Clean up energy innovation

Countries need to agree clean energy definitions and baselines to track essential uplift of research investments to decarbonize the world's energy supplies, write Lucien Georgeson, Mark Maslin and Martyn Poessinouw.

The Paris climate agreement to keep global average temperature rise below 2˚C requires the world to transition rapidly to low carbon energy. Global carbon emissions must peak by 2020, reach zero between 2060 and 2080 and become negative by 2100[1].

Two global partnerships were launched last year to get governments to recognize the scale of the transformation and make the huge investments needed. 'Mission Innovation', a partnership of 20 countries and the European Union[2], seeks to double annual public clean energy research and development (R&D) funding by 2020, from around $15bn to $30bn. The 'Global Apollo Program' is a call led by chemist and former Chief Scientific Adviser to the UK government Sir David King and colleagues[3] for developed countries to invest 0.02% of their GDP in public R&D– estimated to add up to $15 billion a year globally – to make electricity from renewable sources cheaper than that from coal by 2025.

Both Mission Innovation and Global Apollo take different approaches; the former seeks to build bottom up agreement between countries based on what they are willing to commit, and the latter sought to set the priorities from the top down. There are pros and cons to both approaches that have major implications for the expansion of clean energy R&D over the next few decades.

Need to set proper baselines

The Mission Innovation countries announced the baselines and pledges for clean energy R&D in June 2016. The first issue is that each country is free to set their own baselines. The IEA publishes many national R&D budget data on national submissions, including 12 Mission Innovation countries. But only Australia and Canada have used their reported clean energy R&D data to set their pledges. The second issue is how countries define baselines. Under Mission Innovation, some countries have picked a doubling of 3-year average spend in public clean energy R&D between 2010 and 2015, others have picked 2015 as a baseline, or even 2013 or 2016. Some countries speak of R&D, some of RD&D; Research, Development & Demonstration.

Australia is a prime example of how a shifting baseline will change Mission Innovation's clean energy R&D funding. Australia's Mission Innovation statement gives a target of 208m AUD, based on doubling government R&D investment into 'renewable energy, energy storage, fuel cells, smart grids, energy efficiency, nuclear and carbon capture and storage' by 2020, based on the 2015 figure of AUD 104m)[2]. However, according to the IEA, Australia spent AUD 152m in 2014, AUD 599m in 2013, AUD 656m in 2012, AUD 529m in 2011 and AUD 447m in 2010, suggesting R&D funding has declined significantly in 2015. Using the available data from the IEA, a 3-year average from 2012-2014, then doubled (as employed by the EU, France, Mexico, Norway, Sweden and the UK) would give a baseline of AUD 469m and a target of AUD 938m.

The plans also reveal another area of inconsistency in the baselines; will Mission Innovation deliver an absolute doubling or a doubling above 'business-as-usual' R&D funding scenarios? For example, the European Union sets its baseline as a doubling on baseline value, which is a 3-year average from 2013–2015 of €989, for a clean energy R&D target of €1974m in 2020. However, their figures also show that, under a baseline scenario, funding would have reached €1493m anyway. Moreover to ascertain each countries ambition, we have calculated their Mission Innovation targets as a percentage of their GDP (Table 1) and they range from Chile's 0.0037% to Norway's 0.0719. This also makes it possible to compare with the Global Apollo programme; that uses a top down approach suggesting each countries should contribute 0.02% GDP. Table 1 shows this more equal approach produces a radically different target for each country. Whether we look at the pledges in absolute or relative terms completely changes how we look at them and our understanding of the global landscape of clean energy research.

