Electric power system transition and the 'Polluter Pays Principle'[·]

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ABSTRACT

Incumbent power generation and distribution get disrupt by variable renewable electricity supplies. As spontaneous default position is accepted that the disruptors (renewable energy producers) are responsible for the impacts they occasion on established systems. Mostly is added: renewable energies should pay the expenses for systems adaptations necessary to absorb their growing success. This first-hand position is challenged by the "polluter pays principle": because the incumbent power systems are not sustainable, they must cede and adapt to the requirements of the sustainable renewable ones, and pay the transition expenses. The opposite positions are documented with value-price gaps on climate, fossil fuels, and renewable energies. A comprehensive view on liberalized electric power systems frames the proposed dichotomy of power producers in 'commanded generation plants' and 'independent generators of own power (IGOP)'. At prevailing conditions, IGOP power is inferior to and not competitive with commanded power; moreover IGOP disrupt the functioning of commanded power. However, IGOP make up the core of sustainable low-carbon electricity systems. This enigma challenges the policy and politics of electricity sector transition. No detail regulations are recommendable before clarifying the strategic positioning of the various participants.

Keywords: renewable electricity integration; transition expenses; polluter pays principle

Abbreviations: DNO: Distribution Network Operator; IGOP: Independent Generator of Own Power; RE: Renewable Electricity; TSO: Transmission System Operator

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[·] This contribution is based on a lecture presented at IRENEC-2012 in Maltepe-Istanbul (Verbruggen, 2012), reworked and updated in 2013 (this text), and further complemented in cooperation with eleven colleagues in 2014-15 (Verbruggen et al., 2015). The reader may observe that the study and discussion on the topics covered are far from finished.

1. Introduction

The inherited fossil fuel, nuclear and large hydro based power systems are more and more evaluated as non-sustainable. By 2050 their transition to 100% renewable electricity (RE) supplies is considered possible, desirable, and necessary for preserving climate stability (IPCC 2012). Power systems are multi-leveled and their bottom-up development in the industrialized world to continentally integrated systems, with very large generation stations as central nodes, took about a century. Except large hydro dam plants, RE generation units are mostly medium to small scale and distributed at locations where natural resources are available (Twidell and Weir 1997). The transition to 100% RE is not free from tensions between more centralized RE deployments (e.g., off-shore wind parks) and priority to numerous distributed independent generators of own power (IGOP)[1]. The former start from top-down centralized operation (successful in the established systems); the latter want to anchor and grow the future 100% RE systems around distributed generation, with a central role for household PV and micro-generation (Schleicher-Tappeser 2012), nested in smart grids (Eurelectric 2013). Both approaches must obey physical, economic, and social laws to supply power in an effective, efficient and fair way, within continentally wide networks. Shifting back the gravity point of power systems from their tops to the floors where end-users prevail, is unavoidable when sustainable power systems are intended. But in an interconnected system the frequency is regulated at a single value (50 Hz in Europe) for the entire area, and every participant has to synchronize. I.e. a modern power system is always multi-leveled.

The future growth of renewable electricity (RE) supplies will ever more disrupt inherited and incumbent power generation, transmission, and distribution systems. Disruption increases with RE variability, randomness, distance from load centers, and constraints on flexible dispatching by system operators. Dispatching constraints are related to physical conditions, technical factors, and to economic-institutional attributes like ownership, elasticity of demand, and regulatory rules or conventions. Because of their independent autonomy and by swapping bi-directional power exchanges, IGOP are most disrupting incumbent systems. Scholars seem to assign merit to active participation by residential end-users in addressing intricate electricity system balancing issues (Verbong et al. 2013; Geelen et al. 2013). The societal benefit/cost ratio of such active participation is low, and should be taken into account when mechanisms for supporting IGOP are proposed.

