Sustainable Energy Transitions

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Introduction

Climate and energy policies are twins. Both should be governed by sustainable development goals and conditions, but seldom are, as the 2014 climate and energy EU policy documents (EC 2014a,b, EC 2015) and practices reveal.
A short text cannot cover all arguments about sustainable energy transitions. Some are stated with few words like the following propositions:
1) The drastic and urgent changes in energy supplies and use request *exploration of non-conventional approaches and solutions*. People and organizations rooted in the fossil fuel era and with major interests in the continuation of present lifestyles, are unlikely to discover or accept the necessary disruptive pathways. Present nature and resource exploitation, investments, technologies, and institutions, need thorough change or reversal. The *proper beacons for action are sustainability references pursued*, to realize and but fully known in the future.
2) First endowed nations must invent and apply renewable energy transitions of the kind developing nations can emulate. The responsibility to lead disqualifies offsets / hot air mechanisms, because the mechanisms indulge endowed nations neglecting their plight.
3) Overarching principles for global climate policy and energy transitions:

- Universality: global issues are assessed and solved from a universal vision
- Sovereignty: sovereign nations request balanced and fair approaches. Well-designed multi-leveled, nested, policy-centric governance structures with the chief executive role at the UN (FCCC, COPs) assign all practical policy tasks to the Parties, their citizens and constituent organizations.
- Diversity: only specific solutions are effective, efficient, and fair. The uniform carbon price syndrome (via emissions trading or a global tax) is illusory and counterproductive.
- Transparency: for real and persistent commitment in common resolve, confirmed by mutual monitoring.
- Realism: deep change asks resources, time and organization; inaction brings catastrophe. Urgent change excludes futile experiments (e.g. EU ETS), and needs the inputs of established institutes and proven expertise.

Urgency to protect the atmosphere and climate commons

Addressing the annual 50Gt ton GHG emissions deserves first priority because climate change causes or aggravates the other daunting global problems (UNDP 2007). Today's tendency is to convert the +2°C limit into a spendable carbon emissions budget, considered and handled as '*rights to emit'*. This practice raises the likelihood of transgressing the +2°C limit to almost certainty. The dangerous practice of spendable rights is rooted in a particular perception of rights, spread without questioning by economists and most media: '*by mitigating emissions, present generations deliver efforts and make expenses for the benefit of future*

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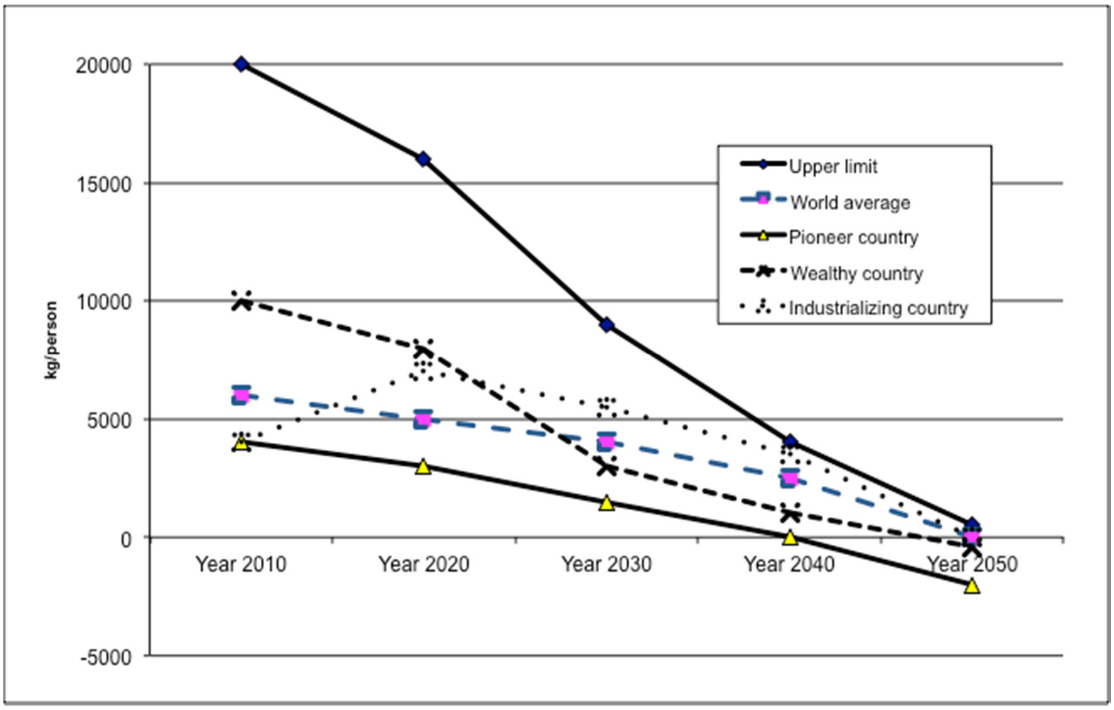
generations'. This means: rights to pollute the atmosphere are assigned to present generations.

