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Heffron, Raphael J.; McCauley, Darren; de Rubens, Gerardo Zarazua

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Balancing the Energy Trilemma through the Energy Justice Metric

Raphael J Heffron, Darren McCauley and Gerardo Zarazua de Rubens

Raphael J. Heffron[1], Darren McCauley[2] and Gerardo Zarazua[3]

[1] Professor in Global Energy Law & Sustainability, Centre for Energy, Petroleum, Mineral Law and Policy, University of Dundee, UK
Email: r.heffron@dundee.ac.uk Tel: +44 78 6857 2784

[2]Senior Lecturer in Geography and Sustainable Development, University of St. Andrews, Fife, Scotland, UK
Email: dam7@st-andrews.ac.uk Tel: +44 01334 464014

[3] Gerardo Zarazua de Rubens, Researcher, Center for Energy Technologies, Department of Business Development and Technology, AU-Herning, Aarhus University, Birk Centerpark 15, DK-7400 Herning, Denmark
Email: gerardo.zarazua@btech.au.dk Tel: +4593508426

Corresponding Author: Raphael J. Heffron; r.heffron@qmul.ac.uk; Tel: +44 78 6857 2784

Abstract:

Energy justice is a fast emerging research and policy tool which captures the injustices across the energy life-cycle, i.e., from 'cradle-to-grave'. The Energy Justice Metric (EJM) quantifies energy justice through analyzing the energy justice performance of different countries utilising data from international institutions and national governments. This paper identifies why there is a need for a modeling tool such as the EJM which focuses on the full energy life-cycle and also has a distributive (inequality-correcting) oriented approach. The EJM demonstrates how a country can achieve an improved balance between the three competing aims of the energy trilemma, i.e. economics, politics and the environment. A key feature of the EJM is modeling energy justice using a ternary plot where the energy justice performance of a country can be transferred directly onto the energy trilemma. In this paper, five countries are analysed, the US, UK, Germany, Denmark and Ireland. The EJM presents a research and policy decision-making tool that can contribute to the growing literature that tackles the issue of inequality in society, and informs on society's decision on which energy source would be more just for a society to build.

Keywords: energy justice; energy trilemma; energy justice metric; distributive justice; energy economics; societal inequality

1: Introduction

Energy justice to-date has lacked engagement with economics. In the literature produced on energy justice there is a very limited amount that engages with the discipline of economics. [1] Currently, economists generally dominate policy formulation in modern society. This is of no surprise as economics provides insights into the trade-offs that societies face, and there is only a limited amount of finance available to governments to distribute to each policy problem. Nevertheless, in terms of policy formulation, society has become too influenced by economists and this applies in particular to the energy sector.

The call for justice in the energy sector has arisen primarily because of the poor management of the sector by policy-makers and economists, and including lawyers (who applied the policy through law). The primary focus of economists on economic growth, efficiency, competition and costs has not worked for the energy sector. While in the case of law, it is only in the last few years that the definition of energy law has expanded to include the issue of waste management.[2] Economists have however, led society down many wrong paths in terms of the energy sector, which has suffered many injustices (and these will be discussed later). Despite this, economists remain the primary influence in energy policy-making. In the UK for example, the Government have recently established a new committee to examine the true cost of energy.[3] And notably they have appointed an energy economist as head of this committee and the results will be interesting to follow. To gain perspective on the view of this latter economist, which typifies an economist's perspective on the energy sector, is that renewable energy support has only just increased electricity prices and reduced competition.[4]

It is precisely the limited perspective of economists that this paper seeks to address. It should be noted that trying to formulate energy policy is complex. The current clear conceptual example of this complexity is via the energy trilemma where there are the competing forces of the economics, environment, and politics.[5] There is no perfect solution but what society can aspire to is achieving a better balance between these three competing aims of energy policy. To-date society has focused more on economics to the detriment of in particular the environment. The energy justice metric (EJM) aims to highlight the relationship between the competing aims of the energy trilemma. It advances a method which can evaluate energy justice performance and hence provide analysis on how to better balance the competing aims of the energy trilemma. Further, the EJM highlights how energy justice can have a role as a decision-support tool for policy-makers as it challenges the current costs of different

[1] Heffron, R. J. & McCauley, D. 2017. *The concept of energy justice across the disciplines*. Energy Policy, 105, 658-667.
[2] Heffron, R. J. and Talus. K. 2016. *The Evolution of Energy Law and Energy Jurisprudence: Insights for Energy Analysts and Researchers*. Energy Research and Social Science, 19, 1-10.
[3] There are multiple reports of this, and for one of these, see: BBC. 2017. *Energy review examining household and environmental costs.* (6 August 2017). Available at: http://www.bbc.co.uk/news/uk-40839433 (last accessed August 2017).
[4] P. 3. Helm, D. 2017. *Burn Out: The Endgame for Fossil Fuels*. New Haven, US: Yale University Press.
[5] Heffron RJ, McCauley D and Sovacool BK. 2015. *Resolving Society's Energy Trilemma through the Energy Justice Metric*. Energy Policy, 87, 168-176.

energy sources and the energy transition (all while aiming to balance the competing aims of the energy trilemma).

It is important to remember the injustices the energy sector causes and the major contribution the sector makes to global inequality. The sector is mired by corruption, taxation issues, environmental damage, undocumented GHG emissions, finance issues, market competition distortions, influence of lobbyists and the powerful influence of multi-national companies. With all these problems it is evident as to why the energy sector leads to inequality and this is further supported by the fact that the energy sector is responsible for the majority of CO_2[6] emissions and research demonstrates that there is a link between the increase of CO_2 emissions and an increased level of inequality in society.[7]

In this paper, the next three sections provide a justification for why the development of the EJM model. Section two highlights EJMs role in the context of the energy transition, while section three then focuses on how it extends on existing energy economic modeling techniques. Section four builds upon the two previous sections and demonstrates how the EJM model aims to bring research in this area beyond a narrow focus on 'cost'. The following sections then introduce and interpret the EJM model. Section five explains what the EJM model is, i.e. the ternary plot, and also explains how the data was constructed and the limitations of the model. Section six presents the data graphically and numerically and provides an interpretation, before section seven concludes the paper. This paper makes three contributions to the literature. First, it contributes to the energy justice literature by being the first quantitative and qualitative model for assessing energy justice performance. Second, it contributes to the literature on energy policy research in general around how to address the energy trilemma and is one of the first to address this quantitatively. Third, it contributes to literature on economics and other social sciences that focuses on addressing societal inequality.

2: Why is Energy Justice important?

In a paper on energy justice, it needs to be stated why this topic is important. Society is changing due to the effects of the energy sector and, as it does, there is a need to ensure that justice becomes part of decision-making in the sector. For too long, profit, finance and economics has driven the energy sector, and many of the private companies involved have been referred to as 'robber barons'. The climate records that were broken in 2016 are evidence of the injustices resulting from the energy sector. For example, seven climate records were broken last year in 2016: melting of Arctic ice; consecutive hottest months; hottest day in India ever; highest temperature in Alaska; consecutive and biggest annual increase in CO_2; hottest Autumn in Australia ever; and highest amount of destruction in Australia's Great Barrier Reef ever.[8]

[6] Ekwurzel, B. *et al.* 2017. *The rise in global atmospheric CO2, surface temperature, and sea level from emissions traced to major carbon producers.* Climatic Change. 144. 579-590

[7] Chancel, L. and Piketty, T. 2015. *Carbon and inequality: from Kyoto to Paris*. Paris School of Economics (November 2015).

