Is Natural Gas "Essential for Ireland's Future Energy Security"?

A Critical Response to the Irish Academy of Engineering

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"Pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems (high confidence). ***These systems transitions are unprecedented in terms of scale****, but not necessarily in terms of speed,* ***and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options*** *(medium confidence)..."*

— IPCC Special Report on Global Warming of 1.5 °C, October 2018 (IPCC 2018 Headline Statement C.2, emphasis added)

"The findings of the IPCC highlight that ***only the most ambitious action possible will mitigate the adverse effects of climate change on human health and welfare*** *and that the time left to act is extremely limited.* ***While neither the 1.5°C or well below 2°C targets of the Paris Agreement are wholly consistent with the human rights obligations of States*** *acting together in accordance with the duty of international cooperation, to protect human rights from the adverse effects of climate change,* ***they do represent a ceiling that States have agreed should not be exceeded.****"*

— Statement by the UN Special Rapporteur on Human Rights and Environment, October 2018 (Boyd 2018, emphasis added)

Executive Summary

It is widely recognised that the current Irish energy system carries a significant security-of-supply risk, due to heavy reliance on natural gas, with very constrained diversity and capacity of import supply routes. This risk *may* become even more severe in the years immediately ahead as the only significant indigenous natural gas source (the Corrib gas field) is depleted and the other (even higher carbon intensity) fossil energy sources (coal, oil and peat) are progressively removed from the Irish energy mix. In July 2018, the Irish Academy of Engineering (IAE) published a major report assessing this evolving natural gas security-of-supply risk, entitled "Natural Gas — Essential for Ireland's Future Energy Security" (IAE 2018). The report argued that substantial continued reliance on natural gas in the overall Irish energy system is unavoidable up to at least 2040. On this basis, it recommended a number of major strategic interventions designed to manage the consequently deepening security-of-supply risk, i.e., measures attempting to assure continued access to natural gas.

In this response to that report[1], we present an independent peer evaluation of the basis for these recommendations. We base our analysis on the presumption that Ireland is committed to good faith action consistent with its ratification of the Paris Climate Agreement (UNFCCC 2015): specifically to play its equitable and commensurate part in holding the increase in the global average temperature to *well below* 2°C above pre-industrial levels and *pursuing efforts* to limit the temperature increase to 1.5°C. We assume the IAE shares this premise.

On this basis we find that the IAE analysis is mistaken both in its assessment of the required speed of decarbonisation of the Irish energy system (and therefore the need to rapidly phase out all fossil fuel emissions, *including* from natural gas), and in its discounting of the technical and economic feasibility of such rapid decarbonisation. On the contrary, given Ireland's large natural resource of variable renewable energy (especially wind), and coupling this with the use of synthetic chemical fuels ("electrofuels") for very large scale energy storage, we find that rapid fossil fuel phase out is not only technically feasible, but can progressively *eliminate* the security-of-supply risks associated with all imported fossil fuels, while *simultaneously* decarbonising with the scale and urgency demanded by good faith participation in the Paris agreement — subject, of course, to securing the comprehensive societal support necessary to enable this transformation.

While the electrofuel storage element of this pathway is challenging in terms of technology maturity and immediate investment cost, this is true of *all* decarbonsation pathways that might credibly be commensurate with meeting the Paris climate goals; but this pathway has the unique advantages of high confidence in the effectiveness of decarbonisation and relatively rapid achievement of very high national energy security. Such a rapid fossil fuel phase out would additionally bring very significant co-benefits in balance of payments and overall national social and economic resilience. These findings also decisively contradict the IAE suggestion that continued exploration for indigenous fossil fuels is in the national interest of Ireland.

[1] This response was commissioned as an expert peer review on behalf of Stop Climate Chaos (SCC), a coalition of Irish civil society organizations campaigning for effective climate action. The authors conducted the review independently and on a *pro bono* basis. All material affiliations of individual authors are disclosed in the author information at the end of the document. The content and findings of this review remain the sole responsibility of the authors.

