**Climate and Energy Topics** **Gordon Taylor** **2017-07-11**

**1) The Urgency of Energy Transition**

In 2013-09-11, 'Some Comments on IPCC AR5 and the omissions of significant 'Feedback Effects' from the Climate-Models used in its preparation', [1] Page 12 includes: 'Global emissions contraction must be fast enough to achieve the objective of the UN Framework Convention on Climate Change [UNFCCC] on a precautionary basis [for example 100% contraction by 2050]'.

So to avoid severe climate change before 2100 requires not Convergence (of all countries' carbon emissions) by 2050 and Contraction (to zero) by 2100, as IPCC AR5, but Convergence by 2020-2030 and Contraction by 2050, as UNFCCC.

**2) The Triple Constraints for Energy Transitions**

In 2016-09-07, 'The sower's way: quantifying the narrowing net-energy pathways to a global energy transition', Sgouridis et al [2] the Abstract includes: 'Planning the appropriate renewable energy (RE) installation rate should balance two partially contradictory objectives: substituting fossil fuels fast enough to stave-off the worst consequences of climate change while maintaining a sufficient net energy flow to support the world's economy. The upfront energy invested in constructing a RE infrastructure subtracts from the net energy available for societal energy needs, a fact typically neglected in energy projections. Modeling feasible energy transition pathways to provide different net energy levels we find that they are critically dependent on the fossil fuel emissions cap and phase-out profile and on the characteristic energy return on energy invested of the RE technologies. The easiest pathway requires installation of RE plants to accelerate from 0.12 TW p yr –1 in 2013 to peak between 7.3 and 11.6 TW p yr –1 in the late 2030s, for an early or a late fossil-fuel phase-out respectively, in order for emissions to stay within the recommended CO 2 budget'.

So the early fossil-fuel phase-out requires the installation of RE plants to accelerate by 7.3/0.12 = 61-fold and the late phase-out by 11.6/0.12 = 97-fold. Further delay would mean that there is no solution.

**3) $EROI_{nat}$ for the UK**

In 2017-04-14 'Developing an Input-Output Based Method to Estimate a National-Level Energy Return on Investment (EROI)', Lina Brand-Correa et al. [3] This excludes both energy imports and exports and embodied energy imports and exports. (See Fig. 2). Despite being a net importer of both, the $EROI_{nat}$ for the UK so defined declined from 9.6 in 2000 to 6.2 in 2012.

The latter is far below the value of 20 in 2014 taken as the starting point for energy transitions by Sgouridis et al, 2016. It reflects policy choices that are energy-intensive, and increase energy consumption, so reducing the solution space for energy transitions. These choices include armaments such as nuclear submarines, aircraft carriers, and military aircraft. Infrastructure such as roads, high-speed railways, airport runways and space-ports would also be unhelpful.

**4) Energy and Carbon Budget for Increased Domestic Agriculture in the UK**

2004, 'Eating Fossil Fuels', Dale Allen Pfeiffer, [4] includes: 'Presently, only two nations on the planet are major exporters of grain: the United States and Canada. By 2025, it is expected that the U.S. will cease to be a food exporter due to domestic demand. The impact on the U.S. economy could be devastating, as food exports earn $40 billion for the U.S. annually. More importantly, millions of people around the world could starve to death without U.S. food exports'.

In 2015-10-01, 'Global cropland and greenhouse gas impacts of UK food supply are increasingly located overseas', [5] the Abstract includes: 'The UK is currently importing over 50% of its food and feed, whereas 70% and 64% of the associated cropland and GHGE impacts, respectively, are located abroad. These results imply that the UK is increasingly reliant on external resources and that the environmental impact of its food supply is increasingly displaced overseas'.

To avoid starvation, the UK must more than double the proportion of food produced domestically before 2025. So the corresponding increase in GHGE must be allowed for in the carbon budget and any energy transition.

**5) EROIs for Renewable Electricity Supply**

With a mean reference value of insolation for the UK of 1000 kWh/m2,y, the $EROI_{el}$ for crystalline silicon as 3.3 and for CdTe as 8.6. With a grid efficiency of 0.31, the $EROI_{PE\text{-}eq}$ for crystalline silicon is 3.3/0.31 = 10.6 and for CdTe is 8.6/0.31 = 27.7. [6]

The EROI of a Vestas wind turbine in medium wind conditions is about 38 and in high wind conditions 44. [7]
The EROI of an Enercon wind turbine for inland sites is about 35, near-coastal sites about 41 and coastal sites 51. [8]

So the EROI of 20 assumed by Sgouridis et al, 2016 can be exceeded by some PV power and by MW-scale wind power.

