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Europe's electricity regime: restoration or thorough transition

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ABSTRACT

Concerns about climate change, diminishing social acceptance of traditional fuels, and technological innovations have led several countries to pursue energy transition strategies, typically by massive diffusion of renewable electricity supplies. The German 'Energiewende' has been successful so far in terms of deploying renewable power, mainly by applying particular feed-in tariffs, and by bundling public, academic, industrial and political support. So far though, only few EU member states proceed with a similar transition. In March 2014 CEOs of Europe's major energy companies publicly opposed a fast and thorough transformation of electricity supplies to become fully renewable. In April 2014 the European Commission published new state aid guidelines, generally mandating renewable energy support mechanisms (premiums, tenders) of lesser performance than regularly adjusted, specific feed-in tariffs. The new guidelines are likely to be pernicious for the fast deployment of renewable electricity supplies.

In light of these challenges, this position paper highlights two implications of power sector transitions. First, the engineering-economics theory of power generation systems needs fundamental revision, mainly since a growing share of power sources no longer function on command. Second, and based on the experience in Germany, the paper sketches out a strategy for a thorough transition of the power sector, which, in the end, also entails normative judgements. Deep changes in energy systems and associated ways of living require societal consensus building based on ethical considerations.

Keywords:

renewable electricity support;
electricity industry transition;
Energiewende;
polluter pays principle;
EU energy state aid guidelines

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Abbreviations:

EEG = Erneuerbare-Energien-Gesetz (German Renewable Energy Act);
FIT = feed-in tariff;
SO = System Operator;
SRMC = Short-Run Marginal Cost

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1. Introduction: Electricity industry transition

Transition of the existing energy systems in industrialized countries is high on the climate and energy policy agenda. According to IPCC [1] CO_2-eq emissions by industrialized economies need to be reduced by 80 to 95 percent by 2050 compared to 2000 emissions and must peak prior to 2020, to stay below 2°C global average temperature increase on earth. This message was reinforced by the 5th Assessment report of IPCC [2]. Deployment of low-carbon energy systems by the year 2050, or earlier, is the key goal, spearheaded by rapid transitions to low-carbon electricity supplies. Since 2007, more and more citizens, organizations, companies, and politicians support IPCC's findings.

Notwithstanding the growing support, lock-in is a strong force of inertia [3]. Many people, companies, and organizations live from fossil fuel and nuclear energy supplies. Infrastructures, equipment, technology, planned projects, practices, theory, mental maps, and beliefs are hooked on low-priced availability of fossil fuels and grid electricity. The related interests are sizeable. The opposition against a fast and thorough energy transition is real and organized. This paper does not study the many lock-in factors. It signals how the organized opposition against a fast transition went more public in March 2014, when the CEOs of the major energy companies in Europe proposed to change the course of successful transition paths and retard the deployment of distributed renewable electricity supplies [4]. New EU Commission state aid guidelines under preparation for some years, where published in April 2014 [5], and help to promote the CEOs agenda.

We contrast these activities with the opposite perspective, which aims for thorough transition towards more sustainable, 100% renewable, electricity supplies, within a few decades. In 2010, electricity globally was generated almost 4/5th by thermal plants [68% fossil + 11.7% nuclear fuelled], and 1/5th from renewable sources [15.8% hydro + 4.5% from biofuels, waste, geothermal, wind and direct solar] [6]. Bringing the renewable energy share in electricity supply to almost 5/5th over the coming decades is a technological, industrial, financial, political, and social challenge at local, regional, and global levels [7, 8, 9].

This article focuses on two aspects of the transition challenge. First, a generic issue is the engineering-economic analysis and representation of integrated electric power systems. A revision of the basic assumptions about power supply sources and of the engineering-economic theory and models based on these assumptions is one example of the fundamental changes (or rather reversals) a thorough transition of electricity systems implies. The tenet of all power capacities being fully under System Operator (SO) command is growing obsolete with every new wind turbine or PV panel coming on line.

