Modern Renewable Energy: Approaching the Tipping Point?

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After a pause in the pace of renewable energy development in the northern Atlantic regions of North America and Europe during the years following the 2008-9 financial crisis and global recession, the momentum of modern renewable energy (RE) – as distinguished from 'low carbon' energy[1] -- has picked up again globally, but also across the Atlantic Basin. Not the anti-renewable energy backlash (both in Northern Atlantic energy policy and in the global investment markets) that followed the crash, nor even the great oil price collapse of 2014-15 -- from over 100 dollars a barrel to less than half that today – has managed to halt the growth of modern RE deployment within the Atlantic world. Although the stated energy plan of president-elect Donald Trump is manifestly pro-fossil fuel and anti-regulation, it will not necessarily represent more than a temporary short-term slowdown in what will likely remain an increasingly intense long-term development of modern REs.

As this chapter intends to demonstrate, a number of key factors have recently shifted their dynamics, while a number of critical protagonists and agents have changed their positions on the relevant global energy maps, such that the arguments of the incumbent energy class – which justify fossil energy subsidization despite the continued structural advantage of the incumbent, while denying the political legitimacy and economic logic of renewable energy support -- are now wearing thin. Recent developments on all four Atlantic continents suggest that modern REs -- primarily solar (photovoltaic, or PV, both utility- and small-scale, along with different forms of concentrated solar power, or CSP) and wind power (both onshore and, increasingly, offshore), but also geothermal power and different forms of bioenergy -- have now positioned the low carbon revolution at a tipping point in the West.

This chapter will bring such long controversial terrain up to date in a brief review of the recent past, the current moment, and some possible futures of the historic transition from a fossil fuel-driven energy economy to a low carbon reality, with a focus on the Atlantic Basin. It will also offers initial reflections on the meaning of a Trump presidency for modern REs. And while such a limited 'chapter' cannot possibly be exhaustive, it hopes be indicative.

Recent evolution of RE deployment

If the shale revolution in the US surprised nearly everyone, the intensity and resilience of the rollout of renewable energy capacity over the last ten years has also caught certain quarters off-guard. This remarkable resilience of modern REs in the face of both the shale revolution and the oil price decline has been particularly noteworthy in Asia, but also across most of the Atlantic Basin. Indeed, the IEA has

[1] For the purposes of this chapter, 'modern renewable energy' is defined to include wind, solar and geothermal power (and, in certain specified instances, it also may include bioenergy). 'Low carbon energy' incorporates 'modern REs' but it also includes nuclear power and conventional 'renewable' energy, like hydroelectric power.

already undershot in its projections for the development of modern REs within the global energy mix on a number occasions in the past – and, as a result, has overstated the future vigor and longevity of fossil fuels, one of the central arguments of the fossil fuel classes.

For example, in 2006 the IEA's World Energy Outlook projection for solar energy generation was for 34 TWh in 2015 and 238 TWh in 2030. However, actual solar rollout has been far more intense: 253 TWh in 2015 (out of a global total of 24,100 TWh, or 1% of the global generation mix). In fact, more than 50 GW of solar power capacity are being added each year to the global energy system.[2] Under-projection characterizes the evolution of wind power, as well: although in 2006 the IEA projected 449 TWh of wind generation in 2015, according to BP wind generated 841 TWh of electricity globally last year.[3]

Investment in Modern REs

Investment in modern REs globally peaked in 2011 at $279bn. With the second phase of the global economic crisis unfolding in Europe, however, and with the wave of consolidation that took place within renewable energy sectors (like bioenergy or solar power), global investment levels fell to a trough in 2013 at $234bn. Since then, a strong recovery has brought global RE investment levels to a level now just above their previous 2011 peak, at $286bn in 2015.[4] (See Table 1) More than half of this investment in modern REs last year was made in solar PV (US$67bn in rooftop solar PV, US$92bn in utility-scale PV systems, and US$267mn for off-grid applications).[5]

Within the Atlantic Basin, investment levels have now either recovered their pre-crisis peak, or continue to rise again towards it – at least in three out of the four continents of the Basin. In the US, the 2011 peak of $49bn has nearly been regained ($44bn in 2015), while in Latin America and Africa current investment levels now exceed their previous peaks. However, in Europe – once the clear leader in RE investment – levels continue to decline each year, falling from $123bn in 2011 to less than $49bn in 2015. (See Table 1). In the meantime, however, the Asia Pacific region (which includes Oceania) has continue to register rising RE investment levels during each of the last five years.

Table 1. Modern Renewable Energy, Investment, $ billion, 2000-15

$ bn	2010	2011	2012	2013	2014	2015
World	**239.19**	**278.5**	**257.26**	**233.99**	**273.03**	**286.19**
Atlantic Basin	**171.38**	**194.44**	**157.61**	**120.99**	**128.19**	**125.57**
US	34.72	49.06	40.65	35.33	**37.05**	44.1
Brazil	7.24	10.23	7.66	4.41	**7.97**	7.14
Other Americas	11.98	9.29	10.09	12	**13.28**	12.83
Africa*	4.06	2.98	10.16	9.27	**7.9**	12.74
Europe	113.38	122.88	89.05	59.98	**61.99**	48.76
Great Crescent**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Asia Pacific	**67.81**	**84.06**	**99.65**	**113**	**144.84**	**160.62**

[2] David Hone, "Solar deployment rates," The Energy Collective, August 31, 2016.
[3] BP *Statistical Review of World Energy*, June 2016.
[4] Frankfurt School-UNEP Centre/Bloomberg New Energy Finance, Global Trends in New Energy Investment, 2016.
[5] IRENA, *The Power to Change: Solar and Wind Cost Reduction Potential to 2025*, June 2016.

China	39.64	47.44	61.7	62.01	**87.78**	102.9
India	8.84	12.78	7.78	6.56	**8.3**	10.16
Other Asian and Oceania	19.33	23.84	30.17	44.43	48.76	47.56

Data from IRENA, Data and Statistics, Featured Dashboard. Source: Frankfurt School-UNEP Centre/Bloomberg New Energy Finance, *Global Trends in New Energy Investment, 2016*. Note: NA = not available. *The data from this source groups RE investment in the Middle East -- a negligible figure up to 2015 -- together with that of Africa; however, given that Africa has installed more than three times as much modern RE capacity as the Middle East (7GW vs 1.27GW), we assume that the large majority of the 'Africa' figures represents RE investment in Africa, as opposed to the Middle East. **Investment figures for Eurasia are not reported by this source.