Key Findings

- The IAE report severely underestimates the rate at which CO_2 emissions from the Irish energy system must now be eliminated — *assuming* good faith action on the basis of the Paris Climate Agreement. This fundamentally undermines the analysis presented.
- We *agree* fully with the IAE that reliance on imported natural gas already raises very serious security-of-supply concerns for the Irish energy system.
- However: any energy policy involving the displacement of other fossil fuels specifically in favour of natural gas, even on a "transitional" basis (a so-called "natural gas bridge"), as suggested by the IAE, would greatly *escalate* that security-of-supply risk while simultaneously *failing* to achieve the required speed of decarbonisation of the Irish energy system. This arises from relying — by design — on a single, high carbon, fuel (natural gas) for critical stability and inter-seasonal balancing of the electricity system, while tacitly assuming progressive electrification of significant proportions of current transport and heating energy demand. Given limited (and rapidly depleting) indigenous natural gas supply, this would introduce, *by design*, a potential single point of failure for almost the entire energy system in the case of any major international natural gas supply disruption, while simultaneously inhibiting the required scale and speed of energy system decarbonisation.
- In contrast, we argue that by far the best way to address both Irish energy security and the pressing need for rapid decarbonisation is to constrain and reduce energy consumption (through efficiency measures and/or absolute reductions in energy services) and to directly exit from the use of *all* fossil fuels, including natural gas, as quickly as is safely feasible, replacing them by indigenous zero- or (potentially) negative-carbon energy resources to the maximum possible extent.
- In the specific case of Ireland, there are clearly identifiable pathways to transition the great majority of its energy requirement to proven indigenous zero- or negative-carbon energy sources (primarily wind, solar, and sustainably cultivated indigenous bioenergy). This does require, inter alia, the development of large scale (multi-TWh) energy storage facilities to buffer variability on at least an annual basis. We find that such energy storage is technically feasible, using well proven conversion and storage technologies, through the use of gaseous and/or liquid "electrofuels": hydrogen, ammonia, possibly synthetic hydrocarbons (with carbon cycling), all produced primarily from indigenous variable renewable energy sources.
- Finally, within the known physical constraints of the Paris Climate Agreement (the "Global Carbon Budget") we find that there is no credible case to be made for bringing *new* fossil fuel resources into production: any such additional production would inevitably add to total global atmospheric concentration of CO_2. Short term, not to say fundamentally misplaced, concerns in relation to national energy security cannot ethically be addressed by compromising climate stability for generations to come (cf. Boyd 2018): therefore neither current energy security concerns, nor, especially, a deliberate choice to further impair future energy security (through a mistaken "gas bridge" decarbonisation strategy) can be taken as valid arguments against the immediate cessation of new Irish offshore fossil fuel exploration which has been proposed in the Petroleum and Other Minerals Development (Amendment) (Climate Emergency Measures) Bill 2018.

List of Abbreviations

AD: Anaerobic Digestion (for biogas/biomethane production)

BECCS: BioEnergy with Carbon Capture and Storage (potential "negative emissions" technology)

CCS: Carbon (CO_2) Capture and Storage

IAE: Irish Academy of Engineering

IEA: International Energy Agency

IPCC: Intergovernmental Panel on Climate Change

LNG: Liquified Natural Gas

NGCCS: Natural Gas with Carbon Capture and Storage

NORA: National Oil Reserves Agency (Ireland)

P2X: Power-to-X technologies, involving the conversion of surplus variable renewable electricity to any of a variety of other energy carriers (such as hydrogen, ammonia or hydrocarbon fuels, all generically denoted "X").

SDS: Sustainable Development Scenario (one of the scenarios presented in the annual World Energy Outlook of the International Energy Agency)

SEAI: Sustainable Energy Authority of Ireland

UNFCCC: United Nations Framework Convention on Climate Change

WEO: World Energy Outlook (published annually by the International Energy Agency)

Introduction

In July 2018, the Irish Academy of Engineering published a major report entitled "Natural Gas — Essential for Ireland's Future Energy Security (IAE 2018). This is a significant contribution to ongoing debate about the evolution of the Irish energy system, especially in the context of required, rapid, decarbonisation. The report contains much valuable information and insightful discussion. Nonetheless, we find that the substantive conclusions are fundamentally mistaken, and would be damaging and counter-productive if applied to Irish energy policy development. We set out here the detailed basis of our critique, and urge further constructive discussion on these critical and urgent issues, including proactive engagement with wider society. The decisions involved will profoundly affect the well-being of all Irish citizens, not just in the decades immediately ahead, but for centuries to follow.

Projecting Future Natural Gas Consumption in Ireland

The specific recommendations of the IAE report which we are concerned with are those in support of the development of import facilities for Liquified Natural Gas (LNG) and of continued exploration for fossil fuels (including, but not limited to, natural gas) in Irish offshore territory.

In the first instance, these recommendations hinge on the projection by the IAE of continued reliance on natural gas for Irish energy needs, a reliance that is anticipated to extend to at least 2050:

> "Based on an examination of long-term energy outlooks from the International Energy Agency and various other organizations, the Academy believes that *natural gas will continue to be a large part of the world's, Europe's and Ireland's energy mix until at least the middle of this century.*" (IAE 2018, emphasis added)

If that projection is accepted, then virtually everything else recommended by the report might arguably follow (albeit, against a background of escalating climate disruption and impacts, both locally and globally). Ireland would indeed be faced with severe concerns over the security of its access to natural gas over the next 30 years (and beyond), and the development of LNG facilities, and the continued support for offshore exploration would appear eminently sensible, if not absolutely essential, things to do.

But is this projection of sustained reliance on natural gas well grounded?