Second, the positions and recent moves by the electric power sector vested interests are discussed. In October 2013/March 2014 the sector interests triggered a restoration campaign, designed to slow this transition. In April 2014 the EU Commission published new state aid guidelines that will likely have a pernicious impact on the deployment of renewable energy supplies. Counteracting restoration requires a renewed emphasis on a thorough transition policy and action, implying several reversals in conventional thinking and practicing.

The paper is structured as follows. Section 2 provides a short description of the engineering-economics theory of optimal composition and least-cost operation of integrated electric power generation systems. The theorems are assuming that the SO can command the power plant capacities. Section 3 describes how the streamlined theory, already in the past was continuously adapted to match technical and economic constraints and facts of the real world.

Section 4 provides an overview of the first transition phase in Europe's electric power sector. The focus is on Germany, and the 'Energiewende' is analysed as an evolutionary model for the future. There is a concise review of main factors that explain the launch of an effective Energiewende.

Section 5 reports a few salient moments and elements of the restoration campaign coordinated by the CEOs of the major energy companies in Europe under the umbrella of Magritte Group. It appears that through the new state aid guidelines for energy (except nuclear power) of April 2014, the EU Commission supports the approach of the major energy companies. Although several power companies announced to undertake more activities and investments in renewable energies and energy efficiency, the danger is real that this restoration campaign will have a strong retarding impact on the transition towards 100% sustainable renewable energy supplies.

Section 6 provides an outline of basic steps needed to avoid such pitfalls and to deploy a path for a thorough transition; such outlines are common in strategic planning. A clear mission provides framing for the fundamental changes (reversals) that make up the thorough transition. This section implies several normative stances. A short conclusion is proposed in section 7.

2. Electricity sector economics 1950-2000

The second half of the 20th century witnessed a tenfold growth of global electricity use. More rivers were dammed for harnessing hydropower. Nuclear power was named backstop technology for substituting fossil fired power, with breeder reactors and fusion to kick in well within the horizon of the 20th century [10]. Nuclear power would provide enough 'electricity to all for all uses' (electric sector advertising in the 1960/70s). Fossil-fired thermal power units scaled up from tens of MW to thousands of MW, with increasing conversion efficiency approaching the limits of physical laws. These large-scale systems were top-down designed and operated, with end-users absorbing ever more electricity. Pollution, waste, and risks were largely rolled off on nature, society, and the future.

Generation and transmission were highly controlled, functioning on command by central system and plant operators, with distributed generation languishing. Engineering-economic models and practices governed investments, operations, and pricing of electric power [11]. The interlinked models answered the major engineering-economic questions on reliably meeting the demand for the non-storable electric current by end-users: When should which capacities be built? How should they be operated? Who should pay which costs?

The sublimated version of the theory assumes a continuum of capacity options, from high fixed / low variable costs (base-load) to low fixed / high variable costs (peak-load). In an optimally composed generation system, installed capacities run their number of hours as least cost generator of the range. All plants function 'on command': they supply power when the system operator (SO) orders it, and they do not supply power when not ordered by the SO. Because electric current is not storable and is very rapidly transmitted over networks, the operations occur 'in real time'. Over brief time spans (e.g., 15 minutes) available generation capacities are ranked in merit-order by variable generation costs (fuel and other avoidable running expenses). The variable cost of the marginally loaded plant equals the short-run marginal cost (SRMC) of the integrated generation system, this being the theoretical proper kWh price of generation for all end-uses during that brief time span.

When the sequence – investment, operations, pricing – fits perfectly, the major issues of power supply achieve neat solutions: all end-users during the real time interval are treated equally via a SRMC-price, signalling the momentary opportunity cost of generated power. In an optimally composed and operated production park, revenues obtained via SRMC-pricing would cover full costs.

