Western Australian Scientific Inquiry into Hydraulic Fracture Stimulation in Western Australia

Submission from Sustainable Energy Now Inc. (SEN)

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Preface – About SEN

SEN (Sustainable Energy Now Inc.) is a non-profit association advocating for the utilization of sustainable energy sources within Western Australia (WA). SEN brings together a mix of multidisciplinary knowledge and capability, providing independent advice on renewable energy.

SEN's working teams consist of volunteers whose professional backgrounds include engineering/science, business, education and the environment. The teams have committed thousands of hours to developing evidence-based solutions toward transitioning WA's energy use from fossil fuels to renewables for the good of humanity, the economy and the environment, as a way for WA to play its part in the global transition to a more sustainable future.

Executive Summary

This submission from Sustainable Energy Now (SEN) addresses the following Terms of Reference of the Inquiry:

- "*Identify environmental, health, agricultural, heritage and community impacts associated with the process of hydraulic fracture stimulation in Western Australia, noting that impacts may vary in accordance with the location of the activity*", with a focus on environmental aspects;
- "*Describe regulatory mechanisms that may be employed to mitigate or minimise risks to an acceptable level, where appropriate*", providing a range of evidence that there are no regulatory mechanisms that can mitigate environmental effects of hydraulic fracturing (fracking), both in exploration and production, to an acceptable level.

SEN's evidence-based submission addresses four issues. The first Section addresses the environmental risks of hydraulic fracturing (fracking), through pollution of the atmosphere by methane emissions, and pollution of aquifers by fracturing of existing fault lines. Recent research about other environmental risks is also discussed briefly.

Section 2 builds on Section 1 and assesses the latest research on the greenhouse gas emissions from methane, finding them to be extremely high, putting pressure on Australia's attempts to meet its international climate targets.

SEN submits in Section 3 that it is unnecessary to increase WA's gas supplies by fracking. WA has sufficient proven reserves of conventional gas to meet its needs into the foreseeable future as the state reduces reliance on fossil fired power generation and transitions power generator from renewable sources. SEN's own technical and economic modelling has shown that the inevitable uptake of cheaper renewable electricity will reduce demand for gas. Gas demand will also be further reduced by fuel switching from gas to electricity for heating (space, water, process, cooking), and by electrical storage (such as batteries and potentially electric vehicles) displacing gas turbines lower the in despatch merit order and providing 'synthetic inertia' for grid stabilisation and ancillary services. International trends also indicate a slowing or decrease in gas demand for similar reasons.

The most certain way of minimising the risks posed by fracking is not to do it, and this analysis shows that unconventional gas supplies are not needed since WA is amply provided with gas from it's 2006 Gas reservation policy requiring 15% of LNG export volumes be set aside for domestic sale.

However, the final Section 4 addresses a situation where the Inquiry may find that the environmental risks from fracking might somehow be acceptable. SEN analyses various types of monitoring that will be required, before exploration, during exploration and production, and long after production has ceased. Weaknesses in current regulation are identified, as well as the costs to the state of adequate monitoring. Even with state-of-the art monitoring, SEN asserts that, given the number of wells and long lifetimes, that well failures are statistically very probable, and remediation of fractured formations impossible. This poses significant long-term financial and environmental risks to WA, unless gas companies are required to indemnify the state.

SEN believes that the most appropriate way to protect WA and the community is to require proponents to meet the costs of regulation and remediation upfront, through implementation of a bond, insurance, or similar mechanism. However, such a move is considered impossible to be achieved as it would make fracking uneconomic.

SEN also asserts that the relatively small companies involved in unconventional gas exploration and production might choose bankruptcy instead of remediation in the case of catastrophic well failures or other consequences as fault slippage. This has happened in the Eastern States with the example of Linc Energy's Underground Gasification project at Kingaroy Qld.

Key Findings

- There is significant environmental risk that fracking that may accelerate seismic or aseismic slips in formations, resulting in emissions of highly potent greenhouse gases into the atmosphere, and of contamination of groundwater supplies both shallow and deep;
- There are significant shortcomings in the scientific investigation of sub-surface conditions and baselines prior to exploration;
- Evidence from the United States shows methane emissions are substantially higher than those claimed by industry, and that inadequate pre-fracking measurement of atmospheric gases masks the true extent of methane emissions;
- There is sufficient supply of gas from existing reserves, obtainable without the need for fracking, to meet WA's domestic demand, and these reserves are demonstrated to meet foreseeable demand for export either to other Australian jurisdictions and internationally;
- SEN's own analysis and research shows that the transition to renewable energy over the period to 2030 is going to significantly reduce demand for gas in WA, and globally:
- Long term revenue and job generating activities from renewable energy projects and exports can supplant potential government income, while prohibiting fracking;
- There are deficiencies in current WA regulations;
- Regulations sufficient to mitigate or minimise the environmental impact of fracking would render the practice uneconomic if enforced;
- Costs of regulation must be internalised to the fracking industry to protect the taxpayer.

Recommendations

SEN recommends that:

1. The Inquiry should advise the WA State Government that unconventional hydraulic fracturing be banned in all circumstances in WA's onshore geological structures as:
    a. The gas field methane emissions from leaks and intentional venting at oil wells and methane and CO_2 emissions from the produced gas burnt will contribute to the world exceeding the 2 degrees of warming level;
    b. Regulatory mechanisms cannot be devised that would mitigate or minimise environmental risks to an acceptable level.
2. The government should define the difference between "conventional" and "unconventional" reserves/extraction, and develop separate regulations governing exploitation in each case. While international standards have not been defined, there are clear differences and the government should classify them. Wells in conventional formations may only be fractured in very small areas around the well bore. On the other hand, unconventional reserves require high fracturing pressures, and very high volumes of water and chemicals/additives with the intent of fracturing large areas of the formation. This increases environmental risks as demonstrated in this submission, despite claims of the industry. (In this submission, the term 'fracking' refers to unconventional hydraulic fracturing).
3. A carbon price should be imposed on industry to ensure the cost of remediating the release of CO2 (in the utilisation of the gas) is borne by the gas consumers, not the wider community;
4. The Inquiry should compare the 'triple bottom line' evaluation of fracking (having a finite, short-term speculative income from declining gas demand and high risk of damaging environmental and climate impacts) against renewable energy projects and exports which can provide long-term sustainable income and employment without such environmental and climate risks.

Should the Inquiry permit the practice of fracking, despite the strong evidence to the contrary, SEN considers the following components of a regulatory regime are required:

1. Regulations must protect the community from the transfer of costs from the industry to the community;

2. Regulations must require bonds to be paid to government to be used to remediate environmental damage, however such bonds would generally be so large to cover potential damage that implementation would not be feasible;
3. The WA State Government must require developers to impute a cost of carbon in their proposals to account for the emissions of carbon through the entire fuel cycle, including GHG emissions through to combustion of the gas;
4. The Inquiry should recommend a legislative change to remove the Strategic Resource status from Oil and Gas. This will enable fracking proposals to be assessed by the Environmental Protection Authority in the same way as other resource projects.

Section 1: Scientific Evaluation of Fracking

The Terms of Reference (ToR) of the Inquiry require the Inquiry to:

- "Identify environmental, health, agricultural, heritage and community impacts associated with the process of hydraulic fracture stimulation in Western Australia, noting that impacts may vary in accordance with the location of the activity";
- "Describe regulatory mechanisms that may be employed to mitigate or minimise risks to an acceptable level, where appropriate"; and
- "Recommend a scientific approach to regulating hydraulic fracture stimulation".

This Section outlines the environmental impacts of fracking in response to the first ToR.

Referring to the other two ToRs, SEN asserts that there are no regulatory mechanisms, even those developed using a scientific approach, that can mitigate environmental effects of hydraulic fracturing (fracking), both in exploration and production, to an acceptable level.

SEN believes the Inquiry's response to the government should be that it cannot describe regulatory mechanisms that may be employed that would mitigate or minimise risks to an acceptable level.

However, should the Inquiry decide to describe regulatory mechanisms that the government could consider despite the mechanisms not controlling effects to an acceptable level, then at a minimum the mechanisms must address the environmental issues raised in this Section. This will almost certainly mean that further scientific research must be carried out prior to reliable conclusions being determined.

Section 1.1 addresses a range of issues that have been identified with fracked wells drilled in WA.

Section 1.2 addresses the effects of methane escaping from wells. Methane is a potent greenhouse gas and its effects on the environment, in particular its contribution to global warming, are addressed further in Section 2.

Section 1.3 sets out other environmental effects of fracking.

1.1 Experience and considerations with fracking in Western Australia

The issues raised in this Sub-section include:

- Risks to (particularly low salinity) groundwater aquifers;
- Stress levels in formations;
- Experiences with exploration wells prior to fracking;
- Wells drilled and fracked so far;
- Data from the wells;
- Extent of methane leakage;
- Effect of regulation; and
- Monitoring of wells during production.

These issues raised are based on the work of Mullen and Archer (in press a; b) and Vogwill (2017). In particular, SEN strongly supports the recommendations included in the recent review of WA's tight gas industry (Vogwill 2017), and has attached this report as Attachment Salient points from these are:

In WA, deep aquifers (>300m) are likely to become an increasingly important water resource in the context of climate change.

Ground water levels are in decline in the shallow aquifers and deep aquifers may be the only option for water supply in the future.

WA has a significant agricultural industry that must be protected and resource management should therefore be conservative.

Deep aquifers are often saline. However, those with salinities of less than 5000 ppm NaCl equivalent are assumed to be potentially useful for mining, agriculture and drinking water. Nevertheless there is no requirement in the current regulatory guidelines for gas exploration companies to assess salinity in deep aquifers proximal to shale gas exploration targets.

There is a risk of fracturing events from existing stress levels in formations/cap rock and subsequent damage/leakage.

In the Perth basin, for example, the formation is highly faulted.

Leaks coming from faults after fracking are magnitudes greater than leaks from the wells themselves. Methane condensate and petroleum vapours are already leaking into low salinity deep aquifers at Woodada Deep due to the Earth's crust being critically stressed from fracking, and as a consequence, flow from the fault is the (main) conduit.

The Kockatea Shale is the regional seal as the underlying Carynginia Limestone was a conventional target in the 1980s. This indicates buoyancy alone cannot explain the present leakage evident, and consequently intermittent fault flow secondary to pressure dependent permeability is a likely cause.

Fracking imposes a large stress on the Earth's crust and leakage is likely to get worse and potentially may include oil and frack fluid breaching low-salinity deep aquifers. Therefore, methane, other hydrocarbons, heavy metals and radioactive element levels are likely to increase significantly in scarce low-salinity aquifers which will be relied on for drinking, agriculture and mining.

Monitoring fracking using micro-seismic monitoring is non-effectual, because the main deformation mechanism in faulted shale is aseismic (more ductile and slower slip rate due largely to clay content in rock). Further, such monitoring is pointless because by the time of identification, leaks hazardous to the environment will already have occurred and even if geological leaks are detected, mitigation is not possible i.

The Department of Mines and Petroleum mandates avoiding of faults because of the potential for movement due to seismic slip, however the Main Deformation Mechanism (MDM) in fracking is aseismic slip (which is not felt) and yet creates the potential for rupture into any level, including aquifers. Micro-seismic measurement is cited by the fracking industry to determine if leakage has propagated into aquifers but this is irrelevant and misleading as the MDM is the main contributor.

Information provided by explorers often does not correlate. For example, Arrowsmith 2 and Woodada Deep wells differ vastly in the parameters put into their respective models for fracture height (distance to aquifer), even though these formations are similar. This produces completely different results for the same formation.