[8] The Guardian, 2016. *Seven climate records set so far in 2016*. (17 June 2016 – Adam Vaughan). Available at: https://www.theguardian.com/environment/2016/jun/17/seven-climate-records-set-so-far-

Today in an aim to reduce CO_2 emissions from society, many countries are going or are planning to go through an energy transition to a low-carbon economy.[9] This transition needs to be a just transition and that is where energy justice has a role. As stated in section one, the energy sector is full of injustices, and as society engages with the energy transition it needs to have 'justice' at the core of it. The energy sector for too long has had to experience and be characterized by injustices. For example, even now there exists far too much fossil fuels in the global energy system.[10] Clearly, at an international level, it should be acknowledged that the transition needs to happen and needs to happen at an accelerated pace, with recent scholarship noting it is not happening fast enough.[11]

It should be highlighted that transitioning away from fossil fuels in society is proving very difficult and in reality happening very slowly. For example, in 2016, of the UK's primary energy needs, fossil fuels provided 81.5%, down only half a percent from 2015.[12] Consider other examples from the UK in relation to investment in energy infrastructure and also foreign aid: in 2016, £18.6 billion (10.3% of total investment in the UK) was invested and of which 34% was in oil and gas extraction, 54% in electricity, 11% in gas, with the remaining in coal extraction, and coke & refined petroleum products industries.[13] Now while the amount of that investment in electricity is not calculated in more detail, considering the majority of the electricity sector in the UK is fossil fuels[14], one could make the assumption that the majority of this investment is similarly towards fossil fuels; though again further research is needed on this point. Nevertheless the picture is clear, the UK still heavily supports fossil fuel in terms of new investments. This is also aligned with UK foreign investment policy where through development aid, the UK supports by a ratio of nearly two to one, fossil fuel projects.[15]

To achieve the energy transition major investment is needed. To meet a 2°C future limit worldwide temperature rise, an estimated $208 billion in investment in low-carbon energy sources will be needed annually over the next 25 years.[16] It is when this

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in-2016 last accessed 30 October 2016. This is just a newspaper report connecting to the issue – however, there are many international reports.

[9] McCauley, D. 2017. *Energy Justice: Re-Balancing the Trilemma of Security, Poverty and Climate Change*. Basingstoke, UK: Palgrave.

[10] Figueres, C. *et al.* 2017. *Three Years to Safeguard our Climate*. Nature. 546 (7660) 593-595. (29 June 2017).

[11] *Ibid,* Figueres, C. *et al.* (2017).

[12] Carbon Brief. 2017. *Six charts show UK's progress on low-carbon energy slowing down*. (31 July 2017). Available at: https://www.carbonbrief.org/six-charts-show-uk-progress-on-low-carbon-energy-slowing-down (last accessed August 2017).

[13] Department of Business, Energy & Industrial Strategy (BIES)/United Kingdom Statistics Authority (UKSA). 2017. *UK Energy in Brief 2017*. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/631146/UK_Energy_in_Brief_2017.pdf (last accessed August 2017).

[14] *Ibid*, BIES/UKSA (2017).

[15] CAFOD. 2017. *UK Support for Energy in Developing Co*untries. Available at: https://cafod.org.uk/content/download/27353/269740/version/2/file/Policy%20briefing%20UK%20Support%20for%20Energy%20in%20Developing%20Countries%20Oct%202015.pdf (last accessed August 2017).

[16] Bloomberg New Energy Finance. 2016. *Mapping the Gap: The Road from Paris (Finance Paths to a Two-Degree Future)*. Available at: http://about.bnef.com/white-papers/mapping-the-gap-the-road-from-paris/ (last accessed June 2016).

investment is made, that energy justice needs to be a consideration in the policy-making process. Improved justice as the energy transition is happening can aid in reducing inequality in modern society. Inequality in society is increasing worldwide, and it represents one of the major research challenges in present day research scholarship (across many disciplines). That inequality is increasing in society is a clear example of policy failure and energy justice scholarship can contribute to finding solutions and there it is clearly important as the energy transition builds momentum.

3: Economics of Energy Sector & Energy Justice

The energy sector is responsible for a litany of injustices across the world and this is the case whether a country is considered a developed or developing country. Indeed, developed countries have not been very successful in managing their energy sectors successfully when considering they continue to produce CO_2 at record levels. For more than several decades neo-classical economics has dominated societies policy formulation and energy policy has been no exception. Indeed, despite even the financial crisis of 2007-2009 there has been little change.[17]

A feature of the development of neo-classical economic thinking has been 'secrecy' in its development. It is well documented that Friedrick von Hayek and many other leading economists (many were future Nobel Prize winning economists and von Hayek was a Nobel Prize winner) used to meet in an invitation only club called the Mont Perlerin Society.[18] Indeed, Karl Popper, the renowned philosopher was invited to the society's meetings and had his calls for openness rejected.[19] The energy sector which has adopted neo-classical economics is mired by similar examples of secrecy. Some of this lack of transparency is being reformed through initiatives such as the Extractive Industries Transparency Initiative (EITI) however, that is only limited action overall.

The prevalence of neo-classical economic thinking still reigns in the energy sector. There are two major examples of this which are detailed below, and the first is the issue of energy policy failure and the second the issue of energy subsidies. The focus on these two issues is because they are noted gaps in the literature on energy justice and energy economics, and they reflect the desire for energy justice to be used as a policy tool.[20] The final issue discussed is also underexplored in the energy justice literature and that is how economics as a discipline is moving towards a key focus on inequality.

Energy Policy Failure

[17] Davies, H. 2010. *The Financial Crisis: Who is to Blame?* Cambridge, UK: Policy Press.
[18] Offer, A. and Soderberg, G. 2016. *The Nobel Factor: The Prize in Economics, Social Democracy, and The Market Turn.* NJ, US, Princeton University Press.
[19] Offer, A. and Soderberg, G. 2016. *The Nobel Factor: The Prize in Economics, Social Democracy, and The Market Turn.* NJ, US, Princeton University Press.
[20] Sovacool, BK and MH Dworkin. 2015. *Energy justice: Conceptual insights and practical applications*. Applied Energy, 142, 435-444.

The energy sector is littered with examples of policy failure. What is disappointing perhaps is the lack of belief in the potential of new policy. For example, a high profile energy economist recently stated that success in fracking in the US was not down to policy but to technology.[21] There is the clear alternate argument that success in fracking was down to policy failure. The fracking industry has been subject to light touch regulation and has been allowed ignore the environmental damage of energy production. An example of this is how the fracking industry in the US did not have to reveal what chemical they used in the process.[22] This sounds very familiar and is the way coal, oil and gas have dominated the energy sector for years.

There tends to be an overstatement of the influence of technology in the energy sector. Research demonstrates that it takes a long time before energy technology is commercially viable.[23] In addition, it would take longer for some forms of energy to be commercially viable if they were not favoured by a system which advocated economic growth, efficiency, competiveness and cost, i.e. such as neoclassical economics. The question should be asked that why there has been no revision of economic thinking in the energy sector when policy failures have continuously re-occurred. The answer is that neoclassical economics remains of significant influence in all areas of the economy despite its failures elsewhere and the energy sector is no different.[24]

Energy Subsidies

Economists are noted for researching trends and data in different sectors of the economy. It is therefore very confusing as to why some trends and data have been ignored in relation to the energy sector, and in particular around the issue of energy subsidies. In the energy economics community, there remains a fundamental issue as to what is the cost of different energy sources. As mentioned earlier, the fact that the UK Government has conducted several cost reviews into the cost of energy sources is commendable but also revealing in that it has not occurred before; indeed, it has been noted in the literature that there is a significant need for a new research agenda on energy subsidies.[25]

However, worrying, is that the economist in charge of this latter initiative views renewables only having developed due to subsidies.[26] This is disappointing considering the subsidies to fossil fuels globally accumulate to $5.3 trillion in 2015, equivalent to 6.5% of global GDP.[27] It should be noted that all energy sources receive subsidies, but fossil fuels receive the majority and this is also the case in the UK too

[21] Helm, D. 2017. *Burn Out: The Endgame for Fossil Fuels*. New Haven, US: Yale University Press.
[22] (1) Bamberger, M. and Oswald, R. 2014. *The Real Cost of Fracking*. Boston, US: Beacon Press. And (2) Zuckerman, G. 2013. *The Frackers*. London, UK: Penguin Books.
[23] Smil, V. 2017. *Energy and Civilization: A History*. MA, US: MIT.
[24] Heffron, R. J. & McCauley, D. 2017. *The concept of energy justice across the disciplines.* Energy Policy, 105, 658-667.
[25] Sovacool, BK. 2017. *Reviewing, Reforming, and Rethinking Global Energy Subsidies: Towards a Political Economy Research Agenda*. Ecological Economics 135, 150-163.
[26] P. 3. Helm, D. 2017. *Burn Out: The Endgame for Fossil Fuels*. New Haven, US: Yale University Press.
[27] Coady, D. et al. 2017. *How Large Are Global Fossil Fuel Subsidies?* World Development. 91, 11-27.

