Submission

to the

Australian Parliament

Senate Select Committee into

Fair Dinkum Power

by

Geoffrey Miell

15 February 2019

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Inquiry Terms of Reference

On 28 November 2018 the Senate established the Select Committee into Fair Dinkum Power to inquire into:

a. the potential for empowering energy consumers to play a more important role in the National Electricity Market, through providing diverse services in:
   i. energy generation,
   ii. demand response and energy efficiency,
   iii. grid stability and reliability services,
   iv. alternatives to conventional network investment, and
   v. peer-to-peer trading between households and businesses;
b. the potential for these services to deliver lower energy costs and increased energy reliability;
c. the changing role of retailers in the National Electricity Market in light of the growing empowerment of consumers;
d. the impacts of privatisation;
e. regulatory reforms which would empower energy consumers, including the following key groups:
   i. households, including low income households and renters,
   ii. farms,
   iii. small businesses, and
   iv. major energy users;
f. the likely long-term impacts, including to emissions, reliability and stability, of energy consumers playing a larger role; and
g. any other related matters.

The committee is due to report on **30 June 2019**.

Declaration

The author of this document, Geoffrey Miell, is a born and raised Australian citizen, residing in the state of New South Wales.

He has a degree of Bachelor in Mechanical Engineering from the University of Sydney.

Most of his professional life has been directed towards developing and designing industrial equipment, including elevated work platforms, scissor hoists, goods hoists, conveyor systems, automated stacking and de-stacking systems, steel structures and (for a few years) underground coal mining equipment. A few earlier years were engaged in the ongoing quality assurance testing and failure analysis of specific military hardware equipment for an Australian defence contractor.

Utilising various data sources (see the references at the end of this document) the observations and sole opinions of the author, as a concerned citizen, are as follows:

Key "Take Home" Messages

Energy is fundamental to life and essential for our society's economic prosperity. We need energy for food production and processing. Our civilisation requires energy for lighting, heating, cooling, transportation, communication, building, manufacturing, mining, exploration, medical endeavours and leisure pursuits. **Nothing happens without energy. Unaffordable energy means life becomes unaffordable.**

The *IPCC SR1.5°C* report warns that **human-induced climate change is now an existential risk to human civilisation.**

Current Paris Climate Agreement pledges are not on track to limit global warming to 1.5°C above pre-industrial levels.

To avoid worst outcomes, global carbon emissions must peak by 2020, then must be cut by half by 2030, and then to net-zero by 2050.

Existential Goal: Humanity must leave petroleum oil, fossil natural gas, and coal, before 2050 (preferably sooner), to mitigate dangerous climate change.

Any new 'Fair Dinkum Power' must be rapidly deployable. **Renewables can be deployed faster than new coal- and nuclear-based generation.**

As renewable energy costs continue to decline, energy storage remains key to solving the problem of intermittency but there is a clear path forward for economic viability.

CSP is an emerging technology that's demonstrating around the world that it can provide affordable, reliable, 'dispatchable' capacity supply, that can displace baseload generators like coal-fired and nuclear-fission power plants quickly.

Adequate new 'firm' generating capacity must be built in a timely manner to replace the outgoing/retiring generating capacities, otherwise the risk of blackouts and higher electricity prices will increase in the 2020s and beyond. Doing nothing is not a viable, responsible, energy secure option.

Nuclear fission-based energy in Australia makes no economic or timely energy security sense when there are other abundant, cheaper, more rapidly deployable, reliable, safer/lower-risk energy technology alternatives.

CCS fails technologically, economically, and as a pollution reduction measure.

The sooner Australia rapidly reduces its dependency on petroleum-based fuels by transitioning to battery-electric and hydrogen-fuel-cell vehicles powered from renewable energy, the more energy secure Australia will be.

Existential Goal: Humanity must leave petroleum oil before oil leaves us.

In November 2018, Australia surpassed Qatar to become the world's largest LNG exporter. Australia's rapidly increasing gas production over the last few years (18% growth in 2017 alone) serves to deplete its limited gas reserves (1.9% global share, ranked world's 12th largest in 2017) much sooner.

Existential Goal: Humanity must leave fossil natural gas before gas leaves us.

