STAGING PATHWAYS TOWARDS ECOMODERNITY[1]

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Introduction

We live in an age that harvests the fruits of modernity. Cultural values that in Europe were released in the 'Enlightenment' era have emancipated us from dogma, promoted individual freedom, and unleashed entreprenurship in science and technology. On this basis the world has developed productivity on a scale never seen before, fostering a material basis for human welfare that has allow the human species to more than quadruple since 1900.

As several scholars, including S.N. Eisenstadt (1992, 2003) and Talcott Parsons (1971), Alberto Marinelli (2005) have pointed out, modernity is closely connected with the processes of economic development, with permanent innovation, and with the unprecedented growth of technology and economic expansion under the emergence of industrial society. Anthony Giddens has argued that this makes modernity vastly more dynamic than any previous type of social order (Giddens 1998, 94). He attributes this to the complex of economic institutions, especially industrial production and a market economy together with political institutions and mass democracy.

Yet modernity in the 21st century has reached a scale and scope that challenges its very foundations, particularly as modern industrial society is still largely carbon based. In what has been called the 'age of the Anthropocene', the footprint of modern human societies on the planet has exacerbated ecological crisis thus bringing modernity into a confrontation with itself.

Paradoxically it is precisely the dynamism that Giddens points to, that has led modern development to transcend its ecological limits. As, Peter Berger (1977) has shown - combining insights from Karl Marx and Niclas Luhman - the dynamic market-economy, once set free, develops into an autopoietic system which may subordinate both society and the environment to economic exploitation. Modernity's hyper dynamism is therefore also its weakness.

One of the contentions of this paper is that modernity is now in need of a serious revision. Indeed there are many indications that modernity is moving to its next phase: *ecomodernity.* Ecomodernity seeks to rebalance modernity's relation to its natural environment and social context, and to set continued modernization on a more sustainable course. At a stage when the massive expansion creates problematic side effects, industrial creativity needs to be redirected, and the ecological and social limitations need themselves to be brought into the commercial equation. Terms such as the circular economy, resource efficiency and pro-sociality indicate a reorientation of the commercial process to ecological and social considerations, and to aim at advanced industrialization to serve not only human welfare, but also well-being.

[1] Based on Midttun and Witoszek (2016) Energy and Transport in Green Transition. Perspectives on Ecomodernity. Routledge, Oxon and New York.

However, ecomodernity does not only imply adjustment at the level of technology, but also entails a deeper change of mindset and overarching world view. Inspiration for this change may, interestingly come from early roots of modernity itself. The Renaissance and early Enlightenment humanists developed thinking that inspired sceptical scientific examination replacing blind traditionalism and theocratic dogma. This type of thinking is equally valid for a pivotal revision of modernity. As Stephen Toulmin (1990) has famously argued in his "Cosmopolis" the limited mechanistic atomism that characterized modernity at its technocratic heyday, moved away from the broader holistic outlook inherent in the Renaissance: humanist foundations of modernity.

Facilitated by modern systems thinking, ecomodernity reconnects with modernity's early scientific and critical roots in seeking solutions to modernity's technocratic exploitative excesses. This involves addressing the socialist critique of commercial exploitation of workers to establish pro-sociality in a hyper-competitive world. Similarly, ecomodernity highlights the consequences of commercial over-exploitation of our natural habitat, and lays a basis for ecological correctives.

As opposed to Romanticism, which was a critique of the Enlightenment's reason, ecomodernity resorts to reason and science to scrutinize its own excesses. Big data, system anslysis and simulation models allows us to better understand the complex interplay between markets, technology, ecology and social behavior.

This paper explores the transition to ecomodernity with a particular focus on climate change. It does so by highlighting new ways of reconciling modernity with ecological concerns. Taking, not a revolutionary, but what can be called a *refolutonary* approach, where triggering reform processes may over time evolve into major systemic change – this paper discusses important mechanisms of ecomodern transition:

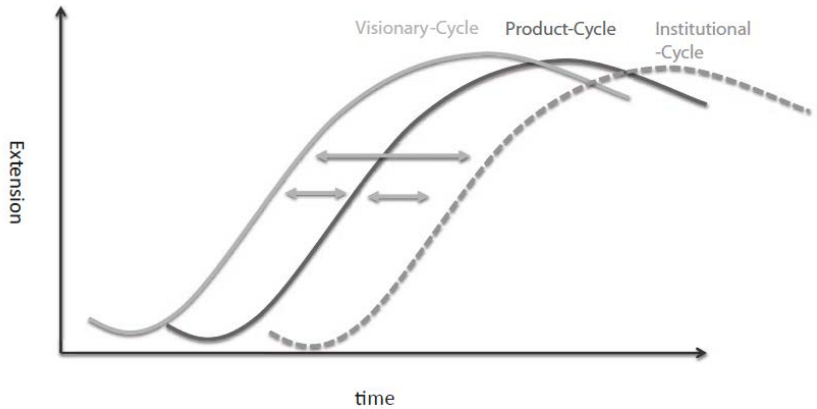
- It highlights the need to introduce a cultural/visionary perspective into our thinking around techno-economic evolution. Transformation of our cognitive outlook thereby becomes an integral part of the innovation process.
- The paper recognizes that ecomodern transition may be controversial and may entail a "battle of modernities" that compete for hegemony. It therefore includes the challenges to forging change, not only at the product, but also at the industry and societal levels.
- The paper argues that the complicated and controversial nature of transition entails a need for staging complex pathways across commercial, political and technological realms. It therefore explores transition to ecomodernity from a strategic game perspective.
- The paper shows how green pathways may evolve across the globe. It therefore analyses innovation journeys where technology migrates from market to market, thriving on global variation.
- The paper ends by illustrating how radical change towards ecomodernity may take place by triggering exponential green growth. It therefore contends that ecologically unsustainable conventional growth can be countered by creative staging of green growth.

Triple Cycle of Innovation

While technology and business are obviously critical to emerging ecomodernity, we argue the parallel evolution of visions and institutions is also essential to understanding the complementary societal change. In our application to the broad green transition we therefor argue that the process towards ecomodernity may be fruitfully analyzed as an interplay between three cycles: a generic product cycle, where new green innovations that launch technological revolutions create new industrial actors and commercial dynamics; a visionary cycle, where a new societal vision develops and matures; and an institutional cycle, which codifies and formalizes supportive organizational frameworks. The paper thus expands the concept of the *product cycle* from innovation studies, which highlights the process from emergent new prototypes towards novel mature products, to also include visions and institutions.

Green transition, as this perspective suggests, plays out through the dynamic interface between the three cycles. As visions consolidate, they motivate public interventions and stimulate new components of the green product cycle. If successful, these new components feedback to—and strengthen—the original vision and gradually institutionalize it. Transition to ecomodernity may thus be driven by a mutual interplay between technology, visionary policy, and green institutionalization, where the three cycles may reinforce one another and together drive green transition in a manner that would not have been possible with only one alone (Figure 1). Firstly, visionary public engagement based on stories, images and role models may trigger policy support for dynamic technology development and commercial entrepreneurship. In turn, successful commercial entrepreneurship confirms the validity and attractiveness of the original vision and mobilizes further visionary development, which is gradually consolidated by supportive institutional structures.