The unwarranted rights position conflicts with a civilized status of environmental policy. Emitting CO_2 in the atmosphere is an activity of dumping without any further concern, what equals '*gaseous littering'*. In developed societies litterers face two obligations: immediately stop further littering and be responsible for the mess occasioned. Due to the global atmosphere being a public commons, it is difficult to impose the vision on civilized societies and people.

Figure 1: Individual Parties' Emissions Contraction Scenarios, materializing respect for the maximum +2°C average temperature increase



Let us assume all Parties are serious about the +2°C as dangerous extreme, not to trespass in no way. The first rule of global climate self-governance consists in designing and agreeing on *Individual Parties' Emissions Contraction Scenarios* (IPECS). For this, the focus is on Cpp = the average energy-related CO_2 annual emissions per person in a nation. The Cpp indicator is yearly assessed for all UN members, and ranges now from less than 100 kg to more than 20,000 kg. The choice for Cpp (emissions per person) reflects a search for more equity. Using as indicator 'emissions per $ GDP' (carbon intensity of GDP) obscures high wealth inequalities across countries. Within the nations the spread of citizens' Cpp around the average may be highly skewed, but the issues of national equity are a sovereign responsibility of the Parties. More fine-tuned Cpp indicators taking into account skewed income and emission distributions in the various countries, is now beyond the mandate and the capability of UNFCCC.

Decomposing Cpp in three, still highly aggregated, factors provides insight and opens the entry to more detailed, hands-on information for the Parties. The three indicators can be devolved further to reach detailed groups of actors emitting CO_2 in specific conditions, offering neat hands-on policy targets. The identity's right-hand side is a multiplication of respectively wealth intensity, energy intensity of wealth, and CO_2 intensity of energy use:

$$Cpp = \{GDP/person\}*\{energy/GDP\}*\{CO_2\ emissions/energy\}$$[1]

Figure 1 presents a stylized view of Cpp 'contraction & convergence' scenarios for a few typical Parties, with also an agreed upon upper limit of Cpp, which contracts to a low point in 2050, e.g., a maximum of 500 kg Cpp. Every Party's scenario starts at its recently verified Cpp value. Every Party designs its Cpp path, respecting the constraint of staying below the commonly agreed upper limit. In its 2015 report the *Deep Decarbonization Pathways Project*[2] documents actual Cpp contraction scenarios for sixteen, major CO_2 emitting nations.

Decomposing energy-related CO_2 emissions in constituent factors is a widespread practice. IPCC reports take advantage of this decomposition for explaining the evolution of energy-related CO_2 emissions (e.g. 2014 Assessment report, working group 3, chapter 6). The SE4All initiative of the General Assembly (UN 2011) wants to half the energy intensity (factor 2 of the identity's right hand side) and double the use of renewable energy (factor 3) in developing countries. Therefore, it is amazing that official COP policy-making neglects the opportunities of decomposition for addressing the 'complex' and 'wicked' policy matters. Numerical indicators are every year available for every factor:

1) The *Budget Reform Index (BRI) for wealth intensity (GDP/person)*.
The BRI should irrevocably increase year after year. Budget reform is financially promoting sustainable low-carbon activities and charging non-sustainable activities, leading to restructurion of the GDP. The monetary total of the GDP may increase or decrease by the restructuring. The discretionary power of how to practically organize the restructuring remains fully with the Parties. The BRI only gauges the overall net monetary thrust of policies for the promotion of sustainable low-carbon technologies and practices.