The IAE report provides only limited detail on the background basis of its projection. It explicitly cites the International Energy Agency's World Energy Outlook (WEO) 2017 (IEA 2017). Three WEO scenarios are referenced, ranging from "Current Policies" to the "Sustainable Development Scenario" (**SDS**). The latter is currently the most ambitious WEO scenario in terms of CO_2 mitigation, and is described by the IEA as being "fully aligned" with at least the 2°C temperature goal of the Paris Climate Agreement (UNFCCC 2015). The Academy of Engineering reports says that even under the decarbonisation objectives of SDS, "Gas consumption [globally] in 2040 would be 20% higher than today"; though it does then acknowledge that, for the EU specifically, SDS would require natural gas use to be "20% lower" (compared to 2016). But if we just apply that latter number to Ireland (as a "typical" EU state) that would still seem to imply large scale natural gas usage (~80% of current levels) at least to 2040, even in the case of such apparently "ambitious" climate mitigation.

So: where is our disagreement?

Firstly, the IEA itself has long recognised that natural gas is still a high carbon energy source, and its continued use would inevitably carry significant environmental risks. As far back as 2012, the IEA Chief Economist was quoted as saying that "[a] golden age for gas is not necessarily a golden age for the climate" (Harvey 2012) and, further, that "**[we] are not saying that [this] will be a golden age for humanity - we are saying it will be a golden age for gas**" (Nathanael 2012).

More particularly, while the IEA World Energy Outlook argues that the SDS is aligned with at least the 2°C Paris temperature goal, there is very significant contention around that claim. The current WEO scenarios formally only run to 2040, but in relation to the claim for SDS Paris alignment, the IEA explicitly acknowledge that:

> "Maintaining [the] rate of reduction of energy- and process-related emissions after 2040 [consistent with the Paris temperature goals] will require continued technological innovation, including for carbon capture, utilisation and storage (CCUS) and *so-called negative emissions technologies that allow for CO_2 to be withdrawn from the atmosphere at scale*." (emphasis added)

So, in effect, to adopt the IEA SDS scenario as a basis for policy *up to 2040* would automatically involve a tacit commitment to, and reliance upon, planetary scale deployment of negative emissions (CO_2 removal) technologies *after* 2040. This is not a minor qualification: it calls into question the entire foundation for the use of the scenario in *current* policy development — at least for any country which considers itself as a good faith party to the Paris Agreement. As summarised in the journal *Science*:

> "Negative-emission technologies are not an insurance policy, but rather an unjust and high-stakes gamble. There is a real risk they will be unable to deliver on the scale of their promise. If the emphasis on equity and risk aversion embodied in the Paris Agreement are to have traction, negative-emission technologies should not form the basis of the mitigation agenda. … [Rather] *the mitigation agenda should proceed on the premise that they will not work at scale*. The implications of failing to do otherwise are a moral hazard par excellence." (Anderson and Peters 2016 emphasis added)

Separately, there is a significant question mark over whether the IEA SDS analysis adequately represents the justice and equity aspects of the Paris agreement: in particular, whether that figure of just a 20% fall in EU natural gas consumption by 2040 would represent a "fair" share of mitigation effort by the EU relative to other less developed regions?

Both of these critiques of the IEA SDS are explained in further detail in a recent Oil Change International report, which concludes:

> "… By accepting a mere 50 percent probability of success [in meeting the 2°C limit], by assuming negative emissions technologies will be invented, and by assuming unrealistically low non-energy emissions, the SDS significantly understates the degree of change in energy systems needed to achieve the [Paris Agreement] goals." (Muttitt 2018)

It is worth noting that, coming toward the end of 2018, the current indications from the IEA itself are that global CO_2 emissions are continuing to *increase* (Simon 2018). So any scenario developed in the last few years (such as SDS) should properly be adjusted to meet today's reality and include

reasonable judgements on tomorrow's emissions. Based on the IPCC AR5 carbon budgets (IPCC 2014), we suggest that for energy-only from January 2019 there is only about 550 $GtCO_2$ of emissions "budget" remaining globally for a "likely" chance of limiting global temperature increase to 2°C (and this still relies on very optimistic assumptions about deforestation and process emissions across the century). Current annual (and growing) global CO_2 emissions from fossil energy use are ~37 $GtCO_2$/yr, representing less than 15 years remaining if the current pattern continues. Note that these figures are focussed on a 2°C threshold of global temperature increase, and predate the further analysis presented in the recent IPCC Special Report on Global Warming of 1.5°C (IPCC 2018). Meaningful near term action in support of the 1.5°C limit would, of course, have to be significantly more stringent even than for 2°C. In short, thinking about 2020 and beyond requires us to take account of what is happening now and very likely to occur over the coming few years. Given how small the remaining carbon budgets are for any prudent or even tolerable limit on global temperature rise, future emission space and appropriate technology pathways are highly sensitive to current and very near term CO_2 emissions.