Figure 1: The Visionary, Product and Institutional Cycles



As in the case of early emergent product innovation, visionary and conceptual innovation towards ecomodernity began from inspiring but often unrealistic initiatives. The pioneering "prototypes" have ranged from "small is beautiful," deep and shallow ecology, sustainability, corporate social responsibility, "green-dark religion," and ecological villages and cities, to massive public mobilizations for the Earth manifest in the success of the social mobilization platforms such as 350.org and Avaaz.

These visions were initially dismissed as mere chimeras by the apostles of the carbon industry. And yet there are reasons to believe that they were crucial to the emergence of the agenda of

ecomodernity based on incremental green innovation. As scenarios of ecomodernity mature, and interface more closely with mainstream politics and business, there are signs that the balance is changing towards realism, but also towards deeper penetration.

There have been rich and manifold visions of ecological correctives to industrial modernity. They grew out of movements such as the Sierra Club in the USA that mobilized one of USA's major grass root societies. The club focused strongly on protecting wilderness, but eventually moved into clean air clean water and endangered species. More recently, the Club has engaged against fossil fuels that cause climate disruption and toward a clean energy economy. In Britain, the Coal Smoke Abatement Society - formed in 1898 and one of the oldest environmental NGOs was instrumental in promoting clean air legislation, notably after the Great London Smog of 1952, when several thousands died. The society gradually moved on to campaign against emissions beyond air quality and took on a broader environmental agenda, rebranded as the Environmental Protection UK. Together with numerous other similar initiatives, visions of alternative, ecological paths for modern development have evolved and matured.

In line with business and the economy in general, environmental NGOs have also scaled up to embrace the global arena. Organisations like Greenpeace and Friends of the Earth are cases in point. Through non-violent direct action and outspoken initiatives, they have captured the public imagination, and have triggered debate around major parts of industrial modernity.

The visionary contributions to redirecting modernity in an ecological direction have also come from leading intellectuals like Schumacher, Amory Lovins and Dennis Meadows. Lovins has systematically promoted energy efficiency, the use of renewable energy sources, and has advocated a "negawatt revolution" arguing that utility customers don't want kilowatt-hours of electricity, they want energy services. Meadows has raised public attention to the need for modern industrial development to come to terms with its limitless resource use and pollution (Meadows et al 1972). Numerous thinkers have followed in their footsteps and helped generate the intellectual underpinnings of an alternative vision of modernity.

Green visions have gradually diffused into most political parties, but in particular through green parties that have specialized in ecomodern transformation. One of the most successful in Europe, have been the German BUND. The party is committed to a broad ecomodern agenda, including issues such as fostering the use of renewable energies, banning the production of genetically modified food and fodder, and reducing the amount of toxic chemicals in everyday life.

The growing strength of the ecological re-framing of modernity is demonstrated through its gradual accomodation by governments and international organizations. For instance, the International Energy Agency's (IEA) global development scenarios have broken down barriers by challenging several dogmas in the carbon-dominated energy supply: 1) that renewable energies (except large hydropower) were not scalable and able to play a significant role in the energy supply; 2) that intermittent renewable energy could not provide a modern stable energy supply; and 3) that renewable energy could not deliver energy at cost-effective prices. Another visionary contribution to green innovation has been the EU and Green Peace joint report, "Energy Revolution: A Sustainable World Energy Outlook" (2007). The report insisted that all that was missing from the feasible cuts of CO2 emissions was the right policy support: a point which started a policy mobilization across continents. Still another contribution to he visionary cycle came with the Vision 2050 report published by The World Business Council for Sustainable Development in February 2010. Its novelty lay in defying the perception of the green transition as a cost-incurring exercise and identifying

unprecedented opportunities for business in the green economy. A multitude of commitments to green transition by governments, unions and regions have followed, including the EU's "Energy Roadmap 2050" (2011), indicating that the visionary cycle is reaching a maturing stage, where green transition is penetrating mainstream thinking. These programs and agendas – and their steady impact both on the perceptions of the green transition and on techno-economic practice – show that ecomodernity has made some progress within existing commercial and political structures.

The visionary roadmaps for green transition have been strengthened by an explicit tie and trend toward green growth. This trend has emerged through a series of international programs and agreements that are gradually redefining the global outlook on ecology and economy. Witness the pioneering United Nations Environment Program (UNEP), launched in 1972 and followed by the Green Economy Initiative, or the United Nations Economic and Social Commission for Asia and the Pacific, which released the Low Carbon Green Growth Roadmap for Asia and the Pacific (UNESCAP 2012).

Moving from the visionary towards the institutional cycle highlights how green reorientation of modernity has fostered the buildup of new organisation and numerous regulatory initiatives. To take the European Union as an example, its environmental reorientation has been institutionalized through a series of so-called Environmental Action Programmes. They have evolved over almost half a century, from controlling a broad range of pollution problems in the early 1970s and 1980s through new complex and holistic framework legislation, such as the Ambient Air Quality Directive and the Water Framework Directive in the 1990s. The current 7th environmental action programme enhances broad and inclusive ecomodernity by protecting, conserving and enhancing the Union's natural capital; by turning the Union into a "resource-efficient, green, and competitive low-carbon economy"; and safeguarding the Union's citizens from environment-related pressures and risks to health and wellbeing. In addition the programme signaled a special focus on greening of cities and on international environmental and climate challenges.

The Environmental Action Programmes have been followed up by a multitude of specific measures that serve to take the vision down to tangible action such as: the EU targets for 20% reduction of greenhouse gasses, 20% increase in energy efficiency and 20% increase In share of renewables, all by 2020. Thereto come specific targets negotiated with individual member countries, and the EU Emission trading scheme, which was launched as a major tool for CO2 reduction. In addition come feed in tariffs, certificate markets that have been developed by individual countries. In the building sector, the EU has set a goal of nearly zero energy use in new buildings by 2019. In transport the measures include energy efficiency targets for ships, emission limits for cars, as well as demands for halving of conventionally fueled vehicles in cities by 2030 and full phaseout by 2050.

The EU has imposed demands on all sectors of the economy to benchmark lifecycle resource efficiency. Furthermore, the Union has taken measures to eliminate waste landfill by 2020, measures for vast recirculation, specific measures for improvement of water quality, as well as bathing water. Measures are also taken to improve management over and avoid overexploitation of natural resources.