	Country	Private Clean Ene R&D ($m)	Global Apollo 0.02 target ($m)	Mission Innovation Baseline ($m)	Mission Innovation Commitment ($m)	Commitment as % of GDP
1	Norway	1130.74	77.90	140	280	0.0719
2	United States	56185.69	3589.40	6415	12830	0.0715
3	Republic of Korea	5730.44	275.38	490	980	0.0712
4	China	39143.93	2196.56	3800	7600	0.0692
5	France	10296.85	484.32	494	989	0.0408
6	Canada	5360.14	310.48	295	590	0.0380
7	Denmark	790.96	59.00	45	90	0.0305
8	Germany	11580.13	671.52	506	1011	0.0301
9	Italy	7105.52	363.16	250	500	0.0275
10	Kingdom of Saudi Arabia	2105.34	130.64	75	150	0.0230
11	United Kingdom	10140.71	569.86	290	580	0.0204
12	Japan	19080.18	824.66	410	820	0.0199
13	Indonesia	5097.86	171.80	17	150	0.0175
14	Brazil	8588.75	354.52	150	300	0.0169
15	Australia	2882.40	244.78	78	156	0.0127
16	India	17059.36	418.14	72	145	0.0069
17	Sweden	1192.25	98.52	17	33	0.0067
18	United Arab Emirates	534.19	69.10	10	20	0.0058
19	Mexico	6399.71	228.86	21	62	0.0054
20	Chile	1092.06	48.04	4	9	0.0037
	European Union	65835.68	3295.44	1111	2218	0.0135
	Total	**277332.90**	**14482.08**	**14690**	**29513**	**0.0408**

Table 1

Mission Innovation states that its members represent 80% of public funding for clean energy R&D. So the doubling pledges are, for global clean energy, a significant step. But is it a problem that R&D funding seems to be concentrated in a few centres? What does this mean for getting technologies to where they are needed? This may have consequences for what must be the ultimate goal of Mission Innovation; developing technologies and deploying them at scale where they are needed. Mission Innovation explicitly states that technologies are for national priorities but there needs to be an understanding of how 'technology transfer' will take place.

How to set priorities

The second challenge revealed by the new Mission Innovation pledges is how to set priorities for clean energy R&D. The Global Apollo Programme gave three main priorities; Solar PV and Concentrating Solar Polar, Electricity Storage and Smart Grids. It therefore represented a highly targeted approach with a clear aim; grid parity for baseload electricity from renewables[3]. Its target of $150 billion over 10 years would make a huge difference to this aim. Mission Innovation countries have pledged an extra

$15 billion a year, covering all aspects of 'clean energy', including nuclear power (Australia, Brazil, Canada, China, Republic of Korea, the UAE, the U.K. and the US) and industrial energy efficiency (all countries except China)[2]. Moreover, the majority of countries have not provided a spending breakdown of their baselines and targets by sector.

There is a clear issue with how countries define clean energy innovation. Beyond renewable energy generation such as wind, solar, hydro, some include energy efficiency, nuclear energy, and carbon capture and storage (CCS). The latter despite the fact that it is controversial and lacks a successful demonstration at an industrial-scale. The definition used matters a great deal. Whether you define clean energy as non-polluting ('Clean'), or low environmental impact ('Green'), or based on carbon emitted ('Low Carbon'), and if you include 'less bad' technologies like 'Clean Coal', changes the R&D budgets radically. For example, the UK claims to have spent £250m over 5 years on nuclear R&D, compared to £50m for Smart Grid budgets. £50m a year for nuclear represents 25% of the UK's clean energy R&D baseline under Mission Innovation.

Confusion over the definitions of clean energy have seeped into the targets and pledges in Mission Innovation; Germany's clean energy definition includes renewable energy, energy efficiency, storage technologies, grid technologies, CCS, fuel cells and other sectors including 'cleaner fossil energy'. But Germany's the 3-year average baseline of €450m is based on research spend on renewable and energy efficiency technologies. For comparison, from data reported to the IEA for 2014 by Germany, €488m was spent on energy efficiency and renewable energy, but this does not include €129m spent on CCS, Hydrogen & Fuel Cells and Power & Storage (inc. Smart Grids), which would all be included in Germany's definition. Greater transparency and baselines set according to shared clean energy definitions and readily-accessible, publicly available data would aid Mission Innovation.

If each country in Mission Innovation defines its own clean energy research agenda, the programme will be less directed. Less coordination will weaken overall progress towards the Paris Agreement goals; and it will mean that R&D will be unable to maximise existing research specialities and comparative advantages, such as trying to understand how the existing strength of wind power sectors (like Denmark and Germany's) could collaborate on major pre-competitive breakthroughs for the next generation of turbines. The Global Apollo Programme called for more directed technical change like this, inspired by the International Technology Roadmap for Semiconductors which mapped out pre-competitive research breakthroughs needed to maintain the pace of technology development. Mission Innovation has published an 'Enabling Framework', but it is non-binding and stresses the 'voluntary, bottom up nature' of programme and the countries' independence to act as they choose, hoping that collaboration will happen more 'organically'[4].