The technical aspects of system stability (frequency), balancing demand and supply (load management & load following), and adequacy (sufficient capacity to reliably meet (peak) loads in the future) received most attention (e.g., IEA 2011; George and Banerjee 2011; Mason et al. 2013). Added is work on the financial trade-offs behind the investments and operations by the German federal ministry BMU as architect of the German RE support system, and by academics e.g., Schaber et al. (2012), and Gawel & Purkus (2013). Costs can be shifted around (IEA 2011) what makes accurate assessments precarious. Most literature on the integration of renewable electricity in power systems focuses on generation and transmission (e.g., IEA 2011; Schaber et al. 2012). The role of distribution networks and of future smart grids changes with the

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[1] IGOP as general and neutral term (Verbruggen 1997) is preferred above e.g. ‘prosumers’ (Schleicher-Tappeser 2012) or ‘co-providers’ (Geelen et al. 2013). The adjective independent is added to distinguish from joint ventures between incumbent power companies and industries that house on site the shared (often cogeneration) power plant.

growth of distributed generation (Verbruggen 1997; de Jode et al. 2009; Nykamp et al. 2012; Verbong et al. 2013; Geelen et al. 2013).

This paper adds to the burgeoning literature in two ways. First, it provides more clarity on some important gaps between economic value and price. Second, it develops an unfamiliar, yet comprehensive perspective on footing the bill of the transition to 100% renewable electricity.

The flow of arguments is as follows. In section 2, important gaps between economic value and price in the energy systems transition debate are addressed for clarifying the boundaries on public energy strategies and therefore also on practical regulation. This comprehensive helicopter perspective frames the substitution of RE, in particular renewable IGOP, for existing power systems. The proper reference point for fixing the analysis and policy is no longer the prevailing power systems and practices, but the future, fully RE based, electricity generation and supply systems. The transition from present systems to the due future electricity systems, is a long-term and expensive undertaking. With the end-state as the valid reference point, and applying the widely adopted "polluter pays principle", the agents accountable for the inherited and present non-sustainable power systems, are also accountable for the transition expenditures. The main components and relationships of today's liberalized electric power systems in Europe are described in section 3. Next to an overview of the bulk and retail activities, the section situates the Independent Generators of Own Power at a different place from the other generators. Other than available power generation dichotomies, section 4 identifies two classes of power suppliers: "Commanded Generation Plants", built to serve power loads of customers, versus plants operated by "Independent Generators of Own Power". Both classes include renewable electricity providers. For being successful the 100% transition to RE will rest on the unfettered growth of IGOP. What makes IGOP special is their autonomy and the bi-directional power exchanges with the central power systems. In section 5 is shown that IGOP will not or poorly develop when a short-run market pricing scope is imposed, what would reflect the observed value-price gaps of section 2. On major aspects making electricity an attractive energy for end-users, IGOP do not deliver simply. Policy implications of the proposed spread of liabilities over actors during the power sector transition are overviewed in section 6. The concluding section 7 discusses whether politics should give priority to present market conditions and rules, or should opt 100% for the transition to a 100% RE sector.

2. Gaps between economic[2] value and price

At the 2009 Copenhagen conference, political leaders of the major world economies joined the EU in targeting +2°C as maximum global ambient temperature increase. Since then, global politics has added one more schism to the sustainable development one, agreed upon at the 1992 Rio conference. The intentions and declarations are fine, but their conversion in reality requires unseen changes (WCED 1987), while deep change actions and practices are not evidenced. Several disciplines study the rifts, and provide elements of explanation (e.g., Meadowcroft et al. 2012).