Modern RE rollout

Despite the drop-off in RE *investment* in the Atlantic Basin as a whole (from $194bn in 2011 to $126bn in 2015), modern RE *rollout* (expressed as accumulated installed capacity in GW) has continued rapidly apace. Installed RE capacity increased nearly ten-fold in the Atlantic Basin from 2000 (46 GW) to 2015 (443 GW), but it rose nearly five-fold from 2005 and nearly doubled again over the last five years (from 223 GW in 2010). Since 2005, the RE rollout pace has been the fastest in Africa (536%) and Latin America (482%) – although they have been growing from much smaller bases – and in North America (455%). Europe still leads the Atlantic continents in terms of absolute levels of installed RE capacity (248 GW in 2015, or one-third of the global total), but its growth rate has slowed considerably during the last five years.[6] (See Table 2)

Table 2. Modern Renewable Energy, Electrical Capacity Installed, 2000-15

GW installed	**2000**	**2005**	**2010**	**2015**	**% of total 2015**	**% growth 2005-15**
World	**59.8**	**117.6**	**305.3**	**757**		
Atlantic Basin	**45.75**	**92.7**	**223**	**442.7**	**58.5%**	**378%**
North America	16.7	23.9	62.5	132.7	**17.5%**	455%
Latin America	5.5	6.0	14.8	34.9	**4.6%**	482%
CA & Carib.	*1.6*	*1.8*	*2.3*	*4.8*	***0.6%***	*167%*
S. America	*3.9*	*4.2*	*12.5*	*30.1*	***4.0%***	*617%*
Africa	0.85	1.1	2.1	7.0	**0.9%**	536%
Europe	22.7	61.7	143.6	248.1	**32.8%**	302%
Great Crescent	**1.39**	**1.54**	**3.05**	**8.67**	**1.1%**	**463%**
Eurasia	1.38	1.48	2.83	7.4	**1.0%**	400%
Middle East	0.014	0.060	0.221	1.27	**0.2%**	2017%
Asia Pacific	**12.5**	**23.3**	**79.2**	**293.5**	**38.8%**	**1160%**
Asia	11.5	20.9	74.6	281.5	**37.2%**	1247%
Oceania	1	2.4	4.6	12	**1.6%**	400%

[6] IRENA, Data and Statistics, Featured Dashboard.

Source: Data from IRENA, Data and Statistics, Featured Dashboard.

At the global level, in 2000 there were 60 GW of installed capacity in modern REs and 842 GW of installed capacity in low-carbon sources (including modern REs and all hydropower). This rose to 118 GW and 987 GW, respectively, in 2005; to 305 GW and 1,331 GW in 2010; and 757 GW and 1,965 GW by 2015.[7] Nearly two-fifths of all globally installed capacity in modern REs is located in the Asia-Pacific region, where it has grown by a whopping 1160% over the last decade (if from what was originally a much smaller base).

Fossil fuel incumbency

One of the most central arguments (and, rhetorically, one of the most effective) long used by the fossil fuel industry and its allies has been to claim that, whatever happens, fossil fuels are here to stay, set to dominate the world's energy mix for decades and decades to come. The claim typically involves invoking the 'business as usual' projections for the global energy scenario, annually developed by the world's most respected national and international energy institutions -- like the International Energy Agency (IEA) or the US's Energy Information Agency (EIA) – and private sector companies (like BP, Exxon and Total), which almost inevitably foresee fossil fuels providing around 80% or so of global energy indefinitely into the future – or at least to 2040. Indeed, according to BP, fossil fuels constituted 86% of the world's primary energy mix in 2015. Furthermore, BP's regularly revised projections of the business-as-usual future currently see this share falling to only 79% by 2035.

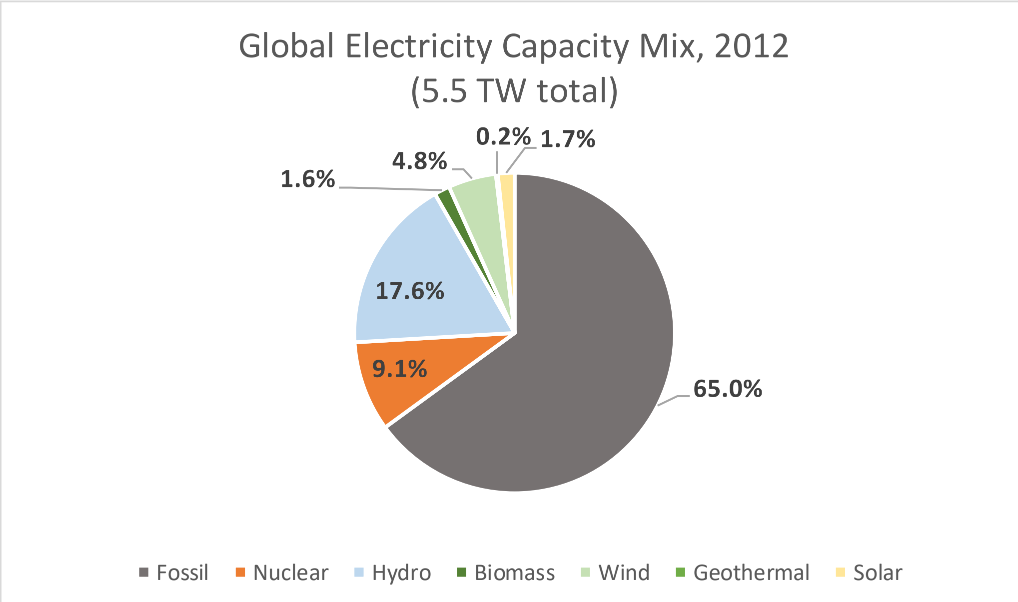
From there the argument usually concludes with the derivative claim that any significant attempt to rapidly and deeply displace fossil fuels with renewable energy is not realistically possible, and that undue pressures on fossil fuel companies to reduce their share of GHG emissions are not sensible, or even legitimate, bound only to reduce growth and destroy wealth. It should be obvious, however, that the argument that fossil fuels should continue to dominate the global energy mix over the mid- and long-run future simply and mainly because they 'inevitably' will dominate it is dangerously tautological, given that such a claim relies upon the assumption that we do not consciously change the trajectory of status quo behavior and dynamics, particularly with respect to fossil fuel incumbency, dominance or centrality.

