Those variables are:

- level of output (measured as real GDP in $US)
- mix of output (as measured by Gross Value Added Composition by broad sectors)
- population
- density
- urbanisation rate.

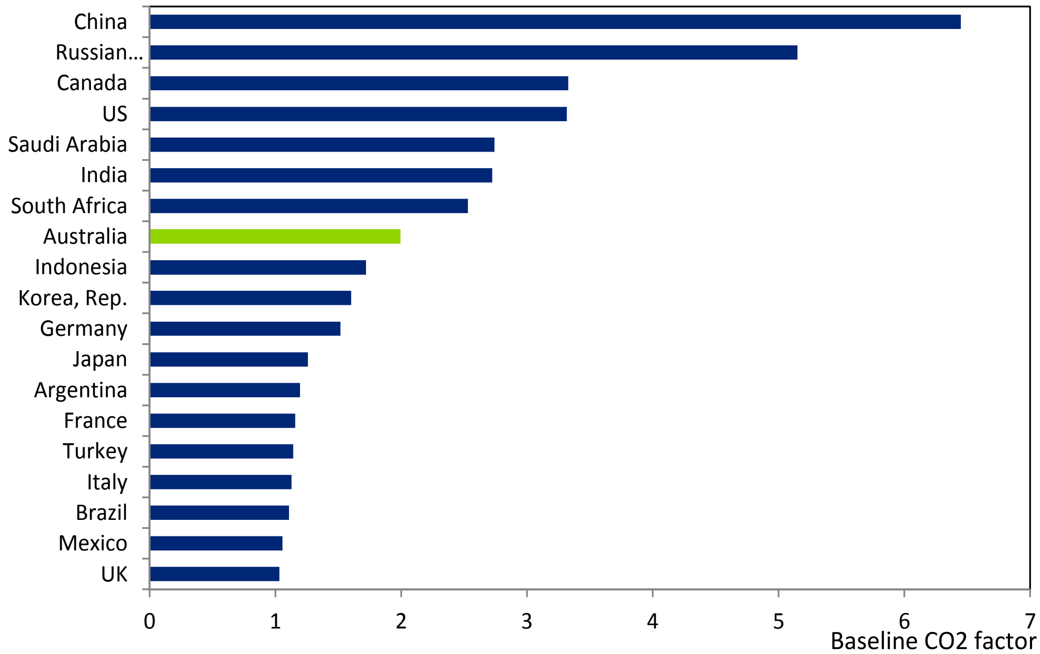
In addition, the model controls for the proportion of energy derived from fossil fuels and the terms of trade. For example, emissions are expected to be higher in countries with higher output and greater populations.

Included in the model is a set of parameters – the country fixed effects – representing the 'baseline' levels of emissions for the countries. Figure 15 below shows the results of this method for the G20 countries.[42]

[41] Because of missing data, the data for some of the countries covered fewer than the eleven years. The estimator is the 'fixed effects' estimator on the panel of data. Most of the variables in the regressions are in log form.

[42] The values in the figure are the exponentials of the estimated fixed effects.

Figure 15 – Baseline fixed CO_2-e estimated



Source: IEA data, Deloitte Access Economics 2014

Because the model is explaining emissions, a country with a large value ranks poorly. The figure illustrates that the level of emissions in China, for example, is greater than Australia's (taking into account the control variables). Generally, while controlling for the amount of goods and services produced in an economy, the model does not control for *how* they are produced – with differing levels of production technology and different drivers such as political and cultural norms.

Australia ranks twelfth amongst the G20 countries.

5.3 Emissions production frontier measure

As described in section 5.1, the methodology involves three basic steps:

1. Define efficiency as in terms of GDP produced per unit of CO_2-e emissions. Higher efficiency means more GDP per unit of CO_2-e emissions, or, equivalently, less CO_2-e emissions per unit of GDP.
2. Define a 'frontier' based on the countries that are most efficient (have the highest ratios of GDP to CO_2-e).
3. Measure all countries relative to that frontier. Countries further from the frontier (large values of the relevant parameters) rank poorly.