(as stated in Section 2). Further, across Europe there are many legal arbitration cases currently between Governments and investors in terms of the subsidy support they were guaranteed for producing renewable energy. The financial amounts that these cases concern are not as significant as the annual subsidies to fossil fuels in these countries (for example, in Spain and Italy). The question needs to be asked is why economists have ignored the data and trends on subsidies over the last 40-50 years, in? In this time economists have pushed for policies of privatization and market liberalization yet ignored the data from energy subsidies which contributes to a serious market distortion.

Study of Economics moves focus to addressing Inequality

The above two examples are just two in a long list of many that could have been stated about what gives rise to inequality in the energy sector. Indeed, there are debates on the rise of inequality in society due to neoclassical economics, issues in international taxation, and the longstanding failure in terms of energy waste management. There are other scholars in the area who note also the destructive influence of neoclassical economics in relation to climate change issues.[28]

The issue in terms of energy justice is that in policy formulation in the energy sector to-date, there has been a lack of 'justice' incorporated into policy. Debates such as whether a policy is fair and equitable have been missing, and this mirrors some of the influential economic literature that is moving towards addressing societal inequality through economics.[29] Further, debates on if a policy had characteristics of distribution, or procedural, or recognition justice have all but been absent. This is what energy justice brings to the policy-making process. It aims to promote the interests of individuals into the energy policy formulation process and in essence reduce the potential for injustices to occur because of 'policy capture' by certain interest groups. The EJM model in particular has a distributive justice characteristic to it. Distributive justice is the most important form of justice as procedural and recognition will differ in their effect owing to the distribution of economic resources. The EJM model aims to provide an economic analysis that is more focused on inequality in the energy sector than current economic analysis.

4: The Right to Choose which Energy Source

One of the aims of the Energy Justice Metric (EJM) is to provide a research and policy-tool that will enable researchers and policy-makers to make a choice on which energy source a society should choose. This aims to counter-balance the prevailing economic influenced view that this choice of which energy source society should use should be based on cost.

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[28] Elliot, B. 2014. *Natural Catastrophe Climate Change and Neoliberal Governance*. Edinburgh, UK: Edinburgh University Press.

[29] (1) Bookstaber, R. 2017. *The End of Theory. Financial Crises, the Failure of Economics, and the Sweep of Human Interaction*. Princeton University Press: NJ, US; (2) Piketty, T. 2015. *The Economics of Inequality* (translated by Goldhammer, A.). Belknap Press of Harvard University Press: MA, US; (3) Stiglitz, J. E. 2012. *The Price of Inequality*. Penguin Books: London, UK; and (4) Scheidel, W. 2017. *The Great Leveler*. Princeton University Press: NJ, US.

The UK in particular, highlights how an energy policy is focused on cost. This is in contradiction to its energy policy's main goal of developing a low-carbon economy or energy transition. A specific example of this issue is through the policy and law for capacity markets in the electricity sector across the EU. In the UK, the capacity market has been described as a 'weak link' in the UK energy transition[30] with the majority of capacity payments going to fossil fuels. Further, and somewhat contradictory to the UK energy transition policy initiatives is the recent view that emanated from the House of Lords Select Committee on Economic Affairs that capacity auctions should be technology neutral.[31] This technology neutral stance presents low-cost fossil fuels with a dominant position (which they are in already from the previous capacity auctions) due to their lower costs and does not align with the goal of an energy transition.

Similarly, it is evident how the rhetoric that surrounds the energy trilemma concept has moved to discussing low-cost solutions and energy-affordability.[32] All this points towards the continued used of low-cost fossil fuel energy sources.

To supplement this perspective economists have focused on utilising 'willingness to pay' methods for energy analysis, i.e. what are consumers willing to pay for different energy sources. This switches the narrative on to the individual, and does not reveal other issues such as the subsidies to different energy sources and previous costs of policy failures for fossil fuels. Further, it contradicts its own view of the how an individual acts, i.e. in self-interest. To apply willingness to pay' method is to expect the answer that the consumer will choose the lowest cost energy source, as this is in their own self-interest. Indeed, the prevalence of consumers having an open 'choice' has long been recognized as being too much a focus of economists who advocated the study of the science of choice.[33] The choice should be societies, and rather it should be in essence a social contract or indeed a science of contract (as espoused by Oliver Williamson).[34]

Finally, there is the influence of a variety of interest groups in society that need to ensure that the low-cost energy sources remain. These are the energy companies, and lobby groups[35] who make their living from exploiting energy resources. For example,

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[30] Energy Live News. 2017. *Capacity Market 'weak link in UK's energy transition* (13 March 2017). Available at: http://www.energylivenews.com/2017/03/13/capacity-market-weak-link-in-uks-energy-transition/ (last accessed August 2017).

[31] House of Lords. 2017. *The Price of Power: Reforming the Electricity Market*. Available at: https://publications.parliament.uk/pa/ld201617/ldselect/ldeconaf/113/113.pdf. (last accessed August 2017). The government response to this does not provide further clarity, see: BEIS. 2017. *Government Response to the Economic Affairs Committee's Inquiry into the Economics if UK Energy Policy*. Available at: http://www.parliament.uk/documents/lords-committees/economic-affairs/The-Economics-of-UK-Energy-Policy/Government-response-Energy-Market-Report.pdf (last accessed August 2017).

[32] Heffron, R. J. & McCauley, D. 2017. *The concept of energy justice across the disciplines.* Energy Policy, 105, 658-667.

[33] Buchanan, J. M. 1975. *A Contractarian Paradigm for Applying Economic Theory. American Economic Review*. 65, 225–30: quoted in Williamson, O. E. 2002. *The Theory of the Firm as Governance Structure: From Choice to Contract*. Journal of Economic Perspectives. 16 (3), 171–195.

[34] Williamson, O. E. 2002. *The Theory of the Firm as Governance Structure: From Choice to Contract*. Journal of Economic Perspectives. 16 (3), 171–195.

[35] Cave, T. and Rowell, A. 2014. *A Quiet Word: Lobbying, Crony Capitalism And Broken Politics in Britain*. London, UK: Vintage Books.

only 90 companies globally are responsible for circa 66% of the world's CO_2 emissions.[36] It is clear that these companies have clear power in society given the evidence that air pollution increases mortality, morbidity and shortens life expectancy in particular in low- and medium-income countries where it is one of leading causes of such increases.[37] It is a key interest of these companies to ensure that low-cost energy sources remain in the system.