Yet despite this recent surge in modern RE deployment, fossil fuels remain entrenched, at least for the moment, as the dominant sector in both the global electricity mix and in the broader global primary energy mix (which also incorporates the transportation sector, the last bastion of oil within the global energy economy, and industry, the last bastion of coal, particularly in Asia).

This continued dominance can be easily grasped from a presentation of the global electricity mix. (See Figures 1 and 2) Approximately two-thirds of both installed capacity and generation globally is fired by fossil fuels, mainly coal and gas but also oil.

[7] IRENA, Data and Statistics, Featured Dashboard.

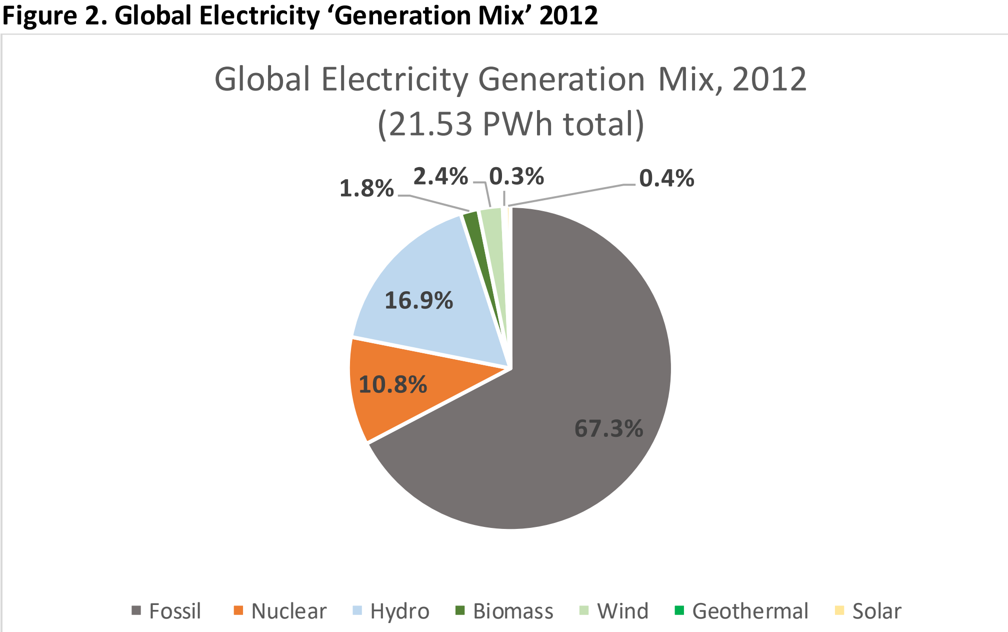
Figure 1. Global Electricity 'Capacity Mix' 2012



Source: EIA, 2016.

Modern REs (wind, solar and geothermal) accounted for only 6.7% of all installed capacity, even after the surge in deployment documented above (and a mere 8.3% if biomass-generated electricity is included in the RE share). Modern RE's share in the global generation mix (3.1%) is even more modest, given the comparatively low capacity factors of 'variable' REs like wind and solar power.

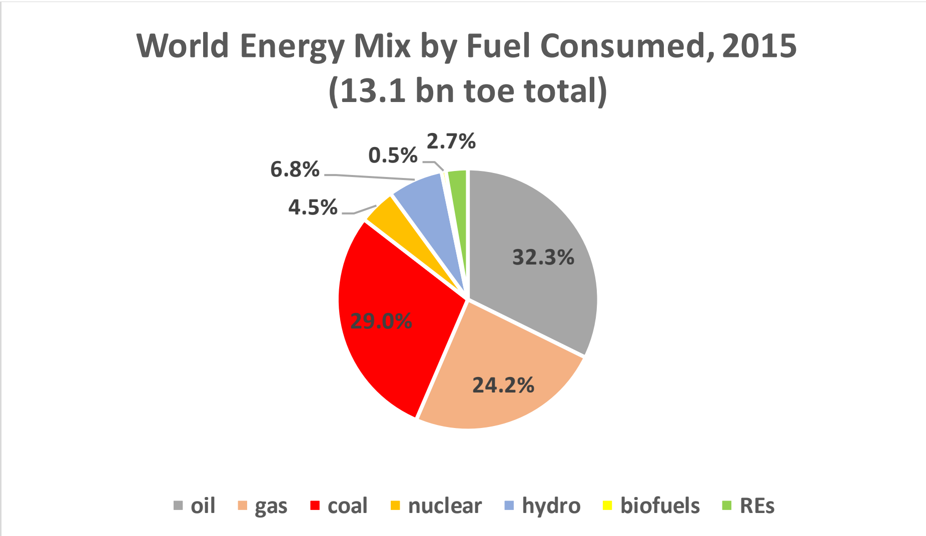
Figure 2. Global Electricity 'Generation Mix' 2012



Source: EIA, 2016.

Current fossil fuel dominance – and modern RE marginality – is even more starkly revealed by the global final energy consumption mix, which includes the transportation, industry and buildings sectors, in addition to electricity. Modern REs accounted for only 2.7% of all the energy consumed in the world last year (see Figure 3). Fossil fuels contributed nearly 86% of all the energy consumed.