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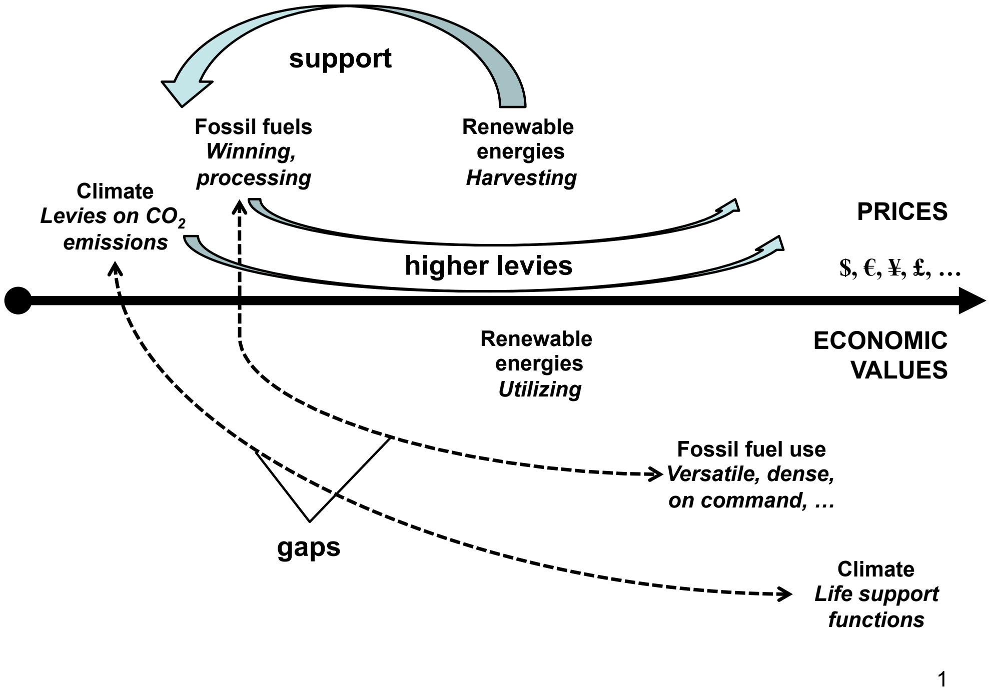
[2] The focus is on economic value, i.e. on direct use value and on option value for preserving future direct use values. Not considered are other components of "total economic value" (Pearce and Turner 1990), for example serendipity, existence, and bequest values.

In energy policy terms, the +2°C limit means the full transition of fossil fuel based economies to economies thriving on renewable energy sources (IPCC 2012). The economics of such transition are challenging, facing two major economic value-price gaps (figure 1). First, the direct use value of fossil fuels is huge because they are versatile, dense in energy content, easily stored and transported, etc. (Verbruggen 2008). Their negative impacts on human health, environment, and in particular greenhouse gas concentration in the atmosphere, are unpaid externalities. Fossil fuels are sold at low prices because only winning and processing expenses are accounted for. The wide gap between direct use value and low prices[3] explains their irresistible use, fuelling the impressive economic growth in some parts of the world since World War II. Second, respecting the +2°C limit implies most of the fossil fuels resources will be left in their natural deposits. Foregoing the huge fossil fuel bequest for preserving sufficient climate stability means the risks of wrecking the climate are evaluated higher by global politics than utilizing the fossil fuel bequest. The gap between the economic value of the natural climate as a major life support system, and the (almost zero) price of global greenhouse gas emissions is even larger than in the fossil fuel case. As a corollary, the global CO_2 emissions continue to grow, increasing the risks of irreversible disruption of the climate. Figure 1 indicates that the economic value-price gap is small for renewable energies: the distance between harvesting and utilizing renewable energies is mostly short, and even reversals in the gap (i.e. harvesting price higher than utilizing value) may occur under local and short-term conditions. For meeting modern energy services of exigent consumers, temporal and spatial spot dependent renewable energies are of lower value than fossil fuels available on command.

Figure 1: Economic value-price gaps for climate, fossil fuels, and renewable energies.



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[3] Fossil fuels moreover are subsidized. The International Energy Agency (World Energy Outlook) estimates US$ 406 bn over 2010, and US$ 523 bn over 2011.

Bridging the value-price gaps is feasible by increasing the prices of fossil fuel use and by setting increasingly higher prices on emitting greenhouse gases, with both pricing policies concurring. Most fossil fuel bequests are national states' property or privatized. Handled as private goods, huge rents and profits for the owners are generated, especially when prices exceed several times the expenses of supplies. Continuous high (and mounting) fossil fuel prices trigger alternative energies substitutions. The substitutions would multiply when the bulk of fossil fuel rents would be appropriated by end-user countries through levies with spending revenues on R&D and subsidies for renewable energies (figure 1). The global climate is a pure public good. The revenues from pricing emissions belong to the treasuries of public authorities, and are welcomed for covering mitigation and adaptation expenses. Presumably the most effective mitigation strategy is the transition of today mainly fossil fuel based electric power systems to very low carbon ones, practically spoken: 100% renewable resources.