There is also the well-documented problem of stranded assets.[38] The valuation of these companies is critically dependent upon these reserves. In addition, the scale of overstatement is probably bigger than realized as evidenced by the recent issue that was highlighted by the fine received by KPMG in the US. This case involved KPMG been fined $6.2 million due to auditing a company who estimated their oil reserves *circa* 100 times their value; the problem was that this company had only bought these assets for $5 million and just two years later estimated them at $480 million.[39]

Energy justice by advancing information that can inform society about which energy source to choose can reduce the current economics-driven view of choosing the low-cost energy solution or the willingness-to-pay method. Energy justice can provide a more robust and broader solution as to why society should choose different energy sources and the next section covers in detail how the EJM contributes to this paradigm shift in thinking.

5: Energy Justice Metric Methodology

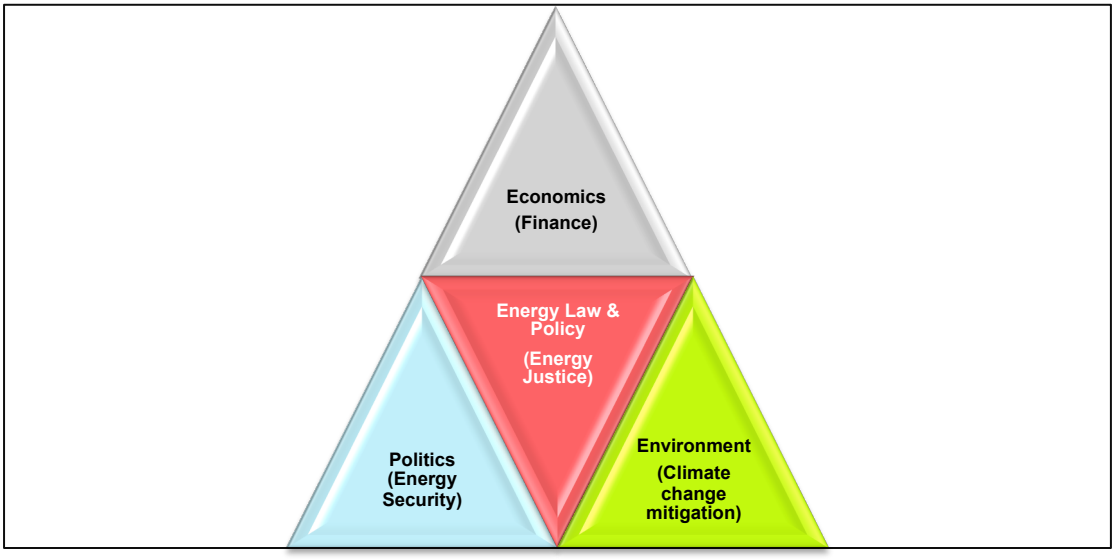
A principle aim of the Energy Justice Metric (EJM) is to provide a quantitative measurement for energy justice and to allow for comparison across countries and in the future for different energy-generating technologies (i.e. to identify their energy justice performance). It is similar in motivation to the earlier research highlighted on energy subsidies which is to have a more complete analysis and not have an overly 'narrow' focus on the research area.[40] This paper builds on earlier research on the EJM which demonstrated the model in action.[41]

The EJM's principle aim is to balance the energy trilemma. There are many variations to what the trilemma entails but they all have the same problems at its core – those emanating from economics, politics and the environment. The energy trilemma is visualized as a triangle and it is advanced here as emanating from the energy law and

[36] Heede, R. 2014. *Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers 1854–2010*. Clim. Change 122, 229–241.
[37] Cohen, J. A., Brauer, M. *et al*. 2017. *Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015*. Lancet. 389, 1907-18.
[38] Caldecott, B. *et al.* (2016). *Stranded Assets and Thermal Coal: An analysis of environment-related risk exposure*. Available at: http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/satc.pdf (last accessed March 2016).
[39] Financial Times. 2017. *KPMG slapped with $6.2m fine over oil company audit errors*. (15 August 2017). Available at: https://www.ft.com/content/0f0393de-81d9-11e7-a4ce-15b2513cb3ff (last accessed August 2017).
[40] Coady, D. et al. 2017. *How Large Are Global Fossil Fuel Subsidies?* World Development. 91, 11-27.
[41] Heffron RJ, McCauley D and Sovacool BK. 2015. Resolving Society's Energy Trilemma through the Energy Justice Metric', *Energy Policy*, 87, 168-176.

policy triangle - this is illustrated simplistically below in Figure 1. A key feature of the EJM is that modeling energy justice using a ternary plot, the energy justice performance of a country can be mapped directly on to the energy trilemma figure below.

Figure 1: The 'Energy Trilemma'



Explanation: Energy law and policy is in the centre of the triangle and on the three points of the triangle are economics (finance), politics (energy security) and environment (climate change mitigation). These three issues are each trying to pull energy law and policy in their direction. In essence, effective and efficient energy law and policy will balance these three aims to deliver the best outcome to society. However, if one examines energy law and policy in more detail, often it is just one of these issues that dominates the energy agenda. And the driver behind energy law and policy is energy justice.

It is worth noting that economics, politics and the environment are competing aims of the energy trilemma and these three issues include the following issues:

- Economics – finance, efficiency, low-cost, competition;
- Politics – energy security, national politics; and
- Environment - climate change mitigation, reducing CO_2 emissions, environmental health.

Source: Adapted from - Heffron, R. J. 2015. *Energy Law: An Introduction*. Heidelberg, Germany: Springer.

It is proposed here that the solution to balancing the Energy Trilemma is through 'Energy Justice'. Significantly, the World Energy Council (WEC), who were one of the first institutions to use the words 'energy trilemma', produced a recent report stating they are in search of how to 'balance' the energy trilemma.[42] Energy justice can achieve a just and equitable balance between the three dimensions of the Energy Trilemma. It is significant that it is a just and equitable balance and not simply an efficient balance that is the aim of energy justice. This represents a move away from solely having economic thinking drive policy aims. Further, it should be noted that the EJM moves beyond the narrow WEC's energy trilemma index, which places

[42] World Energy Council, 2015. *Priority actions on climate change and how to balance the trilemma*. World Energy Council: London, UK. Available at: https://www.worldenergy.org/publications/2015/world-energy-trilemma-2015-priority-actions-on-climate-change-and-how-to-balance-the-trilemma/ (last accessed 27 January 2017).

'affordability' under the economics banner, according to one of the critiques of the WEC approach.[43]

Energy justice is a conceptual framework, that seeks to identify when and where injustices in the energy sector occur and how best law and policy can respond to them.[44] It calls on academics and practitioners to critically evaluate the implications of energy policies. Energy justice begins with questioning the ways in which benefits and ills are distributed, remediated and victims are recognized.[45] The advantage of energy justice is that is a concept that is interdisciplinary and researchers across the disciplines are working on this issue. Energy justice as a policy tool can deliver more direct and long-term change. This is because as well as having distributive, procedural and recognition justice at its core, it is also guided by cosmopolitan and restorative justice.[46] It aims for the application of these forms of justice through the energy life-cycle in order to deliver human rights at each stage of the energy life-cycle across the world.

Modeling the Energy Justice Metric

This paper quantitatively analyses energy justice through the calculation and modeling of an EJM. The EJM can influence what new energy infrastructure is built and consequently may mean that society makes more informed decisions on which energy infrastructure projects to build, i.e. projects that satisfy criteria that allocate and distribute the full costs and benefits in a *just and equitable* method for current and future generations.

The aim of the EJM is to feed directly into economists' models and deliver a concept which has a value that can be calculated and costed, so as the consequence of its application can be more easily understood by the public. In the calculation of the energy justice metric it can produce three results: first an individual country energy justice metric; second, an energy justice metric for environment, economics and politics; and third, it maps the results on to the ternary plot which which represents the energy trilemma figure (see Figure 1 earlier and Figure 2 below).