Figure 3. Global Final Energy Consumption Mix, 2015



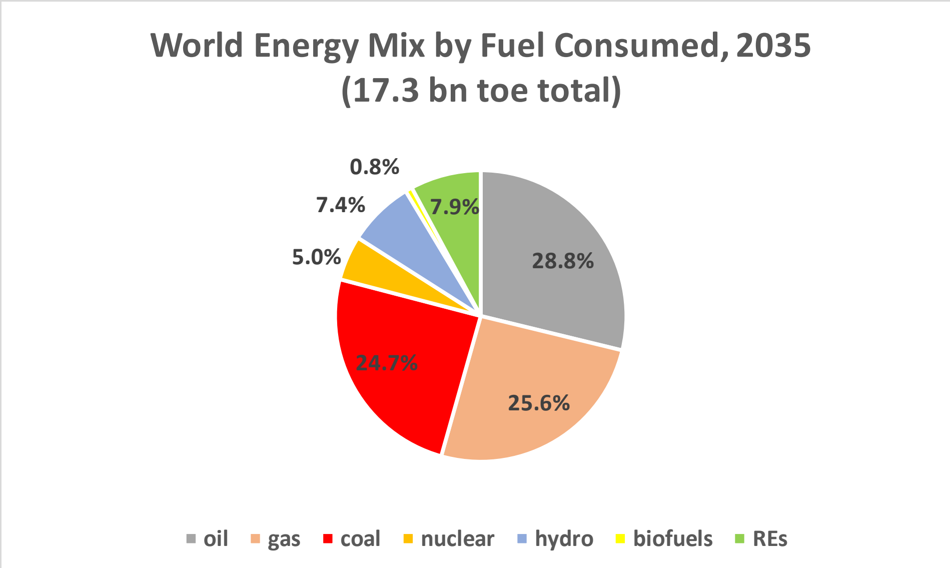
Source: BP Annual World Energy Statistics 2016.

Most current analysis of the evolution and prospects for modern REs focuses on global and national efforts to 'decarbonize' the power sector, where REs have their most direct and obvious applications. According to annual data from the US Energy Information Agency (EIA), as of 2012 the global power sector had a total of 5.55 TW of installed capacity, which generated a total of 21,532 TWh of electricity. This is the 'oil equivalent' of 4.9 billion tons of oil of electricity generated globally in 2012.[8] BP reported 12.52 bn toe of total global energy consumed in 2012. This means that the global electricity sector contributes to only 39% of global energy consumption before accounting for transmission losses, and only 33% if assuming an average 15% transmission loss on average globally.

This has a number of implications. First, efforts to decarbonize the power sector only can reach up to between one-third and two-fifths of the global energy economy. The GHG emissions of the other 60%-70% remain beyond the reach of renewables servicing the power sector as it now stands. Indeed, BP's projection of the most likely future in 2035 (that is to say, the 'business-as-usual' scenario) still foresees, fossil fuels contributing nearly 80% of the total global final energy mix (see Figure 4). As a result, modern REs are likely to prove capable of incorporating the transportation, industrial and buildings sectors *only through the progressive electrification of these, the largest parts of the energy economy*.

[8] One million tons of oil or oil equivalent produces about 4400 gigawatt-hours (= 4.4 terawatt hours) of electricity in a modern power station.

Figure 4. Global Final Energy Consumption Mix, 2035



Source: BP Annual World Energy Statistics 2016.

Second, not only must RE-generated electricity displace petroleum in the transportation sector across the globe, but in Asia-Pacific, in particular, coal's centrality in the power and industry energy mixes must be broken at a much faster rate than the business as usual attrition projected by BP. Table 3, which breaks down BP's global energy mix projections into the global system's two major geographic components – the Atlantic Basin (Europe, Africa, Latin America and North America) and Asia Pacific (the rest of Eurasia and Oceania except the ex-Soviet/Russian sphere and the Middle, or the 'Great Crescent') – reveals the principal difference in the fossil fuel dominance (and its fading) of these two macroregions. While the Atlantic Basin will remain relatively (and overly) dependent on the hydrocarbons (oil 34% and gas 31%), coal will have been significantly displaced (with only 9% of the mix in 2035). On the other hand, in Asia-Pacific, the region's historic super-dependence on coal will still define the final energy mix, under the current 'business as usual' trajectory, in 2035 (nearly 43%).

Table 3. Current and Projected 'Business as Usual' Global Final Energy Mix, 2015 and 2035

	World		Atlantic Basin		Asia-Pacific	
	2015	**2035**	**2015**	**2035**	**2015**	**2035**
Fossil Fuels	**85.5%**	**79.1%**	**84.2%**	**74.2%**	**89.5**	**80.7**
oil	*32.3%*	*28.8%*	*38.1%*	*34.4%*	*27.3%*	*24.7%*
gas	*24.2%*	*25.6%*	*27.1%*	*30.5%*	*11.5%*	*13.1%*
coal	*29%*	*24.7%*	*19%*	*9.3%*	*50.7%*	*42.9%*
Low Carbon	**14.5%**	**21.1%**	**19.6%**	**24.8%**	**10.5**	**19.2**
Nuclear	*4.5%*	*5%*	*7.4%*	*5.6%*	*1.7%*	*4.9%*
Hydropower	*6.8%*	*7.4%*	*7.9%*	*9.2%*	*6.5%*	*6.7%*
Biofuels	*0.5%*	*0.8%*	*0.22%*	*0.28%*	*0.15%*	*0.19%*
Modern REs	*2.7%*	*7.9%*	*4.1%*	*10.7%*	*2.1%*	*7.4%*
Total Energy Consumed (bn toe)	**13.1**	**17.3**	**5.75**	**6.7**	**5.4**	**8.2**

Source: BP Energy Outlook 2016.

Excessive RE costs?

Another increasingly weak argument of the fossil fuel apologists is that renewable energies are simply too expensive, that they cannot compete economically with fossil fuels. Ignoring the numerous structural factors favoring fossil fuels – and even more the long-standing tendency of RE costs to decline rapidly with time – this argument is typically then wedded to the first: fossil fuels will and, therefore (!) must remain the mainstay of the energy mix, simply because to promote renewables through active policy intervention would be, from this 'point of view', simply economic suicide.