The climate and fossil fuel value-price gaps overarch and direct many costs-expenses and benefits-revenues gaps, thoroughly affecting the transition processes. Economic theory defines costs as forgone opportunities of all - private and public - factor use. Economic agents' decisions are based on expenses as the product of prices applied or accounted for factor use. The transformers from full costs to actual expenses are opaque, incomplete and biased by the addition of rents (Verbruggen et al. 2010). In a similar way revenues received by economic agents may be very different from obtained - private and public – benefits. Schaber et al. (2012) "quantify changes in power producer revenue due to variable renewable energy generation" as performance indicator, not clearly comparable with the more standard public economics indicator "overall welfare gain". Mingling concepts leads to confusing vocabulary and statements in the transition endeavor. Confusion mostly strengthens the position of the established or incumbent state of affairs. Especially economists consider 'what is' as the relevant reference point for assessing costs and benefits of propositions or measures deviating from that point. A reference position is implicitly assumed as the best. In case of climate change and non-sustainable energy supply systems, the 'status quo' reference is evidently a very inferior situation. A society fully thriving on renewable energies is a much better reference state, even it is work in progress and ex ante more difficult to describe.

Identification of the proper reference point on the transition track is highly important for the assignment of tasks and allocation of the incurred expenses. First, the superior endpoint of the transition track rightly claims to be vested as reference. Explicitly describing the future state a society should reach also is a major component of "back-casting" analysis (Robinson 1982). Second, reversals in thinking, analysis, vocabulary, evaluations, etc. are necessary when shifting the reference position from the present to the future. Renewable energies cannot be labeled disturbing or disruptive any longer, but every progress in their development and deployment is a step towards the goal to reach. One also will thoughtfully and differently 'integrate' RE in current power systems, when keeping clearly in mind the task of turning current systems in 100% RE based power systems in a proximate future. Third, but not least, loading the expenses of the transition on the solutions and change agents of the superior future is not really helpful to advance that future; remains the bill is better footed to the lagging incumbents. This implies for instance that the costs of integrating RE supplies in existing central power systems and the expenditures for adapting the systems fall largely or entirely on incumbent power sector interests. This approach opposes claims for charging costs of disturbing incumbent production and transmission systems on RE supplies when the latter make inroads on established power systems.

The "polluter pays" principle (PPP) legitimates the imposition of obligations on incumbent power companies to pay for the costs of transitioning from existing high-carbon and high-risks systems, inherited from the fossil and nuclear era, to future RE systems. In 1972 the OECD agreed that polluters should pay the costs of abating the own environmental pollution, for example by installation of filters, sanitation plants and other add-on techniques. This narrow interpretation of polluter pays intended to avoid that governments would (continue to) subsidize polluting industries for building treatment plants, scrubbers, waste incinerators, etc., Rather "the polluter should bear the expenses of carrying out the above-mentioned measures decided by public authorities to ensure that the environment is in an acceptable state" (OECD 1972). The PPP extends the responsibility of polluters when, additionally to abatement expenses, they pay for the damages their residual pollution is causing or may be causing. Eventually the PPP may also scope the impacts of historical pollution, although "allocating responsibility raises a series of practical and ethical questions. The attribution of 'blame' should arguably depend on some knowledge that harm is being caused" (Heyward 2007),

Another extension is the "precautionary polluter pays principle" where potential polluters are mandated to take insurance or preventive measures for pollution that may occur in the future. For example, requiring full-indemnity insurance for the harm and costs that any specific power plant may occasion would increase the price of polluting fossil fuel plants. Arguably, the requirement will preclude the construction and operation of nuclear power plants, because the global re-insurance sector rejects underwriting nuclear accident risks (Verbruggen 2008).