3. Recalcitrant realities preclude theoretical optimality

Multiple technical, economic, and practical factors challenge the sublimated theory [12]. First, economies of scale, discrete sized generation units, sunk costs of long-living assets, and fluctuating input factor prices impede optimal compositions of electricity production systems. At the operations side, start-up costs, limited ramping rates, 'must run' units having priority over cheaper plants and spinning capacities disturb the simplicity of textbook merit-order rankings and blur the meaning of SRMC prices. The difficulty to calculate with precision less visible external costs related to the placement, functioning, emissions and waste of power plants, is used as excuse to reject or minimize the inclusion of these costs in the accounts and in the prices of delivered power. Smart metering and ICT significantly extend the ability to control real time operations, governed by many factors [13]. But how practical is it for most end-users to process themselves the information overload? In the case of most electricity consumers, end-use prices do not reflect the swinging SRMC pointers, but are constant prices per kWh delivered over the month (year) or two-part (per kW capacity and per kWh), and sometimes with separate peak and off-peak period measuring and billing. Also, pricing is highly influenced by regulators with other logics, criteria, and frameworks than engineering-economic optimality.

Second, follow-up of actual power generation systems is a full time expert job, applying theoretical models and various practices under ever-changing circumstances. Distinctive variables fluctuate permanently, as do SRMC signals that mark the functioning of power systems [13]. As a corollary, most non-expert parties (small businesses, households) may lack the knowledge and time to comprehend sufficiently electric power systems to benefit from its erratic intricacies. We assess that the revenues/expenses ratio of small and residential end-users muddling in intricate electricity system balancing issues is very low: promoting such participation holds no societal merit as some expect [14, 15]. By contrast, simple and transparent public regulations shield small power producers and end-users from this duty, e.g., by preferring stable feed-in tariffs (FIT) to fluctuating tradable green certificates or premiums paid on top of power prices settled at power exchanges (sections 4 and 5).

Third, power generators, not commanded by SO, cause nuisance. Apart from several generator and plant classifications (incumbent/independent; central/ distributed; large/small), the distinction commanded /autonomous is the really discerning one. 'Commanded' permits the full institutional dispatching of a generation capacity by SO, i.e., when ordered, current is delivered or throttled (taking into account physical and technical plant constraints). Commanded plants are single-directionally linked to the grid, and only deliver power. 'Autonomous' limits or excludes control by SO, except in protecting the technical safety of the synchronous power system, when autonomous generators are connected to the grid [16]. Due to electric current being non-storable, grid connection mostly ensures the best reliability/cost ratio for autonomous power plants. Electric currents may then flow bi-directionally: either as back-up power from the grid to the autonomous site (bridging the gap between own generation and own demand when the former is lower than the latter), or to the grid as surplus power generated beyond the site's consumption.

In most of the 20th century few autonomous generators survived as on-site (often industrial cogeneration) power plants. The 1978 PURPA legislation in the USA opened the grid to mainly independent generators, some functioning rather as single-directional commanded capacities, others as bi-directional autonomous capacities. By liberalization, more inroads on franchised utility monopolies occurred, often by incumbent electricity companies from other areas. Except for liberalized systems designed with a mandated pool, the authority of SO concentrates on balancing and other ancillary services. Delivery and throttle orders are then sent through hourly system power price signals. Economic rationality normally induces plant owners to only run their capacity during hours when their SRMC is lower than the exchange price at that hour. Notwithstanding the theory's deficiencies, it remains embraced by most academics and practitioners.

4. First transition steps in Europe's electricity sectors

Just as the USA [17], Europe showcases a variety of electricity supply industries rooted in their historical national predecessors, e.g., France's dependence on nuclear power. Most member states housed vertically integrated (public or private) monopolies for generation and transmission in franchised areas. Distribution and delivery to small customers belonged to the vertical monopoly or were assigned to local – generally public – undertakings (e.g., municipal power plants in Germany). Power supply theory and practices (section 2) prevailed in a patchwork of implementations.

So far, EU directives enacted in three stages (1996, 2003, and 2009) impose market liberalization. Unbundling of the main functions, third party access, and privatization allow more exchange and 'foreign shopping' by the EU's incumbent power companies. But limited interconnection capacity, locked-in national customs, and inherited infrastructure and systems retard and mock the single European electricity market. The liberalization agenda was complemented by climate change policies after 1997 (Kyoto Protocol) requiring fundamental changes [18], and by the directive on the promotion of renewable electricity in 2001 [19]. The European Commission organized climate policy at EU scale with the Emissions Trading Scheme as flagship. Already in the early phase of European renewable energy policy different visions of the member states became obvious. In 1998–99, the Commission insisted on establishing a tradable green certificates market for supporting renewable electricity but did not prevail in either Council or Parliament. To rescue its feed-in tariffs (FIT) Germany rejected the European Commission plans [20]. Only few governments then favoured a system based on tradable green certificates.

