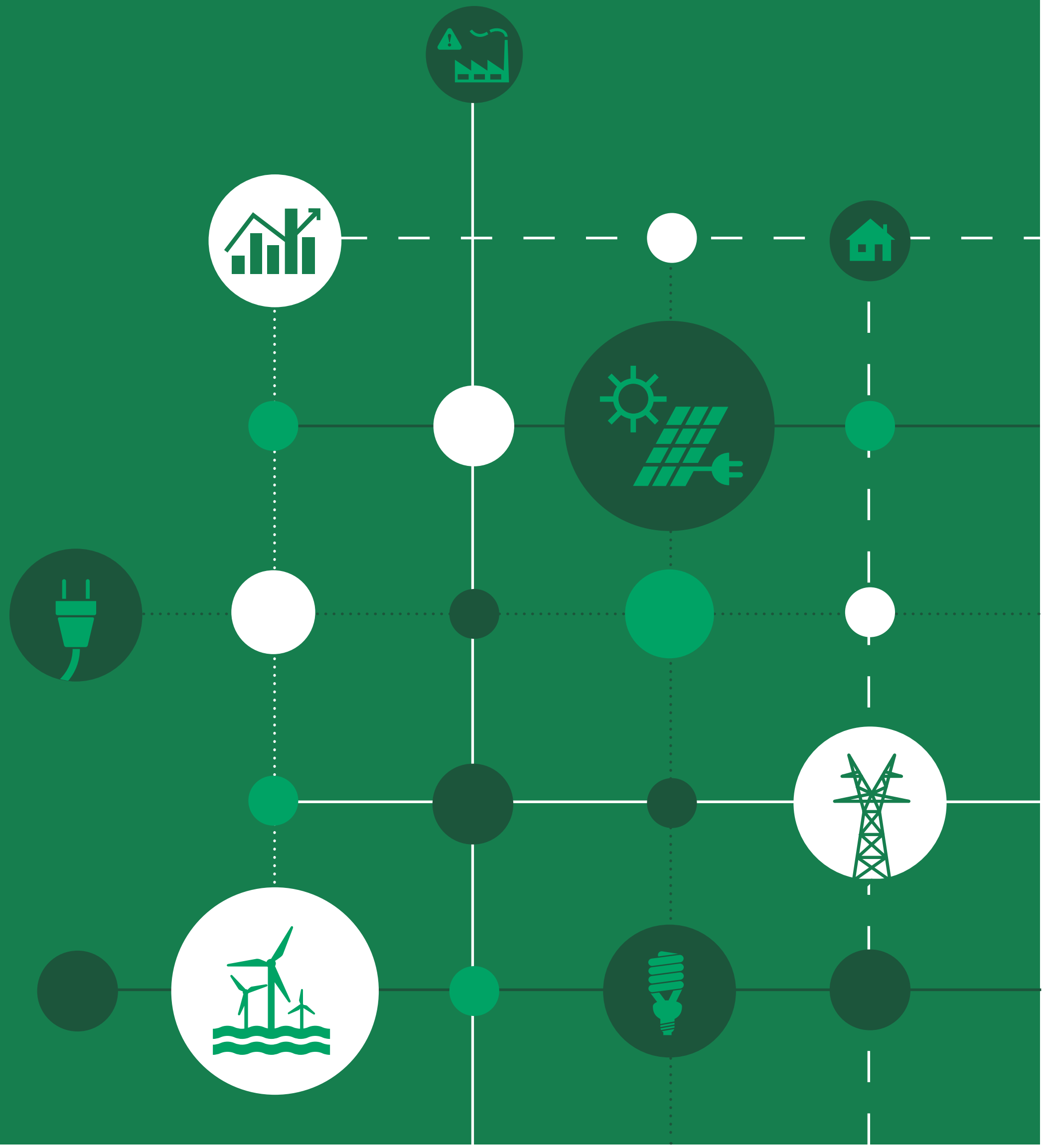
Five minute guide

Fossil Fuels in Transition



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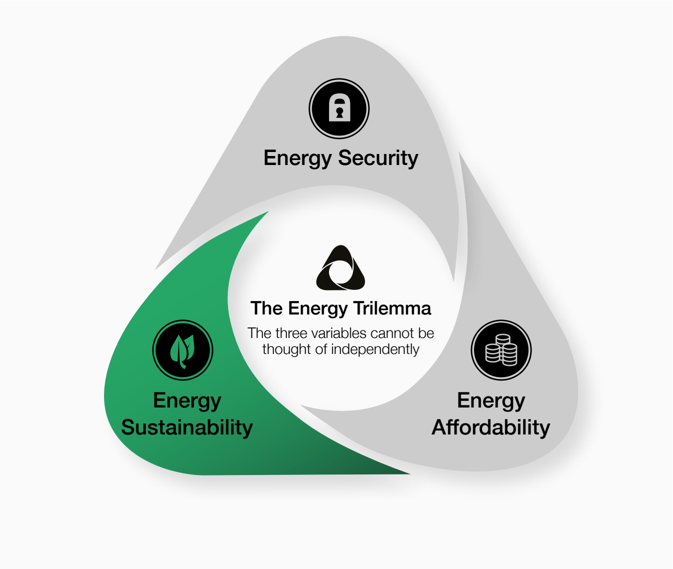
The need for change

In November 2016, the Paris Agreement came into force, reinvigorating international commitment to limiting climate change. The goals are long term but action is needed immediately.