There is much evidence showing Muderong shale leaks (Dewhurst et al. 2004). Cap rock integrity in formations should be demonstrated through stress, mineralogy and depth of burial/burial history.

Monitoring of pressure in aquifer zones may be feasible but pointless because if rising aquifer pressures are detected, it is too late to effect mitigation measures.

Shear failures result in increased permeability of the source rock.

Fracking accelerates the process of gas escapes due to fault slippage from what normally occurs in millions of years to just decades.

Gas leakage to well annulus must be flared or vented to remain within safe operating pressures. In some instances however, the pressures required to perform the fracturing exceeded casing maximum strength, resulting in failure of the casing. In Canada, best practice is measuring and relieving annulus/casing pressure. Why is this not performed in WA?

In the Timor Sea it has been demonstrated that critically stressed faults are resulting in 2km travel of oil to surface. In the Kockatea shale, this distance is therefore possible.

Regulators advise drillers in the Perth basin to steer around faults, a practice that is impossible to implement due to the prolific highly deformed faulting which already exists (Mullen and Archer In press - b).

SEN emphasises the following deficiencies exist in current regulations:

- Stress analysis is not required;
- There are no limits to fracking pressure;
- Reporting is not required on pre-existing gas data in all strata as exploratory wells are drilled (that would indicate the extent of pre-fracking leakage);
- Consideration of frack pressure relative to fault slip threshold is not required;
- Deep low-salinity aquifers are not identified using credible means (developers use spontaneous potential (SP) logs which have been discredited as a means of identification of low salinity aquifers) due to inaccuracy;
- Deep low-salinity aquifers are not currently protected.

SEN asserts there is a likelihood and strong possibility of developers by-passing the regulations due to the proponents providing their own data.

The papers also expose that proponents:

- Use of sonic derived horizontal stress (Arrowsmith 2) is not based on any physical reality, which has implications for fracture modelling, leading to major discrepancies, such as between those of Woodada Deep and Arrowsmith 2.
- Reporting on the suite of gas in baseline monitoring is incomplete in that it does not include all the gases in the deposits, nor the origins of the gases as recommended

(for example reporting on methane only and suggesting this is biogenic is misleading).

Further concerns raised in the papers include:

- Forcing farmers to sign non-disclosure clauses to cover up environmental damage (as in US and elsewhere).
- Allowing exploration and development companies to provide their own self-regulation.

SEN submits that given the above issues, it is not possible to fracture gas formations without significant environmental risk, and the Inquiry must consider the following issues and recommendations:

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Bureau of Meteorology (BOM) predict the south-west of WA can expect a 20% reduction in rainfall by 2030 from the 1990 baseline (Water Corporation 2009). It is likely that deep aquifers will play an increasingly important role in water supply in the future as shallower aquifers are depleted. In the context of a drying climate and the uncertainty surrounding the assessment of leakage into deep aquifers during hydraulic fracturing, low-salinity deep aquifers must be identified and quarantined from shale gas development.

The assessment of salinity in deep aquifers proximal to shale gas targets is not a mandatory requirement in WA's current regulatory regime. This omission must be addressed in the context of the uncertainty related to fluid leakage associated with hydraulic fracturing.

Gas companies commonly use the SP log to estimate salinity in deep aquifers, however errors of an order of magnitude are to be expected using this method (Jorgensen 1989). With errors of this magnitude, low salinity aquifers may be misclassified as saline.

Unlike the SP log, the use of resistivity and density logs in conjunction with Archies equation is well documented in the hydrogeology literature and this method is assumed to be a more credible means to assess salinity in low salinity aquifers.

As a minimum, deep aquifer salinity should be mapped using available geophysical logs from petroleum exploration wells prior to granting unconventional exploration licenses. The use of the total porosity method (TPM) in conjunction with the Archies equation is a more credible method for identifying low-salinity aquifers than the SP log when density log data is limited. The SP method is not recommended.

There is no requirement in the regulatory guidelines for unconventional gas explorers and developers to assess seal integrity in unconventional reservoirs. The Department of Mines advises that geological faults must be avoided during hydraulic fracture stimulation due to the potential for induced seismicity (Department of Mines and Petroleum 2015). However, this requirement is not considered to be realistic as 2-3km long horizontal wells are likely to intersect multiple faults on a routine basis.

There are no permeability data sets for the Kockatea Shale in the Woodada gas field area however, the occurrence of the Carynginia Limestone as a conventional gas target beneath the Kockatea Shale at this location indicates the Kockatea Shale functions as a seal. This suggests that buoyancy is not likely to be a significant mechanism for gas leakage in the Kockatea Shale. In other words, the gas leakage rate is correlated with the proportion of critically stressed fault. The whole Woodada gas field poses risks of hydrocarbon leakage, with high mobility and lateral spread.

The FAST™ risk management system is currently used for conventional hydrocarbon exploration, but "is not currently used in environmental risk assessment in the unconventional setting", and it should be.

Potential fields over the Yaragadee aquifer will require the highest fracking pressures, which increases the risks of leakage into the aquifer.

There is potential for movement along critically stressed faults during hydraulic fracture stimulation, with consequent increase of gas leakage to overlying aquifers. A screening level of assessment based on stress analysis using data acquired from oil exploration wells is a useful application to determine the level of risk to overlying aquifers of increased gas leakage resulting from hydraulic fracture stimulation.

1.2 Methane emissions in the US in fracked gas fields

Extensive work on methane emissions from fracked gas fields in the US indicates methane emissions are much higher than that claimed by the gas industry (see, for example, Ohio Department of Natural Resources 2008; Harrison 1983; Ground Water Protection Council 2009; Rowan, Engle; Kirby and Kraemer 2011; The Royal Society and The Royal Academy of Engineering 2012).

A significant issue is that no baseline testing has been carried out to determine the level of background methane on which comparisons of before and after fracking can be evaluated. Having avoided baseline testing, the industry could not establish the pre-existence of natural methane emissions before their fracturing and disruption of aquifers. For this reason, at the very minimum, this Inquiry must recommend that reputable and independent third party bodies (i.e. universities with no commercial or sponsorship arrangements with the fossil fuel industry) be commissioned to do atmospheric baseline testing in any and all areas where exploration for methane gas is being conducted.

There are emissions from venting or flaring when drilling has occurred but before plugging or in some cases, abandonment. This can happen even in the exploration phase, so baseline testing in areas central to and surrounding exploration and production wells must be conducted prior to any activity by the gas or fracking industry which breaks the ground.

SEN states that the level of risk associated with one well leaking is magnified over the many wells required in the fracking process and that the damage caused cannot be remediated.

Further discussion on these matters is contained in Section 2 of this Submission.

1.3 Other environmental concerns and examples

SEN holds serious concerns regarding other environmental issues associated with fracking such as the:

- Large volumes of water used that become contaminated during the process;
- Use of toxic chemicals and their distribution over large areas;
- Destabilisation of earth's crust leading to regional earthquakes and faulting damage;
- Health effects from methane inhalation;
- Large cumulative physical impact of access roads and clearing; and
- Potential chemical contamination in handling or transport accidents.

Many of these issues have been highlighted by other researchers. In particular, the Union of Concerned Scientists (nd) published the following summary of 15 scientific papers on the environmental impacts associated with fracking in the US (including the work of, amongst others, the US Environmental Protection Agency and Department of Energy):

> ### Water use and pollution
>
> Unconventional oil and gas development may pose health risks to nearby communities through contamination of drinking water sources with hazardous chemicals used in drilling the wellbore, hydraulically fracturing the well, processing and refining the oil or gas, or disposing of wastewater. Naturally occurring radioactive materials, methane, and other underground gases have

sometimes leaked into drinking water supplies from improperly cased wells; methane is not associated with acute health effects but in sufficient volumes may pose flammability concerns. The large volumes of water used in unconventional oil and gas development also raise water-availability concerns in some communities.

Groundwater

There have been documented cases of groundwater near oil and gas wells being contaminated with fracking fluids as well as with gases, including methane and volatile organic compounds. One major cause of gas contamination is improperly constructed or failing wells that allow gas to leak from the well into groundwater. Cases of contamination have been documented in Ohio and Pennsylvania.

Another potential avenue for groundwater contamination is natural or man-made fractures in the sub-surface, which could allow stray gas and hydrocarbon liquids to move directly between an oil and gas formation and groundwater supplies.

In addition to gases, groundwater can become contaminated with hydraulic fracturing fluid and chemicals. In several cases, groundwater was contaminated from surface leaks and spills of fracturing fluid. Fracturing fluids also may migrate from abandoned wells, from improperly sealed and constructed wells, through induced fractures, or through failed wastewater pit liners.

Surface Water

Unconventional oil and gas development also poses contamination risks to surface waters through spills and leaks of chemical additives, spills and leaks of diesel or other fluids from equipment on-site, and leaks of wastewater from facilities for storage, treatment, and disposal. Unlike groundwater contamination risks, surface water contamination risks are mostly related to land management and to on and off-site chemical and wastewater management.

The EPA has identified more than 1,000 chemical additives that are used in hydraulic fracturing, including acids (notably hydrochloric acid), bactericides, scale removers, and friction-reducing agents. (*SEN notes that: Potentially toxic substances include petroleum distillates such as kerosene and diesel fuel (which contain benzene, ethylbenzene, toluene, xylene, naphthalene and other chemicals); polycyclic aromatic hydrocarbons; methanol; formaldehyde; ethylene glycol; glycol ethers; hydrochloric acid; and sodium hydroxide may be found in inventory of hydraulic fracturing activities*).

Only maybe a dozen chemicals are used for any given well, but the choice of which chemicals is well-specific, depending on the geochemistry and needs of that well. Large quantities — tens of thousands of gallons for each well — of the chemical additives are trucked to and stored on a well pad. If not managed properly, the chemicals could leak or spill out of faulty storage containers or during transport.

Drilling muds, diesel, and other fluids can also spill at the surface. Improper management of flowback or produced wastewater can cause leaks and spills. There is also risk to surface water from deliberate improper disposal of wastewater by bad actors.

Water Use

The growth of hydraulic fracturing and its use of huge volumes of water per well may strain local ground and surface water supplies, particularly in water-scarce areas. The amount of water used for hydraulically fracturing a well can vary because of differences in formation geology, well construction, and the type of hydraulic fracturing process used. The EPA estimates that 70 billion to 140 billion gallons of water were used nationwide in 2011 for fracturing an estimated 35,000 wells. Unlike other energy-related water withdrawals, which are commonly returned to rivers and lakes, most of the water used for unconventional oil and gas development is not recoverable. Depending on the type of well along with its depth and location, a single well with horizontal drilling can require 3 million to 12 million gallons of water when it is first fractured — dozens of times more than what is used in conventional vertical wells. Similar vast volumes of water are needed each time a well undergoes a "work over," or additional fracturing later in its life to maintain well pressure and gas production. A typical shale gas well will have about two work overs during its productive life span.

Earthquakes

Hydraulic fracturing itself has been linked to low-magnitude seismic activity — less than 2 moment magnitude (M) [the moment magnitude scale now replaces the Richter scale] — but such mild events are usually undetectable at the surface. The disposal of fracking wastewater by injecting it at high pressure into deep Class II injection wells, however, has been linked to larger earthquakes in the United States. At least half of the 4.5 M or larger earthquakes to strike the interior of the United States in the past decade have occurred in regions of potential injection-induced seismicity. Although it can be challenging to attribute individual earthquakes to injection, in many cases the association is supported by timing and location of the events.