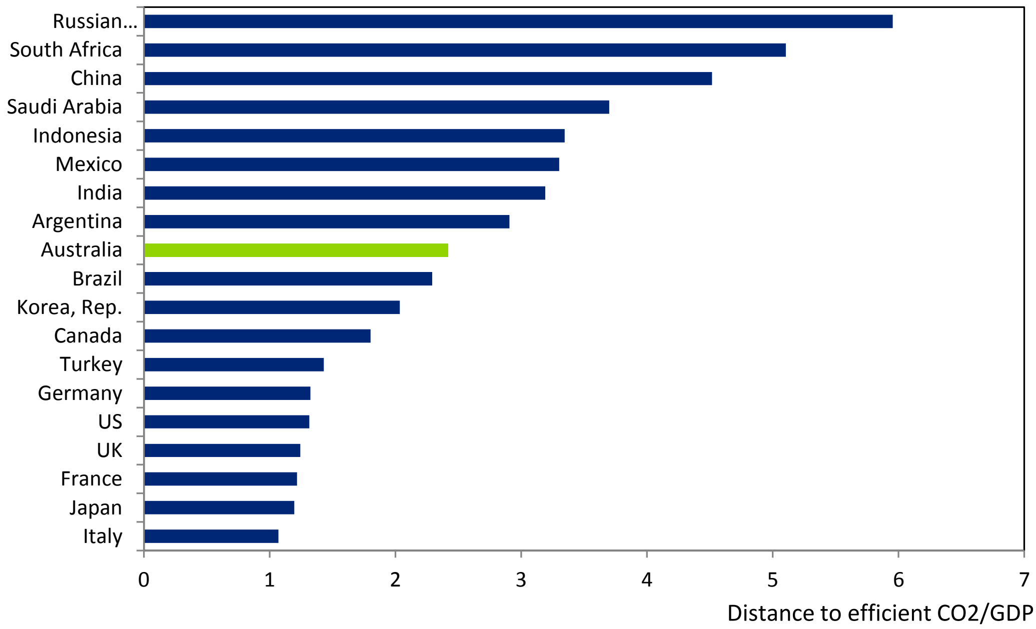
The methodology uses all the available data over the period 2001-2011.[43]

The actual frontier is defined implicitly within the econometric evaluation of the data, although the methodology does produce an explicit measure of inefficiency – the expected distance each country is from the frontier, on average over the sample period.

[43] We use a stochastic frontier analysis.

A country closer to the frontier is either producing more efficiently (higher output relative to its emissions) or emitting less CO_2-e for a given level of output. Figure 16 below illustrates each G20 county's level of inefficiency. Because the model is explaining inefficiency of production per amount of emissions, a country with a large value of the parameter ranks poorly.

Figure 16 – Emissions frontier distance estimates



Source: IEA data, Deloitte Access Economics 2014

As observed in the analysis above, Australia ranks eleventh compared to the G20 countries according to this measure. The US places better by this measure, which may be driven more by the relatively higher GDP productivity than by a lower level of emissions. This highlights a limitation of this approach—that the model is unable to distinguish between a lower GDP/CO_2-e ratio driven by low GDP productivity or by greater emissions. On the other hand, it does highlight that one way to reduce emissions without reducing GDP is to simultaneously implement policies that increase productivity.

5.4 Economic production frontier measure

The model in this section benchmarks emissions indirectly via production efficiency rather than explicitly including them in a frontier model. That is, the approach first asks how inefficient a country is, in terms of generating GDP for given characteristics of production and demographics, and then translates that into a measure of 'excess emissions'. The basic notion is that a country with inefficient production is likely to be wasting energy and hence emitting more CO_2-e that could otherwise be the case.