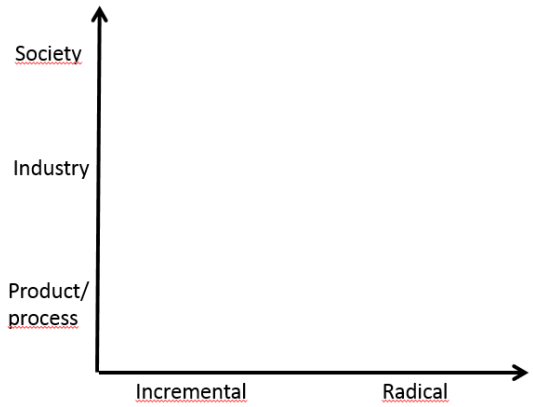
Finally, with regard to the product cycle, the reorientation of policy, institutions and regulation from narrow industrial towards broader ecomodernity has stimulated technological innovation on a broad front. This includes a whole host of renewable energy technologies, as well as efficiency improvement in conventional energy generation, it includes transition to new engines and drive

trains in the transport sector, alongside efficiency improvements in the conventional combustion engine. Across many other sectors of the economy, environmental concerns and regulatory requirements and incentives have triggered rethinking of products, processes and business organisation. One example is the development of building standards in construction industry, where the sector is rapidly moving towards passive house- and zero emission buildings.

Battle of Modernities

Implicit in the understanding of ecomodern transition as a broad, transformative process lies the recognition that we may see not only changes in products and technologies, but also in business models leading to a radical remaking of industries and indeed also of societies (figure 2). At the product and process level, business may engage in innovation by refining, reconfiguring, or inventing green products and processes, while at the same time maintaining stability within business and industry. At the business level, innovation becomes more comprehensive and involves re-engineering of business processes or combining new business concepts. At the industry level, radical innovation forges new industry structures. Such structural change obviously also has wider social and cultural implications, and as previously argued social and cultural visions may in fact trigger industrial and technological change.

Figure 2 Levels and Radicality of Innovation



Transition towards ecomodernity therefore easily entails rivalry with other alternatives. We have called this rivalry the "battle of modernities," where technologies, business models, interests and visions compete for hegemony. Taking energy as an example: What we have defined as "carbon modernity" grew during the late 1800s and through much of the 1900s as a dominant economic mode which allowed modern industrial society to produce goods for mass consumption. In the next phase, nuclear electrical modernity was launched as a civilian application of nuclear technology, which had been developed for military weaponry during World War II. This peaceful application was designed to transcend the limitations of carbon-based energy and give the world oxygen back through the abundance of clean energy. Today's emerging "ecomodernity" is a new wave that stems from the critique of carbon and nuclear excesses and, while encompassing also shifts in culture and politics, is focused on an alternative, post-carbon and post-nuclear economy based on renewables.

In energy, ecomodernity comes in two stages: the first is supply-driven, and depends on solar, wind and hydroelectric energy and adequate management of these resources. But there is a looming second, demand-driven, phase of ecomodernity which is less dependent on outside supply and uses

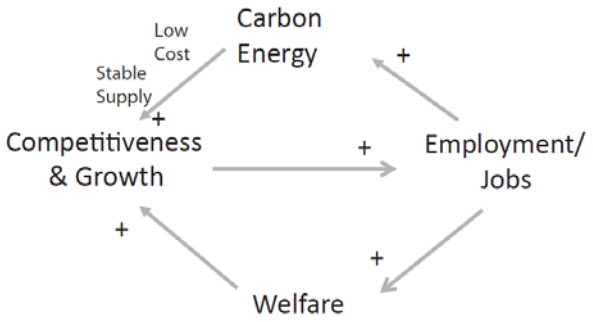
resources located close to the consumer. Concepts such as “energy-plus” houses and “smart grids” and prosumership, present alternatives to carbon, nuclear and renewable-based technologies supplied via the central grid.

In the beginning of the twenty-first century these various modernities competed to reinvent themselves to answer today’s energy and climate challenge. The carbon and nuclear modernities imply a continuation of the scale and scope of existing centralized systems, though with improved climate-performance. Supply-driven ecomodernity adds new resource bases with extensive relocation of electricity generation and raises new demands for balancing intermittent solar and wind supply. Finally, demand-driven ecomodernity moves the focus out of the energy system and implies a radical involvement on the consumer side, with energy efficiency and self-supply becoming dominant concerns.

Ecomodern transition therefore, easily end up as disruptive (Christensen 1997) when seen from the incumbent industry’s perspective. Both wind power and photovoltaics are now taking over substantive market shares from the mainstream carbon-based energy supply. From simple applications at the bottom of a market, they have moved up-market, to some extent displacing established competitors, thereby disrupting existing structures and markets. In combination with information technology that has opened up avenues for new sharing economy and customer-centric green energy ‘prosumership’ they now challenge conventional centralized electricity industry.

In line with our triple cycle perspective, the battle of modernities – exemplified in energy above - is not only a battle of technologies, but also a battle of visions and definitions. The proponents of carbon modernity have traditionally held hegemony in the field by coupling energy, growth and employment. The cognitive formula that buttressed their position has been: a carbon-based energy supply delivers cheap power, which in turn delivers industrial competitiveness and growth, and hence generates employment (Figure 3).

Figure 3: Cognitive Assumptions of Carbon Modernity

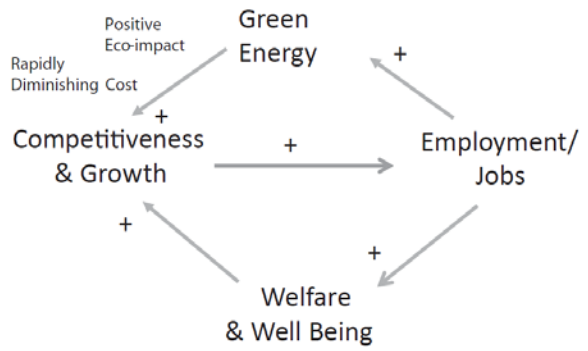


When seen from this perspective, ecomodernity in its initial stage represented the unappetizing alternative: high costs of green technologies and increased energy costs associated with alleged weaker competitiveness, less growth and unemployment.

However, carbon modernity’s cognitive hegemony is breaking up and the pivotal link between renewable energy, growth and employment and is increasingly becoming recognized. Most importantly, from the wider economodernity perspective, the link between green growth and jobs

goes beyond economic welfare; its benefits include an increase in human well-being and quality of life (Figure 4).

Figure 4: Cognitive Assumptions of Ecomodernity



The shifting relationship between growth and jobs from carbon to ecomodernity is eminently illustrated in California: In 2012, broad popular mobilization called the "California New Environmental Movement" defeated oil company-financed initiatives aimed at overturning the state's global warming legislation, recognized as the toughest in the nation. The initiative, sponsored by Texas-based oil companies Tesoro and Valero Energy Resources, funded a campaign under the catchphrase, "California Jobs Initiative," which claimed that too many incentives for clean energy and energy efficiency had destroyed California's economy and cost thousands of jobs. According to the companies' Proposition 23, California's pro-climate legislation was to be suspended unless the state's official unemployment rate fell to 5.5 percent or less for four quarters in a row. Clearly, while the stated goal was to protect jobs and the economy, the de facto objective was to repeal existing environmental legislation. As a response, Californians organized a massive "No to proposition 23" campaign which led to the defeat of the oil companies' "jobs initiative." The result of this campaign was the creation of a network of "Communities United against the Dirty Energy Proposition." which has morphed into "Communities United for Clean Energy and Jobs." The latter has organized to promote green innovation and jobs in California and around the nation.