1.4 Conclusion Section 1

The conclusion SEN draws from the work presented in this Section is that no set of regulations exists or can be devised that can limit the environmental damage caused by fracking to an acceptable level.

The only safe form of regulation is to ban the process of fracking in WA's onshore gas fields.

Section 2: Greenhouse Gas (GHG) Emissions Limits and Fracking

This Section argues the world cannot afford to utilise all known carbon deposits if it is to limit global warming to 2 degrees (or the preferred 1.5 degrees) and thus it is superfluous to allow exploration to identify additional gas reserves and then to permit the fracking of those resources.

Section 2.1 discusses the limits on carbon and GHG emissions.

Section 2.2 provides data on the potency of methane as a greenhouse gas, showing it to be many times that of CO2. It further identifies methane emissions from gas fracking as major inputs into global warming.

SEN argues no regulation is capable of preventing these emissions and therefore fracking should be banned.

2.1 Greenhouse Gas Emissions

The Intergovernmental Panel on Climate Change (IPCC), the international body for assessing the science related to climate change, calculated the total carbon limit remaining if the world is to limit human-induced warming to less than 2 degrees relative to the period 1861-1880 with a probability of >66%.

The total limit figure is 2,900 GtCO2-e within a range of 2550 to 3150 (IPCC Synthesis report RP5 2014, P63).

The atmosphere currently contains approximately 2,150 GtCO2, leaving approximately 750 GtCO2 of the limit yet to be used (Evershed 2017).

However, more recent modelling done on the effect of aerosols (which are emitted into the atmosphere by burning coal), and which provide a 'shading and cooling' effect, indicates that as these are reduced as the burning of coal is phased out, it will cause an additional warming. This essentially means that:

- The emissions limit to stay "well below 2 ºC and preferably a 1.5 ºC peak" has been passed, and the consequences of temperature rises beyond that are now unavoidable. (Spratt 2018)
- Methane emissions from fracking will displace lower-emission conventional reserves and therefore are contributing to very dangerous climate change at a greater intensity than other lower-emissions fossil fuel sources.

- As senior Climate Scientist Michael Mann (Mann 2015) has said:
    - The carbon ‘budget’ concept carries several and significant uncertainties, many of which are not fully appreciated, and which limit the political usefulness of the method.
    - The published 1.5°C carbon budgets all have an unacceptably high risk — of a one-in-three or greater chance — of exceeding the target temperature. Scenarios with a 50% chance of not exceeding the 1.5°C target have a 33% chance of exceeding 2°C of warming, and a 10% chance of exceeding 3°C of warming.
    - All published 1.5°C emissions-reduction scenarios for this century involve significantly “overshooting” the target for several decades (up to 1.8°C of warming) before returning to the target figure by 2100.
    - From a sensible risk-management viewpoint, there is no carbon budget available for the 1.5°C target. Thus, achieving 1.5°C in the medium term means drawing down every ton of carbon dioxide emitted from now on.
    - The damage that will eventually be caused by the current level of warming of 1°C is beyond adaptation for many nations and peoples. 1.5°C is not a safe target.

One estimate of known fossil fuel reserves in the world (Pisupati 2017) suggests the following:

TABLE 1: Estimated world reserves of fossil fuels as at 31 December 2016

World Reserves of non-renewable energy sources	
Petroleum (billions of barrels)	1707
Natural gas (Wet) Trillion Cu. Ft.	6588
Coal (billions of short tons)	948

Using data from the US Energy Information Administration (2016) on the amount of CO2 contained in specified non-renewable fuels, the CO2 produced from burning these deposits can be calculated and the results are set out in Table 2:

TABLE 2: Estimated CO_2 production from burning world reserves of non-renewable fuel

Fuel	CO2 contained	Total CO2 if known reserves burnt
Petroleum	8.89 kg/gallon	637 GtCO2
Natural gas	53.1kg/thousand cubic feet	349 GtCO2
Coal	2,100kg/short ton	1,990 GtCO2

The world emitted 36.3 GtCO2 in 2016 and is estimated to have emitted 36.8 GtCO2 in 2017 (Global Carbon Project 2017).

SEN argues that WA should not permit fracking because any additional gas recovered will contribute to the world not being able to remain below the 2 degrees level.

2.2 Methane and CO_2 Emissions Impact on Climate and International Agreements

Methane is known to be emitted to the atmosphere from wells that are being fracked. Recently evidence has accumulated that the amount of gas escaping is much greater than is acknowledged by the industry.

Methane emissions from wells that have been fracked have a tendency to be considerably higher than conventional extraction methods. These emissions are often referred to as "fugitive" emissions but it should noted that the term "fugitive" is a misnomer as methane is often vented intentionally and sometimes unavoidably in well operations, particularly during drilling and in unconventional oil production to assist in the production of a higher value product. From a short-term global warming perspective, this can make burning such gas for electricity as bad or worse than burning coal.

Methane (i.e. the major component of fossil gas) is a potent greenhouse gas and is responsible for as much as a third of the anthropogenic global warming Earth has seen occur to date (IPCC AR5 WGI, Ch 2, Table 2.3, 2014; Forster et al. 2007).

The potency of methane has been upwardly revised with each IPCC Assessment Report, resulting in frequent misreporting of its potency in the mainstream and climate change literature.

Further to this, the timeframe used to compare methane with CO2 is often chosen as 100 years, but for a gas with a half-life in the atmosphere of approximately 7 years this greatly reduces the global warming potential number associated with its heat-trapping potency. The latest comparison from IPCC (2014) is shown in the table below and indicates that methane can have an environmental impact more than 100 times greater than CO2: See Table 3.

TABLE 3: CO2 and methane relative Radiative Forcings, IPCC AR5, Shindell et al, 2014

	100-year timeframe not including climate feedbacks GWP_{100}	100-year timeframe including climate feedbacks GWP_{100}	20-year timeframe not including climate feedbacks GWP_{20}	20-year timeframe including climate feedbacks GWP_{20}	20-year timeframe including climate feedbacks and its role as a precursor to Tropospheric ozone GWP_{20}
CO_2	1	1	1	1	1
Methane	28x	35x	72x	86x	105x

The first major attention hydraulic fracturing attracted in the climate literature began with the "Cornell Letter" by Howarth et al. (2012). This brief paper hypothesised that if methane emissions in gas fields were significantly higher than industry assumptions then generating power by burning gas from could be significantly worse than burning coal to make power.

This applied to both conventional and unconventional extraction methods, but it was postulated that so-called unconventional extraction methods see even higher methane emissions than conventional fossil gas.

A figure of 3.2% methane emissions was calculated to be the threshold level at which power derived from burning gas was worse than burning most of the coal burnt in the US at that time. Subsequently there was a "Response to Critics" paper and then further field research by the US National Oceanic and Atmospheric Administration (NOAA) and a consortium of Ivy League university partners to directly measure methane levels in the air in and above large unconventional gas fields, such as the Marcellus shale region.

This direct atmospheric detection found that gas levels were actually much higher than industry assumptions (and on which their climate impact is typically assessed and reported), even within the climate literature, and not just government accounting using the standardised United Nations Framework Convention on Climate Change (UNFCCC) methodology used by nation state signatories to Kyoto and Paris agreements.

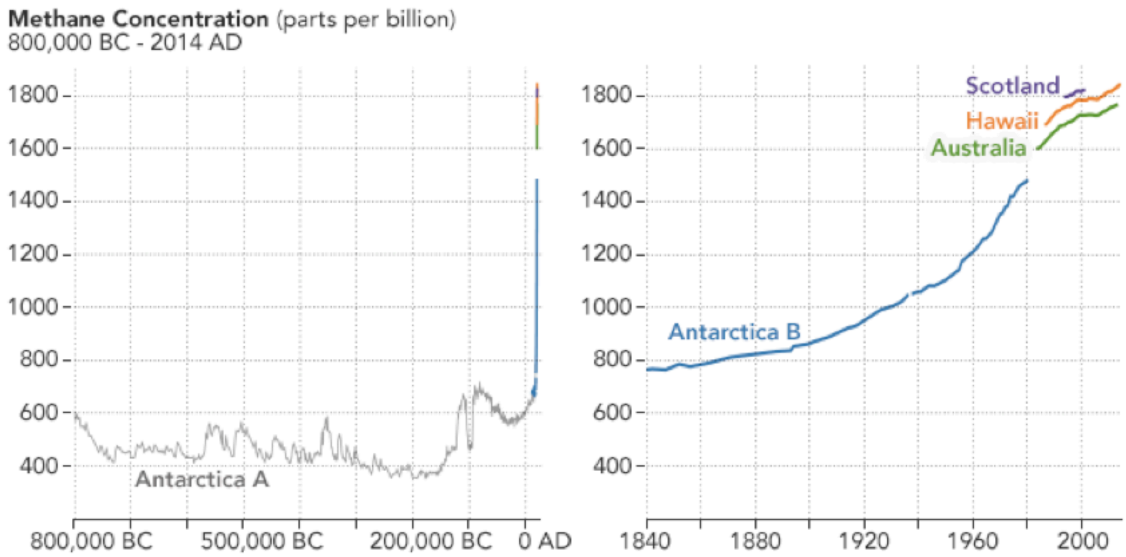
Industry responded by suggesting that these atmospheric levels were "natural" emissions of methane and nothing to do with their activities, in spite of the evidence to the contrary. Having avoided baseline testing, the industry could not establish the pre-existence of natural methane emissions before their fracturing and disruption of aquifers, but none the less made that claim.

For this reason, at the very minimum, this Inquiry must recommend that reputable independent third party bodies (i.e. universities with no commercial or sponsorship arrangements with the fossil fuel industry) be commissioned to do atmospheric baseline testing in any and all areas before exploration for methane gas is conducted. It should be borne in mind however that the previously identified issue that mitigation methods are not possible in the event of cap rock or fault damage, hence SEN does not support this method.

Significant emissions can occur when drilling has completed but before plugging an or abandonment. This can happen even in the exploration phase, so baseline testing in areas central to and surrounding exploration and production wells must be conducted prior to any activity by the gas or fracking industry which breaks the ground.

Evidence of strong increases in atmospheric methane since 2006, based on data from the US Environmental Protection Agency (see Fig. 1 below), is a serious concern and suggests that the rapid growth of new technologies such as hydraulically fractured oil and gas is a likely cause and has contributed almost 70% of this increase. All possible steps must be taken to avoid adding to this environmental and climate change issue.

FIG. 1: Methane concentration (parts per billion) 800,000 BC – 2014 AD

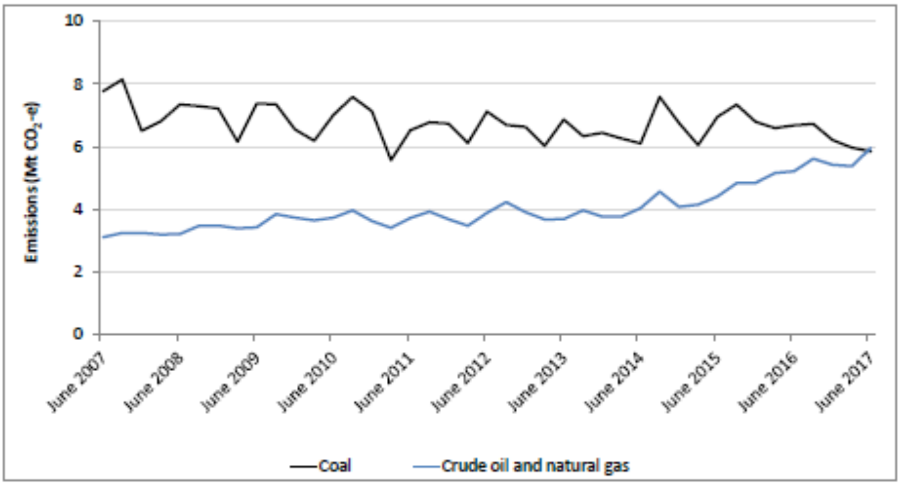


(Fig. 1 reproduced from Voiland 2016)

Australia's own official methane emissions from the oil and gas industry are shown in Fig. 2 below, and illustrate a doubling of emissions between 2007 and 2017. "Fugitive emissions" are defined by the Australian Government Department of the Environment and Energy (2018, p. 31) as:

> Emissions, other than those attributable to energy use, from:
> • Solid fuels: CO_2 and CH_4 from coal mining activities, post-mining and decommissioned mines. CO_2, CH_4 and N_2O from flaring associated with coal mining; and
> • Oil and gas: exploration, extraction, production, processing and transportation of gas and oil. Includes leakage, evaporation and storage losses, flaring and venting of CO_2, CH_4 and N_2O.