This paper provides the energy justice performance for five countries: the United States, the United Kingdom, Germany, Denmark and Ireland. The principle aim is to show the energy just performance in the EU and this is why two large EU countries and two small EU countries are chosen. This provides a good comparator given that

[43] Heffron, R. J. & McCauley, D. 2017. *The concept of energy justice across the disciplines.* Energy Policy, 105, 658-667.

[44] (1) McCauley, D., Heffron, R. J. Stephan, H. and Jenkins, K. 2013. *Advancing Energy Justice: The triumvirate of tenets.* International Energy Law Review, 32 (3), 107-110; 33; (2) Heffron, R. J. and McCauley, D. 2014. *Achieving Sustainable Supply Chains through Energy Justice*, Applied Energy, 123, 435-437; (3) Sovacool, BK and MH Dworkin. 2015. *Energy justice: Conceptual insights and practical applications*. Applied Energy, 142, 435-444; (4) Sovacool, B, Heffron, R. J., McCauley, D & Goldthau, A. 2016. *Energy decisions reframed as justice and ethical concerns*. Nature Energy, doi: 10.1038/nenergy.2016.24; and (5) Heffron, R. J. & McCauley, D. 2017. *The concept of energy justice across the disciplines.* Energy Policy, 105, 658-667.

[45] McCauley, D., Heffron, R. J. Stephan, H. and Jenkins, K. 2013. *Advancing Energy Justice: The triumvirate of tenets*. International Energy Law Review, 32 (3), 107-110.

[46] Heffron, R. J. & McCauley, D. 2017. *The concept of energy justice across the disciplines.* Energy Policy, 105, 658-667.

many other EU countries can identify with the large or small EU country. The secondary aim is then to show how these countries perform in relation to the US as a worldwide performance indicator. Future work in the area will include the examination of countries in the Asia, Africa and the rest of the Americas.

The parameters of the Energy Justice Metric (EJM) are listed below in Table 1 below. Data on all these parameters is available for many countries and energy sources. It is also proposed here that all costs not be discounted into the future so that future generations are treated as ethical equivalents to contemporary ones.[47] The framework for the parameters is from the Energy Trilemma that has at its core economics, politics and the environment; these are the three categories from which the parameters will be derived.

Table 1: The Parameters of the Energy Justice Metric

	Parameters of the Energy Justice Metric
Economics	• Cost-Benefit Analysis for New Energy Infrastructure (X1) • Cost of Subsidies for Energy Source Extraction, Development and Operation (X2) • Cost of Energy to Disposable Income Ratio (X3) • Benefit from Employment Creation in the Short to Long-term for Energy infrastructure Development (X4)
Politics	• Cost of Fluctuation and Instability in Energy Supplies (Y1) • Cost (Benefit) of Import/Export of Energy Supplies (Y2)
Environment	• Cost (Benefit) to (from) Public Health Service from Energy Sources (Z1) • Cost of the effect of Environmental Pollutants from Energy Sources (Z2) • Cost of CO_2 Tax (Z3) • Cost of Accidents (in. Fatal Accidents) to Workforce and Public (Z4) • Cost of Loss of Amenity to Local Communities Direct and Indirect from Energy Sources (Z5)

Data Construction

Data on these nine parameters (see Table 1 above) was collected for these five countries and was collected in 2015 and 2016. The data for the nine parameters was gathered from multiple sources including mainly: the World Energy Council, national government regulators, ACER, Eurostat, IMF, World Bank, the US Energy Information Administration, US Department of Energy, and national health and labour authorities. The data was then aggregated and given weighted adjustments according to the energy justice concept itself (see Table A1 in the Appendix). Where there was limited data a scaling system is then used between 1 to 10 for the performance of each country on each parameter. All the results then are then averaged for the classification under economics (E), politics (P) and environment (EN) before being converted to percentages for generating the Ternary plot, and all against an

[47] This is supported by Parfit, 1983; Barry, 1983; and Weston, 2008: (1) Parfit, D. 1983. *Energy Policy and the Further Future: The Social Discount Rate. Energy and the Future*. Totowa, US: Rowman and Littlefield. pp. 31-37; (2) Barry, B. *Intergenerational Justice in Energy Policy*. In Douglas MacLean and Peter G. Brown (1983) (Eds.) *Energy and the Future* (Totowa, New Jersey, US: Rowman and Littlefield, 1983), pp. 15-30; and (3) Weston, B. H. 2008. *Climate Change and Intergenerational Justice: Foundational Reflections*. Vermont Journal of Environmental Law, 9, 375-430.

'ideal' energy justice performance, based on the 'ideal' as determined by the authors – see Appendix A and Figure 2 below.

Limitations of the EJM Metric

There are limitations in the EJM and these mainly relate to two issues, the data gathering process and the representation of the ideal. These two limitations will be improved as the model develops and aims to capture additional issues of energy justice. In terms of the data gathering process, it is difficult due to not all countries having the same data available from the same sources and this will especially be an issue if exploring the EJM for developing countries. Also, the results of the EJM, are representative of the particular period of data collected, and with an ever-evolving energy sector they are subject to modifications in policy, technology or market development. Then, in terms of the representation of the 'ideal', this is an issue as it is based on the authors' own assumptions of what the 'ideal' energy justice performance of a country should be. While to some degree, modeling different scenarios will always have some element of relying on the author's assumptions, in the future the reliability of the model can be improved. The latter can be achieved in basing the 'ideal' on a survey of respondents.

6: The Energy Justice Metric for the United States, the United Kingdom, Germany, Denmark and Ireland.

The Energy Justice Metric is modeled using the Ternary plot, which is represented graphically on the Ternary Phase Diagram (which corresponds to same diagram of the energy trilemma). This allows for the plotting of the EJM graphically so that comparisons can be made between the energy justice performance of countries, and in this case five countries, the United States, the United Kingdom, Germany, Denmark and Ireland. The same method was used in the earlier paper on EJM.[48]

The Ternary plot is generally used in physical chemistry to describe the interaction between three different forms of matter, a gas, a liquid and a solid. This interaction is then plotted on an equilateral triangle known as a ternary phase diagram. This makes it ideal for analyzing the energy trilemma which is also aiming to describe the interaction between three diverse issues, in economics, politics and the environment. The use of the ternary phase diagram has also been applied to social sciences[49] and, on occasion, in economics[50] where it has been used to plot the components of GDP of different countries, and in game theory.

The advantage of using the Ternary Plot is that it allows for direct comparison with the Energy Trilemma. Data for each parameter can first be inputted in under the three classifications of economics, politics and the environment. The Ternary Plot is a form of 3-D plot but is represented with the Ternary Phase Diagram in 2-D format in print.

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[48] Heffron RJ, McCauley D and Sovacool BK. 2015. *Resolving Society's Energy Trilemma through the Energy Justice Metric*. Energy Policy, 87, 168-176.