2) Energy intensity (energy/GDP) is a long-time documented indicator (Schipper et al. 1992, 2001; Geller and Attali 2006) and widely used by national and international energy administrations. Energy intensity combines the structure of an economy (how much of which activities take place) with energy efficiency (how much commercial energy is used by one unit of activity). The first factor is affected by budget reform (BRI); the second is mainly technological. Lowering energy intensity is generally high on the list of (proposed) energy and climate policies (IEA, EU, China).

3) Carbon intensity (emitted CO_2 per unit of supplied energy) is the keystone for

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[1] The decomposition can go on by splitting GDP in its major composing activities, by identifying actors related to the various activities, by specifying the types of energy used, etc. At UN level the higher aggregate suffices and further detailing is the task of the Parties to design the policies for controlling the values of the aggregate indicators. Agnolucci et al. (2009), Verbruggen (2011) provide examples and suggestions of deeper decompositions.

[2] An international consortium of research centers investigates 'deep decarbonization pathways' for a set of countries, together emitting three quarters of the global energy-related CO_2 tonnage (http://deepdecarbonization.org).

controlling CO_2 emissions. Transitions to zero or almost zero carbon emitting energy uses by 2050 is the mission for all nations in the coming decades. Their transitions will be specific, due to differentiated endowment in resources, applied technologies, installed infrastructures, etc. However, all energy transitions are constrained by a small set of energy supply options [*Figure 2*].

The approach respects '*common but differentiated responsibilities and respective capabilities*' in emission reductions. '*Common responsibility*' is: all countries' Cpp stays below the upper limit scenario. '*Differentiated*' means: high value Cpp countries must contract first and at a fast rate ('deep cuts'); low value Cpp countries (mostly developing and least developed countries) can grow in Cpp value with the obligation to respect the contracting upper limit values in future years.

Spearhead climate policy: eliminate energy-related CO_2 emissions

Since the UN Framework Convention (1992), over the Kyoto Protocol (1997) and the Copenhagen Accord (2009), yearly global GHG emissions continued to grow, as did the yearly use of commercial energy (IEA's yearly Outlook). About 4/5th of GHG emissions are due to present energy supply and use practices. Presumably more than 4/5th of the climate policy studies focus on energy-related CO_2 emissions and their mitigation. Climate policy involves more (e.g., other GHG than fossil fuel related CO_2, land-use, adaptation), also influenced by fossil fuels use (for example methane emissions, changing land-uses affected by low-priced supplies of fossil fuels).

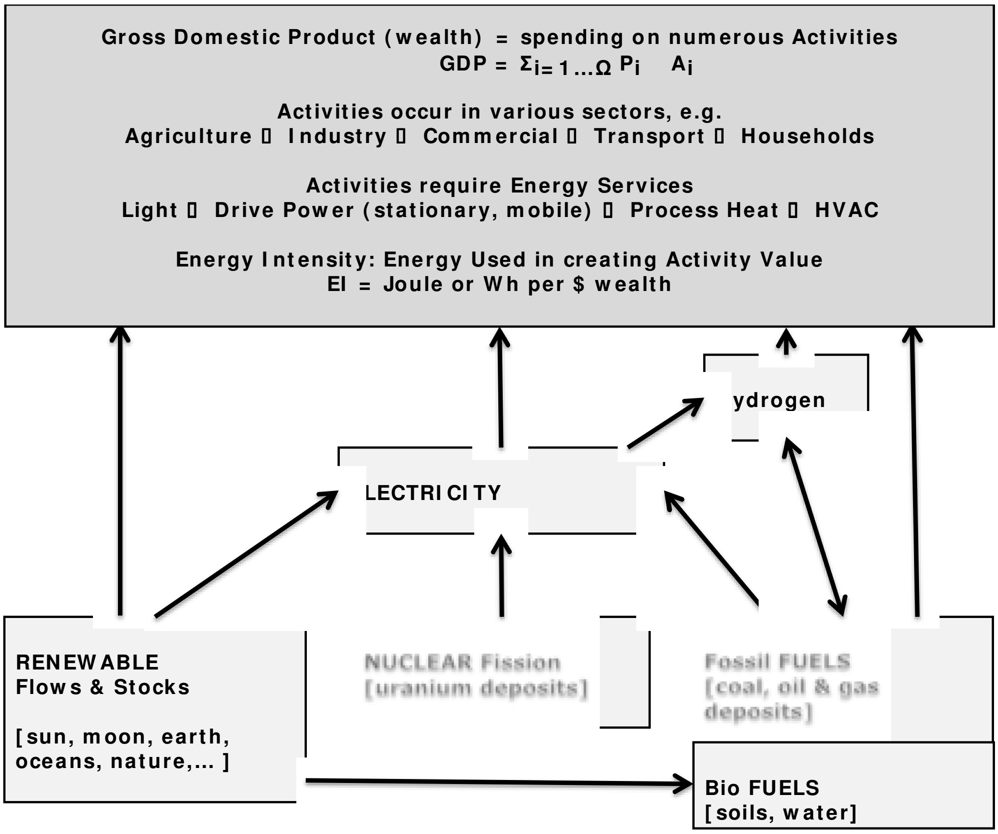
Ongoing climate policy is little effective, partly because many goals on several aspects are prioritized. Contrary to the widespread opinion that UNFCCC must mainstream and simultaneously solve many major problems in the world, rational climate policy detects spearhead issues functioning as locomotive in accelerating mitigation or adaptation. Strategic advance needs spearheading with a selected issue that will break the locks on needed technological, industrial and societal transitions. Thorough transformation of energy supply and use is widely recognized as the predominant change to perform (IPCC, 2012).