FIG. 2: Fugitive emissions by sub-sector, quarterly, 'unadjusted' emissions, June 2007 - 2017



(Fig. 2 reproduced from Department of the Environment and Energy 2018, p. 15)

US environmental advocate Bill McKibben raised serious concerns regarding methane emissions from US gas fracking in March 2016 (McKibben 2016):

> … In February [2016], Harvard researchers published an explosive paper in *Geophysical Research Letters*. Using satellite data and ground observations, they concluded that the nation [US] as a whole is leaking methane in massive quantities. Between 2002 and 2014, the data showed that US methane emissions increased by more than 30 percent, accounting for 30 to 60 percent of an enormous spike in methane in the entire planet's atmosphere.
>
> … if even a small percentage of the methane leaked—maybe as little as 3 percent—then fracked gas would do *more* climate damage than coal. [P]reliminary data showed that leak rates could be at least that high: that somewhere between 3.6 and 7.9 percent of methane gas from shale-drilling operations actually escapes into the atmosphere.
>
> … The EPA had been insisting throughout that period [2002-2014] that methane emissions were actually falling, but it was clearly wrong—on a massive scale. In fact, emissions "are substantially higher than we've understood," EPA Administrator Gina McCarthy admitted in early March [2016].
>
> The EPA's old chemistry and 100-year time frame assigned methane a heating value of 28 to 36 times that of carbon dioxide; a more accurate figure … is between 86 and 105 times the potency of CO2 over the next decade or two, as referenced above.

Similarly, the Union of Concerned Scientists (nd, para. 4), citing 5 scientific reports from sources including the IPCC and the US National Climate Assessment, stated:

> The drilling and extraction of gas from wells and its transportation in pipelines results in the leakage of methane, primary component of gas that is 34 times stronger than CO2 at trapping heat over a 100-year period and 86 times stronger

> over 20 years. Preliminary studies and field measurements show that these so-called "fugitive" methane emissions range from 1 to 9 percent of total life cycle emissions".

2.3 Conclusion Section 2

The industry claims that individual wells have a small risk of fugitive emissions. As hundreds if not thousands of wells are drilled in a typical drilling pattern, it is statistically certain that at least one well will release methane.

It's known that only 5% of production wells (called "super-emitters") can be responsible for over 50% of the methane emissions in a production field (Than 2016). Additionally a Princeton University study estimates that "… emissions from abandoned wells represents as much as 10 percent of methane from human activities in Pennsylvania — about the same amount as caused by current oil and gas production. Also, unlike working wells, which have productive lifetimes of 10 to 15 years, abandoned wells can continue to leak methane for decades." (Sullivan 2014)

Furthermore, the issues raised in Section 1 indicate that gas leakage from faults after fracking is more than well leakage.

SEN argues that the inability of regulations to control or overcome effects of fugitive emissions compels a decision to ban fracking entirely.

Section 3: Existing Gas Supply is Adequate to Meet Demand, and Other Technologies and Trends Are Displacing Gas

In this Section SEN establishes that there is sufficient supply of gas from existing reserves, obtainable without the need for fracking, to meet WA's the domestic demand, and these reserves are also likely to meet foreseeable demand for export either to other Australian jurisdictions or internationally.

There are two components to this argument. The first relates to the existence of proven gas supplies that can be accessed without the use of fracking and is addressed in Sub-section 3.1.

The second component is that an economic transition to renewables will significantly reduce demand for gas in WA for the period to 2030, as addressed in Section 3.2.

Section 3.3 shows the relative gas demand from various sectors in WA, in order to provide insight as to how changes in each could affect overall demand.

Based on the evidence in this Section, SEN argues there is no justification for permitting fracking based on a requirement for the gas. WA's energy security can be better achieved through the use of renewables.

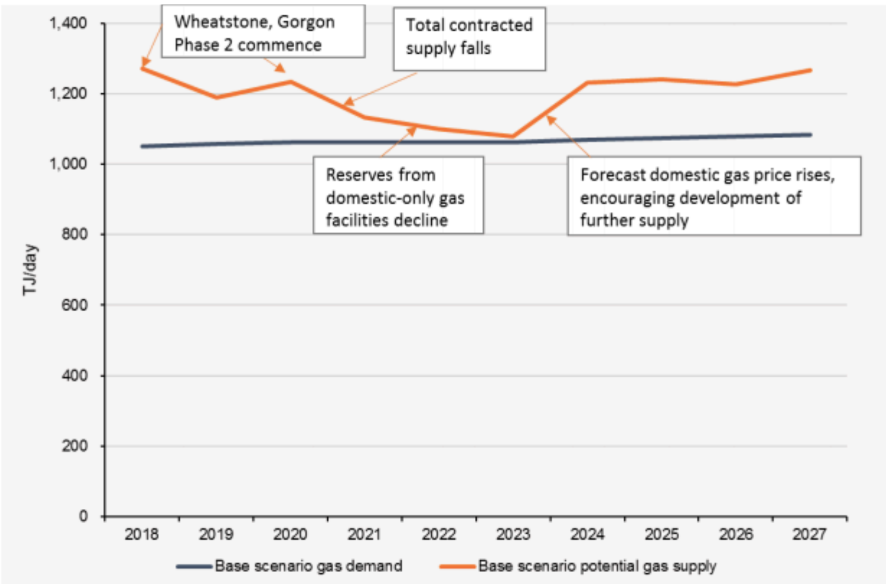
3.1 WA's Existing Gas Resources

SEN asserts that WA's future domestic demand for gas will be satisfied by existing reserves from conventional formations into the foreseeable future, that are accessible without hydraulic fracturing required in unconventional formations.

3.1.1 WA's Existing Reserves Compared to Predicted Demand

Using data from the Australian Energy Market Operator (AEMO), the 'Base scenario' forecasts show WA's potential gas supply exceeds demand by at least 132 TJ/day each year until 2020, as illustrated in Figures 3 and 4 below:

FIG. 3: WA gas market balance (TJ/day), 2018-2027



(Fig. 3 reproduced from AEMO 2017, p. 4)

After 2020, the reserves currently being developed will produce sufficient gas without the need for fracking.

FIG. 4: Domestic gas demand forecasts for SWIS and non-SWIS (TJ/day), 2018-2027

		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	5 year average growth pa (%)	10-year average growth pa (%)
SWIS	Low	663	661	664	660	656	654	658	656	657	659	-0.3	-0.1
	Base	666	666	671	670	668	668	674	677	680	685	0.1	0.3
	High	670	674	683	677	671	685	692	700	707	715	0.0	0.7
Non-SWIS	Low	384	388	389	389	389	389	389	389	389	389	0.3	0.1
	Base	385	390	392	393	394	395	396	397	398	399	0.6	0.4
	High	386	395	408	422	432	437	440	442	445	447	2.9	1.7

Source: MJA with AEMO.

(Fig. 4 reproduced from AEMO 2017, p. 46)

3.1.2 Overview of WA's gas resources, reserves, and exploration

WA's available conventional gas resources and reserves are categorised according to the level of technical and commercial uncertainty associated with recoverability. Reserves are quantities of gas that are anticipated to be commercially recovered from known accumulations.

- Proved and probable reserves (2P) are considered the best estimate of commercially recoverable reserves;

- Contingent resources (2C) are considered less commercially viable than 2P reserves. 2C resources are considered the best estimate of sub-commercial resources.;
- Prospective resources are estimated volumes associated with undiscovered accumulations of gas.

Third-party estimates of WA's total conventional and unconventional gas resources are summarised in Fig. 5 Conventional 2P reserves make up 50% of total conventional gas resources (2P+2C).

FIG. 5: WA conventional and unconventional gas resources and reserves (PJ), Sept. 2017

Attribute	Total
Conventional 2C gas resources	74,231
Conventional 2P gas reserves	73,913
Unconventional: Estimated shale gas resources, range low to high[b]	96,501 - 204,666
Unconventional: Estimated tight gas resources[c]	91,198

Source: DJSTI 2017. *WA LNG Industry Profile*, Sept/Oct, p.5. http://www.jtsi.wa.gov.au/docs/default-source/default-document-library/wa-lng-profile-0917.pdf?sfvrsn=6.
[a] Sum of resources and reserves provided by basin, with the figures for the Bonaparte Basin giving the net entitlement to Australia. Converted from Tcf to PJ. 2C resources reported are over and above the 2P reserves reported.
[b] Based on WA Dept. of Mines, Industry Regulation and Safety's current, best estimates of risked, recoverable resources.
[c] GIIP: Gas-initially-in-place, referring to the total amount of gas contained in each basin, including volumes that are deemed sub-economic, and which may never be recovered.

(Fig. 5 reproduced from AEMO 2017, p. 22)

Referring to Fig. 3, over the 10-year outlook period after growth in 2018 and 2024, AEMO's modelling suggests that the Base scenario for potential gas supply is expected to fall. However, in response to a decline in forecast reserves and domestic gas prices, potential supply recovers after 2023, returning to current levels by the end of the outlook period. Three key factors contribute to the potential gas supply forecast over the outlook period:

- Additions to supply, with excess gas supply forecast to increase to 170 TJ/day in 2020, in line with the assumed commencement of domestic gas production facilities at Wheatstone (in 2018) and Gorgon Phase Two (in 2020).
- At the end of 2020, potential supply decreases as large legacy North-West Shelf gas supply contracts expire. Subsequently, total contracted supply and the quantity of the domestic market obligation of the North-West Shelf are expected to reduce. If the commencement of Gorgon Phase Two is delayed beyond the projected date, the WA gas market balance may start to tighten after 2020.

- From 2022, there is further uncertainty for potential supply, arising from multiple domestic gas production facilities facing reserve depletion. When the Low potential supply scenario (Fig B) is compared to the Base demand scenario, a shortfall of as much as 155 TJ/day may eventuate in 2021. However, the Low potential supply scenario is considered unlikely as there is a realistic expectation that domestic gas prices will respond to forecast demand, encouraging further supply that will alleviate the risk of this potential shortfall.

In addition to the points taken from AEMO data, the recent commitment by Woodside to provide Pluto gas into the 15% reservation obligation means gas will be more plentiful than previously forecasted by AEMO (Harvey 2018).

3.1.3 Probable and Proven Conventional Gas Reserves in Western Australia

In addition to the 2P reserves mentioned above, there are further "probable" (1P) bankable gas reserves underpinning forward demand to satisfy WA's domestic needs.

3.2 Renewables Displacing Gas

SEN argues renewables will substantially displace the use of gas in the foreseeable future throughout the world and in WA.