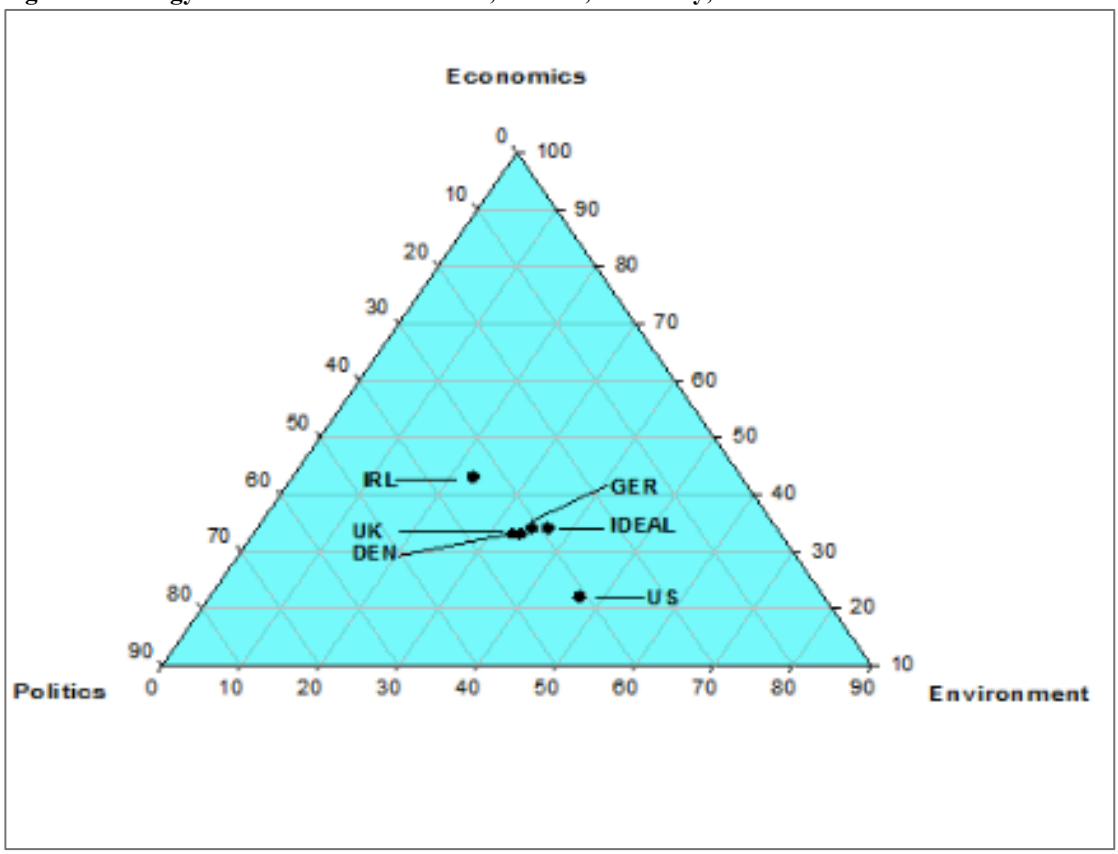
[49] Athanasios Angelis-Dimakis, George Arampatzis, and Dionysis Assimacopoulos, "Monitoring the Sustainability of the Greek Energy System," *Energy for Sustainable Development* 16 (2012).

[50] L. Barron, "A Comparison of Two Models of Ternary Excess Free Energy," *Contributions to Mineralogy & Petrology* 57, no. 1 (1976).

Interpreting the Ternary Plot

There are two approaches to reading and analyzing the Ternary Plot. The first is more straightforward and follows the dots located within the triangle that represent countries – see Figure 2 below (see Section 5 and Appendix A for data construction). There is one dot that has the name 'ideal' and this 'ideal' dot represents the point where all countries should be in terms of the application of energy justice at the moment and is the point where the energy trilemma is most balanced between the various factors within economics, politics and the environment.

Figure 2: Energy Justice Metric for the US, the UK, Germany, Ireland and Denmark.[51]



Then, the dots representing the other countries themselves are plotted in the ternary triangle where two outcomes are demonstrated. *First*, it is evident how far away countries are from the 'ideal' application of energy justice and consequently from 'balancing' the energy trilemma. *Second*, depending on the countries' location and their proximity to one or two of the three corners it will be visible as to which of economics, politics and the environment is the problem.

The data analysis outlined in Section Five is graphically represented above in Figure 2. It reveals that the UK, Germany and Denmark are very close to the ideal. However, Ireland and the US are far away and have a poor energy justice performance. The

[51] This is plotted out using the data collected and calculated as explained in the Appendix and using the software, SigmaPlot 11 (which is from Systat Software, Inc, Point Richmond, California, USA).

advantage of the utilising the Ternary Plot is that provides a graphical representation of the problem and can be presented to multiple stakeholders. The US above has problem with politics and environment, and economics is the clear driver. While Ireland is different having a problem in all three areas with it being far away from all three corners. The individual data supports then the graphical representation.

The second approach to reading and analyzing the Ternary Plot is to read the data directly as plotted. Since a Ternary Plot involves presenting data for a 3-D model into 2-D form the data is interpreted off the grid structure. Here the data can be represented as to how far from the 'ideal' these countries are in terms of an overall energy justice metric for each country, see Table 2. Then it is demonstrated in Table 3 in a more individual breakdown what the energy justice evaluation is for each of environment, economics and politics.

Table 2 – Energy Justice Metric Index for the US, the UK, Germany, Ireland and Denmark

Total	Ideal	US	UK	Ger	Ire	Den
	100	68	92	90	64	96

Table 3 - Energy Justice Metric Index for each of the 3 'parts' of the Trilemma for the US, the UK, Germany, Ireland and Denmark

Energy Trilemma Issue	Ideal	US	UK	Ger	Ire	Den
Economics	100	93	86	83	83	93
Politics	100	46	92	89	62	95
Environment	100	65	97	97	47	100

Interpretation of Results

The results in Table 2 and 3, provide the EJM for each country and for each of the three parts of the energy trilemma. In essence they demonstrate which country is more energy 'just' (based on the authors' perspective and subject to the limitations outlined in section 5). Under this premise, Denmark is the country with the more just energy sector, followed by the UK and Germany. This is perhaps no surprise as the country is known, along with its other Nordic neighbours, to have aggressive climate and sustainability policies.[52] Policies like the Danish Energy Agreement for 2012-2020 that aims to have at least 50% of power consumption from wind energy, have continuously propelled the country as an innovator in terms of wind power and residential district heating systems.[53,54] Denmark, also enjoys the benefits from being part of the Nordic power exchange market, Nordpool.[55] Further, Denmark is traditionally listed the top of social equality indicators, such as the OECD Better Life

[52] Sovacool, BK. *Contestation, contingency, and justice in the Nordic low-carbon energy transition*. Energy Policy 102 (March, 2017), 569-582.
[53] International Energy Agency. (2017). *Danish Energy Agreement for 2012-2020*. iea.org. https://www.iea.org/policiesandmeasures/pams/denmark/name-42441-en.php (retrieved on September 2017),
[54] IRENA. *Market Overview*. Denmark. https://irena.org/DocumentDownloads/Publications/GWEC_Denmark.pdf (retrieved on September 2017).
[55] Nordpool. *About us*. http://www.nordpoolspot.com/About-us/ (retrieved on September 2017).

Index, that accounts for life satisfaction, income equality and job security among others.[56]

In contrast, the lower EJM of the US can be traced to its traditional focus on fossil-intensive generating sources, for example, such as oil extraction in Texas or natural gas fracking in Arkansas, that often lead to injustices as mentioned in previous sections of this paper. These latter issues combined other sustainability- and social-related concerns from projects, for example, such as the Dakota Pipeline and its consequence for the native American cultural heritage, are increasingly leading to social inequality across the country.[57, 58, 59] Similarly, Ireland is a fossil fuel intensive country and has a lack of political leadership in a country that is over reliant on fossil fuel imports.[60]

Importantly, Table 3 disaggregates the energy justice scores into economic, political and environmental performances, which allows to see more specifically a country's prioritisation energy justice performance in relation to economic, environment and politics.. Here, the US and Denmark rank at the top in terms of the economic metric, which relates to the cost of energy infrastructure, considering technology-specific subsidies, as well as elements such as the cost of energy for consumption and social wealth generated. The differentiation between the United States and Germany can be related to the cost of electricity for residential and industrial users, because despite the former nation household power consumption is over 50% higher, the latter country has one of the highest prices internationally, as a result in part of the cost of its *energy transition.*[61,62] Moreover, the UK score is affected in part by the negative relationship household energy spending and disposable income. Despite the country experienced a reduction in residential energy demand resulted from the Energy Efficiency Obligations policy from 1994-2012 promoting measures such as, loft insulation and boiler efficiency, energy prices still increased at a higher rate during the period and disposable income fell around 6.7% from 2007-2012.[63, 64] Comparatively, in the US