To begin with, the fossil fuel industry has not only enjoyed the inherent structural economic advantage that comes with position of the dominant incumbent energy source and technology, it has also been able to leverage that position to increase it protection against the emerging economic competition of alternative energy sources. The IEA estimated last year that fossil fuel subsidies came to more than $550bn in 2014.[9] Data from the IMF confirms these levels – some five times higher than the equivalent figure for subsidies granted to renewable energies worldwide ($100bn in 2012 and $120bn in 2014).[10] Furthermore, the Fund also has estimated that 'post-tax' subsidies to fossil fuel companies were as high as $1.7tn in 2012[11], and that if all of fossil fuel's 'negative externalities' are taken into account (eg, air pollution) then the overall subsidy to fossil fuel energy globally would top $5tn.[12]

But the most important news in the energy sector has been the dramatic decline of RE costs, despite the recent decline in oil prices, and even in the face of the lopsided public subsidy advantage of fossil fuels. (See Tables 4 and 5) Renewable energy costs have been declining by 15% to 25% each year now for nearly two decades and have now reached, in many parts of the world, the cost parity point with subsidized fossil fuel and nuclear energy, even as RE costs continue to decline.[13] One estimate, from Lazard's, shows that the 'levelized cost of energy' from wind and solar power fell by 61% and 82% respectively over the six years to the end of 2015.[14] The tipping point in the US, for example – when wind and solar power will be "firmly in place as the cheapest kilowatt-hours around" – is now projected to occur over the next five years, by the time the recently renewed renewable energy tax credits are set to expire after 2020.[15]

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[9] Kraemer and Stefes, "The Changing Energy Landscape in the Atlantic Space," in Jordi Bacaria and Laia Tarragona, (eds.), Atlantic Future: Shaping a new hemisphere from the 21st Century Africa, Europe and the Americas, CIDOB Monograph Series, Barcelona, 2016, p. 97.

[10] International Monetary Fund, Energy Subsidy Reform— Lessons and Implications, 2013 http://www.imf.org/external/np/pp/eng/2013/012813.pdf. (IMF 2013), and Kraemer and Stefes, 2016, p. 98.

[11] IMF, 2013, cited in Kraemer and Stefes, 2016, p. 98.

[12] Coady et al. 2015, cited in Kraemer and Stefes, op. cit.

[13] Kraemer and Stefes, 2016, p. 95, and p. 92.

[14] Lazard's Levelized Cost of Energy Analysis, Version 9.0, November 2015.

[15] Chris Nelder and Mark Silberg, "Congress extends the renewable investment tax credit: What now" greenbiz.com (https://www.greenbiz.com/article/congress-extends-renewable-investment-tax-credit-what-now), December 28. 2015.

Table 4. Trends in Global RE Levelised Cost of Electricity 2010-2015 (Ranges and Weighted Averages)

2015 USD/kWh	2010	2015
Hydropower	0.046	0.046
Onshore wind	0.071	0.060
Offshore wind	0.157	0.159
Solar PV	0.285	0.126
Solar thermal	0.331	0.245
Biomass	0.056	0.055
Geothermal	0.071	0.080

Source: IRENA, Data and Statistics, Dashboard, LCOEs 2010-2015
http://resourceirena.irena.org/gateway/dashboard/?topic=3&subTopic=33

The International Renewable Energy Agency (IRENA) foresees these costs continuing to plummet over the next ten years, driven by expanded economies of scale, increasingly competitive supply chains and further technological advances. With the appropriate regulatory and policy frameworks in place, IRENA predicts that the costs for wind power will fall between 25% (onshore) and 35% (offshore) compared to levels in 2015, while those of concentrated solar power (CSP) will drop some 43% and costs of solar PV will collapse by as much as 59% by 2025.[16]

Solar power now looms at the edge of an inflection point. With costs projected to fall another 60% over the coming decade, IRENA sees solar PV alone accounting for as much as 13% of the global generation mix as early as 2030 (up from only 2% in 2016)– *far outpacing BP's business-as-usual scenario which projects only 7.9% of the global primary energy mix to be accounted for by all modern REs even as late as 2035*. Already solar photovoltaic panels constitute the most "widely owned electricity source in the world in terms of number of installations." Rollout is accelerating at a much faster rate than anticipated: solar PV accounted for 20% of all new electrical generation capacity in 2015, according to IRENA, and since 2010 global installed PC capacity has expanded nearly five-fold, from 40 GW to 227 GW.[17] Although annual PV capacity additions would need to more than double in 14 years in order to achieve the 13% share in the electricity mix by 2030 that IRENA projects, it does not seem to be out of reach.

[16] IRENA, *The Power to Change: Solar and Wind Cost Reduction Potential to 2025*, June 2016.
[17] IRENA, *Letting in the Light: How solar photovoltaics will revolutionise the electricity system*, June 2016.

Table 5. Cost reduction potential for solar and wind power, 2015-2025

	Global weighted average data								
	Investment costs (2015 USD/kW)		Percent change	Capacity factor		Percent change[2]	LCOE (2015 USD/kWh)		Percent change
	2015	2025		2015	2025		2015	2025	
Solar PV	1 810	790	-57%	18%	19%	8%	0.13	0.06	-59%
CSP (PTC: parabolic trough collector)	5 550	3 700	-33%	41%	45%	8.4%	0.15 -0.19	0.09 -0.12	-37%
CSP (ST: solar tower)	5 700	3 600	-37%	46%	49%	7.6%	0.15 -0.19	0.08 -0.11	-43%
Onshore wind	1 560	1 370	-12%	27%	30%	11%	0.07	0.05	-26%
Offshore wind	4 650	3 950	-15%	43%	45%	4%	0.18	0.12	-35%

Source: IRENA, The Power to Change: Solar and Wind Cost Reduction Potential to 2025, June 2016

After all, as IRENA reports: "Solar PV regularly costs just 5 to 10 US cents (USD 0.05-0.10) per kilowatt-hour (kWh) in Europe, China, India, South Africa and the United States." Record low prices were registered in the United Arab Emirates (5.84 cents/kWh), Peru (4.8 cents/kWh) and Mexico (4.8 cents/kWh).[18] Such low solar auction bids bear out and reinforce the strong trend of cost reduction projected by IRENA for solar power in the coming decade.

Longer term outlook

Although in the short run, the outlook for modern REs may remain muddied, or even become volatile, as a result of the election of Donald Trump to the presidency in the US (more on this below), in the long run the only development that could halt the low carbon revolution, and even the decarbonization of the world's power sectors – at least in the Atlantic Basin and Asia-Pacific – would be cheaper than anticipated fossil fuel energy sources, possibly even increasingly subsidized. Yet even this kind of fossil revival is increasingly unlikely.