'Fair Dinkum Power' must have adequate EROI to sustain our civilisation.

‘Fair Dinkum Power’ must have net-zero carbon emissions

The *IPCC SR1.5°C* report warns that **human-induced climate change is now an existential risk to human civilisation**[i]: an adverse outcome that will either annihilate intelligent life or permanently and drastically curtail its potential, unless dramatic action is taken.

Countries that accept or ‘ratify’ the Paris Climate Agreement submit pledges for how they intend to address climate change. **Current pledges are not on track to limit global warming to 1.5°C above pre-industrial levels.**[ii]

A world that is consistent with holding warming to 1.5°C would see greenhouse gas emissions rapidly decline in the coming decade, with strong international cooperation and a scaling up of countries’ combined ambition beyond current Nationally Determined Contributions (NDCs). In contrast, delayed action, limited international cooperation, and weak or fragmented policies that lead to stagnating or increasing greenhouse gas emissions would put the possibility of limiting global temperature rise to 1.5°C above pre-industrial levels out of reach.

To stay below the upper 2°C temperature increase limit of the Paris Climate Agreement, global carbon emissions would have to peak no later than 2020, then must be cut by half by 2030, and to zero by 2050.[iii] This is an unprecedented task, requiring a reduction rate of at least 7 per cent annually. To meet the lower 1.5°C target requires even more rapid reduction. The only possible response is emergency action to transform our social, economic and financial systems.

Professor Hans Joachim Schellnhuber, founder of the Potsdam Institute for Climate Impact Research, advisor to German Chancellor Angela Merkel and to Pope Francis, said: “***…climate change is now reaching the end-game, where very soon humanity must choose between taking unprecedented action, or accept that it has been left too late and bear the consequences***”.[iv]

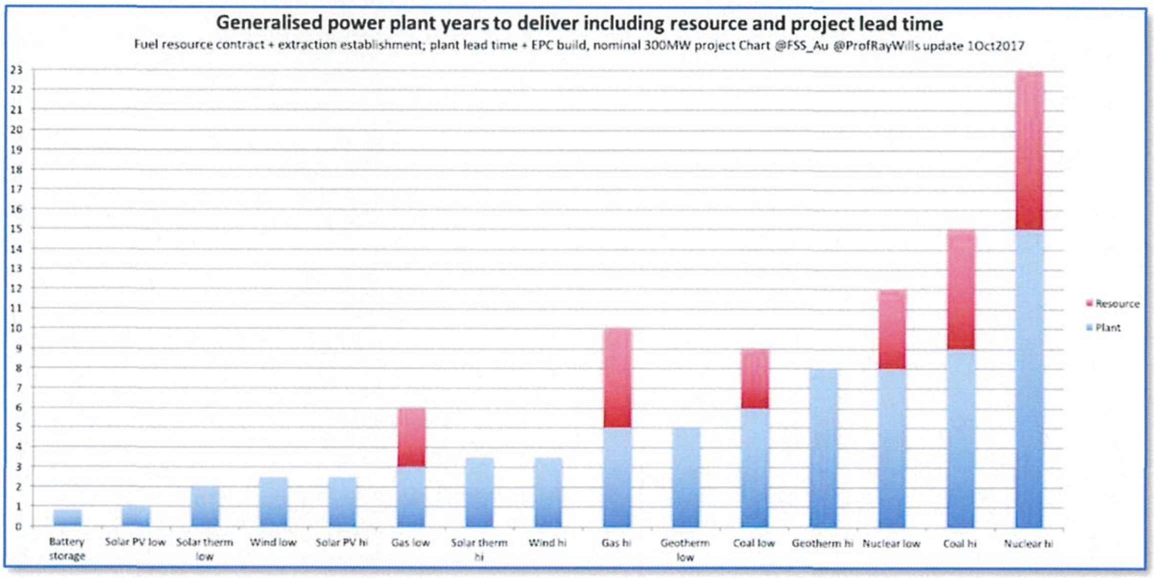
The urgent task now for Australia, and the world, is to cut carbon emissions far more rapidly than current Paris commitments, exiting the fossil fuel era and accelerating the introduction of low carbon solutions, coupled with demand reduction measures.