Section 3.2.1 looks at international demand for gas reducing due to the transition to renewables.

Section 3.2.2 looks at the transition in WA, particularly as the SWIS transitions from gas and coal to renewables.

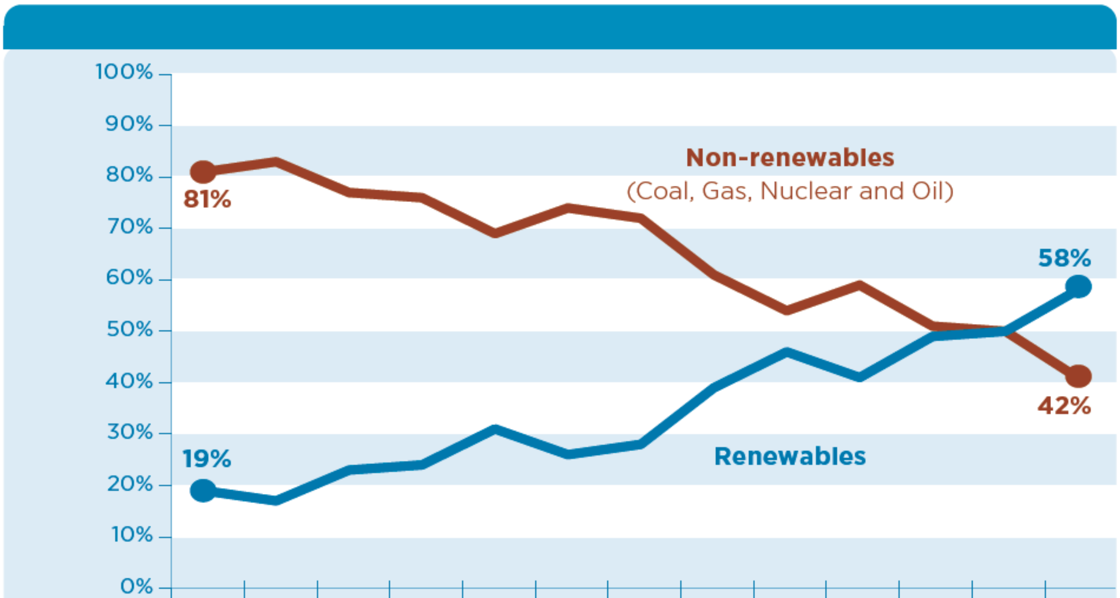
Section 3.2.3 addresses the reduction in gas demand due to stationary energy fuel switching to electricity.

Section 3.2.4 addresses demand for gas as transport transitions from petroleum to electricity.

3.2.1 Reduction in Gas Demand Internationally as World Transitions to Renewables

There is international evidence of renewables displacing gas. The rapidly reducing costs of wind and solar PV energy, plus climate and pollution issues are driving global change from traditional fossil fuels to renewables. Recent global investment in renewable energy generation capacity has exceeded that of all fossil and nuclear energy combined (Figures 6 and 7).

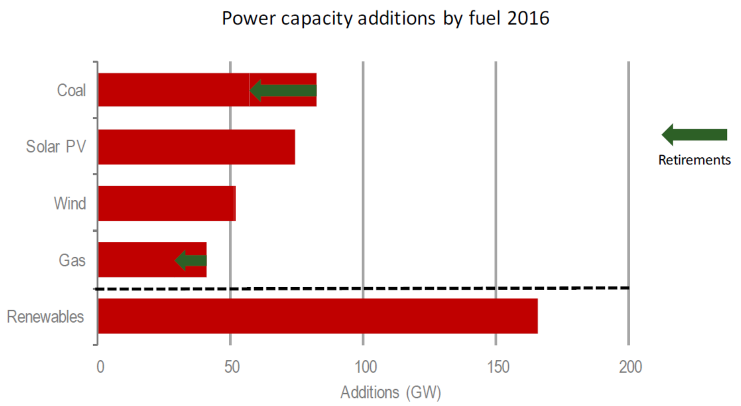
FIG. 6: Renewables as a share of global capacity additions (2001-2013)



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total net capacity added per year	**104**	**134**	**150**	**153**	**134**	**180**	**200**	**174**	**185**	**232**	**234**	**233**	**207**
Renewables	20	22	34	36	41	47	56	67	85	94	115	116	120
Non-renewables	84	111	116	116	93	133	145	107	100	138	118	117	87

(Fig. 6 reproduced from IRENA 2014, p. 25)

FIG. 7: Global renewable energy capacity growth vs. fossil capacity in 2016

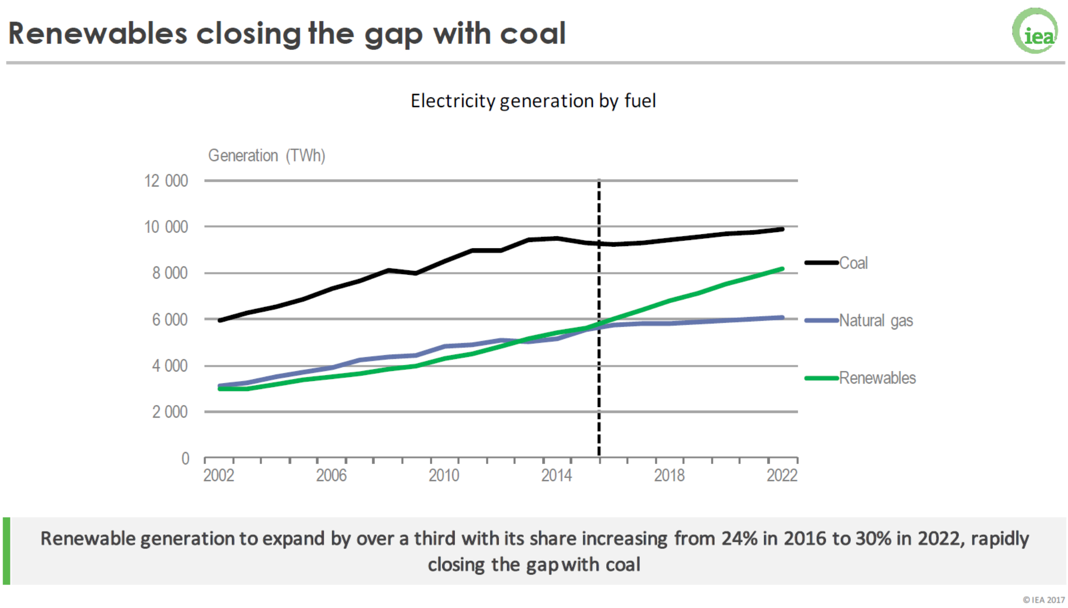


Renewables breaking an all-time record accounting for two thirds of global net capacity additions;
For the first time solar PV becoming the global leader in net capacity growth

(Fig. 7 reproduced from International Energy Agency 2017, no. 3)

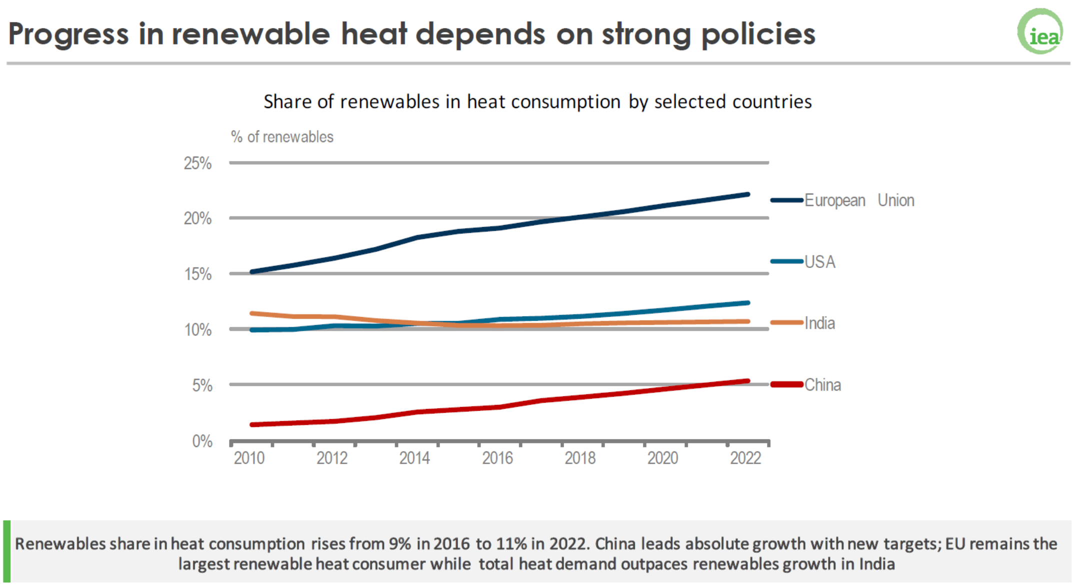
Furthermore, SEN asserts that the global trend of displacement of gas by renewables for electricity and heating will reduce demand for gas internationally thus reducing export demand. The International Energy Agency conservative projections show demand for gas to be at most relatively flat (Figures 8and 9 below).

FIG. 8: Global gas and coal displacement projections to 2022



(Fig. 8 reproduced from International Energy Agency 2017, no. 8)

FIG. 9: Renewable energy for heating applications



(Fig. 9 reproduced from International Energy Agency 2017, no. 11)

3.2.2 Reduction in Gas Demand for Electricity Generation in Western Australia

SEN has modelled energy scenarios for WA's SWIS electricity generation transition to renewable energy as aging coal generation is retired toward 2030. The results indicate there will be a significant reduction in gas consumption as shown in Figures 10 and 11 under a range of scenarios up to a notional 100% renewable energy supply.

SEN's modelling of an 85% renewable energy scenario on WA's southwest interconnected system (SWIS) to 2030 demonstrates that replacement of all coal generation (much of which is nearing end of design life) with renewables at today's prices (along with storage and backup) would be cost competitive with replacing with new coal plants.

The remaining minor gas demand in high RE scenarios for SWIS electricity generation could be largely or all met through local sustainable biomass/biofuel production in a carbon cycle that will not affect the atmosphere in the same way fossil carbon does (SEN 2013; SEN 2017a).