A new study by Bloomberg New Energy Finance (New Energy Outlook 2016) isolates some of the new aspects of the emerging pathway to the future that BP (and other fossil fuel-focused entities) miss in their projections of the likely business-as-usual future -- particularly the radical fall in RE costs. The BNEF study concludes with this central, synthetic projection:

"Cheaper coal and cheaper gas will not derail the transformation and decarbonisation of the world's power systems. By 2040, zero-emission energy sources will make up 60% of installed capacity. Wind and solar will account for 64% of the 8.6 TW of new power generating capacity added worldwide over the next 25 years, and for almost 60% of the $11.4 trillion invested."[19]

Of that $11.4 trillion that BNEF projects will be invested in the global electricity sector in the years to 2040, only $1.2 trillion will go into new coal-burning capacity, and only $892 billion into new gas-fired plants. This may surprise many expecting a gas-based fossil renaissance. Meanwhile, $7.8 trillion will be

[18] Ibid.
[19] BNEF New Energy Outlook 2016.

invested in low carbon electricity (or 'green power' in the language of BNEF), with $3.1 trillion going into (both on- and offshore) wind power, $3.4 trillion into utility-scale, rooftop and other small-scale solar power, and $911 billion into hydroelectricity.[20]

But for the world to follow a 2°C-consistent scenario pathway – like the IEA's 450 Scenario, for example -- would require much larger investment sums: an additional $5.3 trillion in 'green power' by 2040 would be needed, according the BNEF, "to prevent CO2 in the atmosphere rising above the Intergovernmental Panel on Climate Change's 'safe' limit of 450 parts per million." Furthermore, a successful 2°C-consistent pathway may require foregoing much of even the limited fossil fuel investment in the power sector projected by BNEF. In February 2016, a team at Oxford University concluded that to have even a change of defending the 2-degree guardrail, all power plants built after 2017 would have to be zero carbon.[21] This would leave 'stranded' at least the plans for thousands of coal and gas power plants currently on the boards around the world, given that carbon capture and sequestration technologies are not yet available commercially.[22]

If BNEF's new business-as-usual projection (or 'new status quo pathway') captures more of the realities and potentials of the low carbon revolution than those of the fossil fuel sector (represented here by BP), it does not capture all of the aspects and dynamics of the low carbon revolution that might impose themselves upon the status quo simply through the force of economics. First, BNEF's projections are based upon estimates for future declines in RE costs that are significantly more modest than those projected by IRENA (see above). Whereas IRENA projects that costs will fall between 25% (onshore) and 35% (offshore) for wind power, and between 40% (CSP) and 60% (PV) for solar over the coming decade, BNEF foresees that the levelized cost of electricity (per MWh) for onshore wind will fall by 41%, and for solar PV by 60%, *but only by 2040*.[23]

Although BNEF claims that "these two technologies (will be) the cheapest ways of producing electricity in many countries during the 2020s and in most of the world in the 2030s," low carbon electricity would still only generate 70% of Europe's power in 2040, up from 32% in 2015, and only 44% in the US.[24] But to reach a 2-degree scenario, the penetration of modern REs will have to be even higher. Faster than expected cost declines, like those projected by IRENA, could be responsible for a deeper penetration of modern REs into the global power mix than even that projected by BNEF.[25] This suggests that declining RE costs could be the crucial variable in nudging the world onto a 2-degree consistent pathway in time to avert the worst damages from climate change.

The second variable that could change the future of modern REs as a share of the global energy mix would be the question of electrification, primarily of the transportation sector, but also potentially of

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[20] Ibid.

[21] Alexander Pfeiffer, Richard Millar, Cameron Hepburn, Eric Beinhocker, "The '2°C capital stock' for electricity generation: Committed cumulative carbon emissions from the electricity generation sector and the transition to a green economy" *Applied Energy*, available online 24 March 2016, ISSN 0306-2619, http://dx.doi.org/10.1016/j.apenergy.2016.02.093

[22] David Fullbrook, "A turning point looms for electricity and climate" *Energy Post*, August 31, 2016.

[23] BNEF New Energy Outlook 2016.

[24] Ibid.

[25] Interestingly enough, the BNEF outlook does not envision any 'golden age' for gas, or even a significant role as a 'bridge' fuel, except to some extent in North America. The share of gas in the global energy mix is projected to be outstripped by renewable energies in 2027, some 10 years before they are projected to overtake coal.

much of the industrial and building sectors. While it would be unrealistic to expect all of the global energy economy to be electrified, even over the long run, in most of the world's megacities and in densely populated regions (where most of the world's population resides) it would be feasible. We could even expect Europe and Latin America to take the lead.

As mentioned above, in 2012 electricity represented some 39% of the global energy consumed -- before approximately 15% transmission losses are assumed worldwide (ie, the 'secondary mix'), and only 33% after (ie, the final consumption mix). By 2015, the share of energy inputs used for global power had increased to 42%, but it was projected by BP to rise to only 45% by 2035, reflecting only minimal electrification of transport by then, as most of this increase is projected to come from countries where much of the population still remains beyond the reach of electricity services.[26]

The BNEF projection, however, does foresee the penetration of electric vehicles (EVs) increasing electricity demand by 8% in 2040, making a claim on an additional 2,701 TWh to be produced by the power sector annually. By that time, according to BNEF, EVs will have expanded 90 times (to some 41mn cars) and account for 35% of new annual light-duty vehicle sales.[27] Yet, while BNEF foresees a much larger share for modern REs by 2040 than that implicit in BP's projection to 2035, in part driven by a faster assumed penetration by EVs into the global vehicle fleet, it still leaves an insufficient share of the global energy mix covered by low carbon energy, particularly modern REs. This is because the BNEF forecast assumes that the bulk of the transportation fuel mix will still be supplied by hydrocarbon-based liquids over the long run.