Australia needs to eliminate carbon emissions, sector by sector, beginning with the less challenging and affordable sectors first. Australia’s electricity generation sector represents about 35 per cent of total emissions, land transport is about 13 per cent, and low temperature heat is about 7 per cent.[v]

Existential Objective: Humanity must leave petroleum oil, fossil natural gas, and coal, before 2050 (preferably sooner), to mitigate dangerous climate change.

'Fair Dinkum Power' must be rapidly deployable

Given the necessity to rapidly reduce carbon emissions ASAP, **any new 'Fair Dinkum Power' technology must be rapidly deployable.** The graph below indicates how long it takes to deliver a range of different types of electricity generation plant.



Source: https://reneweconomy.com.au/graphs-day-wind-fast-solar-faster-batteries-fastest-68311/

Battery storage is fastest to deploy, then solar-PV, then wind. Solar thermal with energy storage is quicker to deploy than coal-fired plants. Nuclear is the slowest by far and should not be considered a timely solution for rapid emissions reduction. Pumped-hydro energy storage (PHES) is absent (perhaps being site dependent?).

Solar and wind technologies are the lowest-cost 'Fair Dinkum Power'

The CSIRO and AEMO collaboratively published their inaugural *GenCost 2018* report in December 2018, confirming that while existing fossil fuel power plants are competitive due to their sunk capital costs, solar and wind generation technologies are currently the lowest-cost ways to generate electricity for Australia, compared to any other new-build technology.[vi]

The calculated Levelized Cost of Energy (LCOE) by technology and category for 2020 shows wind and solar-PV 'firmed' with 6 hours of PHES is competitive with high emissions gas, brown and black coal flexible 40-80% load with no carbon price.[vii]

Lazard's Levelized Cost of Energy Analysis – Version 12.0, published November 2018, one of the major global industry benchmarks, infers that an inflection point has been reached where, in some cases, it is more cost effective to build and operate new alternative energy projects than to maintain existing conventional generation plants. Lazard's figures are based on US data and US conditions but provides an insight into global trends.[viii]

As alternative energy costs continue to decline, energy storage remains key to solving the problem of intermittency but there is a clear path forward for economic viability.[ix]

Concentrating solar power (CSP): an emerging 'dispatchable' tech

The emerging benefits provided by CSP with molten salt thermal energy storage technology for 'Fair Dinkum Power' are:

- **Energy and Capacity Value:** CSP with molten salt energy storage enables the transition from fossil fuel- to renewable energy-based generation, providing energy security, network strengthening and wholesale price stability. **With enough storage, CSP enables reliable capacity supply, to replace baseload generators like coal-fired and nuclear power plants and operate at high capacity factor.**
- **Ancillary Services:** CSP with storage can provide frequency regulation, "spinning reserve", non-spinning reserve, load following services, and black start capability.
- **Intrinsic Stability:** CSP with storage offers fault ride-through capability, frequency response, and voltage / Volt-Amp Reactive support, complementing high percentages of intermittent renewables.
- **Risk Management:** CSP hedges against future electricity price increases (as it has no fuel cost). CSP hedges against the future cost of integrating a high percentage of renewables into the grid – typically socialised in the cost of transmission upgrades and interconnectors and the implementation of higher reserve margins. **Weather conditions will only affect the number of operating hours – the MWh delivered per day – but will not affect the MW capacity that the system produces.** CSP can also change its behaviour mid-life, 10 or 20 years after commencing operations, to adapt to new market realities.[x]
- **Affordable, 'dispatchable' electricity:** South Australia's Aurora project's lone 150 MW capacity generator unit with 8 hours (1,100 MWh) storage, due to begin construction shortly, is contracted to supply electricity **capped at AU$78/MWh**.[xi] Multiple concurrent-built CSP generator units, with larger capacities and more storage may supply wholesale electricity at significantly lower prices in future.

CSP is an emerging technology that's demonstrating around the world that it can provide affordable, reliable, 'dispatchable' capacity supply, that can displace baseload generators like coal-fired and nuclear-fission power plants quickly.