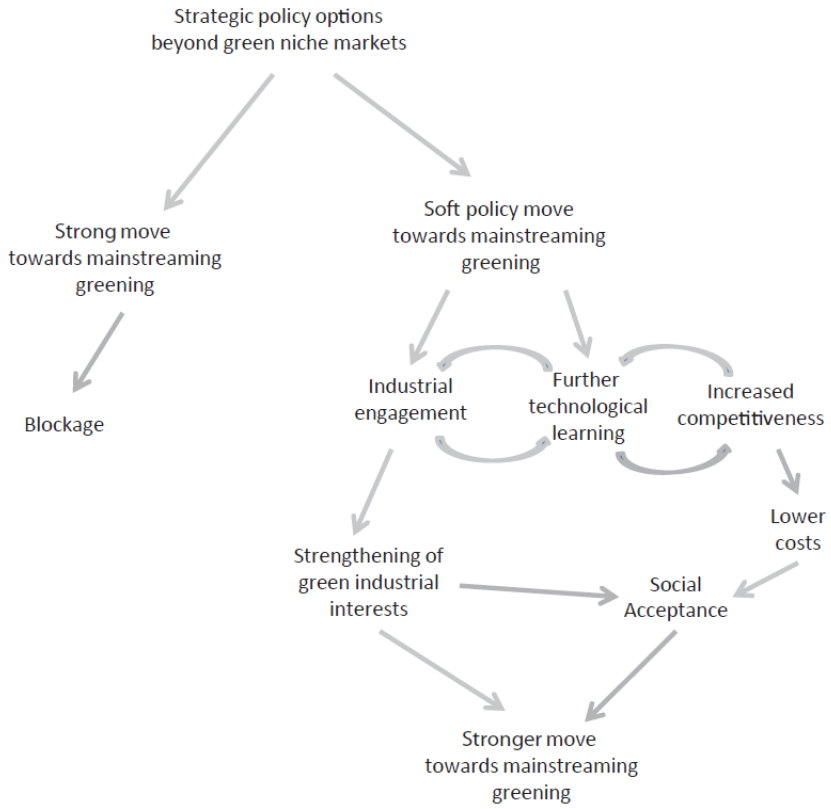
Staging Complex Pathways

Given the complex interplay between technology, commerce and culture, as well as the 'battle of modernities', transition to ecomodernity becomes a complex journey – to paraphrase a widely known US innovation study ((Van de Ven et al. 2008). As carbon, nuclear and ecological strains collide and struggle for hegemony, there are surprising turns, discontinuities, shifts and quantum leaps: a process reminiscent of "punctuated equilibrium" in evolutionary biology, where development is marked by raptures, retardations and sudden advances.

Our suggestion is that the transition towards ecomodern sustainability resembles, in many ways, a relay race, where various factors can drive innovation at different stages (see Figure 5). At one point, change may be driven by politics or governance, while at another point the baton is taken by markets and technology. At still a later stage, civic and cultural mobilization become the main advancing agents. Causality may therefore change as in a relay run, across governance, product and cultural

cycles. In addition, chance events may transform the contest. While strong policies may easily lead to a backlash, softer and less confrontational policies with triggering effects in other institutional domains may have a better chance of success. The sequential triggering may build momentum behind green policies and stimulate a stronger, de facto green effect. In this way, transitions that at first would appear impossible because of the massive counter-forces, may become possible as sequential triggering gradually builds up momentum.

Figure 5: The Relay Model in Open Game Form



Innovation Pathways in a Heterogeneous World

In addition to building momentum through relay processes, green transition may also rely on niches where green initiatives can find favorable conditions at a given stage of their development[2]. Global diversity in industrial institutional and cultural conditions, may hence be essential to ecomodern development. The story of PVs is a case-in-point – indicating how the interplay between diverse regions may create opportunities for technology development that no single region alone could accomplish.

In a recent study (Midttun and Toporowska 2014) we have followed PVs from its early stages in the US space industry, through later phases in Japan and Germany, and finally its mass production in China, from where PV is now spreading on a purely commercial basis (figure 6). We found that

[2] There is, in other words, likely a parallel to the 'niche' concept in biology, where some species find locations with natural characteristics, that they then adapt to and survive under

regional specialization across the world – with diverse cultural, political, financial, entrepreneurial and technological competencies – has provided unique lead-market conditions that at the right moment were crucial to drive the technology down the learning curve. The shift from one lead market to another has typically come as the first market failed. Let us briefly recapitulate the stadia of this journey.

Figure 6: The Innovation Journey of Photovoltaics

US Initiates PV

The early start of PV in the US space program in the late 1960s marked an important move into operative industrial use. By coupling PVs to the space-industrial complex, the US provided a pioneering niche market for early technology development as well as an advanced arena for technological research. Yet the US did not have institutional preconditions, or the political will to take PVs towards deployment in mainstream competitive energy markets. The result was that the US lost out as a lead market for PVs. While the application in the space industry was highly successful, it did not manage to penetrate into larger-volume markets. The technology therefore remained a niche product with a strong research base, but with very limited application in the US.

Follow-up in Japan

Pressure from resource scarcity combined with high technology competence and strong political commitment turned Japan into the second lead market for PVs. Japan took the leading role in PV development in the 1980s with the "Sunshine Project" – a national research and development (R&D) project aimed at developing new energy sources. Japanese PV development stagnated in the mid-1980s due to poor incentives for market deployment.

Germany Takes Over

As the red-green German political coalition in 1998 set ambitious targets for green energy and staged a combination of technology-adjusted tariffs combined with unconditional rights to feed PV energy into the electricity grid proved a forceful tool for boosting PV expansion. With the German Energiewende, PVs were given a formidable boost in a critical phase of development. In less than a decade, Germany drove volumes of PV energy up to unprecedented levels, and in 2004 surpassed Japan. From that point, PV gained status as a significant contributor to the energy market.

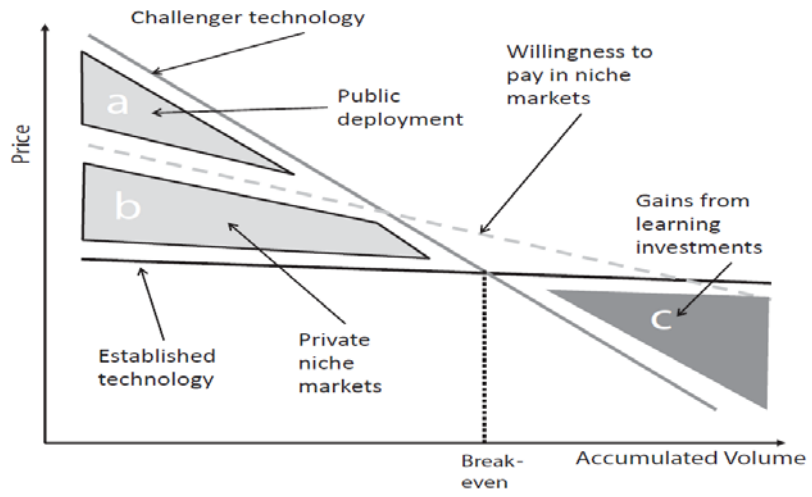
Chinese Market Leadership

Chinese market domination emerged as a result of a two-step process. In the first round, China geared up its industry for PV export to lucrative Western markets. In the next round – as Western markets collapsed in the wake of the financial crisis – China boosted its home market and soon overtook Germany as the market leader. The technology learning undertaken in mature Western markets thus allowed cost-efficient production at rates that were attractive to a catch-up economy.