Germany (second to Denmark) took a lead in transforming its electricity sector from a fossil-nuclear system to near-fully renewable energy supplies. This leadership is rooted in societal, academic, and political circles with a strong aversion to nuclear power and an argued belief in renewable energy potentials [21, 22]. The 1986 Chernobyl disaster brought a majority of the population to reject nuclear power. After a brief reversal in 2010 (postponement of nuclear phase-out), the 2011 Fukushima disaster led to the reinstatement, on a broader political basis, of the phase-out decision taken in 2000. This decision was sealed by the advice from an Ethics commission, which was composed of a representative panel of German civil society [23]. This illustrated how crucial decisions, stretching far in time, ridden with uncertainty, incomplete knowledge and irreversibility, cannot be resolved by technical-economic cost/benefit studies or lobbyism politics, but need the ethical, overarching perspective fostered by civil societies [24]. The ethical dimension has been important in the German nuclear energy policy debates, particularly in the German Parliament from 1986 to well into the 2000s; it reached a summit with the formal instalment of the Ethics Commission in 2011.

Germany is engaged in a fast transition to full renewable electricity supplies [25, 26]. The renewable electricity share increased from 6.6% in 2000 to 27.3% of domestic consumption in 2014 [27]. New renewables now account for the largest share of any energy source in the German power mix. The role of well-designed financial support for renewable electricity generation projects has been vital for this success up to 2014. Key aspects of the support systems included:

- Investment reliability for renewable energy generators was secured via fixed tariffs per kWh for 20 years. Thus, remuneration was not exposed to market risks. These features meant low investment risk and facilitated raising mortgages.
- With support linked to the energy delivered, FITs provide better incentives for efficient functioning of the plants than support linked to capacity or investment expenses.
- Renewable electricity deployment was not curtailed by quota; utilities have to purchase all renewable power on offer. In addition, since the FIT bill is levied on grid electricity end-users via a surcharge, the growth of renewable electricity was not exposed to public budget problems or (except the past few years) political setbacks.
- FITs are set to reflect the projected levelized cost prices of renewable energy projects over 20 years, differentiated by technologies and capacity, adjusted automatically (usually annually) to account for cost degression, and regularly reviewed. Actual growth of renewable electricity supplies systematically far exceeded the forecasts.
- This stable and predictable support system led to the rapid growth of renewable power supplies from non-utilities, mostly private persons and farmers [28, 29]. It also stimulated the German industry to become a world leader in PV and wind turbine technologies, in design and engineering, and in exports of machine tools and whole production factories. The industry has been highly successful at lowering the cost of renewable electricity technologies, but – in the case of PV cells – was severely damaged by a trade war with Chinese producers and a domestic PV policy that reinforced the crisis of the sector.
- Things began to change in 2010 Since 2010 electricity from renewable sources is mainly sold on the day ahead spot market, lowering the wholesale price and revenues from the sale of EEG power by 0.5 - 1 ct/kWh [30], but increasing the surcharge on consumers, while rewarding the incumbent power generators.
- Electricity-intensive industries benefit from this merit-order-effect, i.e. the replacement of fossil fuels with substantial operating costs by wind and solar generation with almost zero operating costs, while being largely exempted from paying the surcharge.
- The EEG surcharge rose from 2.05 €ct/kWh in 2010 to 6.24 €ct/kWh in 2014 and now accounts for nearly 20% of household electricity prices. This increase is mainly due to the fast expansion of renewable power supplies and to increasing exemptions for electricity-intensive industry [31]. These exemptions increased steeply in the first half of the current decade (from one to about five billion Euros), further adding to the surcharge on small consumers.
- The EEG surcharge on small consumers rose from 2.05 €ct/kWh in 2010 to 6.24 €ct/kWh in 2014 and now accounts for nearly 20% of household grid electricity prices. The major causes of this increase are: the merit order effect of lower prices for wholesale power is not passed on to households; more surcharge exemptions for electricity-intensive industry rolled on households; legacy cost of PV installed in previous years when this was still very costly [31].