To be clear: regardless of the detailed analysis, for the present purposes it is enough to say that there are very well founded disagreements with the IEA characterisation of the SDS as adequately aligned with the Paris Agreement goals. It was therefore properly up to the Academy of Engineering report both to acknowledge these differing perspectives, and articulate on what basis it then favours the SDS. In fact, the only critical assessment of the SDS offered by the IAE report is to refer to a specific comparison between projections from "many organisations" that was included in "BP's latest World Energy Outlook" and to state that "[a]ll outlooks show global energy demand continuing to grow over the next 20 to 30 years with [natural] gas growing faster than all other energy sources, apart from renewables." But the IAE report omits to say which (if any) of these "many" outlooks are actually compatible with the Paris temperature goals, and the Paris requirements for justice and equity. Absent that information, the relevance of this "comparison" would be moot at best.

While the IAE don't provide a precise reference here, it appears that they are relying on material from pages 114-117 of the full BP Energy Outlook 2018 document (BP 2018). The critical background provided there is:

> "There are many different published outlooks and it is not possible to do a comprehensive survey. To aid the comparison, where possible the external scenarios selected are based on assumptions for policy, technology and social preferences most similar to those underpinning the ET [BP Evolving Transition] scenario."

So, the baseline for *all* the scenarios in this comparison is the BP "Evolving Transition" scenario. The key, relevant, characteristics of this scenario are well captured in the refreshingly clear and candid commentary from Mr. Bob Dudley, BP Group Chief Executive, on page 5 of the same document:

> "The third, and most important, takeaway ... from this year's Outlook is the need for more downward pressure on carbon emissions. The Outlook's **Evolving Transition** scenario suggests that a continuation of the recent progress and momentum in policies and technologies is likely to cause the growth in carbon emissions to slow markedly relative to the past. But this slowing falls well short of the sharp drop in carbon emissions thought necessary to achieve the Paris climate goals. We need a far more decisive break from the past." (BP 2018)

Thus, the "many projections" cited by the IAE report as providing the fundamental basis for their entire subsequent analysis were explicitly selected for their similarity to a scenario that, by the testimony of BP's own Group Chief Executive, *"falls well short of the sharp drop in carbon emissions thought necessary to achieve the Paris climate goals"*.

There is therefore a clear difficulty with the IAE assessment of the trajectory of natural gas usage in Ireland over the coming decades, and considerable doubt over whether what the report has assumed is meaningfully consistent with the Paris Agreement. To the very limited extent that it addresses the Paris Agreement temperature limits at all, it considers only the 2°C goal; but even since the publication of the IAE report itself, this position has been superseded by the new IPCC Special Report on Global Warming of 1.5°C (IPCC 2018), which makes clear the critical implications and importance of taking action on the basis of that more stringent objective of the Paris Agreement. For all these reasons, recommendations based directly on the natural gas consumption projections adopted by the IAE cannot be regarded as sound.

Natural Gas as an Irreplaceable Backstop to Intermittent Renewable Electricity Generation?

The IAE report goes on to identify another different but complementary argument for a continued critical *reliance* on natural gas in the Irish energy system, specifically in electricity generation. This complementary argument might therefore still support the final recommendations, even if it were conceded that overall Irish energy system decarbonisation has to happen significantly faster than the report has envisaged.

The report essentially asserts that there are hard limits to how much of Ireland's energy needs can practically be serviced by intermittent renewable electricity. Specifically, it states (p. 7) that: "... [r]enewables will account for a growing share of Ireland's electricity supply in the next 20 to 30 years. Wind and solar generation are expected to provide up to a half of Ireland's annual electricity. Fossil fuels will be needed to generate the other half." Given both the essential enabling role of electricity in overall societal energy use, and the likelihood of significant further electrification of the currently largely non-electrified transport and heat energy sectors, this assertion that no more than ~50% of electricity generation can be met by intermittent renewable sources is then critically important. If that assertion is correct then that indeed leaves a gap of ~50% that has to be fulfilled in *some* other way. Further, unless that gap is filled, even access to dynamically available intermittent renewable generation could potentially be compromised due to challenges of stable system operation. Ireland has (pro tem) rejected the deployment of nuclear generation within its jurisdiction, and natural gas, although a very high carbon energy source, is still the least carbon intensive of the fossil fuel options. Thus, the IAE argument is that the bulk of that generation gap will *have* to be filled by natural gas. Such a reliance on natural gas in electricity generation, more or less to the exclusion of other fossil fuels, coupled with progressive electrification of heat and transport, would then make Ireland's overall energy security even more precarious than it is now.

The report does acknowledge that this "residual" (but indefinitely sustained?) reliance on natural gas would then pose a serious difficulty with the goal of achieving progressively deeper decarbonisation (whose *ultimate* necessity is not disputed). Once gas has displaced all other fossil fuels there would be no further "easy", lower intensity, substitute fuel available. The report suggests that this might be addressed through some combination of partial displacement of

natural (fossil) gas by "renewable gas" and the continued use of natural gas but with substantial emissions mitigation via carbon capture and storage (CCS) technology. We will consider each of these in turn.