FIG. 10: SWIS renewable energy transition scenario modelling to 2030 (SEN 2017b)

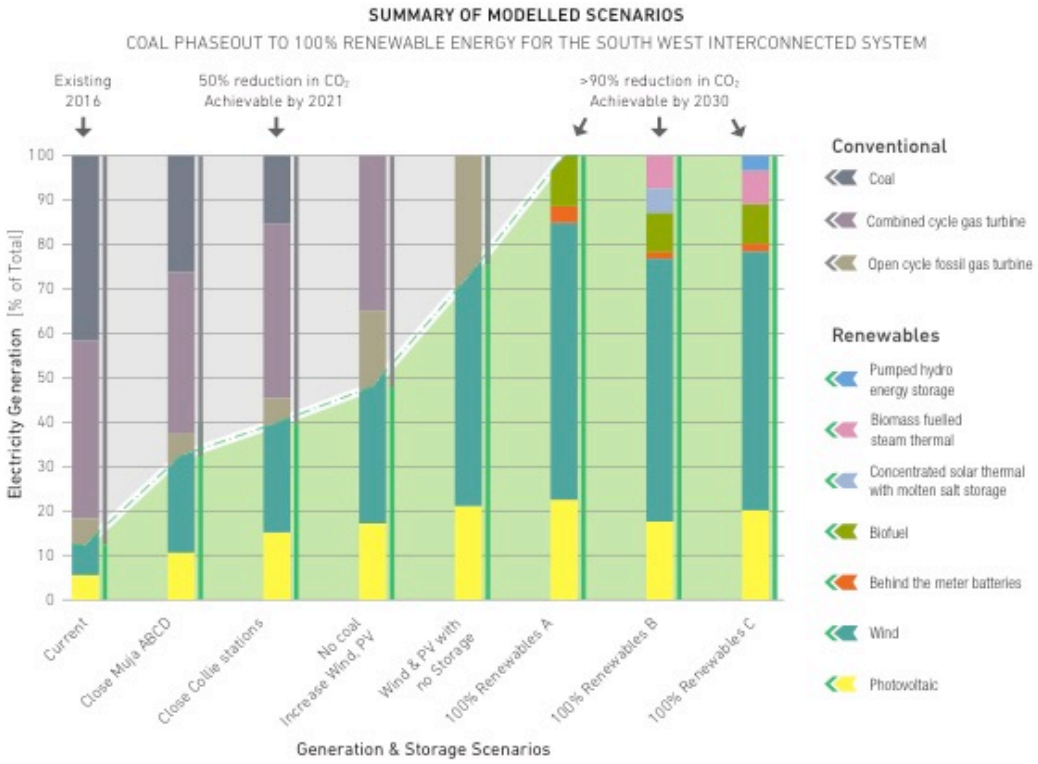


FIG. 11: Potential SWIS transition to 85% renewable energy fuel types, from 2018-2030 in 2-year intervals (SEN modelling unpublished)

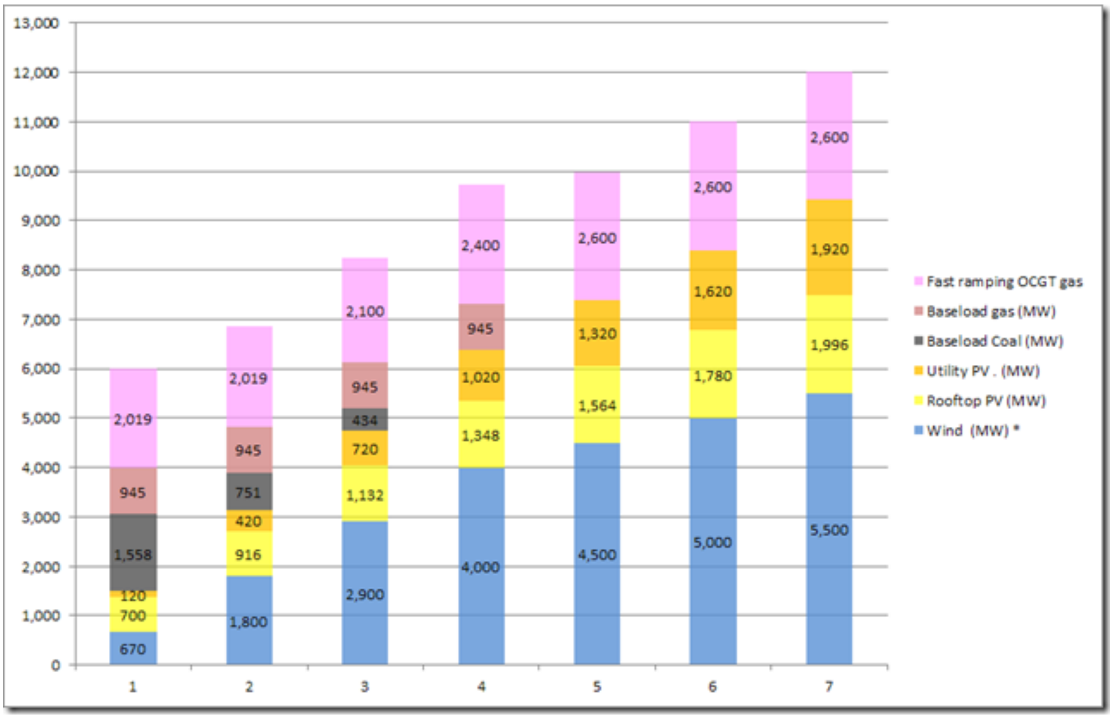
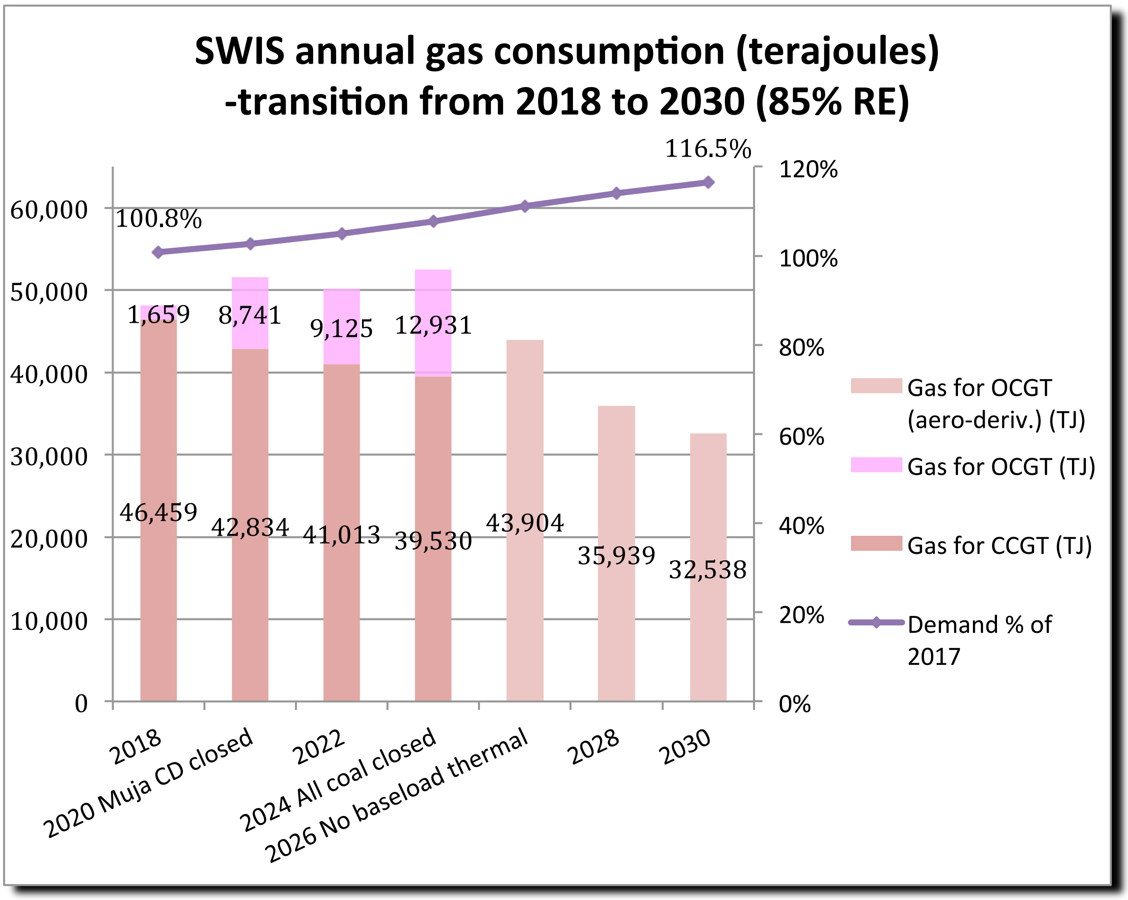


FIG. 12: Annual gas consumption in the SWIS during transition to 85% renewable energy generation (SEN modelling unpublished)



In Figure 12 above, the modelling of an 85% renewable energy scenario by 2030 shows gas consumption would significantly decrease from the present despite an assumed growth in overall electricity demand of 16% by 2030.

Note to Figure 12 that SEN's SWIS energy transition modelling of retirement of coal plants assumes large step-reductions in coal generation retirements, replacing it with a steady growth of renewables. These assumptions result in temporary small increases in gas use initially, however a more refined practical retirement of coal and deployment of renewables would flatten gas demand until the last coal/gas baseload plant is off-line, and thereafter there would be a 33% decrease in gas use as renewable generated electricity reaches 85%. Following on, the demand for gas would continue to fall as renewable energy and storage deployment continues to increase beyond 85% of total SWIS supply.

SEN presents the 85% renewable energy scenario because it is presently the most cost competitive (in Levelised Cost of Electricity (LCOE) terms) for the transition from fossil fuels to renewables. Supporting information is contained in SEN's Briefing Notes on SEN's website (SEN 2017b). SEN's modelling assumes existing prices for renewables, and given the LCOE of renewables are continuing to reduce, SEN projects that the lowest-cost electricity scenario will move toward 100% renewable energy, with associated storage and other technologies.

A further benefit resulting from the 85%+ renewable scenario is that there are large amounts of surplus electricity available (mostly in Summer), due to the inherent 'overbuild' of renewable generation capacity. This provides opportunities for industry to utilise this otherwise wasted low-cost energy resource.

In regard to other parts of Western Australia, the low cost of renewable energy (both with and without storage) increases its attractiveness for regional areas covered by Horizon Power, mining and other off-grid users as it is able to displace the use of typically more expensive gas and diesel generation. This trend is evident in the increasing number of RE projects, which Horizon Power is implementing (Vorrath 2016; Horizon Power 2018)

3.2.3 Gas demand reduction from stationary energy 'fuel-switching' to electric

New electrical equipment and appliances such as heat-pump water and space heating, induction cookers and other technologies offer lower operating cost, greater convenience, improved safety and higher energy efficiency over gas for many stationary applications. Further, the ability for the electrical energy to be generated on-site (by renewables potentially with battery storage) at competitive prices provides the user with security of reliability, and independence from price rise and contractual risks.

These factors are likely to drive consumer fuel-switching from gas to electric energy for various applications, and electricity is increasingly being derived from renewable energy sources in Australia and globally. Examples of substitute technologies for gas include:

- Water heating by solar thermal and reverse-cycle heat pump;
- Space heating and cooling by reverse-cycle heat pump;
- Cooking by induction;
- Industrial process heating in some cases including replacement of aged Combined Heat and Power (CHP) units to use renewable electricity, which could potentially be made further more economically attractive by taking advantage of low-cost surplus renewable electricity generated typically in Summer, as noted in Sub-section 2.3;
- The Dutch government announced in January 2018 that in Holland from 2020 all new housing developments will have no gas connections, as they will be electric only, and furthermore are working toward retrofitting existing gas connections to electric (Dutch National Government 2018). While one of the reasons for this policy is concern over recent earthquakes in the north of the Netherlands (Groningen) caused by the gas extraction, it is also to address climate change/global warming. This demonstration may set the scene for global trends;
- 'Synthetic inertia' from electrical inverters running on battery and renewable generated electrical energy has the ability to substitute for and out-perform gas turbines for grid stability and ancillary services (Parkinson 2018).

3.2.4 Transport: Switching from petroleum fuelled to electrically driven

Transport fuel-switching from internal combustion engine powered vehicles (ICEs) to electric vehicles (EVs) is likely to increase gas consumption by only a small amount relative to the SWIS demand.

For example, SEN's EV modelling using an assumption of 20% of passenger and commercial vehicles being electric, would add approximately 8% to WA's SWIS electricity annual demand (see Table 4 below). However, under SEN's 85% renewable energy scenario, the additional electrical energy for charging EVs would be largely provided by RE generation. Further offsetting this additional electricity consumption however, are the 'vehicle-to-grid' (V2G) benefits which EVs can provide while connected the electricity grid, such as the additional electrical storage services which can facilitate and enable a greater percentage of supply from renewables, (particularly in Summer months of significant surplus generation) and hence further reduce gas energy consumption. Other V2G benefits include peak demand time-shifting, grid firming/stability (ancillary services), and 'demand-side management' (DSM).