The Learning Curve Perspective

This PV- innovation journey makes good sense in a learning curve perspective, which brings techno-economic improvement centrally into the analysis: The thesis is that deployment brings increased efficiency and decreased costs and that technological learning is particularly strong in early phases of technological development. The sequence of niche markets, visionary policy initiatives, and institutionalised support systems may trigger a technological learning process that eventually results in competitiveness in regular markets. Figure 7, illustrates how visionary policy interventions through public deployment may be crucial in triggering industrial learning before private investors are ready to engage – polygon a. That said, when early publicly stimulated deployment has created sufficient industrial learning, private investments may be attracted to niche markets that are willing to pay for the next deployment round—polygon b. At the final stage—if successful—the new technology has the potential to dominate the slower, developing incumbent technologies and establish itself profitably at the heart of mainstream economy– polygon c .

Figure 7: Essentials of Experience Curve and Technology Deployment



Source: Adopted from Wene/ IEA-OECD (2000)

Back to the PV example, the global innovation journey has taken PVs down the learning curve from over USD 500/watt in the 1960s to less than EUR 1/watt in 2013, with the prospect of a further price-decrease (Figure 8). Each lead market has taken its share of development costs, but gradually

experienced limitations which halted further development. Termination or slowdown has occurred because of the limited scope of niche markets, weathering of political support, and institutional weaknesses. However, new lead markets have emerged as a result of the technology learning already accomplished. New interest and capabilities have been mobilized to take technology to the next step. A sequence of lead markets has therefore been necessary to continue the journey to a successful end.

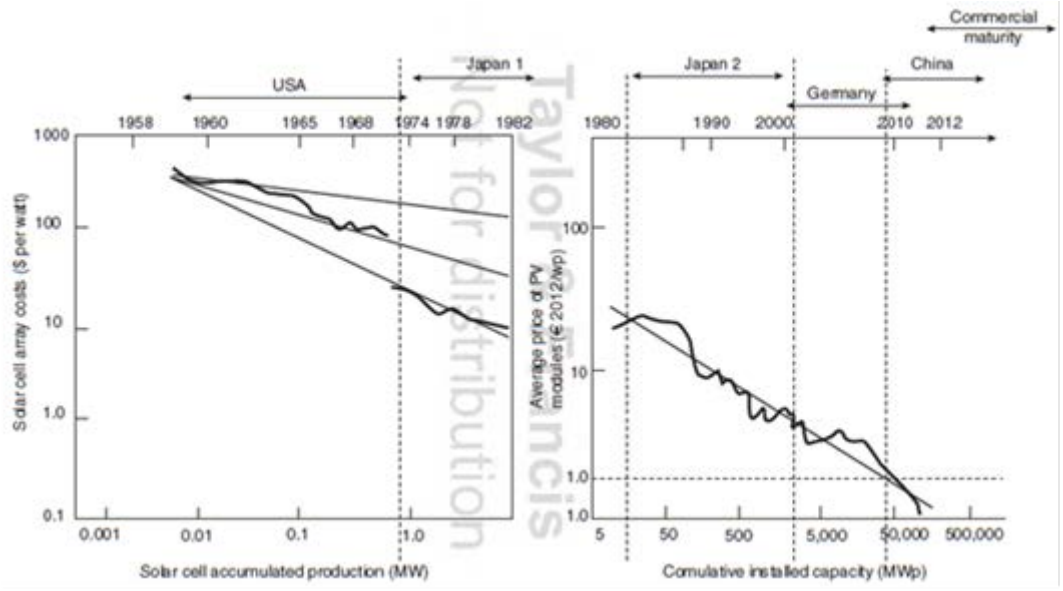


Figure 8 Learning Curve with Sequential Lead Markets for PV
Sources: Etzkowitz (1984) and Wirth (2013)

Back in the USA

A good success indicator is that the PV market is now taking off in several locations on a purely commercial basis. California and several other US states now feature firms like Sungevity, which offer installment of solar systems with guaranteed savings vis-à-vis conventional power. The cost efficiency of PV in sunlight-rich environments, furthermore, has made PV an attractive energy source for Africa. Large programs of solar deployment are therefore emerging in South Africa, for instance.

While the core PV technology has made a commercial breakthrough, innovation in important supportive technologies, such as battery technology and smart grids, carry the promise of making PV available in new fields of application. In the second decade of the twenty-first century the PV innovation journey can now be considered an obvious success, while the "commercial journey" is only starting.

A New Wave of Modernisation

In a broader historical perspective, ecomodernity may be seen as the emergence of a new wave of eco-industrial modernity, with a potential to be a dominant economic growth factor in the coming decades. Innovation scholars like von Weizsäcker et. Al. (2009), Perez (2014) put green transformation, or the Age of Sustainability, on a par with such breakthroughs as the Industrial Revolution, the Age of Steam and Railways, the Age of Steel and Heavy Engineering, the Age of Oil, Electricity, the Automobile and Mass Production, and the Age of Information and

Telecommunications & Biotechnology (figure 9)3. These were all based on breakthrough for new generic technologies, which establish platforms for further innovation, development and refinement, and for proliferation of applications to new fields. This in turn creates new leading industrial or commercial sectors.

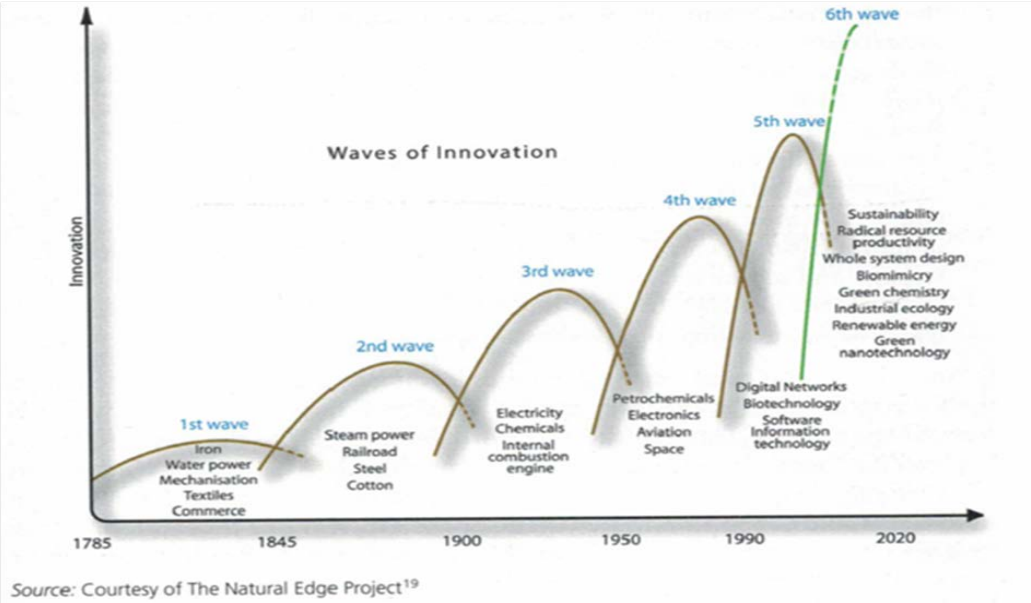


Figure 9: Waves of Industrial Modernisation
From Von Weizsäcker et al (2009)