Without a core definition, countries will be able to 'increase' funding by adding new sectors to their definitions. For example, Chile's definition states 'considering that there is no official definition of this concept, clean energy will be understood as all kinds of energy that contribute to reaching this multidimensional development'[2]. They have nominated 6 focus areas, but countries declaring their focus areas now in no way ties them to staying with this list. Without proper scrutiny, countries could simply amend their definitions to increase reported funding without spending more. 'Additionality' has been a concern in UNFCCC climate finance debates, and it threatens to interfere with clean energy R&D too.

How to measure

Mission Innovation allows countries to set their own baselines. There are significant changes from the initial launch of the programme in Paris in December, to the publication of doubling plans and baselines in June. All but two countries are no longer referring to IEA data, when more did in their initial plans. Every other country is using their own data, but it is not guaranteed that it is easily available, if it is made public. Australia and Canada have used the data reported to the IEA, but based on their own definitions, so it is difficult to properly critique their pledges. Choosing their own measurements means that commitments vary significantly. Denmark's target of 'the average funding to the Danish Energy Technology Development and Demonstration Programme (EUDP) of the years 2015-2016'[2] is a fraction of the clean energy R&D spend reported by them in IEA data. We estimate this, based on Denmark's reported 'all except nuclear' definition, to be $161.6m. There are other discrepancies that merit further consideration; the US' baseline is considerably higher $6415m than our IEA data estimate of $3686.61, and higher than the US' initial baseline from December of $5000m.

But both Mission Innovation and Global Apollo do not consider the role of the private R&D in clean energy, which is huge in some sectors. We are able to measure it using transactional data. The private sector's current spending on R&D can be estimated using unique transactional spend data, which triangulates transactional and operational business data to estimate economic values in areas where government statistics are not available, and the average percentage of revenue spent on R&D reported by companies for each sector. For both, the data used was developed by kMatrix from their 'Low Carbon and Environmental Goods & Services' dataset, compiled from thousands of sources, with at least 7 different sources excluding outliers used to calculate each line of data. In this dataset, on average 85 sources are used for each line of data. As many R&D activities are in-house, measuring direct spending on R&D (transactions between firms for R&D contracts, for example) can lead to inaccuracies, as it does not capture in-house R&D activities for which there is no economic 'footprint' that can be measured with transactional data. Transactional data has also been recently used to explore other harder-to-measure sectors, such city-level climate change adaptation spending[5]. Using transactional data for this study allowed a comparison of absolute and relative spending between cities, showing disparities in adaptation responses that may be linked to market-based responses to protecting capital, rather than at-risk populations.