Limiting climate change to 2°C will require significant changes in almost every area of human activity, not least a change in how we generate energy. About two thirds of the emissions budget for keeping warming below 2° has already been used and a significant proportion of global emissions are related to the unabated use of fossil fuels [Nature 2016]. A transition to alternative methods is needed.

However, this transition cannot happen overnight. There are also significant differences in the environmental impact of energy generation technologies. It is therefore logical to start the transition by focusing on the transition away from technologies with the greatest impact.

The energy transition must also offer solutions that are affordable and meet energy security requirements, this document focuses on the Environmental aspects of the Energy Trilemma. For wider issues see Arup Five minute guide to the Energy Trilemma. As signatories to the Paris Pledge for Action, Arup is committed to its ambitions which align closely to our own vision. But it is also clear that as for many organisations, including our own, the transition away from fossil fuels represents an opportunity for growth and resilience in the face of potential uncertainty. The drivers for change are aligning. This guide is therefore setting out a framework for assessment and consideration of the various energy generating technologies and the context for their possible application.



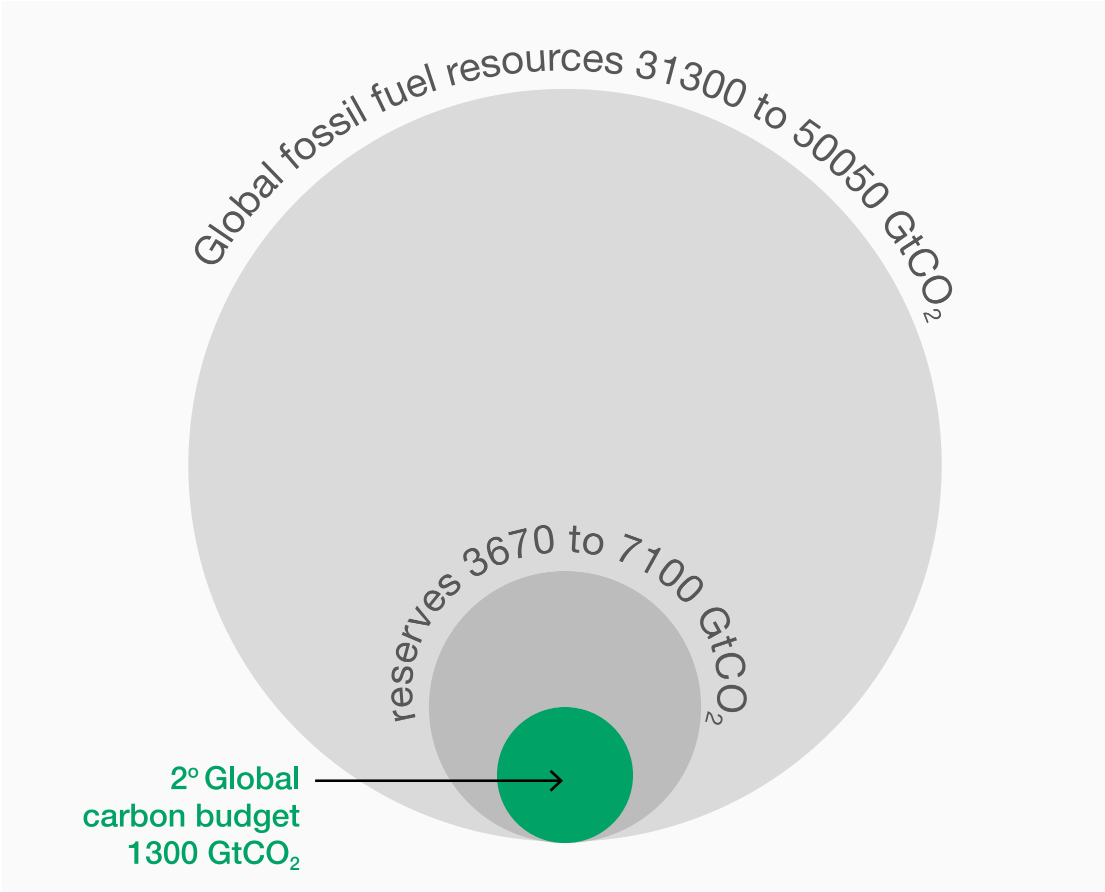
The challenge

The potential environmental impacts of large projects are extremely complex and the enormity of evaluating them accurately can induce decision paralysis that defaults to the status quo.

The most widely communicated, and readily quantifiable, aspect of the environmental impact of fossil fuels and related technologies is their emission of carbon dioxide and other associated greenhouse gasses that directly contribute to climate change.

Many projects have much wider environmental consequences as a result of impacts on ecology, land use change, and water chemistry amongst others. These wider effects are equally important when considered against the global challenge of maintaining a stable planetary biosphere.

Each of these issues is highly complex and understanding them fully requires comprehensive research. However, those in decision-making positions are seldom experts and there is therefore a place for a methodology that compares these various environmental impacts at a high level. Fossil Fuels in Transition sets out such a methodology in this guide, with the aim of catalysing industry debate.



Source: Data sourced from table 2.2 page 64, IPCC Climate Change 2014, Synthesis Report

Relative emissions levels

The greenhouse gas emissions of fossil fuels do not arise solely from gases released when they are burnt. Indirect effects of infrastructure and supply chain emissions are also significant.