The BNEF scenario only projects just over 40mn EVs in 2040, when there could be as many as 2.5 billion vehicles operating on the planet (BP projects around 2.3 bn for 2035). In other words, there remains tremendous scope for the electrification of transportation and other sectors to amplify the capacity of modern REs to reduce the outstanding GHG emissions gap by more deeply displacing fossil fuels. Indeed, the real bastion of the entrenched market-place advantage of fossil fuel structural incumbency lies in the transportation sector; more rapid expansion of EVs and widespread potential for electrification of the economy is what threatens it the most.

Peak oil demand

More than any other variable, the penetration rate of electricity into the transport fuel mix will determine the longevity of fossil fuel dominance and the approximate date of the 'end of oil.' A broad and interesting range of projections have recently been made concerning the future evolution of global oil demand. Some oil companies, like BP and Exxon, do not foresee oil demand peaking any time before 2040. BP projects oil demand will rise from 87mbd in 2015 to 100mbd in 2035, while Exxon believes oil demand will grow 20% by 2040.[28]

However, the IEA's 450 scenario (in theory consistent with defending the 2-degree guardrail) requires oil demand to be as low as 80mbd in 2035 and 74mbd in 2040.[29] In addition, two out of the three recent World Energy Council scenarios for 2040 project global oil demand to peak in 2030.[30] But the recent

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[26] BP Energy Outlook 2016.
[27] BNEF New Energy Outlook 2016.
[28] Tyler Durden, "Shell Warns that 'Peak Oil Demand' May be Reached in 2021," zerohedge.com, Nov. 6, 2016.
[29] Claudio Aranzadi, "Introduccion" in Energia y Geoestrategia 2016, IEEE-CECME-Enerclub, Madrid, 2016, p. 12.
[30] World Energy Council, World Energy Scenarios 2016.

acceleration of the rollout of electric vehicles, together with the slowdown in demand from China and the continued increase in conventional vehicle efficiency are beginning to point to the possible risk of an earlier peak in the global demand for oil than even the WEC has foreseen.

BNEF recently projected a potential crisis in the oil sector as early as 2028, driven by peak oil demand being brought forward by accelerated electrification of transportation, generating a supply glut of some 2mbd – equal to that which provoked the 2014 collapse in oil prices -- and sending hydrocarbons companies into a "death spiral" in the markets. An update by BNEF, along with a similar yet more recent projection made by Fitch, brings this crisis date for oil forward to 2023.[31] Finally, the most telling projection of all has just come from the industry itself – from Shell -- which allows for the possibility of peak oil demand occurring as early as 2021.[32]

The upshot is that the current business-as-usual trajectory for global energy – modified recently by the acceleration of EV penetration – will imply the prospect of significant 'stranded assets' in the fossil fuel industries. Recent studies posit that "more than 80% of current coal reserves, half of all gas reserves and a third of oil reserves must remain unburned through at least 2050."[33] Carbon Tracker has estimated that such usuable, 'stranded assets' currently on the books of global energy companies could be worth $2.2 trillion.[34] This is the equivalent of decades of global hydrocarbon sector profits.

Although such an accelerated scenario may seem to reflect the increasingly strong economic in favor of modern REs, it certainly signals a coming struggle for the world's markets, as the hydrocarbons sector is likely to continue vie with the renewable energy sector for regulatory influence and infrastructural lock-in.

The Policy Horizon for Modern REs

International Scene

The Paris Climate Accord firmly establishes the international community's goal and universally accepted imperative to limit the future rise in global temperatures to no more than 1.5C-2C above pre-industrial levels. This historic international agreement is an undeniable signal of the inevitable low carbon transition to come: it lays down a clear policy marker for national governments, the energy industry and the investor community and provides for a powerful stimulus for the creation of new clean energy markets.

The agreement establishes the critical framework within which the relevant protagonists – energy and related companies, investors, consumers and policy makers at all levels of jurisdiction – make decisions moving forward. The agreement engages a critical mass of global actors with a different pattern of incentives and therefore a different dynamic than that which dominating energy markets and policies for the past several decades. It has already been ratified by the required 55% of the parties to the agreement covering at least 55% of global GHG emissions, and would still meet such quotas even should

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[31] Joe Romm, "Electric car revolution may drive 'oil investor death spiral," ThinkProgress.org, October 16, 2016.
[32] Durden, ibid.
[33] Christophe McGlade and Paul Elkins, "The geographical distribution of fossil fuels unused when limiting global warming to 2 °C," *Nature*, January 2015, vol. 517, p. 187.
[34] Barbara Grady, "Stranded assets may add up to $2.2 trillion – blame COP21?" Greenbiz.com, November 24, 2015.

the US ‘withdraw,’ as the new president-elect has promised during the recent election campaign. In any event, the design of the Paris accord allows that US presidential executive authority is sufficient to ‘ratify’ it (as opposed to requiring the ratification of the US senate, as in the case of a formal binding treaty), and the same is true for a withdrawal or even an eventual re-entry.

Nevertheless, even with perfect compliance with the commitments contained in the 187 INDCs there will remain a significant ‘emissions gap’ with the levels required to defend the 2-degree guardrail. The five-year reviews which the parties must submit themselves to will help by allowing for the possibly of ‘ratcheting up’ national commitments, but they will also remain vulnerable to the disruptions caused by possible exogenous shocks along the way.

Massive uncertainties remain, as most national commitments are vulnerable to domestic policy changes. Furthermore, a newly emerging backlash to international climate action is potentially taking shape in the form of ethno-nationalist right-wing movements that could capture the governments of many Western countries, at least for some years.

<u>The potential impact of a President Trump in the US</u>

The election of Donald Trump in the US presents just the kind of exogenous shock the could symbolically scuttle the Paris agreement and throw more roadblocks in the way of renewable energy in the US, in many ways the global sector’s leader. Trump’s energy plan during the election campaign was a superficial reproduction of the long-standing Republican party platform which prioritizes domestic fossil fuels under the banner of an ‘all of the above’ national energy strategy (meaning open, if not necessarily free, competition between all domestic energy sources). He has also pledged to eliminate the EPA and to reverse all of the EPA’s action under Obama, along with the rest of Obama’s executive orders on energy and climate change. Such pledges also include a repeal of Obama’s Clean Power Plan and a ‘withdrawal’ of the US from the Paris Agreement. Trump’s proposed rollback of regulations includes an extensive opening of federal lands (and offshore areas) to more oil and gas drilling, and a more *laissez faire* federal attitude toward ‘fracking’. He has also promised to reverse the Obama Administration’s rejection of the Keystone XL pipeline.