- Since 2014 (2010 for PV) there are 'flexible caps' on renewable electricity expansion, reducing compensation if caps are exceeded. EEG 2014 [32] means to cap the former unlimited growth, e.g. at 2.5 GW/year each for onshore wind and PV. To enforce this constraint, the EEG 2014 amendment provided for faster and steeper adjustments of support levels than in the past (monthly for PV, quarterly for onshore wind and biomass), also as a response to growing critique since 2010 that FIT expenses, or quantity of capacity installed, or both, came down too slowly, in particular for PV.
- The costs of renewable power technologies have dropped significantly since the EEG was introduced. Most prominently, the system costs of photovoltaic installations in Germany decreased by over two thirds in the last eight years, i.e. from 5100 EUR/kWp in 2006 to 1640 EUR/kWp in 2014 [33]. The speed of the transition accelerated continuously between 2000 and 2014. To put an end to this acceleration, EEG 2014 nips the growth to a lower rate than that achieved in recent years.

The German Energiewende is embedded in a supportive socio-technical environment, including R&D-intensive providers of renewable technologies and system components. R&D results are broadly disseminated (www.bine.info). Despite relatively high power prices for end users, which burden low-income households, support for a decentralised Energiewende remains overwhelming [34]. After all, Germany is a wealthy country, and the GDP share of end-user electricity expenditures in 2012 was only about 2.5%, roughly the same as in 1991 [35].

Since 2011 (Fukushima; Ethics Commission), the German Energiewende builds on an even broader societal, but not political, consensus, spanning also across the lines of the major political parties, despite some wavering government decisions. At least two of the four big utilities (notably EnBW and E.ON, more recently also Vattenfall) are reconsidering their business models. Electricity-intensive industries continue to request lower energy prices despite they enjoy comparatively favourable electricity prices for German industry [36]. Other industrial companies benefit from the new opportunities and some changed their strategy (notably Siemens which quit building nuclear plants and now is the worldwide leader on offshore wind turbines). New societal preferences are triggered by citizens, communities, grassroots initiatives, and cooperatives. Citizens own about half the installed renewable capacity and a growing share of renewable electricity generation is forthcoming from small-scale projects [37, 38]. However, replacing FITs by bidding systems in 2017 (a reform laid down in EEG 2014, in line with new EU state aid guidelines, and which started in 2015 with a first pilot non-rooftop PV installations) is likely to inhibit the growth of prosumers as non-professional investors might have difficulty to deal with increasing transaction costs and related risks.

The strong post 2011-societal consensus on renewable power contrasted with growing disagreements on EEG at the level of political elites. A new consensus between the two major parties (CDU, SPD) is reflected in EEG 2014 whose purpose it is to reduce the annual growth rate of renewable capacity by caps and to reduce the cost of such power by forsaking feed-in tariffs and market premiums by a shift to bidding systems. So far the EEG 2011 targets for 2050 – 80% renewable electricity by 2050, in stages – have not been modified, except for the fact that former minimum goals now became upper limits (caps).

Energiewende in Germany is not just a story of smooth deployment. In recent years its critics became more vocal, especially as regarded the supposedly high costs of feed-in tariffs and in particular PV tariffs [39]. PV tariffs however came down radically since then, and the cost debate is distorted, for example by confusing high legacy costs of pioneer technology investment with lower later costs of more matured technology, that however only could be obtained by the high investment in preceding pioneer projects [40]. The Bavarian government continues to militate against wind energy, while nearly all other Bundesländer improved the supporting schemes for wind energy. Some connections of offshore wind farms are behind schedule. Foreign critics argue that paradoxically Energiewende led to a higher use of coal. But the brief trend of higher use of coal in 2012 and 2013 was mainly due to lower coal prices, which were not counteracted by CO_2 emissions taxes or sufficiently priced emissions allowances. The insufficient pricing of externalities and risks of fossil fuel and nuclear-based power generation is a major bias against the deployment of renewable energy supplies. However, the trend of more coal use was broken in 2014. Also, peaks in supplies of wind and of solar power at almost zero marginal cost, disturb the standard merit order loading of commanded capacities. The oversupplies by inflexible capacities, occasionally lead to very low (a few times negative) system prices, not rewarding the actual generation costs of the plants, with inroads on the returns of incumbent companies owning large-scale base-load plants.