Crescent Dunes Solar Energy Project, Nevada, USA. 110 MW with 10 hours (1,100 MWh) full load storage (SolarReserve)

Australia's ageing coal-fired electricity generator fleet

The information contained in the table below is sourced from the Australian Senate Environment and Communications References Committee inquiry into the Retirement of coal fired power stations, which published a *Final Report* in March 2017.[xii]

Rank Number	Power station (>140 MW capacity) ranked oldest to youngest	State	Primary fuel type	Commissioning date(s)	Nameplate capacity (MW)	Announced closure year	Years to announced closure, OR on reaching 50 years old
1	Liddell	NSW	Black coal	1971-73	2000	2022	<4
2	Yallourn W	VIC	Brown coal	1975 & 1982	1480	ND	<7
3	Gladstone	QLD	Black coal	1976-82	1680	ND	<8
4	Vales Point B	NSW	Black coal	1978	1320	ND	<10
5	Muja	WA	Black coal	1981 & 1986	1070	ND	<13
6	Eraring	NSW	Black coal	1982-84	2880	ND	<14
7	Bayswater	NSW	Black coal	1982-84	2640	2035	<17
8	Tarong	QLD	Black coal	1984-86	1400	ND	<16
9	Loy Yang A	VIC	Brown coal	1984-87	2210	2048	<30
10	Callide B	QLD	Black coal	1989	700	ND	<21
11	Mt Piper	NSW	Black coal	1993	1400	ND	<25
12	Stanwell	QLD	Black coal	1993-96	1460	ND	<25
13	Loy Yang B	VIC	Brown coal	1993-96	1026	ND	<25
14	Collie	WA	Black coal	1999	340	ND	<31
15	Callide C	QLD	Black coal	2001	810	ND	<33
16	Millmerran	QLD	Black coal	2002	851	ND	<34
17	Tarong North	QLD	Black coal	2002	443	ND	<34
18	Kogan Creek	QLD	Black coal	2007	750	ND	<39
19	Bluewaters 1	WA	Black coal	2009	208	ND	<41
20	Bluewaters 2	WA	Black coal	2010	208	ND	<42

Note: **ND** = Not disclosed.

Internationally, only 1% of power stations in operation are older than 50 years.[xiii]

Within 10 years, it's likely that Liddell (NSW), Yallourn W (VIC), Gladstone (QLD), and Vales Point B (NSW) could all be retired, representing a loss of up to 6480 MW of generating capacity that have been contributing to the National Energy Market (NEM).

Within 20 years, it's likely that Muja (WA), Eraring (NSW), Bayswater (NSW), and Tarong (QLD) could all be retired, representing a further loss of up to 7990 MW of generating capacity.

Adequate new 'firm' generating capacity must be built in a timely manner to replace the outgoing/retiring generating capacities, otherwise the risk of blackouts and higher electricity prices will increase in the 2020s and beyond. Doing nothing is not a viable, responsible, energy secure option.

Nuclear: mistimed, expensive and long-term unsustainable choice

Some reasons that suggest that nuclear fission power for Australia is a mistimed, expensive, and long-term unsustainable energy choice are:

1. Nuclear power generation within Australia is currently prohibited by Federal Australian law, specifically:
   a. *Australian Radiation Protection and Nuclear Safety Agency Act 1998*; and
   b. *Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)*.[xiv]

   A completely new legal and regulatory framework would need to be established, with the acceptance of most of the Australian electorate. This will take time that Australia doesn't have.

2. Only governments, and therefore taxpayers, will underwrite a nuclear power industry; and pay dearly if dire incidents occur. This also requires an acceptance by most of the Australian electorate.

3. There's currently minimal nuclear power generation technical and engineering expertise within Australia. An extensive recruitment programme (likely sourcing key skilled personnel primarily from overseas) would be required to establish a completely new, highly complex industry.

4. Large-scale nuclear power generators require 7.7 years on average to construct.[xv] This point, together with the required planning process and the other points above, would suggest any electricity generated by nuclear fission within Australia would probably be closer to 15–20 years away from when the decision was made to proceed. With many ageing Australian coal-fired power stations due to retire within this timeframe (beginning with NSW's 2000 MW Liddell power station in 2022), deploying nuclear power would take much too long. Australia cannot afford to wait for nuclear power to become available if it needs to keep the lights on in the 2020s, and beyond.