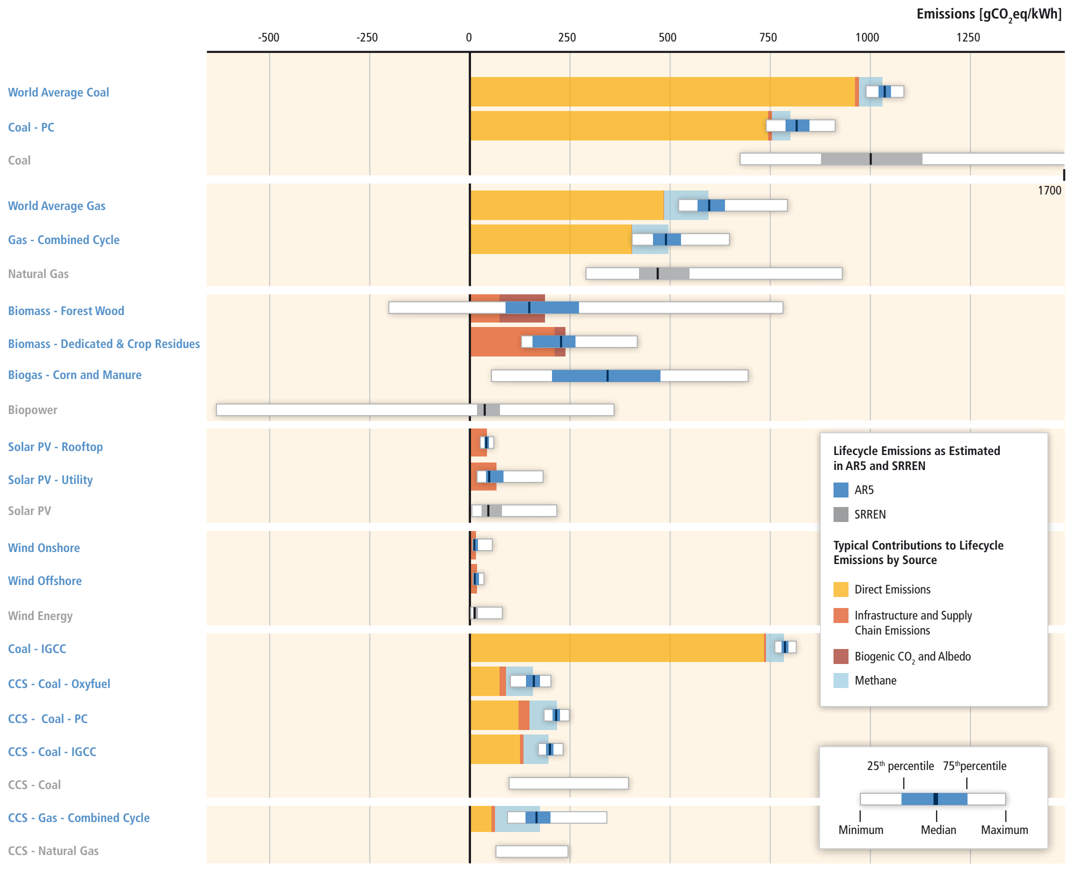
A Lifecycle Analysis is needed to combine and quantify the many potential sources of impact. The most comprehensive existing study has been carried out by the Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report.

The IPCC study is based on many hundreds of papers produced over the preceding five years and provides a robust assessment of the overall impacts of specific hydrocarbons when used as a fuel for power generation. It also considers non-fossil fuel energy generation. Emissions are normalised against the electricity generated, expressed as gCO_2e/kWh.

Even this comprehensive study has omissions, with no variance shown within the fuel type categories where, in reality, significant differences can be seen as a result of the processing required or specific project conditions. For example, the recovery of oil from tar sands is considered to result in higher lifecycle emissions compared with conventional oil sources because of greater use of steam to recover oil, higher fugitive emissions from tailing ponds and significant land use change.

The IPCC report expresses these variations by quantifying the 25^{th} and 75^{th} percentiles along with the average (median) value. It is these figures that are used in our methodology.

The Sixth report due out in the first half of 2022 should be referred to once available.



Source: Diagram extracted from figure 7.6, page 539 Intergovernmental Panel on Climate Change (IPCC), Fifth Assessment Report

Impacts

Fossil hydrocarbons exert a profound and pernicious effect on global climate change but they can have an equally damaging effect on other environmental assets.

The mining, processing and use of fossil fuels can exert varying levels of impact on environmental parameters, at each stage of operations. For this study we have considered effects on: the aquatic environment; airborne pollution; biodiversity and landscape; marine habitats; geology; and waste materials. In addition, we have considered the environmental consequences of hazards during processing.

Each of the parameters has its own rigorous procedure for assessment which, in an ideal world, would be applied to this study. However, the scale, cost, and complexity of this approach exceed the scope of the study and we have therefore relied on professional judgement to provide a qualitative estimate of wider environmental impacts. We are aware that more extensive reviews would be beneficial, and we welcome broader professional inputs.

For each technology, a generalised scale of impact from 0 (least/no impact) to 10 (greatest impact) is used for each individual environmental factors. These impacts are then summed and normalised to provide a median overall impact that once again ranges from 0 to 10 across all technologies. These scores were then calibrated according to current knowledge of each specific fuel, process and regulatory context to provide a variance above and below the median score. This variance between the upper and lower scores is shown on the y-axis of the diagram overleaf.