The critics of the before 2014 Renewable Energy Act joined forces with the EU Commission (section 5 of this manuscript), to facilitate the enactment of EEG 2014, whose purpose it is to rein in 'excessively' rapid renewable power deployment. Among other things, EEG 2014 aims to end accelerated growth of renewable power (achieved up to now), which suits the major power companies and those who argue that more rapid deployment might endanger Germany's competitive position in the world economy.

Many other European governments have been arguing for some time that Europe as a whole has taken on excessive climate policy burdens, which endanger its industry. Some criticize the German nuclear phase-out for 'lack of solidarity'. This inertia is related to habits, convictions such as disbelieving renewable energy potentials while trusting incumbent accounts of a 'transition crisis', vested interests and technological lock-ins also play an important role (e.g. coal in Poland; nuclear in the UK). Many governments consider the 2008 EU target of 20% renewable energy, and the new, non-binding overall target of 27% by 2030, as ambitious enough. The (formerly) high cost of PV, the merit-order effect's impact on incumbents' profits and the 2014 reorientation of the Energiewende in Germany became an argument for several other European governments to limit their efforts for a similar energy transition [40].

5. Restoration by vested interests

Modest growth of renewable electricity supplies, often the result of wavering policies and ineffective support systems, makes slight inroads on established power supply systems, resistant against low degrees of nuisance. But already ten percent of renewable wind and solar electricity have a substantial impact on incumbents' profits through the merit order effect (reducing wholesale prices) and of course reduce the output of gas, coal and nuclear plants.

The CEOs of the largest European energy companies defend their present core assets. On March 19, 2014 under the aegis of the Magritte Group, they issued a 'call for government and state heads to implement immediate and drastic measures to safeguard Europe's energy future' [4]. 'Nine recommendations to reform Europe's energy and climate policy so as to achieve the three key objectives of competitiveness, sustainability and security of supply', are complemented by three proposals (www.gdfsuez.com): preference for 'mature renewables in the regular market', 'priority to the utilization of existing competitive power capacity rather than subsidizing new constructions', and 'restore the ETS as a flagship climate and energy policy'. The proposals are likely to slow down the deployment of, mainly decentralized, renewable power, and of the further development of so far non-mature technologies.

On April 9, 2014, the EU adopted new "Environmental and Energy State Aid Guidelines for 2014-2020" [5]. The Guidelines make bidding systems the central support instrument for renewable power in the future and ban feed-in tariffs for most situations, thus abolishing a key instrument of Energiewende. They consider exemptions from renewable energy surcharges for industrial companies as state aid and require that these companies make a contribution, which however may be limited to a fraction of the rates small customers pay. On July 23, 2014 the European Commission accepted a compromise German EEG 2014. The overall goal of these guidelines is to reduce the supposed burden from renewable power support in the name of European competitiveness and affordability of the electricity bills. The likely intention is to contain renewable power growth to lower levels than so far, and to give big corporate operators a better position to replace prosumers as chief generators of renewable electricity (in Germany and some other FIT countries, the corporates largely underestimated the role of prosumers).

The common practice of juxtaposing and trading-off 'quid pro quo' the three EU energy policy goals hides their hierarchic and interdependent relationships. When analysing the three interrelated goals, the first and leading one is sustainability; this first goal can only be realised by the thorough transition to harvesting renewable energy sources available on European lands and seas. Such sustainable energy systems naturally bring security of supply as a corollary because use is made of domestic European energy sources, and dependence on precarious imports and unreliable external forces diminishes by every new local renewable flow harvested. The sustainable and secure energy systems become affordable through technological innovation, because technology is the par of energy sources to obtain energy supplies. Technological success is feasible when unfettered priority is given to the transition, demonstrated clearly by the German Energiewende. The actual cascading interdependencies contrast with the official trade-off narrative between sustainability, security, and affordability.