Trump’s plans for energy have generally been considered to be beneficial, on balance, for fossil fuels, and negative, or at least potentially problematic, for renewable energy. But Trump has shifted positions on both renewable energy and climate change over the years, so there is little clarity or certainty generated by his stated positions at any particular moment – at least until policy begins to be formulated and implemented. Nevertheless, the transition team athat Trump has begun to appoint includes a number of climate change ‘sceptics’ and advocates for the oil and gas industries.

On the other hand, energy and climate change do not appear to be high on the list of priorities for Trump’s transition team and the first 100 days of the new administration. Far more attention is being given to tax proposals, border issues and ‘national security.’ Furthermore, there are some reasons to suspect that even an aggressive policy of fossil fuel deregulation by the Trump administration will not necessarily derail the nascent boom in modern REs.

First, coal won’t survive on Trump’s rhetoric alone, and the new shale gas boom he promises would undercut much of what is left of the sector, and modern REs will take care of the rest through the force of lower costs. Opening up more federal lands to more oil and gas drilling will also change little -- in part because this argument has always been something of a canard, given that oil companies have left undeveloped most of the leases they have long held on the federal lands that are open to fossil fuel activity; and in part also because the oil and gas companies already have an abundance of booked reserves to develop. Low oil and gas prices – and their increasingly muddied future outlook – along with the continued momentum of REs – are the major barrier to more drilling in the US and they may actually present the danger of significant stranded assets.

Trump could revive the Keystone XL pipeline, and assist the struggles of the Dakota pipeline, but the overall impact will be minimal beyond some localities and for some companies. Congressional oversight could at least complicate Trump's intention of reversing Obama's executive directives to the EPA, and the Democrats in the Senate retain the capacity to block any legislation, including an elimination of the EPA, by using the 'filibuster' mechanism which requires a supermajority of 60 votes. Furthermore, infrastructure proposals, in general, continued to face the same stock 'fiscal' opposition as always from the Republican leaders of Congress.

While none of the above will help the deployment of modern REs, such actions, effective or not, may not have much direct impact. Much more important to the short and mid-term future of renewable energy development in the US are the investment and production tax credits for REs which were recently reinstated by the US congress. If Trump or the Congress were to rescind these tax credits (which are the principal support for renewable energy at the national federal level in the US), the short-term outlook would be negatively affected. The last time the Production Tax Credit (which provides a wind farm with a tax credit of 2.3 cents per kilowatt-hour of electricity produced during the first 10years of production for a new project) expired in 2012, new wind power projects dropped by 92% the following year, although they rebounded once the credit was renewed.[35] The Investment Tax Credit, for its part, provides a 30% tax credit to individual households or commercial solar plants against the cost of installing a new renewable energy project.

However, many 'red states' in the Midwest, Prairie and Western states are heavily invested in wind power and stand to gain if they are not rescinded, and vice versa. For example, while Texas is the largest fossil fuel producing state, it is also the leader in wind power. Renewables also generate jobs and other co-benefits, which accrue not only on the coasts but also across various US heartlands. Already 600,000 jobs have been created in the wind and solar sectors (equal to what critics of NAFTA says were the lost as a result of that trade deal). Although there are 3.6 million employed in the US fossil fuel industries, these sectors also contribute three-quarters of the US energy mix; but they will continue to lose share in the future. In any event, there is evidence that modern REs are more intensive in both skilled and unskilled labor than any of the fossil fuels.

Although it is true that US public opinion is increasingly polarized on climate change, more and more Americans favor renewable energy, in any case. In a recent Pew poll in the US in October, 2016, 89% wanted more solar installations and 83% wanted more wind.[36] In a March 2016 Gallup poll, 73% of

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[35] Maggie Koerth-Baker, "It's Hard To Tell Whether Trump Supports Renewable Energy — And That May Not Matter Much" FiveThirtyEight.com, Nov 14, 2016.

[36] PEW Research Center, The Politics of Climate, October 4, 2016. http://www.pewinternet.org/2016/10/04/the-politics-of-climate/

Americans claimed they preferred more alternative energy to more oil and gas, including a majority (51%) of self-defined Republicans.[37]

Finally, 29 states and many cities have put into place renewable energy portfolio standards (which mandate certain percentages of the electricity generation mix be provided by renewable energy) and nearly all states have at least some kind of policy incentives for RE which have already begun to reoriented markets. Not only will energy policy continued to be made closer to the ground in the states, but this reality nullifies much of the potential of a Trump presidency to stop, let alone roll back, the ongoing investment in the deployment of renewables.

Tentative conclusions

The American hydrocarbons revival of recent years – driven by the shale revolution – now faces the combined headwinds of the depressed prices that the surge in US production in part generated and the flattening demand that is structurally built into the future. Easier access to resources on federal lands and less government interference in pipelines will not materially alter the long-term outlook for fossil fuels. Ending the Clean Power plan will not save coal, and it will not stop modern REs. Withdrawing from the Paris agreement will not create an American energy renaissance out of the shale revolution – although it might undermine American leadership in the low carbon revolution, given that the Paris accord generates the parameters for global markets to be created in precisely the modern RE goods and services that US companies excel in. Eliminating the current RE tax credits, which already are set to expire in 2020, would pose a barrier to RE development in the US, at least in the short-run, it will not stop their development globally. And domestic politics could save the US renewable energy tax credits in the end.

Although there are a number of other factors beyond the scope of this overview which could hinder the development of modern REs in the future, pushing back the tipping point between fossil and RE dominance some years into the future, and perhaps even placing the 2-degree climate goal out of reach, the essential pre-requisites for a low carbon, RE-based future – competitive and falling costs and successful early deployment -- have now been demonstrated. Developments on these fronts demonstrate that with somewhat more policy guidance modern REs are capable of, and likely still could, even in the face of a Trump presidency, make the key contribution to the world's avoidance of the worst catastrophes of fossil fuel-induced climate change.

[37] Koerth-Baker, op. cit.

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