Environmental Factors

Energy Generation Technologies	Water	Land	Air	Process	Waste	Shorelines	Geology	Normalised Overall Impact
Solar PV	0	3	0	0	0	0	0	0.0
Onshore Natural Gas	3	3	3	2	2	0	1	2.0
Forest Biomass	4	8	4	1	3	0	0	3.1
New Nuclear	1	4	1	5	5	3	3	3.5
Deep Sea Oil	0	0	5	9	6	9	0	4.7
Bituminous Coal	5	9	9	6	9	3	8	8.4
	Water use, water treatment, surface water pollution, ground water pollution	Landscape degradation, habitat destruction, biodiversity loss, habitat fragmentation, land use change	Fugitive emissions (gas, oil), airborne pollution (gases, particulates)	High risk processes, hazard response difficulties	Waste management impact, raw materials supply, residual by-products (adverse, beneficial)	Marine pollution, estuarine pollution, fisheries impact	Ground subsidence, induced seismicity	

A combined assessment

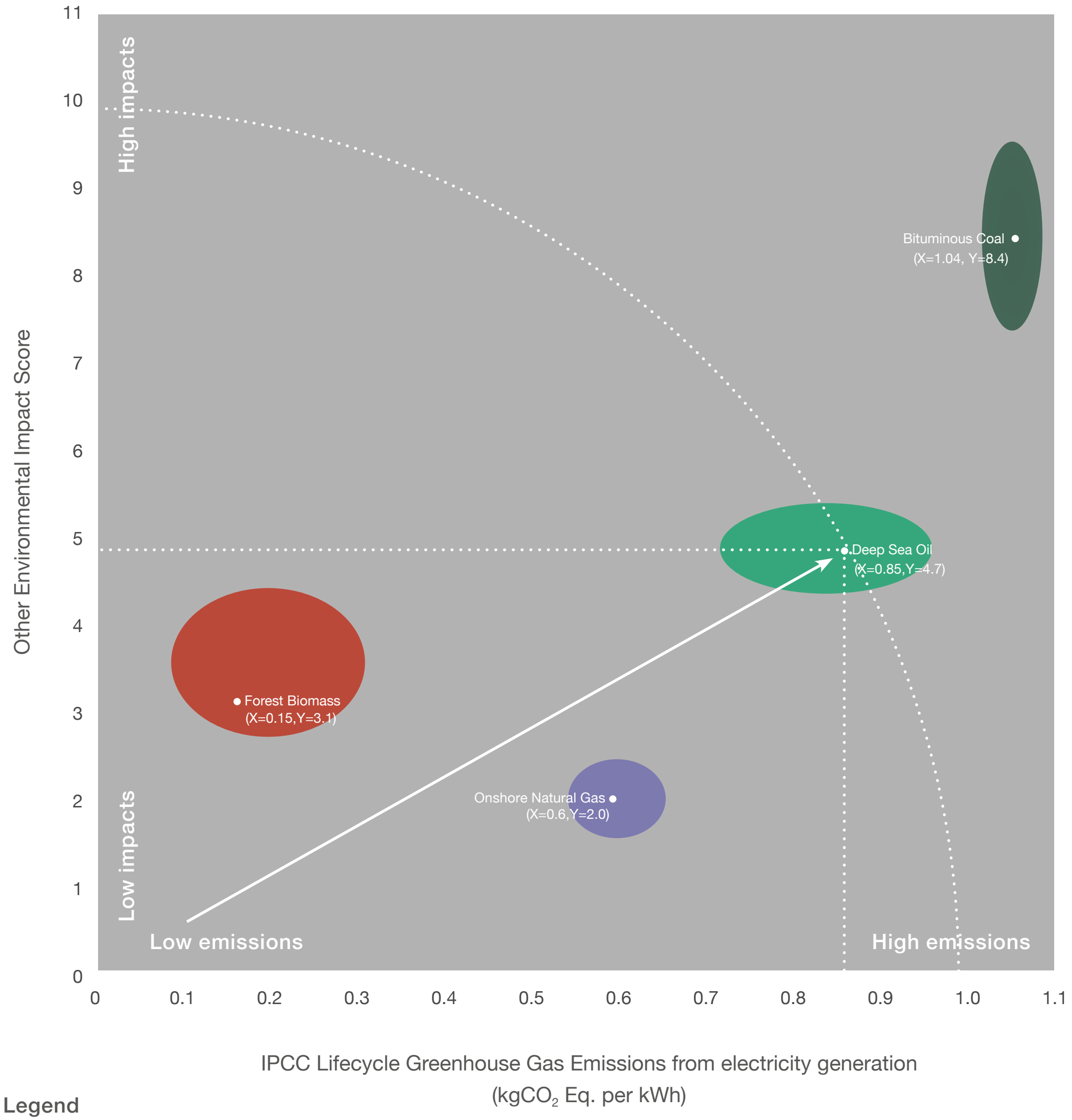
With a defined methodology for both relative emissions levels and wider environmental impact, the next challenge is to combine them into an overall assessment.

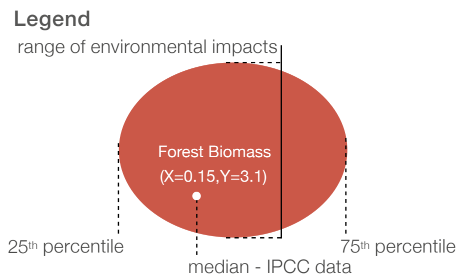
Addressing the emissions of energy generation and its wider environmental impacts are both essential requirements for progress. Quantitatively combining the two different metrics would, however, be problematic. Any combined methodology risks unintentionally affecting the results or masking important issues within the underlying scores of each metric.

We have therefore opted to combine the metrics visually using versions of the diagram shown to the right. It shows how each of the energy generation technologies relates to each other. The lifecycle emissions are indicated on the horizontal axis and the wider environmental impact score shown on the vertical axis. Technologies with low emissions and low impact are therefore shown towards the bottom left corner.