**6) Global Limits of Wind and Solar Electricity**

In 2011-06-29 'Global wind power potential: Physical and technological limits', de Castro et al. [9] the Abstract includes:
'We propose a top–down approach, such as that in Miller et al. (2010), to evaluate the physical–geographical potential and, for the first time, to evaluate the global technological wind power potential, while acknowledging energy conservation. The results give roughly 1 TW for the top limit of the future electrical potential of wind energy'.

In 2013-08-11 'Global solar electric potential: A review of their technical and sustainable limits', de Castro et al. [10] the Abstract includes: 'Although it is very difficult to give a global limit to the expansion of solar power, an overview of the land and materials needed for large scale implementation show that many of the estimations found in the literature are hardly compatible with the rest of human activities. Overall, solar could be more limited than supposed from a technological and sustainable point of view: around 60–120 EJ/yr'. (i.e. 1.9 to 3.8 TW average).

Hence the solution-space of Sgouridis et al may be further reduced by the global wind and solar power limits of de Castro et al.
Fig. S19 mentions a turbine power density of 5MW/km2 while de Castro et al, 2011 P 6681 mentions 1W/m2 (= 1 MW/km2).
Fig. S20 shows a Total (Solar) Energy Resource of 362,500 Twh/y (41.4 TW average), while de Castro et al, 2013 mentions 60–120 EJ/yr'. (i.e. 1.9 to 3.8 TW average).

**7) Scope for Energy Saving**

In 2010-12-14, 'Reducing Energy Demand: What Are the Practical Limits?', Jonathan M. Cullen, Julian M. Allwood, and Edward H. Borgstein, [11] the Abstract includes: 'The result demonstrates that 73% of global energy use could be saved by practically achievable design changes to passive systems'.

In 2012, 'Energy Costs of Energy Savings in Buildings: A Review', [12] Page 1725 includes: 'Dahlstrøm [84] studied the energy budget of advance windows in the Norwegian context. They noted that the energy payback time of improving the insulation of a window from U = 1.2 to U = 0.8 by an additional glazing and low-e coating to a double window, with argon filling and one low-e coating was roughly a year. Over a 35 years lifetime, this would translate in an EROI ≈ 35, which is broadly consistent with previous values [77–80]'.

And: 'For a U.S. residential home build in Michigan, Keolian et al. [86] obtained an EROI of 60 from a specific so-called "Energy-Efficient Home" over a period of 50 years. This high EROI can be credited to the numerous strategies for lowering life-cycle energy consumption used. These strategies mainly focused on methods to reduce utility-supplied energy, but the reduction of the embodied energy and increased product durability were also addressed. Uzsilaityte and Martinaitis [87] studied the impact of various rebuilding strategies on a school building in Vilnius, Estonia. The derived EROI values were between 11.9 to 55.5 as a function of the measures that were implemented'.

**8) Scope for Increased Energy Efficiency**

In 2010-03-05, 'Theoretical efficiency limits for energy conversion devices', Jonathan M. Cullen, Julian M. Allwood, [13] the Abstract includes: 'The result estimates the overall efficiency of global energy conversion to be only 11 per cent; global demand for energy could be reduced by almost 90 per cent if all energy conversion devices were operated at their theoretical maximum efficiency'.

Experience shows that, given the chance, engineers can design and manufacture affordable and durable devices that achieve within factor two of the thermodynamic minimum energy consumption. For example, working between the same top and bottom temperatures, the thermal efficiency of real internal combustion engines is about half that of the ideal Carnot engine. Taken with the above, this suggests that global energy demand could be reduced by about 45% if all energy conversion devices operated at half their theoretical maximum efficiency.

The lifetime primary energy use of GLS (incandescent) lamps is 3300 kWh, while that of an LED lamp is 700 kWh.
The production energy for an LED lamp = 10 kWh. [14]
So replacing GLS with LED, the lifetime primary energy saving = 3300 – 700 = 2600 kWh and the EROI = 2600/10 = 260.

The above two studies by Cullen et al are complementary as many energy-using devices involve both energy losses from passive systems (First Law of Thermodynamics) and active energy conversion (Second Law of Thermodynamics). For example, a refrigerator consists of a (passive) insulated box and an (active) electric heat pump.