While ecomodernity shares many of the typical characteristics of previous industrial waves, it introduces a strong focus on resource efficiency, as opposed to previous waves that focused more on labour efficiency. While labour productivity rose considerably with industrialisation, and dramatically after WW II with extensive mechanisatmion and automatisation, the focus is now shifting. With the impact of industrialisation on our natural surroundings growing rapidly, resources and the carrying capacity of eco-systems have come into more central focus. Demands for resource-efficiency, recirculation and renewable energy – all central to ecomodernity – have come to stimulate green innovation over a broad frontier of industrial applications.

Visions and Collective Action

In addition to its emphasis on resource efficiency, ecomodernity does, more than other waves, rely on collective action, and visionary public policy. The new wave of renewables focused and resource efficient ecomodernity could only, however, emerge with the support of visions and policy interventions as a strong driver. Other major industrial transformations thrived on attractive technological opportunities within the reach of business on a commercial basis. In the case of ecomodernity, however, core concerns such as the climate challenge, transcend the confines of conventional business models both with respect to scope and time horizon. The ability to mobilize public interest behind green transition is therefore of more paramount importance than in previous transitions, where commercial entrepreneurship was more readily at hand. Civic support and visionary public policy is, thus, needed to set a direction for handling compelling potential long term

[3] Von Weizäcker here draws on the Russian economist Nicolai Kondratieffs theory of longe waves in economic development and further refinement by several generations of innovation scholars, including Joseph Schumpeter, Christopher Freeman, and Carlota Perez.

ecological imbalances, and bridging the relatively long lead time to early commercial applications. In other words, green transition is to a large extent dependent on decisions where members of society act in their own enlightened self-interest overriding the immediate, narrow self interest of business as usual[4].

In a complex global economy with multiple vested interests, one can hardly expect full consensus around 'Kantian' enlightened self -interested solutions. However it suffices that dominant actors adopt 'Kantian' strategies and thereby trigger new directions of growth, that in turn drive technological evolution that over time will replace undesirable outcomes of narrow short term focused self interested strategies. Admittedly, some parts of the green transition could reap win-win opportunities where ecology and economic efficiency go hand in hand, but other and crucial parts are dependent on long term technological development and buildup of infrastructure that transcends normal business horizons.

Given the need to motivate collective action beyond short term commercial interest, the ability to create visions and mobilise political support are crucial in triggering change in policies and business strategies that subsequently drive the actual techno-economic transformation on the ground. Hence our previous focus on the triple cycle of innovation. Visions shape the policy outlook by defining preferred societal agendas; they also consolidates value-bases and ethical frameworks that remain central fundaments for shifts in policy and technology. In other words, visions and images are the "software" of innovation in policy and economy. Without the compelling, value-charged ideas, images and modes of action which have laid the contours of ecomodernity, the very idea of the "green transition" would have had much less public resonance, appeal and selling power.

Ecomodernity and Climate Change

While the scale and scope of green transition as a new Kondratieff wave is debated, so is our capacity to meet the climate challenge. This challenge currently represents the largest ecological threat to modernity. The literature on responses to climate change features widely different opinions: According to the Oxford energy specialist Dieter Helm (Helm 2013: ix) Very little has been achieved in addressing climate change in the last two decades. Coal power stations continued to be built on an enormous scale in China and India. He points out that indeed, Europe is back in the new coal power stations business and the European Union's Emissions Trading Scheme has come perilously close to collapse.

But according to the Roland Berger consultancy company (Berger 2011: 1), The world has turned green. They argue that we are experiencing a revolution, perhaps as profound as industrial revolution, which has altered every facet of life as it was known and understood.

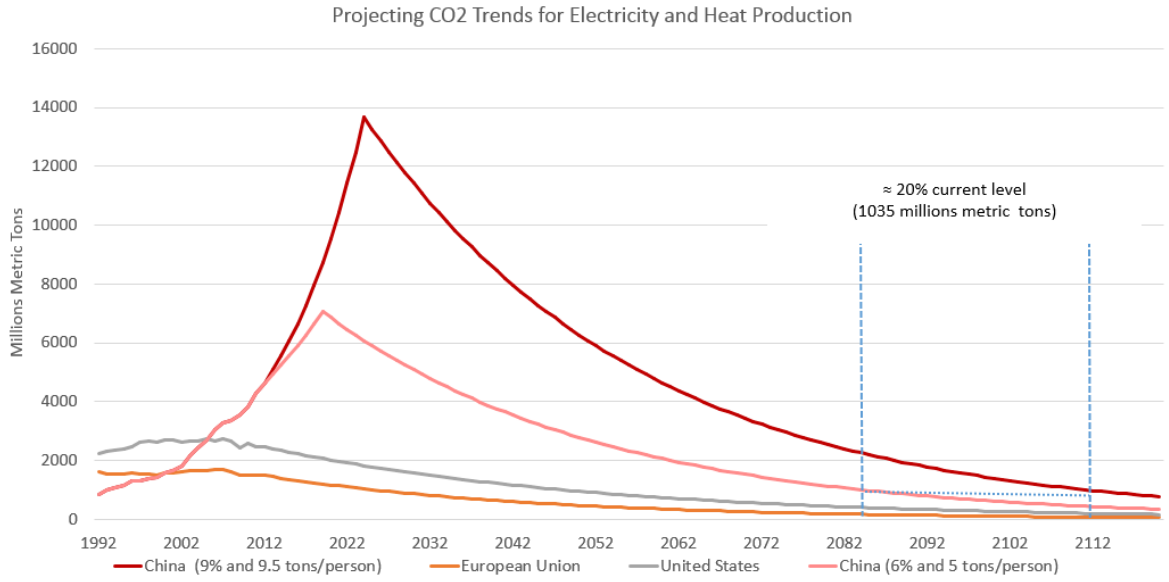
How to square these opposing scenarios?