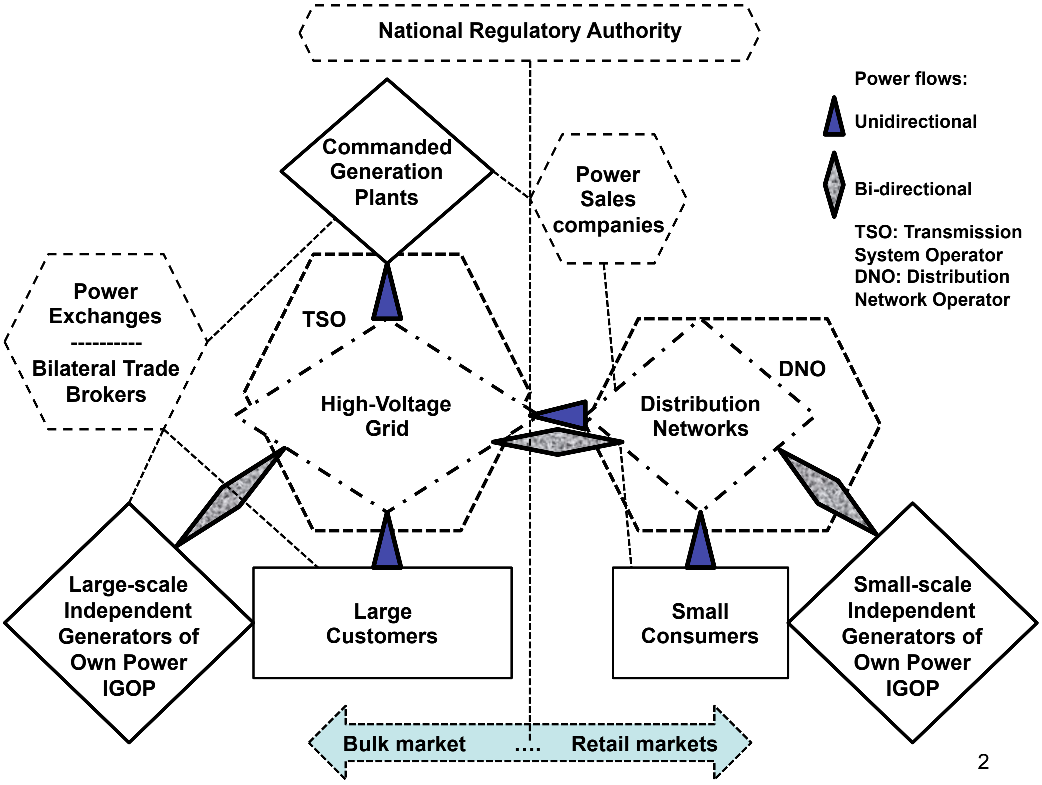
Polluter pays is also known as "extended polluter responsibility". This makes actors responsible for the effects and impacts of their actions, not necessarily limited to directly objected and observed harm to living people whom property rights exclusivity is trespassed (Cordato 2001). Applying extended responsibility to incumbent electric power interests equals charging them with objective liability, making one accountable for causing societal harm without establishing guilt. It signifies the application of payment for actions in the past where the power sector planners and investors being held accountable did not or could not have foreseen the consequences. The practical application of objective liability is utterly difficult and contentious, and every measure "needs to somehow reflect degrees of responsibility for the causes of the problem" (Heyward 2007).

In focusing on the main principles, this article is not attempting specific solutions for implementing the extended polluter responsibility. When discussing policy implications in section 6, some specific issues of footing the transition bill in Flanders are examined.

3. Extended participants in EU's liberalized electric power supply systems

Liberalization of electric power systems started during the 1980s (Joskow and Schmalensee 1983) and ever since affected national power systems on a global scale (Besant-Jones 2006). In February 1997 the EU published a directive on the internal electricity market, but its design and implementation delivered a variety of mixed market structures all over Europe (Glachant and Finon, 2003). Figure 2 shows the main components of, and participants in, present-day electric power supply systems in Europe, and some of their relationships. The left side of figure 2 represents the bulk electricity market; the right side the retail markets within a given geographical area.

Figure 2: Components and relationships in liberalized electric power supply systems in Europe



Before liberalization, electricity supply was a fully vertical integrated industrial activity covering generation, transmission, and distribution. The latter main economic activities were organized as separate entities within the vertical column, and guided by the central intelligence of a multi-leveled system operation unit. Investment and operational decisions were optimized with the help of scientifically based algorithms. Central supervision provided stability and neat balancing of supply of and demand for the non-storable power flows. Internal system operators continuously maintained system equilibrium. They were entitled with full command (unit commitment, dispatching) over the generation capacities, and covered a national or sub-national territory. Exchanges with adjacent control areas were limited, with some arbitraging of peak loads and last resort back-up power supplies by colleagues (IPCC 2012).