The methodology involves the following steps:

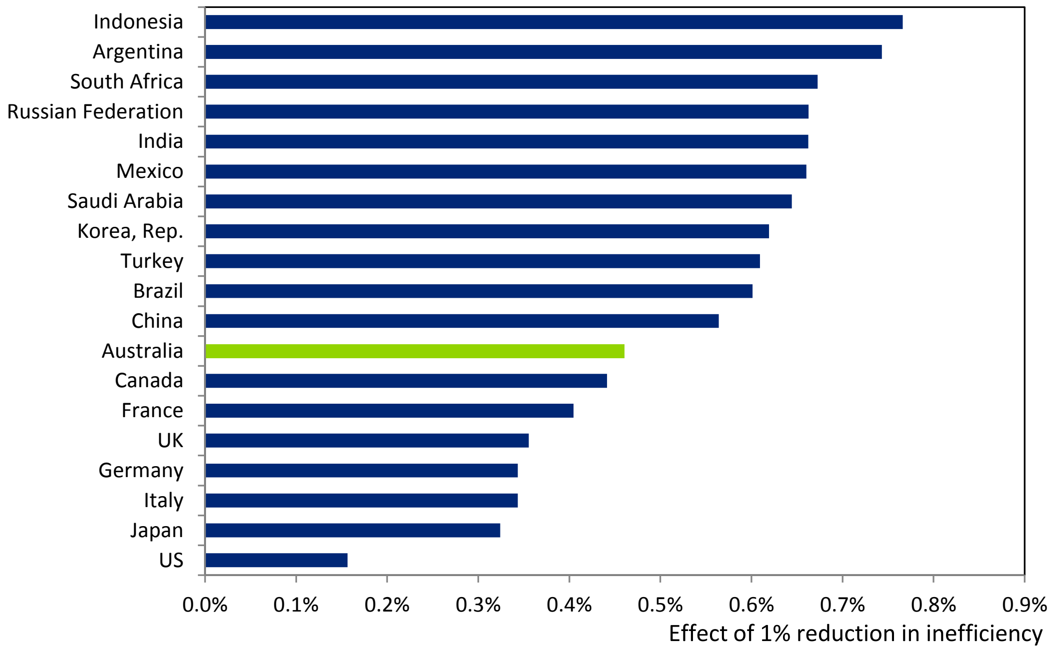
1. Use the frontier approach to model GDP per capita and obtain an estimate of the inefficiency of GDP per capita

2. Estimate a simple model relating CO_2-e emissions per capita to GDP per capita. That model (given in the Appendix) implies that a 1% difference in GDP per capita is associated with a 0.5% difference in CO2-e per capita. Thus, a country that is 1% inefficient may be able to eliminate 0.5% of its CO_2-e emissions by eliminating that production inefficiency.

This analysis does not provide a direct measure of carbon emissions efficiency. Rather, it indicates how efficiencies in production could relate to a reduction in carbon emissions.

Figure 17 shows the results for the G20 countries. Because the model is measuring 'wasted' emissions, a large value of the parameter means that a country ranks poorly.

Figure 17 – Economically inefficient emissions



Source: IEA data, Deloitte Access Economics 2014

The results suggests that, if Australia were to adopt more efficient production technologies resulting in a 1% increase in its productivity, then Australia's carbon emissions may be reduced by nearly 0.5%. Indonesia, for example, is much less efficient and hence a 1% increase in its productivity is associated with a larger percentage fall in its emissions.

This method of analysis places Australia on the eighth position compared to the G20 countries.

5.5 Summary

Table 5.1 below summarises the results of each method in terms of the rankings within the G20 and also shows average rankings across the three models (in the column headed 'Overall').

Australia places a little above half way down the ranking of the G20 nations in terms of relative emissions levels, and that result is consistent across the three models.