Judging by the long term trends, Helm appears to be right: In the 20 years since the Rio summit in 1992—the period when climate change became recognized—the EU has reduced its CO2 emissions

[4] From a game theoretical perspective we do, in other words need to see a move from a Nash towards a Kantian equilibrium where strategies that lock-in to maximization of short run competitiveness only, need to be supplemented with "enlightened" self-interest following Kant's categorical imperative - an imperative that demands that strategies should be long term sustainable if followed by all. (Kant, Immanuel; trans. Ellington J.W. [1785] (1993), *p43)*

from electricity and heat at an average rate of 0.40 percent, while the US has increased its own by 0.5 percent annually. This is a trend towards serious climatic disruption on the planet. If we extrapolate CO2 rates of decline just since 2011, the picture becomes only slightly more encouraging (-2.5 percent for the US and -3.2 percent for the EU). At these rates the two regions would reach 80 percent emission reduction from the 1992 level by 2080 (US) and 2063 (EU)—far behind the schedule for getting climate change down to tolerable levels.

Predictably, the biggest challenge is rapid-growth economies like China, which aim to catch up with the West. If China were to continue its present CO2 emissions growth curve—around 9 percent—until it reached per capita levels of 9.5 tons, around 1 ton above the EU, but around 7 tons below the USA, there would be a massive emissions spike, peaking at 14 billion tons in 2024, which would dwarf any decline in the US and EU economies combined. If, after the Chinese peak at 9.5 ton levels, we assumed a decline rate equal to the high EU rate (-3 percent), we would be well into the next century (2110) before reaching 80 percent reduction of today's levels. Even halving the Chinese CO2 growth rate, and assuming a maximum CO2 emission per person at 5 tons before starting reduction would grossly overshoot the 2 degree goal (Figure 10).



Source: Compiled by authors, based on World Bank Indicator http://data.worldbank.org/indicator/EN.CO2.ETOT.MT

Figure 10 Projecting CO2 Trends for Electricity and Heat Production

It is, however, possible to chart a second scenario, built on trends of radical innovation taking place as part of green transition towards ecomodernity (see Figure 11). To take the EU electricity sector as an example: At its basis lies the extrapolation of a slow growth rate for the total electricity consumption of 0.5 percent from recent trends. The scenario shows the prolongation of recent exponential growth trends for wind and PVs in the European market and estimates how long it will take before the European electricity supply is completely renewables-based. Hydropower is assumed constant throughout the period at its present level of ~600 terawatt-hours (TWh), while biomass is expected to grow by 10 percent until it reaches the same volume as hydropower. Under these conditions, the European electricity supply would be expected to be completely based on renewables with a good margin by 2025.

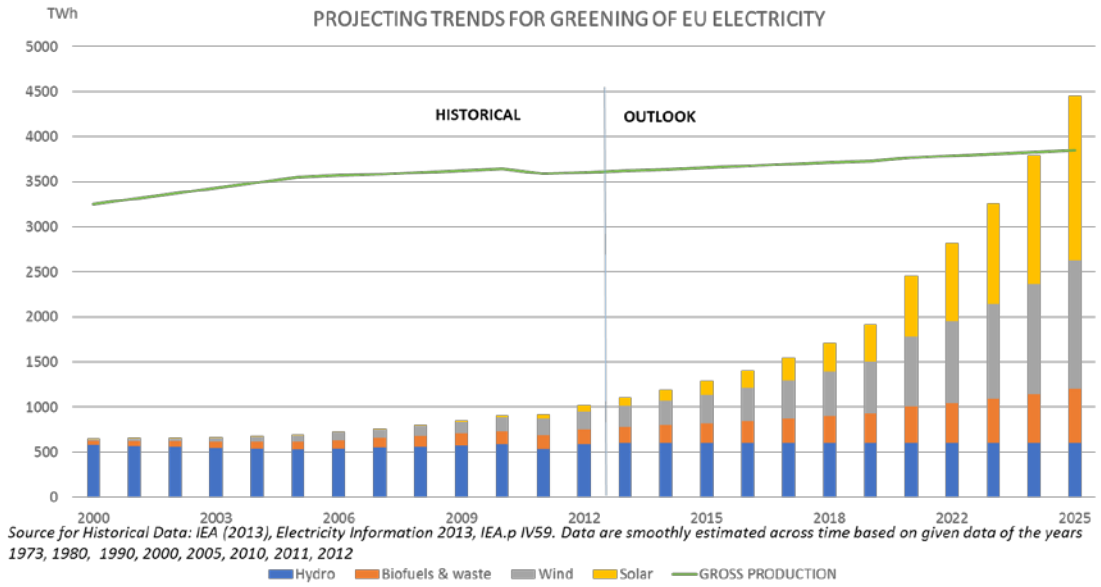


Figure 11 Projecting Trends for Greening of EU Electricity

Source for Historical Data: IEA (2013b: IV59). Data are smoothly estimated across time based on given data of the years 1973, 1980, 1990, 2000, 2005, 2010, 2011, 2012.

The picture for USA is not very different. Under assumption of a continued growth of electricity consumption of 0.3% - the average annual growth rate for 2005-2015 – the US electricity supply could also become completely renewables based by 2025 (figure 12). This development assumes a continuation of the last decade's extraordinarily high growth rates for solar and wind energy.