5. New nuclear fission-, gas- and coal-based electricity generation technologies are now decisively more expensive than new renewables (wind and solar-PV) with 'firming'[xvi] – the economics and deployment times required renders the nuclear energy option unappealing for Australia.

6. There's approximately 100 years global supply of high-grade uranium ores remaining at current rate of consumption.[xvii] Additional demand from Australia (and other countries) intending to expand their nuclear industries will by necessity deplete remaining reserves sooner, exacerbating existing strains on providing adequate nuclear fuel for current demands, and likely increase nuclear fuel prices further.

7. The thorium nuclear fuel cycle is not yet fully established,[xviii] and thus to date the technology has not been demonstrated in large-scale practice and prospective operating costs remain speculative.

8. Nuclear fission energy produces nuclear waste that needs to be safely contained for tens of thousands to billions of years (for high level waste).[xix] Few

people in Australia want a permanent nuclear waste repository near them.[xx] Due to strong resistance by local communities to various proposals, the Federal Government is having little success to date at establishing a permanent low and intermediate level nuclear waste repository in Australia (with anticipated operations over 100 years and monitoring up to a 300-year lifespan) for dealing with waste generated from various sites including the Lucas Heights research reactor facility and nuclear medicine facilities at various hospitals around the country. Establishing a nuclear power generation industry in Australia would likely produce much greater quantities of nuclear waste that need to be safely contained for a very long time.

Nuclear fission-based energy in Australia makes no economic or timely energy security sense when there are other abundant, cheaper, more rapidly deployable, reliable, safer/lower-risk energy technology alternatives. Establishing a nuclear power generation industry in Australia only makes sense if the objective is to source adequate quantities of key materials necessary for nuclear weapons production to perhaps mitigate a perceived strategic military threat.

CCS fails technologically, economically and for pollution reduction

There are three reasons why Carbon Capture and Sequestration (CCS) is not a viable option:

1. **It doesn't work.** Some examples that have tried and failed include:
    a. Southern Company's Kemper "clean coal" plant in Mississippi, USA – US$7.5 billion;[xxi]
    b. SaskPower's Boundary Dam 110 MW unit CCS plant in Saskatchewan, Canada – C$1.4 billion;[xxii]
    c. Queensland government's Stanwell ZeroGen CCS retrofit project abandoned – AU$96.3 million.[xxiii]
2. **It's more expensive to produce energy with CCS than without.** Significantly more fuel is consumed, and a substantial quantity of energy diverted to operate the associated CCS equipment for a given net output, compared with a generator unit without CCS. New renewables with 'firming' are now cheaper than new gas and coal electricity generator technologies without CCS, and cheaper than existing gas and coal plants with retro-fitted CCS. There's simply no economic benefit for coal- and/or gas-fired generators to utilise CCS.
3. **CCS will not stop all CO_2 emissions entering the environment.** CCS doesn't capture 100 per cent of a plant's emissions. Any emissions that are captured need to be captured forever. Any storage site will inevitably leak (whether that's in a few years' time, decades, centuries, millennia, or more) posing ongoing toxic air pollution risks to people and the environment nearby. CCS does nothing to reduce methane and dust emissions during extraction and transportation of coal and does nothing to reduce dust from the disposal of fly ash after the coal is burnt.

CCS fails technologically, economically, and as a pollution reduction measure.

'Fair Dinkum Power' must compensate for global post- 'peak oil'

Evidence indicates global supplies of petroleum oil are likely to peak soon (i.e. 2020s), then begin a sustained decline. 'Fair Dinkum Power' must take up the energy supply slack as the transition from petroleum-based fuels to renewables progresses.

Per *BP Statistical Review of World Energy 2018*, from pages 12 and 14, **the world's top ten oil producing countries in 2017** were as indicated in the table below: [xxiv]

Rank	Country	2017 Oil Production – Annualised Average (*x10⁶ barrels / day*)	Global Share (%)	Proved Reserves-to-Production At end-2017 (*years*)
1	USA	13.057 ▲	14.1	**10.5**
2	Saudi Arabia	**11.951 —**	12.9	61.0
3	Russian Federation	**11.257 —**	12.2	**25.8**
4	Iran	4.982 ▲	5.4	86.5
5	Canada	4.831 ▲	5.2	95.8
6	Iraq	4.520 ▲	4.9	90.2
7	United Arab Emirates	**3.935 —**	4.2	68.1
8	China	**3.846 —**	4.2	**18.3**
9	Kuwait	**3.025 —**	3.3	91.9
10	Brazil	2.734 ▲	3.0	**12.8**

Includes crude oil, shale oil, oil sands and NGLs. Excludes liquid fuels from other sources such as biomass, CTL and GTL.