Table 5.1 – Average Emissions rankings

Country	Fixed baseline	Emissions Frontier	Production Frontier	Overall
Italy	4	1	3	1
UK	1	4	5	2
Japan	8	2	2	3
France	6	3	6	4
Germany	9	6	4	5
US	16	5	1	6
Turkey	5	7	11	7
Brazil	3	10	10	7
Mexico	2	14	14	9
Australia	**12**	**11**	**8**	**10**
Korea, Rep.	10	9	12	10
Canada	17	8	7	12
Argentina	7	12	18	13
India	14	13	15	14
Saudi Arabia	15	16	13	15
Indonesia	11	15	19	16
China	19	17	9	16
South Africa	13	18	17	18
Russian Federation	18	19	16	19

Source: IEA data, Deloitte Access Economics 2014

The approach of applying a set of models and then averaging the results is a common econometric approach. That is because no single statistical model is exactly correct, with each relying on a specific set of assumptions. Similarly, adding new data when it becomes available could change the rankings. However applying a number of different methodologies adds a degree of confidence to the results, especially with results that do not vary across the methodologies.[44]

The table above suggests that there are several countries that place consistently, such as Italy, the UK, Australia and India. We can be more confident of the position of those nations within the G20. However, it also suggests less confidence about the ranking of some countries, such as the US, Mexico and Argentina.

Recognising that policy can influence the choice of energy fuel, we have also evaluated emissions without the choice of fuel as a parameter, with results presented in table 5.2

[44] We also considered, *inter alia*, a fixed effects model on the second half of the data – Australia's ranking changed by only one place.

below. If fossil fuels are removed as an explanatory variable Australia's ranking does not substantially change, moving from 10th to 11th in the G20 countries.

Table 5.2 – Emissions rankings without fossil fuels variable

Country	Fixed baseline	Emissions Frontier	Production Frontier	Overall
Italy	5	2	3	3
UK	2	5	5	4
Japan	4	3	2	2
France	1	1	6	1
Germany	7	4	4	5
US	16	6	1	7
Turkey	3	9	11	6
Brazil	8	7	10	8
Mexico	9	16	14	12
Australia	**12**	**14**	**8**	**11**
Korea, Rep.	6	10	12	9
Canada	13	8	7	9
Argentina	10	11	18	12
India	17	12	15	16
Saudi Arabia	15	15	13	14
Indonesia	19	17	19	17
China	11	13	9	14
South Africa	14	18	17	18
Russian Federation	18	19	16	19

Source: IEA data, Deloitte Access Economics 2014

Appendix A - Model specification

The following section provides estimates of the regressions performed in analysis.

Fixed Effects Regression

Table A.1: Fixed Effects Model Statistics

Statistic	Value
Dependent variable	Log CO_2
N	1352
Countries	125
Min per country	1
Average per country	10.8
Max per country	11
R^2 within	65.29%
R^2 between	87.29%
R^2 overall	87.27%
$Corr(u_i, X_i\beta)$	0.4537
σ_u	0.7468
σ_e	0.0918
ρ	0.9851

Table A.2: Fixed Effects Model Estimates

Parameter	Estimate	Standard Error
Log GDP	0.4265*	0.1125
Log Population	0.3792*	0.1601
Urbanisation	0.0145*	0.0053
Log Density	0.0559	0.1124
GVA – Agriculture	-0.007	0.0050
GVA – Mining	-0.0060	0.0047
GVA – Construction	0.0019	0.0089
GVA – Manufacturing	0.0028	0.0040
Fossil Fuels (% energy derived from)	0.0063*	0.0014
Log Terms of Trade	0.0725	0.0473
2002	-0.0035	0.0067
2003	0.0066	0.0110
2004	0.0018	0.0156
2005	-0.0089	0.0205
2006	-0.0299	0.0262
2007	-0.0401	0.0312
2008	-0.0544	0.0349
2009	-0.0599	0.0361

2010	-0.0498	0.0419
2011	-0.0633	0.0467
Constant	-14.9936*	3.0378

Note: * indicates that the variable is statistically significant.