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[56] OECD. *How's life*?. OECD Better Life Index. http://www.oecdbetterlifeindex.org/#/11111111111 (retrieved on September 2017).
[57] Ridlington, E. and Rumpler, J. (2013). *Fracking by the Numbers Key Impacts of Dirty Drilling*. Environment America. http://www.environmentamerica.org/sites/environment/files/reports/EA_FrackingNumbers_scrn.pdf (retrieved on September 2017).
[58] Levin, S. (2016). *Dakota Access pipeline: the who, what and why of the Standing Rock protests*. The Guardian. https://www.theguardian.com/us-news/2016/nov/03/north-dakota-access-oil-pipeline-protests-explainer (retrieved on September 2017).
[59] University of Stanford. (2011). *20 Facts About U.S. Inequality that Everyone Should Know*. Stanford Center on Poverty & Inequality. http://inequality.stanford.edu/publications/20-facts-about-us-inequality-everyone-should-know (retrieved on September 2017).
[60] Heffron, R. J. 2015. *Energy Law (in Ireland)*. Thomson Reuters (Roundhall): Dublin, Ireland.
[61] Thalman, E. and Wehrmann, B. (2017). *What German households pay for power*. Clean Energy Wire. https://www.cleanenergywire.org/factsheets/what-german-households-pay-power (retrieved on September 2017).
[62] Ovo Energy. *Average electricity prices around the world: $/kWh*. Ovo Energy. https://www.ovoenergy.com/guides/energy-guides/average-electricity-prices-kwh.html (retrieved on September 2017).
[63] Odysse-Mure. (2015). *Energy Efficiency trends and policies in the United Kingdom*. Odysse-mure. http://www.odyssee-mure.eu/publications/national-reports/energy-efficiency-united-kingdom.pdf (retrieved on September 2017).
[64] ONS. (2014). *Full Report: Household Energy Spending in the UK, 2002-2012*. Office for National Statistics.

energy expenditures in relation to household disposable income were reportedly lower than averages from 1960, however, this is also attributed to the improved efficiency in other aspects such as vehicle fuel and fuel source for heating.[65]

The political aspects of the EJM are influenced by the stability of energy supplies, related to its commercial balance and price sensibility. In this case the US and Ireland are comparatively low. Ireland has problems in that it imports the majority of its energy needs but also suffers from general instability due to political leadership. The latter has affected the US where political uncertainty due to the difficulty of President Obama been able to deliver of his energy policy goals in the latter years of his presidency. On the other hand, Denmark has a very high score due to its political stability for energy policy and also it being almost entirely energy self-sufficient.[66] The UK and Germany are perhaps surprisingly close to Denmark but this perhaps represents the importance placed on the energy sector by the respective governments and also the active role of government in the market to ensure there is more stability in energy prices.

Finally, the environmental aspect of the energy justice metric, comprises elements such as health and environmental damages from energy infrastructure in each of the countries. Here Denmark, Germany and the United Kingdom ranked significantly higher than the US and Ireland. This can be exemplified in part, from the governance structure and standard delivery of the European Union and its European Commission, where the community set climate targets for 2020, 2030 and 2050, as well as having directives for buildings and energy efficiency, transport, and other sustainability-related frameworks. In this regard, both Denmark and Germany have achieved major progress that is reflected in the national electricity mix with around 60% and 30% of renewable sources for Denmark and Germany, respectively.[67]

What is more, this element of the EJM is affected by a public health aspect, such as impacts of pollutants, cost to the health sector and even fatalities in which the US ranks comparatively worse than its counter parts. This can be explained in part by the size of the fossil generating industry in the countries, where in the US and UK reported accidents are significantly higher than the other researched nations. Interestingly, despite Germany showing progress in terms of renewable energy, the country also shows a high level of damages associated with air pollution, which is considered as the EU's most hazardous health danger, created from the coal and

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http://webarchive.nationalarchives.gov.uk/20160105200123/http://www.ons.gov.uk/ons/rel/household-income/expenditure-on-household-fuels/2002---2012/full-report--household-energy-spending-in-the-uk--2002--2012.html (retrieved on September 2017).

[65] EIA. (2014). *Today in Energy*. U.S. Energy Information Administration. http://www.eia.gov/todayinenergy/detail.cfm?id=18471# (retrieved on September 2017).

[66] Danish Energy Agency. 2016. *Danish Energy Statistics 2015: renewables now cover 56% of electricity consumption*. State of Green. https://stateofgreen.com/en/profiles/danish-energy-agency/news/danish-energy-statistics-2015-renewables-now-cover-56-of-electricity-consumption (retrieved on September 2017).

[67] ENTSO-E. (2015). *Statistical Factsheet 2015*. European Network of Transmission System Operators for Electricity. https://www.entsoe.eu/Documents/Publications/Statistics/Factsheet/entsoe_sfs2015_web.pdf (retrieved on September 2017).

biomass burning industries; and the latter are still predominant generating sources of the German power mix. [68, 69, 70]

Therefore the energy justice metric allows to quantify the levels of justice of a particular energy technology or a combination of these, allowing for better analysis and decision-making when looking to implement energy-related policy. The metric and results show the clear link between the selected energy infrastructure mix per country, and the perceived consequences of them, as it is shown with the example of the German issue with air pollution in connection with its over 40% of coal-based generation mix. Additionally, the EJM allows to see the country's prioritisation with regards to energy-related policies, showing the economic-centred focus, as with the US, compared to a more wholly-inclusive approach with the environment as it is seen in the Danish context. Ultimately, the framework allows for analysis of the current and previous energy justice performance of a country, as well as the forward-looking scenarios. Indeed, the 'ideal' could be set lower to match the country's goal in terms of the energy transition but that remains research for the future as more data is inputted into the model.

7: Conclusion & Future Outlook

The energy sector is a key driver of the modern economy. In most reports it accounts for near circa 10% of global GDP and is similar to health expenditure in that context as one of two of the most important sectors to the international economy. It has been and remains a sector of the economy that causes many injustices, and that is why new research and policy tools need to be advanced. Energy justice is a fast emerging research and policy tool which captures the injustices across the energy life-cycle, i.e., from 'cradle-to-grave'. The EJM quantifies the energy justice performance of different countries. It achieves this by aiming to balance the three competing aims of the energy trilemma, i.e. economics, politics and the environment (as in Figure 1 earlier).

As stated earlier, the paper has three primary contributions to the literature. The first, is its contribution to energy justice literature through the EJM, a quantitative and qualitative model for assessing energy justice performance; and aims to build on the previous interdisciplinary literature in the area.[71] Second, it contributes to the literature on energy policy research in general around how to address the energy trilemma and is one of the first to address this quantitatively. Third, it contributes to literature on economics and other social sciences that focuses on addressing societal inequality.

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[68] DW. (2016). *Air pollution is 'top health hazard in Europe.* Deutsche Welle. http://www.dw.com/en/air-pollution-is-top-health-hazard-in-europe/a-36489555 (retrieved on September 2017).
[69] Ibid. ENTSO-E. (2015).
[70] DW. (2017). *EU Commission warns Germany for air pollution breaches*. Deutsche Welle. http://www.dw.com/en/eu-commision-warns-germany-for-air-pollution-breaches/a-37563911 (retrieved on September 2017)
[71] Sovacool, BK and MH Dworkin. 2015. *Energy justice: Conceptual insights and practical applications*. Applied Energy, 142, 435-444; Heffron, R. J. and McCauley, D. 2014. *Achieving Sustainable Supply Chains through Energy Justice*, Applied Energy, 123, 435-437.