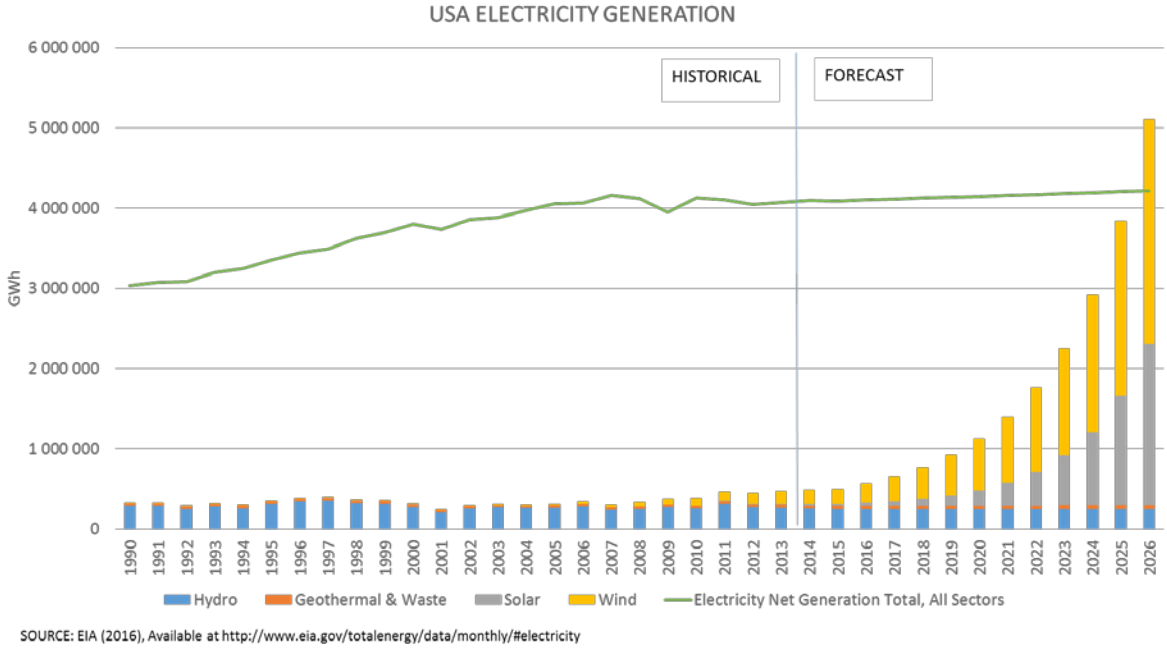
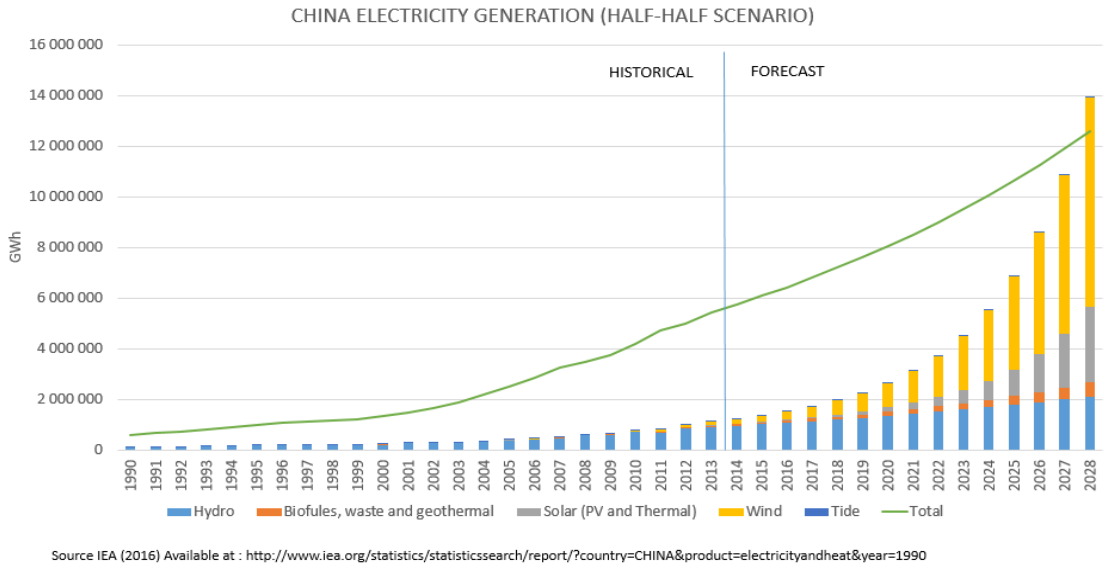


Figure 12 Projecting Trends for Greening of US Electricity

Even the Chinese rapid growth economy could produce a renewables based electricity supply before 2013 if renewables growth continued at only half of the current level (figure 13). We are then assuming halved growth rates in total electricity consumption (ca 6%) as opposed to almost 12% over the last decade (2003-2013)



Source IEA (2016) Available at : http://www.iea.org/statistics/statisticssearch/report/?country=CHINA&product=electricityandheat&year=1990

Figure 13 Projecting Trends for Greening of Chinese Electricity

The above scenarios are not predictions. They are alternative, conditional projections of possible futures and possible modernities. There are signs, however, that the energy system has come to a turning point where changes in the direction of the renewables dominated scenario is taking place in advanced nations, and may drive disruptive change at a speed that overruns the smooth trend of the first. The fact that climate mitigation with the 2015 Paris agreement, has moved on from being largely a European endeavor to also becoming embraced and supported by major economic powers like the USA and China, is a sign of progress.

Multiple Modernities and Innovation Pathways In A Heterogeneous World

The two scenarios in figures 10 -13 indicate the challenge involved for classical industrial modernity in meeting one of the major ecological challenges of our time. Yet they also illustrate the potential for ecomodern transition. The contention in our paper is that by deploying the very strengths of modernity that have triggered the climate threat –today's major ecological challenge to humanity - ecomodernity may be about to come up with the solution. Yet, as the green transformation must take place on a global scale, spanning vast differences in economic and societal conditions we are dealing with multiple modernities where there is no single, one-size-fits-all trajectory towards ecomodernity. Our comparison of transformation in mature economies such as the US and Western Europe, rapidly growing economies such as China, and developing economies such as those that dominate in Africa (Midttun and Witoszek 2016), illustrates some of the plurality of existing models of green transition:

> Mature economies such as the US and EU are characterized by saturation and slow decline, in crucial climate sectors such as energy and automotive industry, which reflects a

combination of incremental innovation, growing energy efficiency, and changing behavioral patterns. As illustrated in figure x there is evidence that these economies are doing too little and too late, given their starting points of sharp CO2 over-emission—particularly in the US. However, ever-new, breakthrough green technologies which signal the potential for more radical transformation and at a much higher pace. Photovoltaics and wind have thus seen exponential growth rates. The same goes for the electric car.

China, the dominant catch-up economy, has become the world's largest CO2 emitter, and is rapidly approaching EU per capita emissions. However, while China is championing growth in the carbon economy, it is also championing growth in green energy and green transport. China's booming expansion gives room for anything and everything, resulting in the unique situation where the conflict between carbon modernity and ecomodernity can be avoided. Twenty-first century China runs both trains at full speed. Here, the strong motivators of exponential green growth are resource scarcity, local pollution, foreign policy imperatives, and trade balance.

Sub Saharan Africa, on the other hand is often locked into structural problems that on the one hand limit growth, and on the other, sustain energy-inefficient technologies. Not only are Africans, as developing nations, rightfully "unapologetic about growth", but CO2 efficiency, for instance in the automotive sector is constrained by low-quality refineries and petrol, bad roads, older vehicles, and mechanics with competencies suitable only for older cars. The energy sector shows weak or missing grid infrastructure and reliance on extensive backup from local diesel generators. However, even here, both sectors show signs of breakthroughs. The limited fixed-line electricity supply in the countryside, as well as frequent urban electricity blackouts leave entry points open for photovoltaic solutions which are gradually emerging in several African countries. Increasingly, a growing urban, middle-class consumers demand advanced energy efficient cars, which slowly raises ecological standards of African car markets. Yaro (2016) and Mahamma (2016)

The strenght of the global economy is that it allows these cultures an eonomies to play together. As indicated in our own story of Photovoltaics, technologies for green transition may profit extensively from cultural and institutional variation found in diverse 'habitats' at different stages of development. If wisely stimulated, this could provide the boost needed for taking modernity one more step to ecomodernity. As Freya Mathews has argued:

> [T]he hallmark of modernity is radical change—in the form of development, control, management, design, intervention, progress, improvement, even salvation. […] This is reflected in the very etymology of the word "modern," which is derived from "mode," meaning "of the present," as in "a la mode," keeping up with the latest. Modernity is that period which is characterized in terms of its commitment to the ever-emerging new, its dissatisfaction with the given. (Mathews 2002: 227) .

In this sense ecomodernity—although undermining some of modernity's "holy cows," such as the rule of the carbon economy—is ultimately the child of modernity. It is a product of modernity's eternal impatience with the crisis-ridden here and now. But it is also the result of modernity drawing upon its roots, revisiting the holistic outlook of the late Renaissance and the critical reason of early Enlightenment. It is these roots that gives it the power to reform and correct itself.

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