Each technology is represented by a point and a surrounding oval. The point shows the median position of each technology. The extents of the oval show the potential variations in each metric as discussed in previous sections. The proportions of the oval indicate the scale of opportunity to affect the impacts of a project or technology type.

Two versions of the combined assessment have been produced tailored to upstream and downstream projects. The fuel type can be accurately determined for exploration and extraction, or ‘upstream’ projects. However, ‘downstream’ projects involved in processing and generation must rely on fewer fuel types due to uncertainty over fuel sources but can consider the end use of the fuel.





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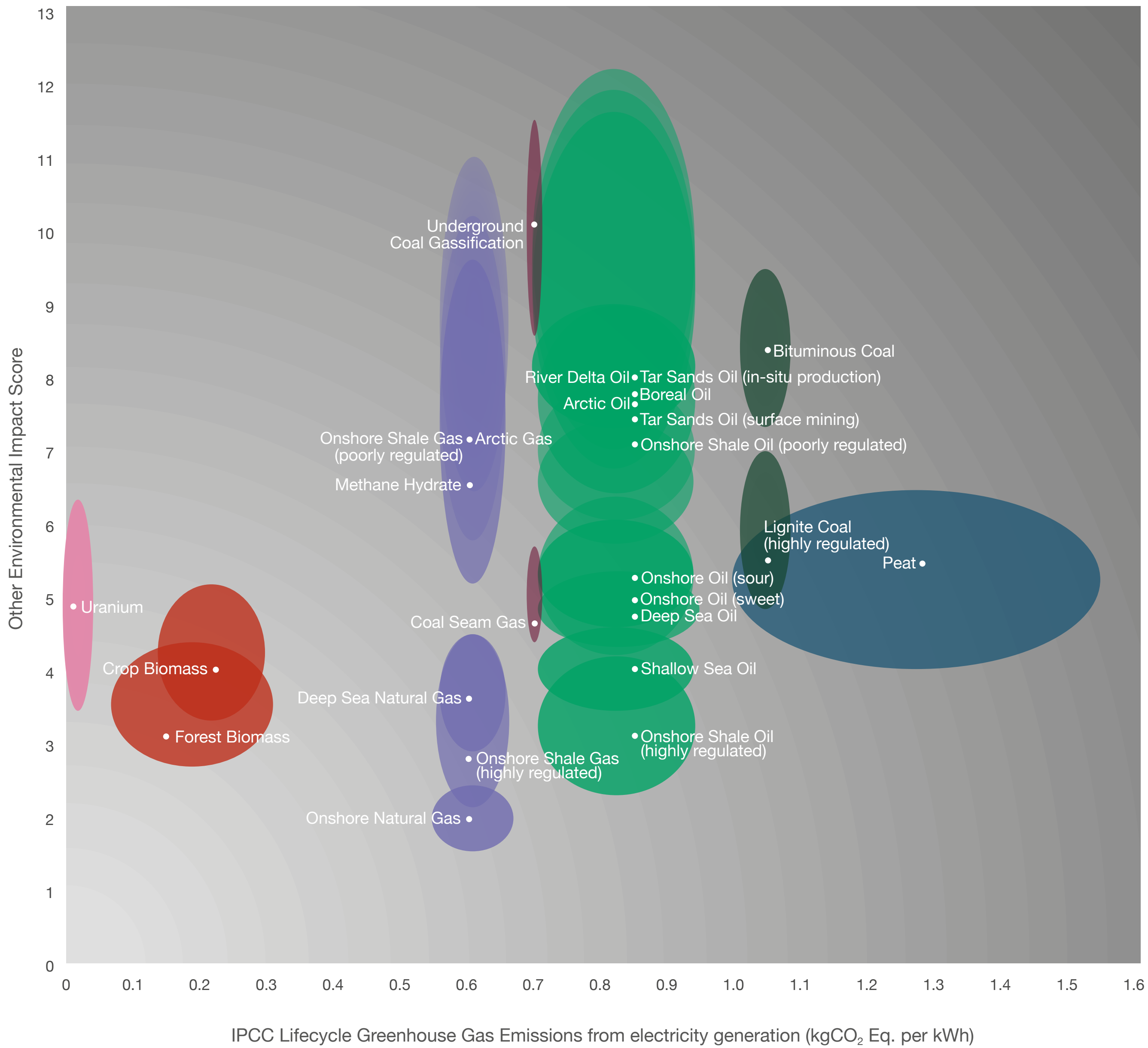
Upstream assessments

In addition to end-use effects, greenhouse gas impacts of each type of hydrocarbon will vary with the technologies used in their extraction, to create a highly nuanced picture.

The complexities of arriving at a comparative review of hydrocarbon fuels have been evaluated in a number of life-cycle-analysis (LCA) studies. For this initiative, the main source of LCA data has been the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report. IPCC data is considered to be a robust proxy for the overall carbon footprint of specific hydrocarbons.

Differences between individual fossil hydrocarbons result from the specific properties of the mineral, its source location, extraction methods and any processing required. For example, the recovery of oil from tar sands results in higher lifecycle GHG emissions than conventional oil sources due to energy inputs required to recover oil, higher fugitive emissions and often catastrophic land use change. So this is adding the contextual aspects of the nature of the source.