While "renewable gas" is not precisely defined in the report, the discussion is focussed exclusively on indigenously produced biomethane and concludes that the contribution from this source, within the next two (critical) decades, will be very modest, at best:

> "Biogas from renewable sources has the potential to supply some of Ireland's gas needs. Gas Networks Ireland estimate that up to 20% of Ireland's gas demand could potentially be met from renewable [primarily biomethane?] sources. However, there are significant challenges to be overcome – planning and permitting, public acceptance, scale and costs of infrastructure needed, gas quality control etc. It is likely to take several decades to develop a large-scale renewable gas industry in Ireland. *In the Academy's view, renewable gas will account for only a small part of Ireland's gas supply by 2040.*" (emphasis added)

As an aside, it is important to note that the overall climate mitigation benefit of bioenergy relative to fossil fuel use is highly variable at best, and may even be non-existent for some specific production pathways (EEA-SC 2011). In the case of biomethane from anaerobic digestion (AD), the risk of methane leakage to atmosphere – itself an extremely potent greenhouse gas – means there is a requirement for extremely robust (and potentially costly) independent regulation and monitoring of production sites (Liebetrau et al. 2017). Separately, in considering AD pathways, it is essential to account fully for any additional use of nitrogen fertilizer – which would inevitably lead to increases emissions of N_2O, another potent and long-lived greenhouse gas. We would therefore agree with the Academy conclusion that bioenergy can be prudently relied upon only for a relatively small contribution to overall energy system decarbonisation (in Ireland and globally).

So we are left with the second option, continued large scale use of natural gas electricity generation, but with carbon capture and storage (NGCCS), as apparently being essential to achieving deep decarbonisation of electricity (and the wider energy system) in Ireland. In this case, based on the Academy's assessment, natural gas would still account for something like ~40-50% of Irish electricity use at least to 2040 (and, by extrapolation of asset lifetimes, would suggest continued significant natural gas usage well into the second half of the century). Penetration of natural gas in the energy system as a whole would depend on the degree of electrification of heating and transport, and the continued role of natural gas in the remaining non-electrified energy use; but overall penetration could hardly be much less that that indicated for electricity alone (assuming higher emission fossil fuels are already displaced in all uses). In such a scenario, Ireland would indeed be acutely exposed to disruption of natural gas supply (or, equivalently, to severe constraints on CO_2 emissions arising from mandatory international action — e.g., imposed at collective EU level). Any such disruption could fundamentally compromise the entire energy system. Indeed, absent other measures, even the intermittent renewable electricity elements might only operate provided that there is a significant, dispatchable, backstop, which, in this scenario, must come primarily or solely from natural gas power plants. In case of serious natural gas supply disruption there would be a real danger of losing almost *all* societal energy services (transport, heating, and all "conventional" electricity use).

The key point here is that, even if it is conceded that much faster decarbonisation is necessary, the logic of the IAE analysis is *still* that (absent nuclear power and with only limited bioenergy availability) Ireland would continue to require a very significant and critical role for fossil natural

gas. In this approach, the *only* substantive implication of faster decarbonisation would be that the deployment of CCS in natural gas electricity generation would have to be greatly accelerated (along with associated electrification of heating and transport to shift unabated fossil fuel consumption in those sectors to electricity instead). However, the *relative dependence on imported natural gas, and the energy security risk associated with that, would be just as severe, if not more so* — precisely because Ireland would be focusing down on natural gas, to the exclusion of other fossil fuels, even more quickly. *If* that is the scenario Ireland is necessarily navigating toward, then it would appear that the central IAE recommendations (LNG import, and continued promotion of indigenous fossil fuel exploration) all still follow.

Of course, quite aside from this continuing, and indeed intensifying, natural gas supply security issue, there would be other very significant problems with such a strategy for (rapid) decarbonisation: problems that the IAE recommendations (which deal only with supply security) do not consider or even acknowledge. Specifically, there is the 5-10% of CO_2 emissions that CCS may not feasibly capture, the energy penalty of CCS (therefore requiring more fuel combustion for given delivered electricity), and the significant challenge of upstream emissions associated with natural gas extraction, processing and transport, again including direct methane leakage to atmosphere (Gibon et al. 2017; Anderson and Broderick 2017). Separately, there is potentially very limited capacity for geological storage of CO_2 within the jurisdiction.

Some of these issues *might* be eased, to an extent, by further technology development. For example, the so-called Allam Cycle gas turbine technology may feasibly and efficiently allow almost 100% CO_2 capture of power station emissions in the specific case of natural gas electricity generation (Allam et al. 2017). Or, applying CCS to even the modest available biomethane supply might — arguably — yield some nett CO_2 removal from the atmosphere (Price et al. 2018) which could conceivably compensate for residual positive emissions from natural gas CCS. Similarly, if indigenous Irish CO_2 storage sites proved unsuitable or inadequate, CO_2 might be transported by ship for geo-storage in other jurisdictions (Skagestad et al. 2014); indeed, it has been reported that Norway has an active interest in delivering such internationally traded CO_2 storage services (Tannenberg 2017). But the timeframe for such developments (at relevant scale) is likely at least two to three decades, which is not aligned with the rate of decarbonisation now immediately required; and in any case, they would still not address all the specific challenges (such as continued "upstream" emissions of both CO_2 and methane) which such a natural gas CCS "decarbonisation backstop" pathway would present.