The world's top five oil producers represent almost half (49.7%) of global share, and the top ten represent more than two-thirds (69.3%) of global share.

USA, Iran, Canada, Iraq and Brazil are oil producers currently at pre-peak (i.e. still increasing production year-by-year). Saudi Arabia, Russian Federation, United Arab Emirates (UAE), China and Kuwait oil producers are currently at peak (i.e. production has plateaued).

Many oil producing countries are now post-peak, including Australia, which peaked in year-2000[xxv], and has declined since then, now producing only 0.4% global share (in 2017), yet consumes 1.1% global share.[xxvi] More than 90% of Australia's transport liquid fuels and oil for transport are now imported.[xxvii,xxviii]

A balancing act is occurring between declining and growing oil producing countries. The whole system will peak when US shale oil peaks (in the Permian Basin) because of geology, lack of finances in the next credit crisis, and/or other factors, and when Iraq peaks possibly because of social unrest or military confrontation in the oil producing regions. Added risks include continuing disruptions in Nigeria and Libya, steeper declines in Venezuela, and the impact of sanctions on Iran.[xxix] Global 'peak oil' supply is inevitable – exactly when is the question.

From *Cassandra's Legacy* weblog post headlined **Peak Diesel or no Peak Diesel? The Debate is Ongoing**, dated Dec 16:

> ***Shale oil has changed a lot of things in the oil industry, but it couldn't avoid the decline of conventional oil. That, in turn, had consequences:***

shale oil is light oil, not easily converted to the kind of fuel (diesel) which is the most important transportation fuel, nowadays. That seems to have forced the oil industry into converting more and more "heavy" oil into diesel fuel but, even so, diesel fuel is becoming gradually more scarce and more expensive, to the point that its production may have peaked in 2015. In addition, it has created a dearth of heavy oil, the fuel of choice for marine transportation. In short, the famed "peak oil" is arriving not all together, but piecemeal — affecting some kinds of fuels faster than others. [xxx]

That perhaps explains why diesel fuel is now more expensive than petrol, even when crude oil prices drop.[xxxi] Scarce and/or expensive diesel supplies mean higher transport, mining and agricultural costs impacting on the whole economy.

The sooner Australia rapidly reduces its dependency on petroleum-based fuels by transitioning to battery-electric and hydrogen-fuel-cell vehicles powered from renewable energy, the more energy secure Australia will be.

Existential Objective: Humanity must leave petroleum oil before oil leaves us.

'Fair Dinkum Power' must compensate for global post- 'peak gas'

Evidence indicates global supplies of fossil natural gas are likely to peak soon (i.e. 2020s), then begin a sustained decline. 'Fair Dinkum Power' must take up the energy supply slack as the transition from fossil natural gas to renewables progresses.

Per *BP Statistical Review of World Energy 2018*, from pages 26 and 28, **the world's top ten gas producing countries in 2017** were as indicated in the table below:[xxxii]

Rank	Country	2017 Gas Production – Total Annual (*billion cubic metres*)	Global Share (%)	Proved Reserves-to-Production At end-2017 (*years*)
1	USA	734.5 ▲	20.0	**11.9**
2	Russian Federation	**635.6 —**	17.3	55.0
3	Iran	223.9 ▲	6.1	148.4
4	Canada	**176.3 —**	4.8	**10.7**
5	Qatar	**175.7 —**	4.8	141.8
6	China	149.2 ▲	4.1	**36.7**
7	Norway	123.2 ▲	3.3	**13.9**
8	**Australia**	113.5 ▲	3.1	**32.0**
9	Saudi Arabia	111.4 ▲	3.0	72.1
10	Algeria	91.2 ▲	2.5	**47.5**

Includes natural gas produced for GTL transformation. Excludes gas flared or recycled.