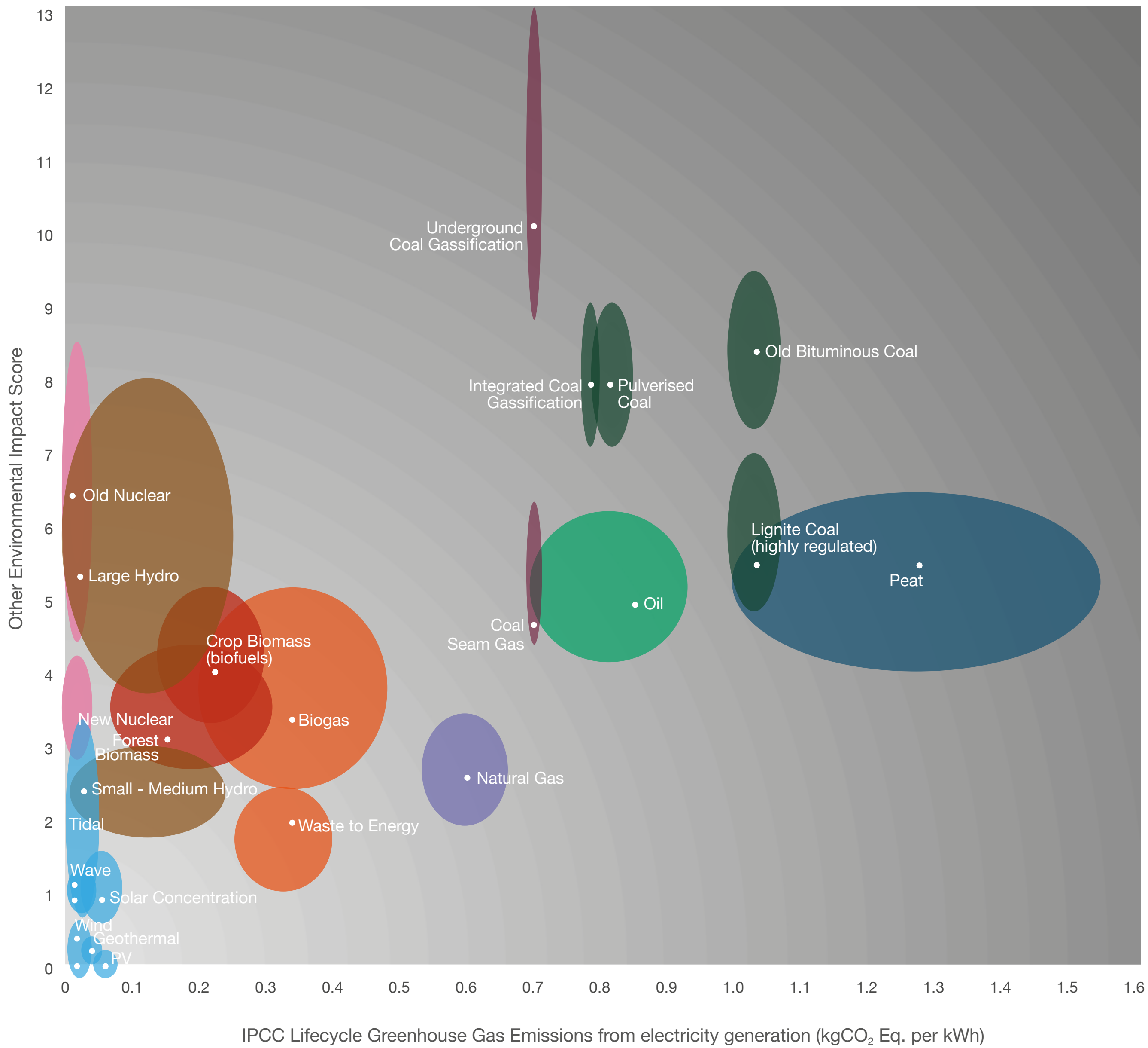
Downstream assessments

Fossil hydrocarbons currently comprise the dominant fuel in power generation, although GHG emissions from this source are declining due to substitution.

In some parts of the world, coal is the main fuel source for electricity generation, although its use is generally declining, particularly in NW Europe. The IPCC data used in this assessment framework to rank the impact of individual fossil fuels for this purpose is robust, but does not include other downstream uses or potentially mitigating end-use technologies.

Oil forms the primary fuel for motorised transport and underpins investment in refining facilities. In the longer term, electric vehicles will replace conventional engines, while batteries, hydrogen or fuel cell technology may create further constraints on the use of oil. Natural gas is a primary source of space heating, and occasionally combined heat & power.

The relative hierarchy used in this assessment framework includes refinements to the baseline data and represents a high-level comparison of fossil hydrocarbon and low carbon energy systems. It can be used to categorise the reputational, climate change, and environmental risks of projects in the energy sector. It is not exhaustive and should be used as a guide to impacts, rather than a suite of rigidly applied criteria.