The IAE report does consider, but quickly dismisses, one other route to energy decarbonisation that *would* in principle allow the progressive elimination of more or less all fossil fuel use, even including natural gas, and thus also defuse the intensifying gas security challenge. This route is for a transition to a predominantly electrified energy system, primarily supplied by indigenous intermittent renewable resources (mainly wind), but with the addition of sufficient (dispatchable) energy storage to allow full compensation for both short-term (inter-hour, inter-day) and long-term (inter-season, inter-year) fluctuations in supply. Just two potential storage technologies are (briefly) considered: battery and pumped hydro. However, based on an assessment that neither of these can conceivably function at the required scale (an assessment which we would agree with), this section of the report then concludes: "The Academy does not believe that electricity storage is a realistic solution to the problem of intermittent renewable electricity supply… in the Academy's view Ireland will continue to depend on fossil fuels for electricity generation, especially natural gas, until at least the middle of this century."

So, to summarize this central argument of the IAE report, it appears to reduce to the following:

- There is "no alternative" to indefinite reliance on substantial (~40-50%) natural gas use in electricity generation (with or without CCS) because of the fundamental intermittency, specifically on inter-seasonal timescales, of the main indigenous renewable sources (primarily wind).
- This strategy can (somehow!) be reconciled with the rate of decarbonisation required to limit risk of climate disruption and impacts to "tolerable" levels (locally and globally) — even though this assumption is *prima facie* entirely inconsistent with the best available scientific assessments (IPCC 2014, 2018); or, alternatively, that local impacts in Ireland will be minimal, and Ireland will be somehow decoupled from widespread impacts elsewhere.
- But this comes at an (unavoidable?) price of deepening natural gas security-of-supply risk and *therefore:* all feasible measures must be taken to secure natural gas supply.

Our critique, in response, is then two fold:

- For the reasons already described, the implied natural gas CCS rapid decarbonisation "backstop" pathway is itself just as impractical, both technically and economically, as any of the options otherwise dismissed by the IAE (nuclear, bioenergy, variable renewables coupled with battery or pumped hydro energy storage); worse, it is highly uncertain in its climate mitigation effectiveness while committing either to deepening energy insecurity or high cost counter-measures (or both).
- There is, in fact, an alternative and feasible strategy, that *can* reliably address all the issues identified, *specifically including national energy security,* and also the need for rapid deep decarbonisation: this is firstly to to constrain and reduce energy consumption (through efficiency measures and/or absolute reductions in energy services), and secondly to shift the bulk of the (reduced) supply requirement to variable renewables coupled with large (multi-TWh) scale energy storage *based on one or more synthetic chemical fuels ("electrofuels") as the energy carrier* (so-called Power-to-X or P2X technologies). But the IAE report does not substantively consider the possible roles of either consumption constraint or the large scale use of electrofuel based storage (unless very obliquely through ambiguity in the use of the term "renewable gas").

The specific option for Irish energy supply based primarily on variable renewables, with a dispatchable storage backstop using large scale synthetic electrofuel (produced during periods when variable renewable supply exceeds demand), has, in fact, been already extensively modelled and evaluated (Connolly and Mathiesen 2014). That particular study argued that "... a 100% renewable energy system [for Ireland] can provide the same end-user energy demands as today's energy system and at the same price." That study envisages separate large scale storage of liquid and gaseous synthetic hydrocarbon fuels (respectively methanol and/or dimethyl ether/DME, and methane). This particular approach does raise detailed issues around carbon (re-)capture and recycling; but in fact, small scale, turnkey, closed-carbon-cycle energy storage has already been demonstrated (Goodall 2017). Alternatively, targeting of non-hydrocarbon electrofuels (avoiding any overhead of carbon recycling) is also feasible. Detailed (positive) assessment of hydrogen based storage systems is provided by, for example, (Steward et al. 2009; cH2ange 2018). The commissioning of the world's largest hydrogen storage facility has recently been announced in the US (Air Liquide 2017). This is currently supplied from a high-carbon H_2 pathway but nonetheless

fully demonstrates the technical and economic feasibility of such very large scale H_2 storage systems. Ammonia is another emerging non-hydrocarbon electrofuel candidate (Wang et al. 2017), with a pilot demonstrator already in commissioning (Evans 2018). Additionally, both hydrogen and ammonia based systems offer the possibility of early "drop in" end-use decarbonisation of significant transport and heating applications, with some round-trip efficiency gain, and without relying on prior end-use electrification (as they would not require or rely on carbon recapture/re-cycling at the point of use). It is of note, for example, that hydrogen fuel cell passenger trains have already entered commercial service, offering an additional pathway to rail decarbonisation that does not rely on line electrification (Agence France-Presse 2018). Similarly, a large scale deployment of fuel cell based heavy goods vehicles has recently been announced in Switzerland (Wiseman 2018). Quite aside from their specific suitability for heavy transport applications, deployment of hydrogen fuel cell vehicles may represent a beneficial diversification from exclusive reliance on full battery electric vehicles where rapid global scale-up may be specifically constrained by lithium and cobalt supplies (Andrews 2018). It is also significant that extensive elements of the existing Irish natural gas network could be re-purposed for hydrogen use, thus protecting against early stranding of this critical public asset through the decarbonisation transition.