The world's top five natural gas producers represent more than half (52.9%) of global share, and the top ten represent more than two-thirds (68.9%) of global share.

USA, Iran, China, Norway, Australia, Saudi Arabia and Algeria are gas producers currently at pre-peak (i.e. still increasing production year-by-year). The Russian

Federation, Canada, and Qatar are gas producers that are currently at peak (i.e. production has plateaued).

Conventional gas production is in decline in Europe (since the 2000s) excluding Norway, and North America (since the 1970s).

Shale gas production in USA is unlikely to see significant further expansion. The nature of shale play developments is that they decline quickly, such that production from individual wells falls 70–90% in the first three years, and field declines without new drilling typically range 20–40% per year. Continual investment in new drilling is required to avoid steep production declines. Shale plays also exhibit variable reservoir quality, with "sweet spots" or "core areas" containing the highest quality geology typically comprising 20% or less of overall play area. Drilling has focussed on these "sweet spots" which provide the most economically viable wells. As these "sweet spots" are exhausted then new shale developments are by necessity left with less productive and more costly areas to exploit.[xxxiii]

The Russian Federation, the world's second largest gas producer (not far behind USA), faces a struggle between declining production from ageing fields and new expensive and time-consuming developments in Northern Siberia and offshore. The delayed developments of Shtokmanskoye in the Barents Sea and of other fields in the Yamal Peninsula are unlikely to be sufficient in the longer-term to compensate for the decline of ageing current fields.

Domestic consumption in Russia and growing demand from Asia will put greater stresses on volumes available for export from Eurasia to Europe in the coming years.

Iran and Qatar are expected to feed the rising demand for liquefied natural gas over the next decades. Though these countries have large reserves, it's highly probable that these reported reserves are exaggerated.[xxxiv]

In November 2018, Australia surpassed Qatar to become the world's largest LNG exporter.[xxxv] Australia's rapidly increasing gas production over the last few years (18% growth in 2017 alone) serves to deplete its limited gas reserves (1.9% global share, ranked world's 12th largest in 2017) much sooner.

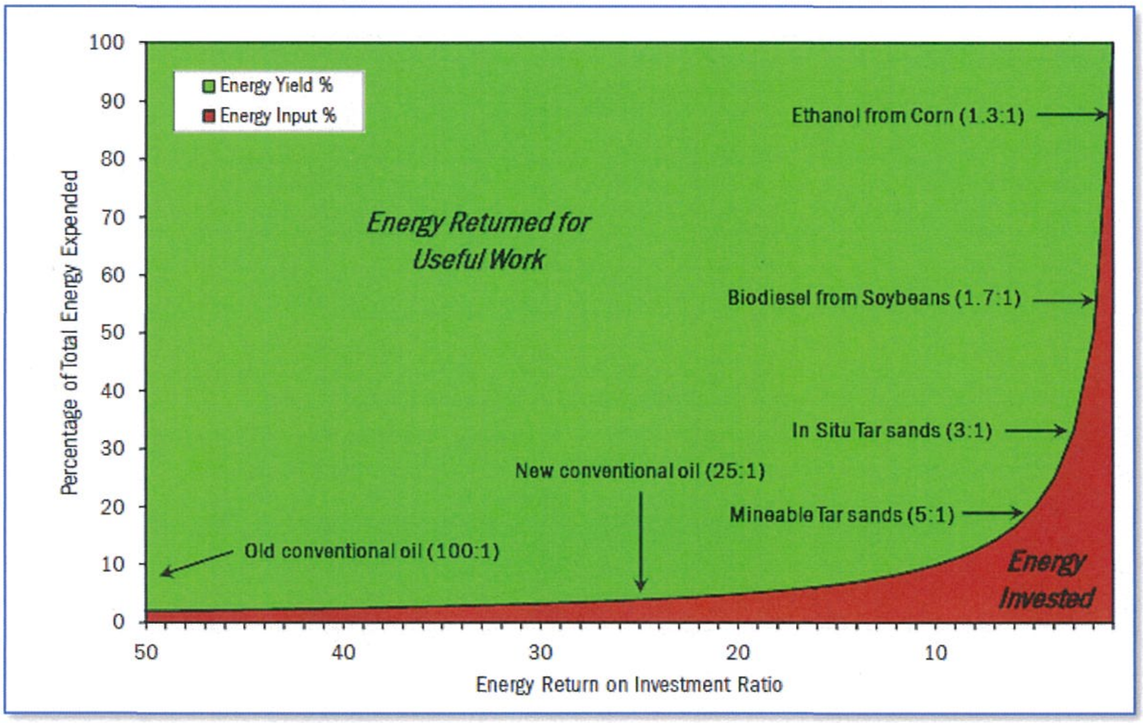
A balancing act is occurring between declining and growing gas producing countries. The whole system will peak when US shale gas peaks (in the Marcellus and Utica plays) because of geology, lack of finances in the next credit crisis, and/or other factors, and adverse weather and geological conditions within the Russian Federation's remote production regions. Added risks include Canada's gas production declining because of geology, and the impact of sanctions on Iran. Global 'peak gas' supply is inevitable – exactly when is the question.