Taken together, the above two studies imply that global energy use could be reduced by about 80%. Moreover, some energy demand measures have EROIs far greater than 20, the average value assumed for energy supply measures by Sgouridis et al, 2016. By including such demand measures, the accelerations could be reduced from 60-fold (early) or 97-fold (late), to more like 60/5 = 12-fold or 100/5 = 20-fold. Together these supply and demand measures could be far less challenging to implement, and keep the renewable energy supply capacities below the global limits of de Castro et al 2011 and 2013.

1 2013-09-11, 'Some Comments on IPCC AR5 and the omissions of significant 'Feedback Effects' from the Climate-Models used in its preparation', http://www.gci.org.uk/Documents/IPCC_AR5_Underestimates_Climate_Change.pdf Page 12.

2 2016-09-07, 'The sower's way: quantifying the narrowing net-energy pathways to a global energy transition', Sgouridis et al., http://iopscience.iop.org/article/10.1088/1748-9326/11/9/094009/pdf and http://iopscience.iop.org/1748-9326/11/9/094009/media/erl094009_suppdata.pdf

3 2017-04-14 'Developing an Input-Output Based Method to Estimate a National-Level Energy Return on Investment (EROI)', Lina Brand-Correa et al. http://www.mdpi.com/1996-1073/10/4/534/pdf

4 2004, 'Eating Fossil Fuels', Dale Allen Pfeiffer, https://www.fromthewilderness.com/free/ww3/100303_eating_oil.html

5 2015-10-01, 'Global cropland and greenhouse gas impacts of UK food supply are increasingly located overseas', http://rsif.royalsocietypublishing.org/content/13/114/20151001

6 2015-12-08 'A comprehensive assessment of the energy performance of the full range of electricity generation technologies deployed in the United Kingdom', Raugei and Leccisi. https://www.researchgate.net/publication/289992002_A_comprehensive_assessment_of_the_energy_performance_of_the_full_range_of_electricity_generation_technologies_deployed_in_the_United_Kingdom/fulltext/569fac7b08ae21a564270f68/289992002_A_comprehensive_assessment_of_the_energy_performance_of_the_full_range_of_electricity_generation_technologies_deployed_in_the_United_Kingdom.pdf Fig. 2.

7 2015-09-21 'Life Cycle Assessment of Electricity Production from an Onshore V112-3.3 MW Wind Plant', http://www.vestas.com/~/media/vestas/about/sustainability/pdfs/life%20cycle%20assessment_v112-3%203mw_mk2c_version_2_1_210915.pdf

8 2012-02 'ENERCON receives certificate for life-cycle assessment', http://www.enercon.de/fileadmin/Redakteur/Medien-Portal/windblatt/pdf/en/WB_02-2012_en_web.pdf

9 2011-06-29 'Global wind power potential: Physical and technological limits', de Castro et al. https://doi.org/10.1016/j.enpol.2011.06.027 https://www.researchgate.net/profile/Margarita_Mediavilla/publication/227415450_Global_wind_power_potential_Physical_and_technological_limits/links/56f6873208ae7c1fda2fd211/Global-wind-power-potential-Physical-and-technological-limits.pdf

10 2013-08-11 'Global solar electric potential: A review of their technical and sustainable limits', de Castro et al. http://dx.doi.org/10.1016/j.rser.2013.08.040. https://www.researchgate.net/profile/Luis_Miguel3/publication/276115660_Global_solar_electric_potential_A_review_of_their_technical_and_sustainable_limits/links/575833d808aef6cbe362aba6/Global-solar-electric-potential-A-review-of-their-technical-and-sustainable-limits.pdf

11 2010-12-14, 'Reducing Energy Demand: What Are the Practical Limits?', Jonathan M. Cullen, Julian M. Allwood, and Edward H. Borgstein, http://pubs.acs.org/doi/abs/10.1021/es102641n and http://pubs.acs.org/doi/suppl/10.1021/es102641n

12 2012, 'Energy Costs of Energy Savings in Buildings: A Review', http://www.mdpi.com/2071-1050/4/8/1711/pdf

13 2010-03-05, 'Theoretical efficiency limits for energy conversion devices', Jonathan M. Cullen, Julian M. Allwood, http://www.sciencedirect.com/science/article/pii/S0360544210000265

14 2009-08-04 'Life-cycle assessment proves how environmentally friendly LED lamps are', https://www.siemens.com/press/en/pressrelease/?press=/en/pressrelease/2009/osram/osram_oekobilanz_led-lampen.htm