Separately from these various approaches to electrofuel energy storage and end-use, there may also be a practical and economic role for large scale inter-seasonal thermal energy storage (e.g., Lund et al. 2014). Recent research strongly supports integration of electrofuels (P2X), battery electric transport and long-term thermal energy storage as offering the most cost effective routes to deep decarbonisation of energy systems in Europe, and especially so under conditions of relative geographical isolation/limited electricity interconnection such as typified by Ireland (Brown et al. 2018).

The technical and economic feasibility of inter-seasonal energy storage via *liquid* electrofuels is already fully demonstrated in Ireland by the holding of strategic stocks of liquid *fossil* fuels. NORA, the Irish National Oil Reserves Agency, maintains a strategic reserve, primarily within the island of Ireland, sufficient to supply current national demand for those fuels for at least 90 days. As noted in the IAE report itself, while Ireland does not currently operate any large scale facility for *gaseous* fuel storage, the Southwest Kinsale reservoir was previously used to provide natural gas storage with capacity equivalent to about 18 days' supply, and other countries in Western Europe operate gas storage facilities with an average capacity equivalent to 100 days' supply. While there would be, of course, detailed design differences between gas storage facilities according to the specific target fuel (hydrogen, ammonia, methane etc.) the general technical and economic feasibility of very large scale (inter-seasonal) gaseous fuel storage is not contested by the IAE.

This does highlight the one point of at least partial agreement with the IAE: of the report's three main recommendations (LNG import, offshore fossil fuel exploration, and large scale natural gas storage), large scale chemical fuel storage of some sort is clearly intrinsic to the scenarios outlined above.

In relation to indigenous energy *supply* potential, the Sustainable Energy Authority of Ireland (SEAI) has estimated availability of Irish wind energy alone (onshore plus offshore) as being at least 140 TWh/yr (SEAI 2011). The most recent (2016) figure for total primary energy requirement in Ireland is 168 TWhr/y, fulfilling final energy consumption of 136 TWh/y (SEAI 2017). Allowing for continuing technological improvements in wind generation, for additional supply from solar and bioenergy sources, and for significant available energy efficiency gains, there is clearly the potential for the great majority of Irish energy needs to be met from indigenous renewable energy sources.

We acknowledge that the inherent inertia represented by our existing energy infrastructure, and the need to maintain essential societal energy services during the decarbonisation transformation, will require *some* ongoing transitional combustion of natural gas (and other fossil fuels): and for that (limited) transitional use, there may be an argument to minimise the associated CO_2 by deploying CCS in carefully targeted cases. CCS can also usefully support immediate mitigation of critical non-energy CO_2 sources (such as cement manufacture), and in building expertise and capability for future CO_2 *removal* from atmosphere (the success of which should not be *relied* on in current policy, but can certainly be a target of prudential preparation and active development).

Much more detailed technical planning and design, and a programme of very significant capital investment (both public and private) will be required to realise the rapid transformation to a fully fossil-free energy system as outlined above; but this would be entirely consistent with known general conditions for optimal climate mitigation investment (Vogt-Schilb et al. 2018). As noted, and given the short time now available, significant *reductions* in some energy uses will likely also be an essential intervention until decarbonisation is substantially complete (Grubler et al. 2018). Significant investment is certainly implied by all conceivable energy system decarbonisation pathways that would now be at all commensurate with the climate change challenge, based on good faith action in accordance with the Paris Agreement.

One preliminary but useful upper bound on likely levelized costs of electricity (which reflects investment costs) in such decarbonised energy systems, across a range of European countries, has recently been published based specifically on hydrogen electrofuel as the storage energy carrier (Brown 2018). While significant, even this upper bound (estimated at c. €87/MWh by 2030, in Ireland) would still be well within the range of economic feasibility. Moreover, these costs must be compared to the substantial ongoing investment that conventional high carbon energy systems require anyway (including, for example, the specific interventions positively recommended by the IEA).

The key point is that even at the very highest estimates of practical energy system decarbonisation costs, this transformation will still be immeasurably cheaper than continued use of fossil energy, once climate “externalities” are accounted for. See, for example Steffen et al. (2018) for the existential scale of what is now at risk. Most importantly, precisely because the approach outlined here localises the great bulk of Irish energy supply to entirely indigenous, sustainable and renewable sources, it would, at one transformational stroke, decisively resolve the chronic energy supply insecurity that has dogged Ireland virtually since the foundation of the state. Finally, this transformation would of course carry with it the potential for significant additional economic co-benefits in terms of indigenous employment and favourable trade balance.