In this paper, the focus of the first half of the paper is on the limitations of current energy sector analysis which is dominated by primarily economists. Analytical tools such as energy justice can provide society (including policy-makers, regulators, jurists, and think-tanks) with a decision-making tool that gives a more accurate analysis from which to make decisions.[72] It achieves this by capturing issues across the energy life-cycle and also having a focus on redistribution of economic benefits of the sector (i.e. reducing the inequalities in the energy sector. In section two the importance of energy justice was examined and its role in the energy transition explored and highlighted in relation to the new energy infrastructure needed to ensure there is an energy transition. Section three then delved into the relationship between the economics of the energy sector and energy justice, and examined why the issue of 'justice' has received limited attention in energy economics scholarship to-date. Section four built upon both the previous sections and analysed how the choice given to society concerning which energy infrastructure it should build is flawed and how a research and policy tool such as the energy justice and the EJM can inform the decision-making process.

The EJM is the centre point of this paper and advances earlier research on this energy-modeling tool.[73] The description of the EJM model and data construction is presented in section five with the results in section six. In this paper the an EJM was modeled on a ternary plot, graphically represented on the energy trilemma, for the following countries, the US, the UK, Germany, Ireland and Denmark. Importantly, the EJM can reveal where injustices occur and whether they are in the domain of economics, politics and/or the environment. The EJM demonstrated that there is a high level of energy justice in the UK, Germany and Denmark, while both Ireland and the US are in need of significant improvement.

The EJM presents as a research and policy decision-making tool that can contribute to the growing literature that tackles the issue of inequality in society. Energy justice is based around three forms of justice, distributive, procedural and recognition. The EJM is aiming to provide an economic model that has a 'distributive' focus and follows the current economic literature that focuses on inequality.[74] As mentioned earlier, with the energy sector accounting for near 10% of worldwide GDP, correcting the injustices in the energy sector can impact upon current societal inequality. The EJM captures the energy sector as it moves throughout the energy life-cycle, whereas traditional energy economic tools have focused more narrowly on one particular stage of the energy life-cycle. In re-addressing this narrow focus of previous economic modeling, the EJM aims to restore equality in eventual outcomes in the energy sector.

In future, the EJM model can also include analysis on less-developing countries and how these countries compare between themselves and with developed countries on

[72] Sovacool, B. K. and Dworkin, M. H. 2014. Global Energy Justice: Problems, Principles, and Practices. Cambridge, UK: Cambridge University Press.
[73] Heffron RJ, McCauley D and Sovacool BK. 2015. Resolving Society's Energy Trilemma through the Energy Justice Metric. *Energy Policy*, 87, 168-176.
[74] Dorling, D. 2015. *Injustice: Why Social Inequality Still Persists*. Bristol, UK: Policy Press; (2) Atkinson, A. B. 2015. *Inequality: What can be done?* MA, US: Harvard University Press; (3) Piketty, T. 2015. *The Economics of Inequality* (translated by Goldhammer, A.). Belknap Press of Harvard University Press: MA, US; and (4) Stiglitz, J. E. 2012. *The Price of Inequality*. Penguin Books: London, UK.

their energy justice performance; there is work in this area already started by the National Resource Governance Institute which focuses solely on the extractive industries and use both qualitative and quantitative data.[75] Another feature of the EJM that will be explored in future is how it illuminates multi-national company behaviour. The EJM achieves this by its focus on new infrastructure development, and it will provide a challenge to existing theory on firm behaviour and corporate finance.[76] For example, it should provide for the energy sector an answer as to how an energy regulatory body and/or government energy department can ensure that both society (through Government action) and energy companies can both benefit from the energy sector in the future as the ongoing move to low-carbon economies continues. And finally, there may be merit then in the future of exploring supplementing the EJM with a series of questions, or an additional questionnaire of different stakeholders in the energy sector; or as has been identified as an 'energy justice checklist'.[77]

Appendix A

Table 1A - Comparison Scale

1	2	3	4	5	6	7	8	9	10
A. Poor Policy Initiatives and Law B. Poor Performance on Trilemma Issue		A. Mediocre, problematic, static and (maybe) dis-improving Policy Initiatives and Law B. Mediocre, problematic static and (maybe) dis-improving Performance on Trilemma Issue			A. Moderate and Improving Policy Initiatives and Law B. Moderate and Improving Performance on Trilemma Issue			A. Excellent Policy Initiatives and Law B. Excellent Performance on Trilemma Issue	

Table 2A: Statistical Steps and Equations for Calculating the EJM for plotting on the Ternary Diagram

Step 1: calculation of parameter values (Data aggregated from for the nine parameters was gathered from multiple sources including mainly: the World Energy Council, national government regulators, ACER, Eurostat, IMF, World Bank, the US Energy Information Administration, US Department of Energy, and health and labour authorities.)

[75] Natural Resource Governance Institute. 2017. 2017 Resource Governance Index. Available at: https://resourcegovernance.org/analysis-tools/publications/2017-resource-governance-index (last accessed 26 February 2018).

[76] For example such as Jean Tirole's work in this area: Tirole, J. 2006. *The Theory of Corporate Finance.* NJ, US: Princeton University Press.

[77] Sovacool, B.K., Sidortsov, R. and Jones, B. 2014. Energy Security, Equality, and Justice. London, UK: Routledge.

X1 + X2 + X3 + X4 = ΣX/4 = E (Economics)
Y1 + Y2 = ΣY/2 = P (Politics)
Z1 + Z2 + Z3 + Z4 + Z5 = ΣZ/5 = EN (Environment)

Step 2: normalization of the parameters by conversion to percentages
ETP (Economics Ternary Plot Point) = [E/(ΣE+P+EN)] x 100
PTP (Politics Ternary Plot Point) = [P/(ΣE+P+EN)] x 100
ENTP (Environment Ternary Plot Point) = [EN/(ΣE+P+EN)] x 100

Step 3: plotting the normalized data
Involves inserting the data in SigmaPlot Version 11* software package by clicking on the ternary plot icon in the graph gallery; the coordinates may be read from the lines parallel to the sides of the equilateral triangle opposite the vertices for E, P and EN, respectively.

Step 4: EJM for each country
The plotted points show the Energy Justice Metric (EJM) for each country. Steps 1 and 3 are repeated for each individual country.

*SigmaPlot 11 is from Systat Software, Inc, Point Richmond, California, USA.

Table 3A - EJM – Parameter Data Inserted and Statistical Step 1 Performed

Energy Trilemma Issue	Ideal	US	UK	Ger	Ire	Den
Economics ΣX/4 % of Σ(E+P+EN)	7 29	6 31	5.25 33	6.25 34	4.5 34	7.25 31
Politics ΣY/2 % of Σ(E+P+EN)	9 37	9 47	5.5 34	6 33	3 23	8 35
Environment ΣZ/5 % of Σ(E+P+EN)	8.2 34	4.2 22	5.4 33	6.2 34	5.6 43	7.8 34

Table 4A - EJM – Parameter Data – Statistical Step 2
Energy Justice Metric Index for each of the 3 'parts' of the Trilemma

Energy Trilemma Issue	Ideal	US	UK	Ger	Ire	Den
Economics ΣX/4 % of Σ(E+P+EN)	29 100	31 93	33 86	34 83	34 83	31 93
Politics ΣY/2 % of Σ(E+P+EN)	37 100	47 46	34 92	33 89	23 62	35 95
Environment ΣZ/5 % of Σ(E+P+EN)	34 100	22 65	33 97	34 97	43 47	34 100

Table 5A – Energy Justice Metric Index for each Country – (Statistical Step 4)

Total	Ideal	US	UK	Ger	Ire	Den
	100	68	92	90	64	96