Assigning superior weight to 'market' functioning above sustainable development is a case of confusing means and goals. The electricity 'market' is still dominated by major power companies, with fossil-nuclear fuelled capacities that produce a range of accompanying externalities and risks. The Guidelines and EEG 2014 impose the biased markets as basis for future renewable plants >100kW [32]. On April 9th, European Commissioner Almunia, then responsible for competition policy, stated: 'Many renewable energy sources have reached a scale and a level of maturity that allows them to compete with other sources.' This statement would undoubtedly hold if 'other sources' were priced at total costs, including externalities and risks, and if the available energy infrastructures and institutions suited renewable energy. But this is not the case, something that hinders the establishment of a level playing field. Renewables may be on the way to competitiveness even so, but their progress will be slowed. Moreover, on 8 October 2014 EU's competition commissioner, Joaquín Almunia approved intended loan guarantees and price commitments for UK's nuclear power project Hinkley Point C [41]. A level playing field does not seem to be required for new construction of nuclear fission power.

Premiums, quota with tradable certificates, and bidding systems (tenders, auctions) become substitutes for FIT tariffs (except for < 100kW new projects during the next 10 years), although earlier experience evidenced high windfall profits, more administrative and transaction expenses, higher risks for small investors, and lower effectiveness [42, 43]. Stop/go jamming of the deployment pace is caused, for example, by legislators squeezing the funding or by speculative uneconomic bids. Some countries experienced widespread failure to deploy schemes that had been awarded contracts under competitive biddings [44,45,46, 47].

We assess that the overall result of the Guidelines will be not only to slow the current dynamics of renewable technology deployment, but also its development; this will weaken the European market and most likely affect the international positioning of many European renewable power manufacturers [48]. Germany as a well-endowed and experienced renewable electricity developer may eventually overcome such setbacks. But what about member states at an earlier phase of the transition path?

6. Vision for a thorough transition

Corporate strategy theory and practice teach that success is preceded by visions. Without a vision, success is unlikely. The thorough transition of electric power systems from fossil fuel and nuclear dependent top-down constructions, towards exclusively renewable energy supplies from mainly local resources and therefore bottom-up directed, means a full U-turn. In such cases, it is important that practical action follows a strategic meta-vision on the transition to low-carbon electricity supplies, specifying a mission and fundamental changes (reversals) prerequisite in accomplishing the mission. The explicit formulating of a mission (the end-goal) and changes (the way from here to the end-goal) requires a thorough sustainability assessment of what a 'good' electricity industry is. Pending the results of such assessment, a default version is proposed here. We thereby abstract from comparing the possible designs of technical power systems and markets [49, 50, 51]. 'Flexibility options' may protect incumbent power systems against surging inroads by fast and unforeseen expansion of renewable power flows form wind and PV. Our position is that such inroads are necessary to generate the destructive Schumpeterian innovations the future needs.

6.1. Mission.

Leading industrialized and industrializing countries and regions in the world (e.g., G20 and OECD member countries; EU) transform their electricity sectors to 100% renewable energy based supplies. Locally available natural flows (wind, solar, water, biomass), harvested to a large extent by prosumers, deliver the main share of the supplies. Centralized renewable power plants are placed and designed to complement and back-up the local sources, with the caveat that the need for such centralized back-up is minimized by giving priority to flexibility options (demand responses, load management, storage facilities, opening the heat market as a sink for surplus electricity) and to strengthening grids and interconnections. Electric utilities design business models to assist prosumers, guaranteeing network services, frequency and voltage stability. Regulators control the performance of the utilities and the prices charged for delivered services. The transformations are kick-started without further delay, and the highest pace is pursued.