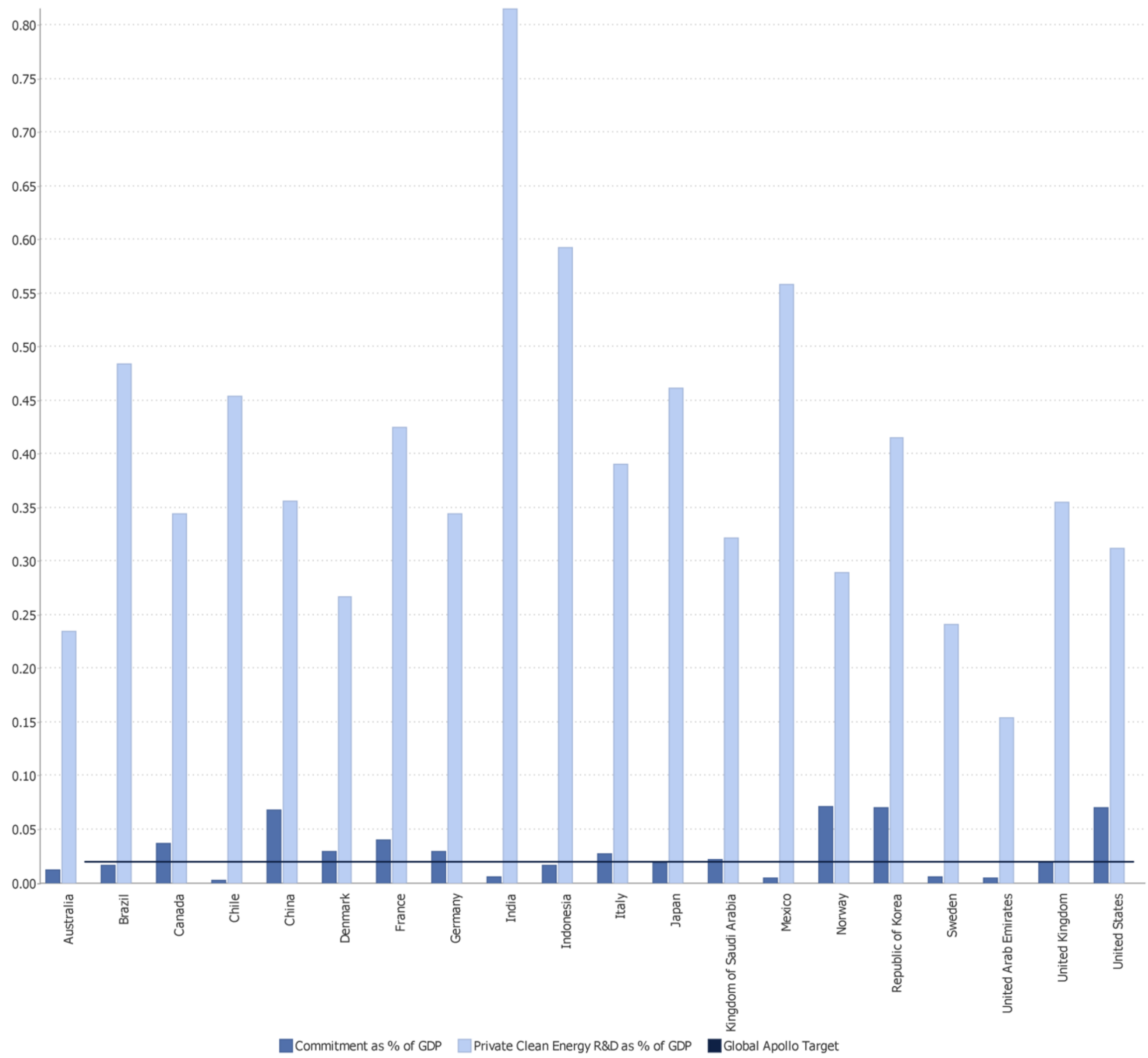

Fig. 1

The scale of private clean energy R&D is very high, given that an estimate from a study for the UK's Department for Business, Innovation and Skills suggested that 70% of all R&D in the UK was privately funded[6]. Studies on the relationship between public and private R&D show that there is no conclusive answer on whether public funding 'crowds out' or encourages private research. However, if private R&D is anywhere near as high as estimated using this method, we would question whether privately-funded R&D is currently being spent efficiently and whether it needs to take a more long-term view and work alongside public research more effectively.

At a sector level, these data show the differences in priorities between public and private funding between technologies already deployed at scale and those that are in the developmental phase. For example, comparing IEA public R&D data and private R&D data from transactional data, for the US the ratio of public:private R&D spend ranges from 1:0.56 for CCS to 1:25 for renewable energy. This suggests that R&D challenges across clean energy sectors are not uniform. Analysing this data could help countries to better direct focus into areas that are currently under-invested in private R&D such as those with low public:private ratios from our comparisons, like CCS or Hydrogen & Fuel Cells, and thus need more public R&D to get to new commercialisable technologies.

Public R&D is not just 'blue sky' research but also can shape markets and drive innovation where the private sector is too risk averse[7]. The 'Breakthrough Coalition', a group of investors who pledged to support technologies arising from Mission Innovation with 'patient capital' (making a long term commitment to important investments, instead of investing in companies for the quickest profit) was launched alongside Mission Innovation[8]. This gives signals to the Breakthrough Coalition about where they need to target their investments to meet their commitment and provide useful, patient capital, not make the quickest IPO exits.

As Prof Mazzucato[7], an economist, put its, there needs to be a symbiotic, not parasitic, relationship between state-funded R&D and the private sector. Not only do we need to leverage public funds to better direct and set priorities in private R&D, also public R&D needs to drive greater collaboration between public, transformative, early stage research and private sector research to marketization. There has to be some overlap and benefit to the State for developing technology ultimately commercialised by the private sector. Similarly, the private sector has to be ready to deliver in these new markets, which also needs the right financial mechanisms. But Mission Innovations baselines and priorities are set by national priorities and business-as-usual, so it threatens to less connected, less collaborative, and deliver less impact to clean energy transitions.