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Impact of renewables

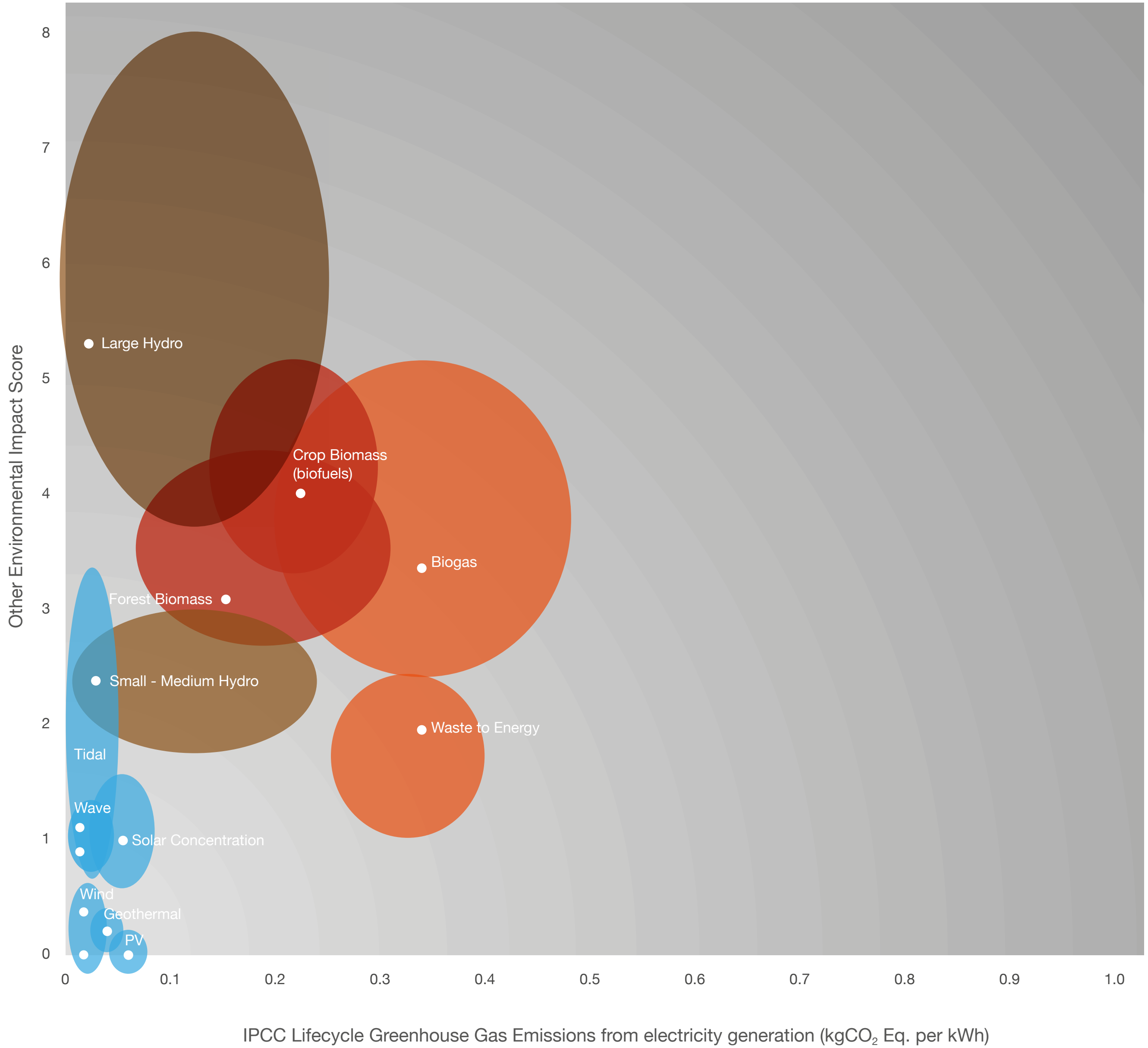
Whilst renewables are the best option in many cases, they are not devoid of impact. It is important to recognise this in order to encourage a balanced debate.

Many renewable technologies generate near-zero carbon energy in operation. However, the IPCC emissions figures also rightly include the potentially significant construction or manufacturing impacts. As a result, lifecycle emissions have the potential to be sizeable enough to impact on decision-making when comparing them with other renewables.

This is particularly true of hydropower projects requiring significant infrastructure and construction to realise the potential of a renewable source.

In contrast to this issue of up-front impacts, renewable energy sources that still rely on combustion such as biomass and biogas can have sufficient whole-life emissions to place them close to the low environmental impact fossil fuels.

In addition, the wider environmental impacts of the larger-scale technologies have the potential to be significant. For example, hydropower on river ecologies, tidal schemes due to their potential impact on marine and estuarine life, and biomass on long-established agricultural and forest habitats. Each of these issues needs to be considered using the Other Enivronment Impact Score approach for a spread on the vertical axis.