Electricity sector liberalization intended to substitute free market principles for vertically integrated supply structures. However, realizing workable competition in such tightly managed systems was contingent on a logical sequence of prerequisites, viz. proper harmonization of rules and conditions for participants in the to become "competitive" markets, transparency of the institutions and activities, unbundling of the main functions (generation, transmission, distribution), and firm guidance and supervision by excelling independent regulators (Verbruggen 1997). The three EU regulatory packages (1997, 2003, 2009) could not fully impose the prerequisites on the member states; one had to continue with very different institutional and political contexts. The three packages could not yet iron the inherited uneven systems to a single internal electricity market, and competition remains partial and incomplete with influential roles by remaining state companies (e.g., EDF, Vattenfall AB).

Figure 2 shows an unbundled structure of power generation activities, the high-voltage grid transmitting power to bulk demand nodes, and distribution companies operating low-voltage networks to serve the retail demands. Liberalization forced unbundling of the organizational entities that are processing physical power flows, and added several new entities, such as power exchanges, bilateral trade brokers, power sales companies (also called: suppliers), embroiled as intermediaries in contracting power transactions. The new institutions function on legal and financial terms, not intensely interfering in physical electricity flows; they are shown as hexagons with dashed borders in figure 2. At the top of figure 2 is shown the national regulatory authority, supervising the electricity sector. System operators can function independently of any physical power supply activity. In Europe they mostly are merged with grid owners and operators, and named transmission system operators (TSO) that also assume responsibility for overall balancing power generation with loads. In large areas, TSO decentralize to subdivisions and to distribution network operators (DNO). System operation is growing more challenging, because of limitations on the authority and on the flexibility in unit commitment and dispatching of many low-carbon power plants (nuclear stations, flow renewable energy sources), exponential growth in number of new power producers (Schleicher-Tappeser 2012), and more technical or institutional constraints on operating individual plants. Technical constraints are for example ramping rates in loading and de-loading generation units. Institutional constraints are related to ownership, legal or contractual privileges (e.g., 'must run' or interruptible), reliability priority for supplying particular end-users (e.g., hospitals), and similar factors.