Stochastic Frontier Model

Table A.3: Stochastic Frontier Model Statistics

Statistic	Values
Dependent variable	Log GDP per CO2
N	1330
Countries	123
Min per country	1
Average per country	10.8
Max per country	11
Log likelihood	654.333

Table A.4: Stochastic Frontier Model Estimates

Parameter	Estimate	Standard Error
Log Population	0.0037	0.0402
Urbanisation	0.0071*	0.0019
Log Density	0.0919*	0.0369
GVA – Agriculture	-0.0199*	0.0027
GVA – Mining	0.0038*	0.0015
GVA – Construction	0.0053	0.0033
GVA – Manufacturing	-0.0034	0.0019
Fossil Fuels (% energy derived from)	-0.0063*	0.0005
Log Terms of Trade	0.0410	0.0223
G20 Nation	-0.2554	0.1303
Heat Days	-0.0005*	0.0002
Heat Days^2	0.0000*	0.0000
Heat Days^3	0.0000*	0.0000
Cool Days	-0.0010*	0.0003
Cool Days^2	0.0000*	0.0000
Constant	4.6366*	0.6657
μ	0.8406*	0.1815
Log σ^2	-0.3165	0.2501
η	4.0216*	0.2586
σ^2	0.7286	0.1822
γ	0.9823	0.0044
σ_u^2	0.7157	0.1822
σ_v^2	0.0128	0.0005

Note: * indicates that the variable is statistically significant.

Structural Model

GDP Stochastic Frontier

Table A.5: GDP Stochastic Frontier Model Statistics

Statistic	Values
Dependent variable	Log GDP per capita
N	914
Countries	145
Min per country	1
Average per country	6.3
Max per country	8
Log likelihood	1051.20

Table A.6: Stochastic Frontier Model Estimates

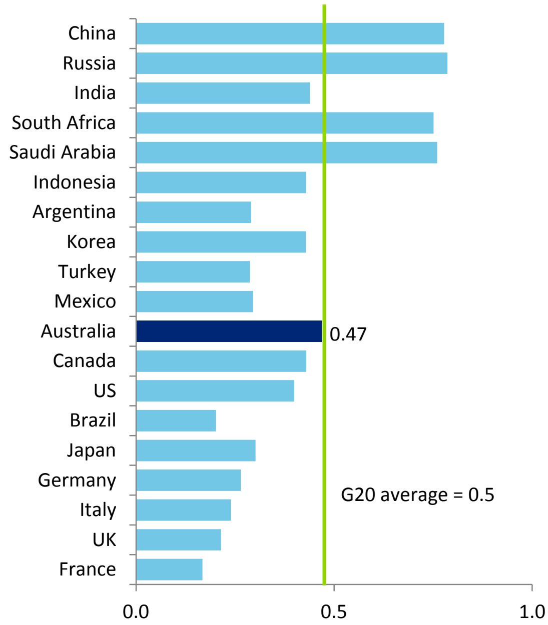
Parameter	Estimate	Standard Error
Log Energy per capita	0.2089*	0.0174
Log exports per capita	0.1949*	0.0096
GVA – Agriculture	-0.0156*	0.0022
GVA – Mining	-0.0002	0.0011
GVA – Construction	0.0142*	0.0018
GVA – Manufacturing	-0.0057*	0.0017
Log Terms of Trade	-0.0547*	0.0204
G20 Nation	1.1266*	0.1628
Urbanisation	0.0133*	0.0017
Log density	0.0412	0.0287
Constant	16.5041*	0.2265
μ	1.5612*	0.0947
Log σ^2	-0.9382*	0.1362
η	5.3088*	0.1488
σ^2	0.3913	0.0533
γ	0.9950	0.0007
σ_u^2	0.3894	0.0533
σ_v^2	0.0019	0.0001

Note: * indicates that the variable is statistically significant.