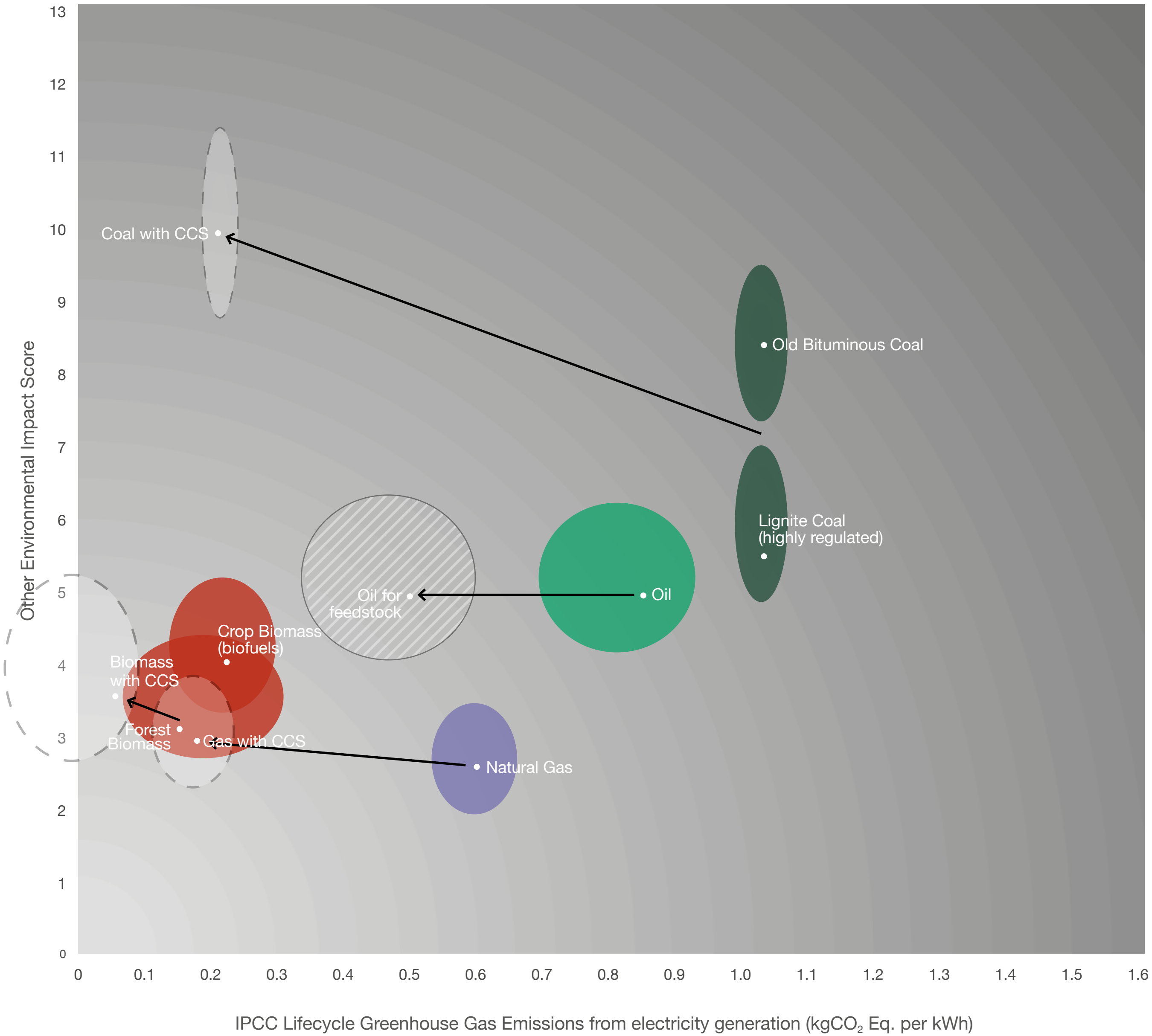
End use effects

The assessment framework focuses on fossil fuels for electricity generation. However, impacts may be affected by end-use technologies such as CCS or uses other than power generation.

Carbon capture and storage (CCS) is a basket of emerging technologies that capture, transport, and store CO_2 emissions that show potential in extracting emissions from fossil fuel power generation waste streams. Whilst the process uses significant amounts of energy (up to 30% of that generated), over 90% of CO_2 emissions may be captured leading to a net emissions reduction. However, many of the parts of this chain of technologies are not proven at scale, most notably long term storage solutions.

Hydrocarbons also play a dominant role in transport and form a critical feedstock for many processes, especially in the chemical and agricultural industries. Although substitutes for some uses may be developed, hydrocarbons are likely to constitute a key part of many manufacturing processes in the medium to long term.

The scale of climate change impacts varies according to the use of specific processes or end-uses. The assessment framework includes a mechanism for evaluating such issues – the likely effects shown in the figure to the right.



Call for collaboration

No methodology to combine so many disparate issues will ever be perfect. However, in the face of a period of unprecedented change in our energy infrastructure, it is important to start the debate.

This guide sets out an approach and an assessment framework to enable projects for power generation to be compared and ranked. It is not attempting to set any mandate on what is or is not acceptable because that is a larger socio-political challenge. However, its aim is to provide a means for informed decision-making and selection. Providing this visibility gives the opportunity to consciously transition towards the better technologies.

Engagement and collaboration is undoubtedly needed with a fair degree of urgency to progress towards the better solutions. This will become ever more important as the need to reduce carbon emissions becomes ever more pressing to keep climate changes within acceptable limits.

For example, the use of arcs in the diagram visually implies that a median Natural Gas project has a similar overall impact to Old Nuclear, despite the latter having lifecycle emissions approximately 20 times lower.

To an extent this just is a consequence of how we have chosen to visualise the outputs. Should there be a different 'weighting' between the axes, implying a hierarchy between the two categories?

Even such a seemingly simple question raises issues of priority of impact that may vary depending on geographical location and highlights the dichotomy of the global consequences of carbon emissions and the wider environmental impacts that are more likely to be felt at a regional and local level. Similarly, there is currently no feedback between carbon emissions (and the associated climate change) and wider environmental impacts. For example, the appraisal of the wider environmental impacts of using peat as an energy source recognises its likely minimal impact on marine and estuarine life. However, the contribution of this high-carbon fuel to climate change and the resultant sea-level rise and ocean acidification would indirectly have significant impacts on the habitats not directly affected in the short term. Should this be included or is it double-counting an impact?

Discussions around these and many more issues have the potential to increase the robustness of this methodology. However, it is important to maintain the simplicity of the approach as far as is possible as long as the outputs are accurate enough to meaningfully contribute to a debate. This is a complex field and it is important to recognise the value of simplicity in communicating to policy-makers in governments and decision-makers in businesses.

Arup has a great deal of practical experience in many fields relating to this debate, such as energy system design, ecology, air quality and socio-economic issues. However, no one organisation can possibly be at the forefront of every issue in this rapidly changing landscape. Arup has developed a modelling tool to accompany this guide to assess individual projects; whilst recognising that there is the potential for collaboration to improve upon this work.

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