6.2. Fundamental changes (reversals).

The electricity supply systems intended by the mission, are of a very different nature than today's dominant fossil-nuclear fuelled ones. Significant adaptations and reversals in electricity supply paradigms and market structures are prerequisites for starting the transformations with proper impulses in the right directions. The main reversals proposed here:

- Adopting a mission similar to section 6.1 for the intended transition. This societal-political adoption is crucial and prerequisite for undertaking successful transitions.
- The fast development of local renewable, reliable electricity supplies, as core of smart energy systems, is the principal goal of energy and related R&D and industrial policies.
- The mission reverses previously dominant perspectives, positions, responsibilities, and cost allocations:
    - Perspectives: the future electric power systems are the vantage points to evaluate proposed and ongoing actions and transition programs. Back casting prevails over forecasting. Clarified perspectives avoid the new build of non-sustainable fossil and nuclear power plants.
    - Positions: the established, inherited electric power systems are main sources of climate and nuclear risks, nature and environment degradation, human health dangers. The old systems have to be replaced as-soon-as-possible, also when this implies stranded investments.
    - Responsibilities: today, variable renewable electricity supplies disrupt established power systems. The obsolete discourse tells the disruptors that they are responsible for their impacts on existing systems. The opposite must be upheld: non-sustainable, incumbent systems are responsible for damage and risks, and their phase-out is a necessity.
    - Cost allocation: the obsolete discourse wants to charge renewable electricity challengers with the expenses of their integration into obsolescent incumbent generation and network systems. This conflicts with the polluter pays, alias extended producer responsibility, principle. The principle implies that non-sustainable, prevailing power systems assume the responsibility for the expenses of 'disruption' caused for giving way to the requirements of upcoming, sustainable, renewable supplies. At minimum, incumbent systems should stop increasing the burdens for a thorough transition.
- The theory and handbooks on electricity economics need revision. The old model assumes all power capacities function on command. The future sustainable power systems own limited capacities on command (hydro reservoirs, bio fuelled plants, and new forms of storing energy from converting power), compared to overwhelming redundant capacities for harnessing natural energy flows (wind, solar, water). Natural flows can be by-passed, not commanded, either by people or by system operators. With SRMC near zero they claim first places in the merit-order loading. Next to large renewable plants, there will be a huge number of small-scale plants, often set up as smart energy systems with integration of heat, power, transportation and gas, and owned by customers, cooperatives, and communities. They first serve own needs and interact with the grid bi-directionally. Such electricity sources are the future default, normal ones. Their integrated functioning requires continuous utility support in transmission, central storage, backup and balancing power. The future theory and practice rejects the axiom that the sustainable sources 'disrupt' the present non-sustainable power systems. This rethinking of power systems with all its consequences is challenging the creativity of scientists, engineers, and regulators.

Formulating the new sustainable energy mission and exploring the changes necessary for its accomplishment, surpasses the boundaries of traditional cost-benefit analysis. It implies an iterative social learning process and ethical norms as the foundation for a wide consensus.

7. Conclusion

IPCC [1, 2] already stated that mitigation should reduce emissions by 80 to 95% in industrialized societies by 2050. This implies electricity generation will need to be practically carbon free. The electricity sector is essential for spearheading the transition to a low-carbon energy economy. Vested interests locked into carbon intensive power and/or into nuclear generation options retard the breakthrough and the full deployment of renewable electricity supplies. . A major lesson learnt on the promotion of renewable energy is that its deployment is a long-term and evolutionary process that requires enduring policy support [43]. In contrast the April 2014 EU State aid guidelines strengthen the restoration, which could lead to wasting precious years for mitigating climate change [50]. For avoiding further lock-in by non-sustainable energy systems, infrastructures, and institutions, a thorough energy transition strategy is required. Agreement on a clear mission, and awareness and acceptance of deep reversals, are major ingredients of this strategy. For example, applying the extended polluter pays principle assigns the responsibility for present system disturbance not to the renewable energy challengers but to the non-sustainable incumbents. The reversals also call for novel electricity engineering economics theory and practice. The proposed strategy is not fully developed, but a first response to recent turns in electricity policy making which are likely to extend carbon lock-in. Maybe the emerging sustainable renewable electricity options are already developed enough to resist these efforts to delay the energy transition. But we must also realise that time is of essence, and that we need clear orientations for an electricity policy that can help minimise climate change.

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