TABLE 4: SEN Estimated Electricity Consumption of Electric Vehicles (SEN unpublished).

Description	Quantity in 2017 (all types)	Est % of EVs	Total EVs	Average Daily Distance Driven (km)	Energy Required (kWhr/km)	Total Energy (MWhr/day)	Notes
Personal Vehicles	1,645,748	20%	329,150	40	0.13	1,712	ABS reports 2,142,307 registered vehicles in WA in 2014. Assume 75% are passenger vehicles (general ratio for Aust) and 90% of these are in the SWIS. Also 1% increase per year till 2030.
Light Commercial Vehicles	292,578	20%	58,516	80	0.30	1,404	ABS reports 2,142,307 registered vehicles in WA in 2014. Assume 24% are light commercial vehicles (25% general ratio for light and heavy commercial vehicles for Aust) and 50% of these are in the SWIS. Also 1% increase per year till 2030.
Heavy Commercial Vehicles	12,191	20%	2,438	400	1.00	975	See note 4. ABS reports 2,142,307 registered vehicles in WA in 2014. Assume 1% are heavy commercial vehicles (25% general ratio for light and heavy commercial vehicles for Aust) and 50% of these are in the SWIS. Also 1% increase per year till 2030.
				Total		**4,091**	
				Annual Total		**1,493,306**	
				SWIS Annual est 20 TWh		**20,000,000**	

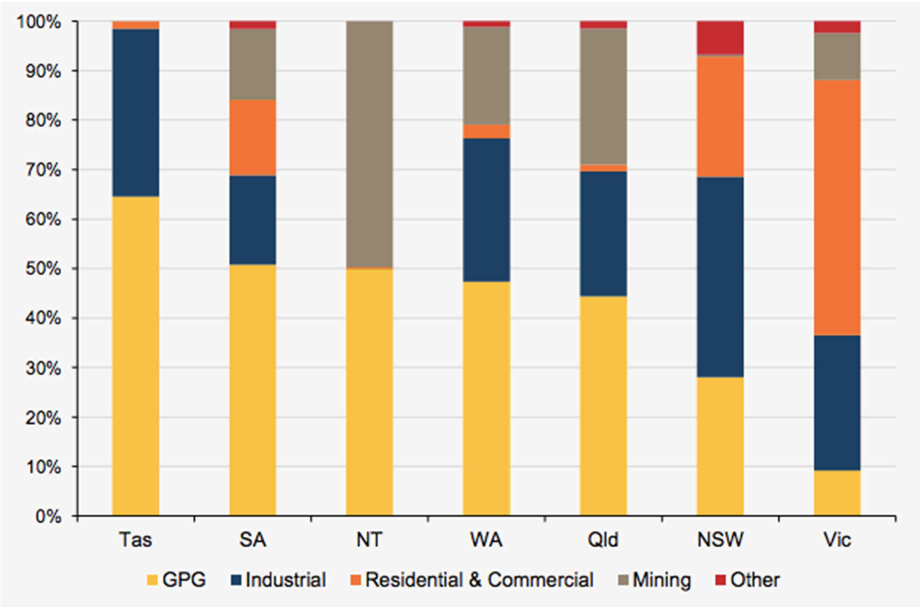
NOTES

1. Assumption: modest growth rate in vehicles of 1% pa.
2. Assumption: EV efficiency improves slightly to 0.13 kWhr/km. Not expected to improve significantly as mostly due to car aerodynamics which have already progressed along the learning curve significantly.

3.3 Sectors of Gas Demand in WA

To understand how overall gas demand may change, it is useful to consider the relative consumption of gas for different applications, as shown in Figure 13 (below):

FIG. 13: Major category gas consumption by state (% share of total), 2015-2016 (Department of the Environment and Energy 2017)



Source: Department of the Environment and Energy 2017. *Australian Energy Update 2017 – Australian Energy Statistics*, September, https://www.energy.gov.au/publications/australian-energy-update-2017.

The following table illustrates the potential for displacement by renewable energy:

TABLE 5: Potential for displacement by renewable energy

Application	Portion of total gas use	Potential reduction
GPG (electricity generation)	47%	>33% for 85% (and higher) RE scenarios
Industrial	28%	Direct heating as applicable, by RE ref: Section 3.2.2
Residential and Commercial	3%	Displacement by new electrical technologies
Mining	20%	RE electricity and/or direct RE heat as applicable
Other	2%	unknown

3.4 Conclusion Section 3

SEN maintains that WA has adequate known gas reserves which do not require fracking that will meet demand for the foreseeable future. Identifying new gas resources is superfluous as the existing reserves cannot all be utilised if the world is to remain below 2C warming. Renewables will meet WA's energy needs for less cost without the environmental damage caused by fracking.

Section 4: Financial and Other Aspects of Fracking

In this Section, SEN discusses a range of finance related issues associated with fracking.

SEN asserts that the industry is only viable if many of the costs of fracking are externalised. Otherwise the price of the gas obtained by fracking would be too expensive for the market.

In section 4.1 a number of issues regarding the companies that are involved in fracking are raised. All point to the community having to take on the risks posed by the industry for it to be viable. SEN proposes the best response to these issues is to ban fracking outright but if that is to be ignored, then SEN asserts these costs must be internalised to the industry in the regulatory framework.

Section 4.2 shows there are other revenue generating activities from renewables that would supplant any revenue lost by fracking being banned. These activities do not have the environmental disadvantages associated with fossil fuels.

In section 4.3 SEN argues for the imposition of a carbon price on the industry to ensure the cost of remediating the release of CO2 in the utilisation of the gas is borne by the gas consumers, not the wider community.

4.1 Costs of Fracking Externalised by the Industry

If fracking was to be permitted, SEN argues that the costs of regulation, monitoring and compliance, as well as the costs of remediation, if even possible, of environmental damage caused by fracking should be borne by the industry, not by the community.

Observation of companies involved in unconventional gas exploration indicates that many are relatively small – characterised as 'small- or mid-cap' companies. While the largest resource companies might be able to absorb the costs of effective regulation over the lifetime of a fracking project, any regulations need to apply to companies of all sizes.

The following discussion refers to a hypothetic, small-cap, exploration company. Its size makes it profit motivated, with one eye on the stock market for the reserves of gas discovered. Initial gas production pressures from hydraulically fractured gas wells are reported to the stock market. However, this pressure is known to fall off rapidly and is only 'economic' by using write-downs and stock market speculation schemes (Buurma and Malik 2017).

Financial pressures may lead to a small-cap explorer conducting operations to minimise costs. This may lead to regulations being complied with in name only, implying a need for a rigorous monitoring regime. However, regulatory agencies do not have the staffing or budgets to properly enforce regulations, without substantial extra funding.

If well failures and/or regulatory breaches are discovered, it may be difficult to hold a company accountable for damages caused. Small limited-liability companies, with limited budgets and highly risk tolerant management, can use protections such as bankruptcy to avoid responsibilities when things go wrong and liabilities arise.

Such operations and companies must be guarded against in the regulatory regime. However, such regulation and requisite monitoring is expensive and governments are reluctant to provide the resources necessary to ensure adequate protection is obtained. This leads to a conclusion that the cost of adequate supervision must be recovered from the industry, so that it does not become a taxpayer burden.

Fracking proponents need to demonstrate how the community can be protected from stock market speculation and unsustainable economics as occurs in the US shale oil industry.

There is a need for independent baseline testing (paid for by industry) prior to both the exploration and production phases because significant fugitive emissions can occur during the initial drilling phase.

Often exploration wells are converted to production wells, so if measurements are done during or subsequent to exploration the data collected will not be a true indication of the original background methane concentration.

The data must capture the entirety of fugitive methane emissions when much occurs in the first hours or days after initial drilling, before casing/capping wells has been completed and when well pressures are high and not counter balanced.

Continuous monitoring of well fields commencing before exploration is required to properly capture the fugitive emissions profile and to ensure the full extent of fugitive emissions is recorded over the life of the well and the surrounding environment where escape of gas may occur due to fault damage from the fracking process.

A serious concern is for the long-term consequences of the many thousands of wells that are typically needed, which along with fractured formations may leak or propagate in a number of possible ways, immediately and for decades to hundreds of years into the future. Long-term monitoring and remediation (if at all possible) in this 'caretaker' mode must be accounted for in the business model of the industry, to protect the state and community. The companies concerned have no answer to whom will bear this long-term responsibility and cost.

Costs also need to be allocated to address consequences of aquifer contamination from well and fractured formation leakage.

SEN asserts the government should require companies applying for exploration licences to price the costs resulting from the exploitation of the gas fields discovered, including the cost of water used, and liability insurance. A bond must be paid to the prior to the granting of the exploration licence, to cover all costs of exploration and long-term caretaking, in the case that they are not developed. If development does proceed, the bonds to be paid would be based on the costs incurred through the production life cycle and long-term caretaker period of the process.

Imposing these conditions would ensure the industry does not place the burden of the externalised costs on the government and community, given that fracking no longer has a social licence in Australia, and the community no longer has faith in the regulatory environment.

Finally, the Inquiry should recommend a legislative change to remove the 'Strategic Resource' status from Oil and Gas. This will enable fracking proposals to be assessed by the Environmental Protection Authority in the same way that other resource projects are.

4.2 Alternatives to Permitting Fracking

There are currently no royalties received by government for onshore gas in WA.

There are however alternative sources of revenue the government can access to replace revenue lost from permitting fracking in WA.

SEN submits that the Inquiry compare the long-term costs and short-term speculative income of fracking (in what is likely to become a declining industry in gas demand), to the long-term sustainable income and employment benefits from potential renewable energy exports, which do not present the risks to the environment of fossil fuel combustion and fracturing of geological formations.

As mentioned in this submission, the gas export market is likely to be displaced by growth trends in renewable energy globally.

Fortunately, WA's enormous renewable energy resources makes it a prime candidate to generate and export energy worth tens of billions of annual revenue, in various ways.

Some proposals for electricity export to the ASEAN countries from NW Australia include:

- Australian Government-funded "Northern Research Futures Collaborative Research Network" (Campbell, Blakers and Blanch 2013);
- Beyond Zero Emissions Inc. "Zero Carbon Australia – Renewable Energy Superpower" report, noting $11Bn annual revenue, and reduce average cost of electrical power in Indonesia (Zero Carbon Australia 2015, p. 37; Parkinson 2017);
- Asian Renewable Energy Hub proposal by CWP Energy Asia, Intercontinental Energy and Vestas generating 15 TW hours of electricity annually, worth $1.2Bn if sold at 8c/kWh (Milne; Evans and Dougherty 2017);

Over time there is the potential to establish a sustainable biomass/biofuel industry in Great Southern WA. (SEN Presents 2013; Goss 2014).

Options also exist for the export of renewable-generated Hydrogen for very low emission production of:

- steel (Instead of carbon from coking coal);
- ammonia for fertiliser (instead of methane) .

(Zero Carbon Australia 2015, p. 35)

4.3 Allowance for International Carbon Price

As well as the methane leakage emissions, gas contributes CO2 to the atmosphere as a by-product of its burning. In some deposits there may also be CO2 present in the gas mix that has to be vented before the gas can be on-sold.

SEN argues that these greenhouse gas contributions need to be allocated a carbon price in any consideration of licencing for exploration and production, as the gas would be exported into a global market which is trending to carbon costing.