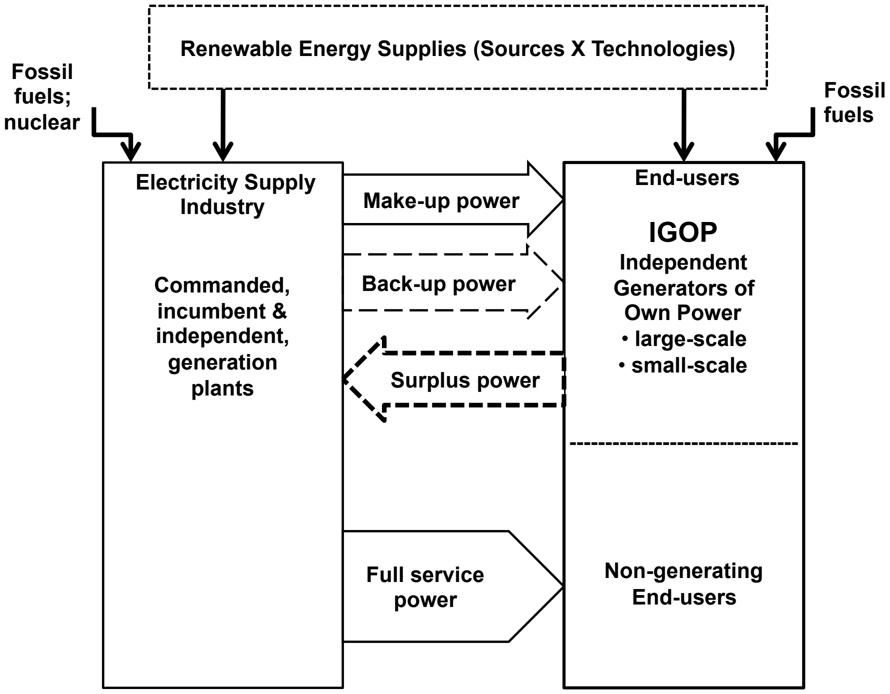
4. Two main classes of power generators

Power generators are classified according to specific purposes, with terms and definitions often unsettled, for example: central versus distributed; independent versus incumbent; (variable) renewable energies versus (on command) fueled plants; small-scale versus large-scale. Figure 2 identifies two main classes. At the top of the figure are mentioned "Commanded Generation Plants", permitting full institutional dispatching of their capacity on contract with the TSO, i.e. delivering power when requested or withholding generation when demand for power is low. It encompasses the production facilities of previously vertically integrated incumbent power companies, mostly consisting of several stations and units of a wide variety and range of capacities, including (very) large-scale plants. This class also includes independent power producers that exclusively generate power for selling to customers through the integrated power system. Liberalization and unbundling are anyhow blurring the differences between incumbent and independent ordered generation. Both may deploy conventional nuclear or fossil fuel technologies, combined heat and power, or renewable supplies (now mostly biomass, hydro, wind; in the future, presumably more concentrated solar power). Generally, the independent plants are more small-scale and distributed than the plants of incumbent power companies.

The other class of power generators (bottom of figure 2) consists of – large and small – "Independent Generators of Own Power (IGOP)". They are often named "on site" generation because they are placed at the premises of large customers (industrial plants, commercial sites) or of households and small businesses (PV at building roofs, small-scale cogeneration). IGOP use fossil fuels (often cogeneration or combined heat and power units) or renewable sources and technologies. They build and run power plants to serve primarily the own loads but in interaction with the – high-voltage or low-voltage – power grids. Grid connection is preferable for attaining the best reliability/cost ratio, due to the non-storable character of electric power.

Commanded (incumbent or independent; central or distributed) generation plants are single-directionally linked to the power system: they only deliver power. IGOP (large-scale and small-scale) are bi-directionally linked (figures 2 and 3). IGOP mostly switch roles from (net) supplier to (net) consumer of electricity, forth and back. This aspect created the name "prosumer". When technically feasible and financially opportune IGOP first serve the own loads and eventually send surplus power to the grid. When the own loads exceed the power output of the IGOP plants, electricity is imported from the grid as "make-up" or as "back-up". The distinction between the latter flows is important when electricity tariffs include a high fixed term (price per monthly kW-peak) argued as coverage of high investment outlays in base-load plants. Power use by energy intensive industrial sites is generally labeled as base-load power, with electricity tariffs including high payment for the monthly requested (quarter-hour peak) capacity. It is not grounded to apply this tariff on a demand spike for back-up purposes of short duration (Verbruggen 1990).

Figure 3: Two main classes of power generators: standard generation plants versus independent generators of own power (IGOP)



Surplus power from IGOP delivered to the grid is disturbing power system balancing when overall low load is already challenging TSO in keeping commanded, inflexible (often large-scale), generation capacities on line. The short-run price of the kWh may then fall to zero, or become negative when payment is needed to purge superfluous power. Structurally, the system is too heavily locked in large-scale fossil and nuclear production plants resisting to be reduced in output. Also the system is short in buffering facilities where power can be converted in storable energy, which can be reconverted back to electricity. Technically, spiky fluctuations are wearing and tearing electricity supply equipment. Financially, longer periods of running below full-load capacity erode the bottom line accounts of generation plants.

Assigning a central role to IGOP will increase the size of surplus power deliveries to the grid. When for example cogeneration IGOP is dimensioned on heat demand of some industries, significant electric power capacity may be installed when the terms for delivery to the grid of surplus power are financially guaranteed. Also private persons and small companies with large, well-oriented roof surface may yearly generate double or more PV electricity than the own activities absorb.