Existential Objective: Humanity must leave fossil natural gas before gas leaves us.

In an inevitable global post- 'peak oil' and 'peak gas' supply world, oil and gas will become scarcer and more expensive. Preparation for a contingency oil and gas allocation system is needed to minimize disruptions to critical infrastructure.

'Fair Dinkum Power' must have adequate EROI

The economy of a modern developed nation slips into recession if its net fuel Energy Return on Investment (EROI) drops below 6:1[xxxvi] and starves if EROI drops below 3:1.[xxxvii] The inevitable consequence if such low EROIs persist is industrial collapse and regression of civilization to agrarian-age economics (see figure below). Purposely displacing high-EROI energy sources with anything that returns less than 6:1 is to foolishly and harmfully push economies toward recession and civilization toward regression.[xxxviii]



Source: *Drill, Baby, Drill: Can Unconventional Fuels Usher in a New Era of Energy Abundance?* by J. David Hughes, Post Carbon Institute, Feb 2013, p45

The figure below shows the estimated minimum EROIs to sustain various activities:

Minimum EROI for Conventional Sweet Crude Oil

Activity	Minimum EROI Required
Arts, Sports, Leisure, etc.	14 : 1
Health Care	12 : 1
Education	9 or 10 : 1
Support Workers' Families	7 or 8 : 1
Grow Food	5 : 1
Transportation	3 : 1
Refine Energy	1.2 : 1
Extract Energy	1.1 : 1

To get usable energy we must first spend energy to access primary resources and convert them into a usable form.

EROI = Energy Returned from energy gathering and conversion activities / **Energy Invested** in that process.

Source: https://www.youtube.com/watch?v=teDqDyvnTxc, time interval 0:52:17 to 0:55:37

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Note: All references listed below were accessed using the respective web address Uniform Resource Locators (URLs) between 11 and 14 Feb 2019. If any of the links fail, please try using an appropriate web search engine together with the respective **bold** text reference.

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v Video: **CURF Annual Forum – Andrew Blakers keynote**, University of Canberra, 30 Nov 2017, duration 37:54, Figure shown at time interval **27:10**, https://www.youtube.com/watch?v=y1lC6TiNDRc

vi Press Release: **Annual update finds renewables are cheapest new-build power**, CSIRO, 21 Dec 2018, https://www.csiro.au/en/News/News-releases/2018/Annual-update-finds-renewables-are-cheapest-new-build-power

vii Report: ***GenCost 2018: Updated projections of electricity generation technology costs***, CSIRO & AEMO, Dec 2018, Figure 4-2, see reference **vi** above for link to document

viii Article: **Lazard hails "inflection point" as wind, solar costs beat new and old fossils**, by Giles Parkinson, *RenewEconomy*, 11 Nov 2018, https://reneweconomy.com.au/lazard-hails-inflection-point-as-wind-solar-costs-beat-new-and-old-fossils-72497/

ix Report: ***Comparison of Dispatchable Renewable Electricity Options: Technologies for an orderly transition***, by Keith Lovegrove et al., prepared for ARENA by ITP Thermal Pty Ltd, Oct 2018, https://arena.gov.au/assets/2018/10/Comparison-Of-Dispatchable-Renewable-Electricity-Options-ITP-et-al-for-ARENA-2018.pdf

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