Energy supply options

For performing activities, people want energy of the right type and quantity, supplied at the right place and time. Energy supplies combine energy *sources* with *technologies* for winning, converting and transmitting energy. In sequence of importance, available sources are: renewable flows and stocks in the natural environment, fossil fuel deposits in mines and wells, and uranium deposits (figure 2). The environment supplies for free most energy, useful with little technology, e.g., daylight, heat, ventilation, drying. Natural processes concentrate diffuse renewable flows (photosynthesis, the water cycle). Over the last decade, the costs of man-made technologies harvesting renewable flows dropped significantly (IPCC 2012). Technological capability announces further cost cuts, for example levelized kWh prices of PV to €ct.4 to 6 by 2025 and €ct.2 to 4 by 2050, although dependent on financial and regulatory conditions (Fraunhofer 2015).

Nuclear fuel is fabricated from refined and enriched uranium, whose dense deposits are limited (American Nuclear Society 2001). Uranium shortage may be overcome by breakthroughs in breeder or fusion technology. Commercial new breeder and fusion plants are not expected before 2050, the year wherein carbon free electricity systems should be operational. Nuclear is no sustainable option (Verbruggen et al. 2014).

Figure 2: Overview of energy supply categories, with sources in [.]



Fossil fuels cover a market share of above 85% of commercially traded energy supplies (BP 2015). Their success is the result of being versatile, dense, for all scales divisible, abundant, storable, and performing on command. However, fossil fuel combustions cause various environmental harms, and inevitably fetch CO_2. In a low carbon future their use will be stifled (IEA 2014), but 'carbon lock-in' and related interests are exceptionally strong. A smooth phasing-out of fossil fuels is rather unlikely to happen. Hydrogen is a carbon free fuel, not naturally available on earth, difficult to manage safely. New industrial infrastructure may fabricate hydrogen from low carbon electricity. This is a costly, long-range undertaking.

Energy transitions of a different kind

The mitigation spearhead is the elimination of energy-related CO_2 emissions (ca. 4/5th of GHG emissions) by richer countries, which should develop and deploy renewable energy supplies of the kind and size also applicable and affordable by developing countries. Suitability of pathways for emulation by developing countries is highly relevant for global CO_2 emissions reductions in the coming decades. The attribute of readiness for emulation is essential, because it will bar the way for transitions to low-carbon energy systems mainly composed of non-sustainable nuclear power and centralized large-scale renewable plants. However, in 2014 the EU promoted the non-sustainable centralized low-carbon pathways while blocking the successful innovation financing of the German Energiewende (EC 2014b, Verbruggen et al. 2015).

The EU is a showcase of different 'low-carbon energy' systems. Every EU Member State plans its own energy future, leading to widely divergent pathways, most apparent in electricity supplies.