Fair pledges

Mission Innovation has done what the Global Apollo Program has not yet managed to do: get countries to publicly sign up to an R&D pledge for clean energy. But for Mission Innovation to be a success and to make it more than a political statement, more governments must sign up and all countries need to meet their 2020 pledges based on their actual research spend using a fair baseline and sensible, shared definition of clean energy innovation.

Governments need to work out how to direct their funding, both allowing for 'blue sky' research for radical new technologies and targeted research to drive technological change with commercial potential. But first, Mission Innovation needs baseline figures, and more agreement about what clean energy means. Here, it might follow some of the Global Apollo Program's target-setting approaches, combined with the political buy-in and momentum at the highest level that Mission Innovation has achieved.

We urge governments to use studies of transactional data such as ours to examine what private R&D offers to the clean energy equation and the relationship between public and private R&D. Such data could aid governments to direct the additional R&D from their pledges into the areas that are currently underdeveloped. It could aid the commercialisation that the private sector is not, despite its grandstanding, currently achieving.

The complete decarbonisation of the global economy in 40-60 years is a massive undertaking that requires equally massive responses. It could happen: in 1800, the British Navy took up over 25% of per capita government expenditure to establish Britain as the world's major naval power[9]; the US Interstate Highway System cost $560 billion (adjusted to 2007 dollars) and took 37 years to construct[10]. A similarly huge, genuinely global commitment to clean energy R&D is required if global climate change is to be kept to below 2°C.

Lucien Georgeson[1]*, Mark Maslin[1], Martyn Poessinouw[1,2]
[1] Department of Geography, University College London, Pearson Building, Gower Street, London WC1E 6BT, UK
[2] kMatrix Ltd, Greetham House, Greetham, Rutland LE15 7NF, UK

* lucien.georgeson.13@ucl.ac.uk

Figure Captions

Table 1: Public R&D targets under the Global Apollo Programme and Mission Innovation and Private R&D spend for 2014/15 for the 20 Mission Innovation Countries and the European Union. Countries are ranked by their Mission Innovation Commitment as a percentage of GDP. The European Union is not ranked as its commitment, based on the EU budget, is not comparable.

Figure 1: Public and Private R&D as a percentage of GDP in the 20 Mission Innovation Countries. Public R&D is presented as the target for public clean energy R&D made by each country in their Mission Innovation commitment. Private R&D figures are derived from sale figures from the kMatrix Low Carbon & Environmental Goods & Services (LCEGS) dataset, and average reported % of sales used for R&D for each subsector, covering categories that match the Mission Innovation clean energy sectors as closely as possible. LCEGS data covers 2014/15 financial year and was converted to USD at the US Treasury historic rate from the closest date. GDP figures used in calculations are 2015 estimates of GDP at current prices in USD from the International Monetary Fund's April 2016 World Economic Outlook.

References

1 Hare, B. *et al.* Policy Brief: Below 2°C or 1.5°C depends on rapid action from both Annex I and Non-Annex I countries. (Climate Action Tracker, 2014).
2 Mission Innovation. Baseline, Doubling, and Narrative Information Submitted by Mission Innovation Countries and the European Union. (2016).
3 King, D. *et al.* A Global Apollo Programme to Combat Climate Change. (LSE, London, UK, 2015).
4 Mission Innovation. "Enabling Framework" for Mission Innovation. (2016).
5 Georgeson, L., Maslin, M., Poessinouw, M. & Howard, S. Adaptation responses to climate change differ between global megacities. *Nature Climate Change*, doi:10.1038/nclimate2944 (2016).
6 Economic Insight. What is the relationship between public and private investment in science, research and innovation? A report commissioned by the Department for Business Innovation and Skills. (2015).
7 Mazzucato, M. *The Entrepreneurial State*. 2nd edn, (Anthem Press, 2015).
8 Mission Innovation. Joint Launch Statement. (Mission Innovation Countries, Paris, 2015).
9 Sánchez, J. J. Military Expenditure, Spending Capacity and Budget Constraint in Eighteenth-Century Spain and Britain. *Revista de Historia Económica / Journal of Iberian and Latin American Economic History* **27**, 141-174, doi:10.1017/s0212610900000732 (2010).

10 Allen, T. & Arkolakis, C. Trade and the Topography of the Spatial Economy. *The Quarterly Journal of Economics* **129**, 1085-1140, doi:10.1093/qje/qju016 (2014).