Conclusion

> "If a country brings any additional fossil fuel reserve into production, then in the absence of strong climate policies, we believe it is likely that this production would increase cumulative emissions in the long run. This increase would work against global efforts on climate change." (MacKay and Stone 2013)

Returning to the core point of the IAE report: it does provide an excellent presentation of the acute energy security risks that *would* attach to prolonged and progressively more concentrated reliance on natural gas as essentially Ireland's single dispatchable electricity source (as well as, currently, an essential component of meeting direct heat demand). But the report then fails to follow the logic of its own analysis. Its prescription is, in effect, to fatalistically *accept* that such dependence on natural gas is "inevitable", to fundamentally understate the climate change implications of such continued dependence, and then consider progressively more problematic ways to shore up security of natural gas supply (LNG, offshore exploration).

The alternative, of course, is to attack the (genuine) energy security problem at its source, and proactively identify ways of avoiding having natural gas (or any other imported, high carbon, energy source) play a central role in Ireland's overall energy system. And given that there are realistic, affordable, pathways of doing that, which are well understood, already proven at the technology level, in the process of scaling up, and much better aligned with commensurate climate action, we conclude that the report's specific recommendations for locking in continued reliance on natural gas are without satisfactory foundation. Instead, the IAE recommendations present steps effectively leading in quite the wrong direction, undermining precisely those alternatives that would genuinely address the challenges of *both* decarbonisation and energy security.

Of course, it may be suggested that the huge scale and speed of change envisaged in the early elimination of all fossil energy is simply "unrealistic", that wider society is not ready or willing to endorse it, and that, above all, we must not "allow the perfect to be the enemy of the good". In response we would contend that the truly "unrealistic" path now is the one that imagines consigning to young people of today the burden of severely compromised planetary support systems that have been critically, perhaps irreversibly, undermined by a (lack of) decisive action today (Hansen et al. 2017; Spratt et al. 2018). As the meteorologist and commentator Eric Holthaus has recently remarked: "A livable world achieved through incremental changes may have been possible in the 1980s, but it's a fantasy now" (Holthaus 2018). Forget the "perfect": our true challenge now is to prevent the (superficially) "good" being the enemy of the desperately *necessary*.

Finally, we must comment on the following brief (but nonetheless deeply significant) remark, which appears on page 24 of the IAE report:

> "Banning [fossil fuel] exploration in Ireland will not reduce Ireland's gas consumption or greenhouse gas emissions. On the contrary, it would result in more gas imports and less energy security. It would result in an increase in greenhouse gas emissions as the imported gas is likely to be transported over very large distances, as well as increasing Ireland's cost of imports."

This appears to be a tacit, but clearly critical, comment by the IAE on proposed legislation currently before the houses of the Oireachtas, namely the Petroleum and Other Minerals Development (Amendment) (Climate Emergency Measures) Bill 2018 (Oireachtas 2018). That Bill does, in effect, propose precisely such a ban on further fossil fuel exploration in the national territory (onshore or offshore).

While there is much more that could be said about this Bill, for the purposes of this particular discussion, we will just emphasise that the critique presented above fully addresses the specific points raised in this IAE report. That is, provided that rapid energy system decarbonisation is given the policy priority that is now absolutely essential (cf. McMullin 2018), then there is no contradiction whatever between that Bill and achieving *both* radical emissions reduction in the short term *and* profound energy security for generations to come. Combining these imperatives offers a genuinely *inspirational and attainable* vision for Ireland's energy future, and we have no hesitation in commending enactment of this Bill as soon as possible, as one key measure to catalyse this essential transformation.

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About Stop Climate Chaos

Stop Climate Chaos is a coalition of civil society organizations campaigning to ensure Ireland does its fair share to tackle the causes and consequences of climate change, in line with the best available scientific evidence and on a basis of global equity and solidarity. The following is the full list of organisations currently affiliated with Stop Climate Chaos:

> Afri,BirdWatch Ireland, Christian Aid Ireland, Comhlámh, Community Work Ireland, Concern Worldwide, Cultivate, Cyclist.ie, Dublin Friends of the Earth, Eco Congregation Ireland, ECO UNESCO,Feasta, Fossil Free TCD, Friends of the Earth, Good Energies Alliance Ireland, Self Help Africa, Jesuit Centre for Faith and Justice, Just Forests, Kimmage Development Studies Centre, Latin America Solidarity Centre (LASC), Liberia Solidarity Group, Methodist Church of Ireland – Council of Social Responsibility, Mountmellick Environmental Group (MEG), National Youth Council of Ireland, Oxfam Ireland, Peoples Climate Ireland, Presentation Ireland, Tearfund Ireland, Trócaire, An Taisce, VITA V.O.I.C.E., and Young Friends of the Earth.

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