Germany embarked for a drastic reversal, aiming at an entire power supply from PV, wind and biogas (Agora, 2013). In the high diversity of projects a significant role is plaid by small-scale installations of end-users producing electricity. Five salient characteristics of the German approach are:

1) The transition is interwoven with a nuclear phase-out, politically decided after advice by a representatively composed ethics council (Töpfer et al. 2011). Public initiatives, politicians, academics, innovative industries, and local energy companies are motivated for change.
2) Technological innovation is crucial in increasing efficiency and decreasing costs of RE collection and conversion equipment. PV and wind turbines continue to show fast decreasing costs per kWh generated.
3) National tariffs per RE category pay specific levelized cost prices for a period of mostly 20 years. With technological progress, tariffs by category decrease to the level sufficient for proofing and launching the transition. After some years RE supply prices cut the line of grid parity, phasing in the full transition.
4) Superior RE technology can competitively harvest mediocre (low capacity factor) RE sources. Decreasing PV and wind technology costs (Fraunhofer 2015) make redundancy in electricity capacities affordable. Redundancy in generation capacities is a luxury but also challenging for power systems' technical integrity. Then, regulatory solutions are decisive, showing the influential role of independent public regulators, not captured by major corporates.
5) Every country may emulate the RE pathway. Some countries and regions with excellent RE sources (for example Africa) are now missing affordable harvesting technology. Cheap distributed RE technologies are a crucial factor of energy supply in developing countries, and hence for prosperity and sustainable development.

The UK HM's Government (2009) plans for new pressurized water reactors (PWR), carbon capture and storage (CCS), and large-scale RE projects (off-shore wind; tidal; biomass as substitute for coal). In contrast to Germany's original model of Energiewende, the UK approach is characterized by:

1) Large-scale projects fit to the business model of major incumbent energy (power) companies, and override local initiatives.
2) Innovation is difficult. PWR standard costs increase; waste and risks stay. CCS faces high costs and delays in starting a demo project. Biomass combustion is old technology. Large-scale tidal projects are not welcome.
3) Price guarantee at £92.50 (about €127.50) per MWh during 35 years for technological mature PWR reactors, mainly paid by household electricity customers. The money is supporting an economic activity without innovation perspective.
4) Power supply systems are planned as predominantly composed of capacities on command. Also from RE projects high capacity factors are requested.

5) Emulation of the pathway by developing countries is unlikely, if not impossible.

The sustainable renewable energy alternative as such is not costly when fully deployed. Evidently, the sustainable energy transition itself is challenging. Depending on the scores by progressive, viz. reactive strategies, forces, and public support, the transition difficulties and costs will be modest or high. For overcoming lock-in, urgent transitions bring earlier depreciation of sunk investments. The latter are more significant when incumbent energy companies reacted little or very late on the 1992 Rio summit and ensuing conventions. For example after 2000, incumbent electricity companies have still built coal power plants in the Netherlands and in Germany (two countries of high exposure in energy transition literature and practice). This happened under the cover of the low CO_2 emission permit prices of the EU ETS.
Transition costs are spent for the first time development and deployment of new technologies, infrastructures and institutions. The transition will be smoother and cheaper when a clear mission is defined (Verbruggen et al. 2015). One fundamental change in the logic is adopting the future sustainable goal situation as reference to measure and evaluate present states and evolutions. In the transition of the electricity sectors, the incumbent reactive viewpoint is: '*intermittent and stochastic renewable energy supplies disturb the reliable delivery of power; power on command is the reference'*. This must be replaced by: '*intermittent and stochastic renewable energy deliver the most sustainable supplies, and merit priority over the non-sustainable supplies; given this priority, the reliability of power is organized'*.

Conclusion

'Energy transition' is a term covering a spectrum of realities, from thorough and sustainable to superficial, deferring and non-sustainable lock-in. One slips in the latter without a clear definition, vision, mission and strategy of sustainable and thorough change. The incurred delays by the slips make the thorough path steeper, and the irreversibility of climate change more probable.
Fully sustainable renewable energy systems are not just technologically and economically feasible, but they are the cheapest and only sustainable option for the peoples of the world. Like every successful transition, sustainable energy transitions need profound change in the minds, thinking, beliefs, preferences, … to adopt the novel paradigm, perspectives, technologies, practices. In society wide transitions, the public interest should prevail over private interests. In the energy supply sector, incumbent private interests are incredibly mighty and influential. Since a few years, the vocabulary of sustainability, climate change, energy transition, is twisted to push the superficial version of a low-carbon energy future. It seems majorities in the wealthy nations prefer to fool themselves for another couple of years or decades.

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