This Sub-section provides indications of ways it is possible to determine a price for carbon even in the situation where there is no Federal Government price.

Many large fossil fuel companies already impose on their projects a cost of carbon or undertake abatement programs that imply a cost of emitted carbon.

In WA, Chevron is spending $2 billion on sequestering CO2 stripped from the gas it supplies to customers from the Gorgon project (Milne 2017).

However, on Chevron's Wheatstone project, because there was a price on carbon in Australia when the project was approved the original requirements of the company to sequester carbon were dropped by the state government at the time.

With the demise of the Australian Carbon Pollution Reduction scheme, negotiations have commenced to develop a mechanism to ameliorate the carbon being emitted from the project, which will implicitly result in a price on carbon.

Globally, a study undertaken in 2016 found 1,249 companies disclosed their practice of pricing carbon emissions, or their plans to soon do so (CDP North America 2016, p. 2). This report's findings are based on disclosures of 5,759 companies who responded to CDP's 2016 climate change and supply chain information requests, made on behalf of investors with US$100 trillion in assets, and purchasing organizations with over US$2 trillion in spending power.

The Centre for Climate and Energy Solutions (Ahluwalia 2017) stated:

> Since 2012, **Microsoft** business groups have paid a fee, from $5 to $10 per metric ton, on the carbon emissions associated with their electricity consumption and employee air travel. The revenue is used to buy renewable energy, increase energy efficiency and e-waste recycling, and buy carbon offsets. Microsoft has been carbon neutral in its global operations since July 2012 [see also United Nations Framework Convention on Climate Change 2014].
>
> **Shell** has used an internal carbon price of $40 to $80 per metric ton since 2000 to evaluate investment decisions. Its greenhouse gas Project Screening Value has influenced decisions to invest in carbon capture technology, gas, and biofuels. Shell reduced its direct greenhouse gas emissions from facilities by 2 million metric tons of carbon dioxide equivalent from 2015 to 2016.
>
> **Mahindra & Mahindra** (M&M), the world's largest manufacturer of tractors, became the first Indian company to launch an internal carbon fee of $10 per metric ton in 2016. The funds help reduce waste, water usage, and carbon emissions through projects such as LED lighting, energy-efficient motors, and waste-to-energy projects. M&M's goal is to reduce its greenhouse gas emissions intensity 25 percent by 2019 from 2016 levels.
>
> Mining company **BHP** has had a shadow price of $24-$80 per metric ton of carbon dioxide equivalent since 2004 to inform decisions to improve energy efficiency, reduce greenhouse gas emissions from its existing operations, and diversify its portfolio for a carbon-constrained future. The company reduced emissions 13 percent from 2015 to 2016.

Countries and regions accounting for half the world's economy currently have carbon-pricing schemes in place and the number is growing.

The World Bank has reported that "As of 2017, 42 national and 25 subnational jurisdictions are putting a price on carbon …" and that "These jurisdictions account for about half of the global economy and more than a quarter of global GHG emissions" (World Bank; Ecofys and Vivid Economics 2017 p. 22).

Australia implicitly imposes a price on carbon reflected in its RET and LRET programs which subsidise renewable energy projects and the Direct Action program which pays companies to reduce their carbon emissions.

SEN asserts it is therefore possible to develop a price for carbon contained within fracked gas that should be used in applications for finance and exploration licences.

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Appendices

Appendix 1

TRANSLATION:

"New campaign Energy-saving is promoting energy-saving" National Government (Dutch Government) (2018-b): housing; *https://www.rijksoverheid.nl/onderwerpen/energie-thuis/nieuws/2018/01/22/nieuwe-campagne-energiebesparendoejenu-promoot-energiebesparing-woning*

> *The government is committed to the construction of energy-efficient homes and the natural gas-free production of 30,000 to 50,000 existing homes each year, in order to reduce CO2 emissions. Housing corporations will get to work on this, but homeowners and VVEs can also make their homes more sustainable. In order to promote the available subsidy for housing insulation and sustainable systems for hot water and heating, the #Energiebesparendoejenu campaign starts on 22 January.*
>
> *Make homes more sustainable*
>
> *There are approximately 9 million buildings in the Netherlands, 8 million of which are homes. They contribute 16 percent of total CO2 emissions in the Netherlands. They all need an alternative to natural gas for heating and cooking. That is more than 250,000 homes per year. In addition, the more than 1 million businesses, shops, schools and other buildings must also dispose of natural gas.*
>
> *Minister Ollongren (Interior and Kingdom Relations): "Together with municipalities and housing corporations, I work together on energy-efficient buildings. More and more home owners are also working on energy saving. Energy saving always produces something positive. Whether it's for wallets, a comfortable home, the future of your children or the environment. "*
>
> *Survey energy saving households*
>
> *In order to gain insight into energy savings in Dutch households, Kantar Public has conducted a survey among homeowners on behalf of the Ministry of Economic Affairs and Climate. This shows that 90 percent of Dutch households have heard that we are going off with natural gas. More than a quarter even think that we will no longer use gas in the coming decade (2021-2030). A lot has to be done before that happens. For example, making our homes more sustainable.*
>
> *Minister Wiebes (Economic Affairs and Climate): "More and more people are replacing their gas-fired boiler with a sustainable alternative, such as a solar water heater or a heat pump. A sensible investment, especially if your old central heating boiler needs to be replaced, because in the Netherlands we are going off with natural gas. Thanks to subsidies, it has now become extra attractive to make the switch and to contribute to reducing CO2 emissions. "*

100 million for natural gas-free heating systems

The research shows that 14 percent of Dutch homeowners think they will heat the house with a heat pump in ten years' time. Half a million households have already made the switch to an alternative heat source. In order to further stimulate the transfer, the government is making available 100 million euros for the purchase and installation of a heat pump, solar water heater, pellet stove or biomass boiler. This subsidy can rise from 1,500 to 1,800 euros for a hybrid heat pump. This makes energy saving and sustainable living more attractive.

Discover what you can do yourself

In the Energy Saving campaign, residents are now speaking who have already made the switch to an isolated house and sustainable heating. People who also want to switch can use a menu on energiebesparendoejenu.nl to see which measures save the most energy for their specific home. For example better insulation of roof, facade, floor or windows. Or the installation of a heat pump, solar water heater, biomass boiler or pellet stove. These devices can replace the current gas-fired boiler and provide a comfortable home. The website contains links to consultants, suppliers and installers.

Appendix 2

TRANSLATION:

Dutch discontinuing gas connections: “Mandatory heating and cooking without gas: This is what you need to know” 14 July 2017 15:51 Last update: 02 November 2017 https://www.nu.nl/wonen/4814598/verplicht-verwarmen-en-koken-zonder-gas-moet-weten.html

If it is up to the government, in 2050 no Dutch home will be connected to the gas grid. The measure must help to reduce CO2 emissions. This has consequences for almost all households in the Netherlands. We have to deal with new ways of heating, showering and cooking.

"We have 33 years to get gas out of houses, that sounds a long time, but it's not exactly something you can do within a year, and we really need that time." This is what Susanne van Suylekom of climate agency Stichting Hier, initiator of hierverwarmt.nl*, says about natural gas-free living.*

Minister Henk Kamp of Economic Affairs also does not leave it at all. Last week he introduced a legislative amendment that marks the beginning of the end for natural gas: in new homes a gas connection is no longer required.

Van Suylekom: "At the moment, 31 municipalities are already investigating future scenarios and identifying the needs of residents, because there are many different alternatives to natural gas, but not everything fits equally well with a certain type of house or household."

It is not only in the hands of the municipality and the grid manager: homeowners will also have to take care of some of the measures, says Van Suylekom. "Just think of the construction of a heat pump in your house, or better insulation."

Measure must help to reduce CO2 emissions

See also: Gas connection no longer required for new homes with the whole neighborhood to a solution

It is important that residents take an active part in the alternatives to natural gas, emphasizes Van Suylekom. Also because part of the solutions apply to an entire neighborhood, such as the construction of a heating network with constant hot water or steam flowing through pipes. Of these, the temperature is often only high enough for heating your house, but not for showering.

At the moment, however, work is already being done on a geothermal heat network that can provide ten thousand existing homes with high temperatures. In any case, it will almost always be the case that you move to a solution with your entire neighborhood at once.

"This is also very new for municipalities and grid operators, but it is not a bad plan to start the conversation right now, even when it comes to financing constructions, where you agree, for example, that the necessary adjustments will be spread over a number of years, so that the monthly expenses do not suddenly go up.

Vereniging Eigen Huis has indicated that it is worried about the complex operation and asks Minister Kamp for clarity about the alternatives. Rob Mulder of VEH: "The costs of disconnection and conversion can amount to tens of thousands of euros per home."

Only if there are good alternative sources of energy for natural gas and if there is financial support for the more than four million private homeowners who will have *to adjust their homes, the government can realize their ambition to become 'gas-free', according to VEH.*

Better for your wallet

The good news is that the solutions are not only more environmentally friendly, but ultimately also better for your wallet. That tells Ruud Scholten from web shop TS24.nl, which sells many alternatives for heating with gas. Consumers do not yet see massively responding to current developments, but suppliers even more.

"Almost all new products use electricity, and can be used in homes without gas, and the consumption costs are also lower, especially if you use self-generated solar energy."

One of the new ways to heat a house, for example, is taking floor heating. And not one with milled pipes, but simply a mat that you roll out under your parquet, for example. Your house must be well insulated. Or think of infrared panels on the ceiling, which emit a heat similar to summer sunlight.

There are also remarkable alternatives. There is special wall paint with ceramic balls, which reflects heat back into space and does not let the walls go outside. Furthermore, experiments are taking place with the use of the heat generated in server rooms of large companies with many computers. It is estimated that up to several hundred euros per household can be saved on heating costs.

Thanks to the rapid developments that these products are now experiencing, they are becoming more and more affordable for households. Scholten: "It used to be that electrical heating cost a power, but that is no longer true." And you do not have to wait until switching to a gasless household is inevitable: the sooner you start with sustainable heating, the sooner you have the investment out of it.

"We will have to get used to looking for an alternative to natural gas, even if it is not yet immediately addressed." Susanne van Suylekom - climate agency 'Commit the future' Because the switch is often a joint decision, namely together with your municipality and grid operator, it is difficult to make a choice now. Yet there are quite a few things that you can already do to anticipate the future. Susanne van Suylekom of Stichting HIER: "For example, when you buy a new kitchen for an induction cooker, you can not go wrong with that, and it is safer and easier to clean, and make sure you insulate your house better, which means you'll save energy anyway, so you'll automatically get it back. "The government's decision to reduce CO2 emissions is based on the climate agreement concluded at the end of 2015 in Paris. Criticism that the Netherlands wants to be the best boy in the class, Van Suylekom rejects. "We're not doing that very well at all, only Malta and Luxembourg are performing worse in the field of renewable energy." The Netherlands is unique in the amount of natural gas connections. After finding the gas bubble in the Groningen Slochteren, we quickly started building the natural gas network in 1961. And eight years later, 75 percent of households owned a connection. The Netherlands currently has a 135,000 kilometer gas grid that is home to seven million households. Suylekom: "At the time, it was the solution for everyone." But times are changing, and it is also better to stop further earthquakes in Groningen. natural gas as fossil fuel And: ultimately it will get lost. "The coming years form a transition period, she says. "We will have to get used to having to look for an alternative to natural gas, even if that is not yet directly addressed, but one thing is certain: no household can escape it."

Attachment 1

Western Australia's Tight Gas Industry - A review of groundwater and environmental risks. Conservation Council of Western Australia, Perth - Vogwill R (2017).