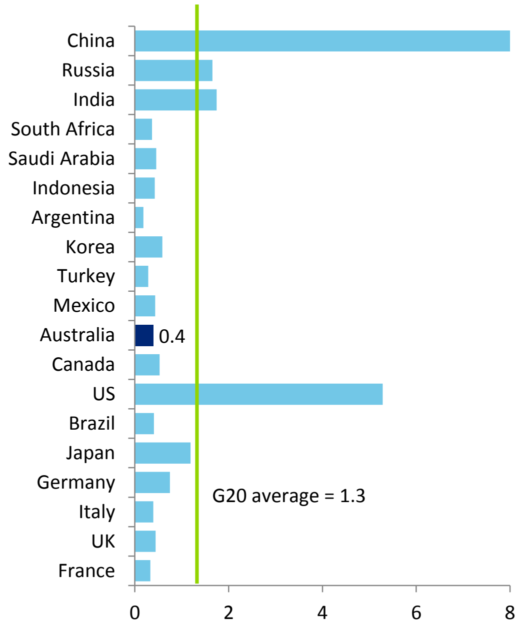
Appendix B

CO_2-e/GDP metrics using GDP based on Purchasing Power Parity (PPA)

Energy CO_2-e (kilotonnes)/GDP (millions, PPP), 2011 data



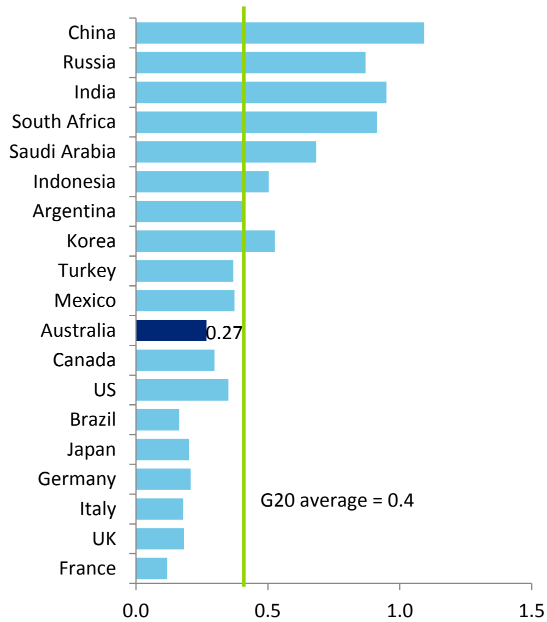
CO_2-e from energy (GT), 2011 data



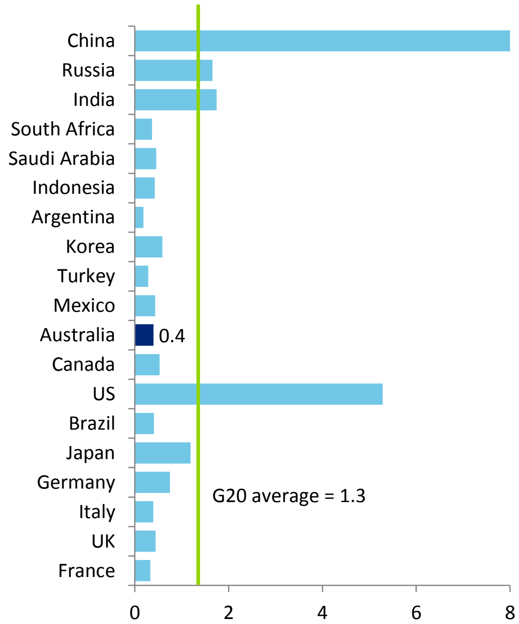
Source: IEA data, Deloitte analysis

CO_2-e/GDP metrics using GDP based on current prices

Energy CO_2-e (kilotonnes)/GDP (millions, current prices), 2011 data



CO_2-e from energy (GT), 2011 data



Source: IEA data, Deloitte analysis

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