A completed transition to 100% renewable based power systems, may find IGOP as the most common and predominant type of power supplies. Growing importance of IGOP is inevitable, and regulation can play a stimulating role not a choking one. Germany is applying premium schemes to safeguard positive stimulation. Gawel and Purkus (2013) provide an evaluation of the schemes, and confirm that “limited possibilities of wind and PV installations to react to short-term price signals impose fundamental constraints on the (premium) instrument’s ability to improve their system integration”, with as logical next step that “systemic concepts are required, which draw on all components of the energy system (…)”. They express “doubts whether the current electricity market design is suitable at all for integrating large scales of RES.” This quote and several other positions in their analysis, reveal that they look at the transition challenges from the present, incumbent perspective, while concluding another view is necessary. The latter finding is argued in this article.

Geelen et al. (2013) sympathize an active role as co-providers for end-users connected to smart grids, but observe “little is known yet on how to shape active participation of residential end-users in smart grids and thus how to support them in achieving the role of co-provider.” They join Verbong et al. (2013) in observing that technology and financial incentives dominate the discussions and the development. They consider “the focus on technology and the protection of vested interests” as main threat to smart grids. Nykamp et al. (2012) investigate various regulation designs on effectively stimulating DNO investment in innovative smart grid solutions (local storage, voltage regulation).

If one adopts the future 100% RE system as reference position (as argued in section 2), we propose to deploy a different approach by regulators, as follows: DNO are hold liable for all cases where small scale IGOP investments or activity are curtailed; TSO assume similar liability for large scale IGOP. Penalties paid by DNO and TSO (and charged on electricity consumers) for such shortcomings are redirected to fund innovative smart grid investments, storage facilities, dedicated fast ramping, decentralized generation units, optimization of IGOP activities and their power grid interactions, etc. Remedying the problems is directly linked to penalizing their symptoms.

5. Integrating IGOP in power systems

Table 1 provides an overview of five variables (column 1) affecting the transient quality and therefore the spot market value of the supplied kWh. In columns 2 and 3 is assessed how commanded power generators and how IGOP perform on the five variables. On time and speed, commanded generation by far outperforms IGOP; this is due to their respective roles in dispatching and optimizing integrated power supplies. The differences sublimate in the attribute 'liability to serve'. Commanded generation plants adopt full liability if ready to supply when the system requires their contribution, and if abstaining from delivery when there is no demand for their power. 'Full' liability is attenuated by specific terms in the relationship between commanded plants and the TSO. In principle, IGOP assume no liability to serve: they are not engaged to supply when the TSO would want it, and they deliver power to the grid when technical feasible and matching their financial self-interest. This reduces the market value of IGOP power compared to the value of power from ordered generation plants. By accepting some liabilities to manage their plant availability, IGOP enhance the market value of their kWh supplies (Gawel and Purkus 2013).

Table 1: Market value of a kWh supplied depends on five variables, implemented differently by IGOP and by commanded generation plants

Market value of a kWh supplied depends on	**Commanded generation plant**	**Independent generator of own power (IGOP)**
Time of delivery (synchronous with system base to peak load fluctuations)	Delivery at command if unit was committed; variable RE contribute when sources deliver on time of request	Delivery not at command; net power offered according source supplies (renewable) and own demand for power, and for heat (cogeneration)
Speed of delivery (immediate, within seconds, minutes, hours)	Plants ready for dispatching but limited by ramping rates and flexibility; some plants specialized in high flexibility	Most IGOP capacity not available for dispatching.
Liability to serve	Produce power on demand – shunt power production if not demanded	Deliver power in surplus of own needs when profitable; IGOP switch roles producer-consumer
Place of delivery	Central large-scale stations supply bulk power; renewable sources often distant from the grid (e.g., off-shore wind; hydro dams)	Distributed locations near load centers, creating meshed deliveries; participants in smart grids.
Reliability	Source, technology, project, environment, … specific	Source, technology, project, environment, … specific

Mostly IGOP is well located, avoiding transmission activities and corresponding losses. The advantages of being located near the power load centers are difficult to measure and to quantify, because they depend heavily on the momentary simultaneity between IGOP surplus delivery to the grid and demand for power by consumers on the local grid. Because IGOP may request full back-up power when the plant is down, the compensation advantages may have only minor impact on grid capacity and thus on a significant share of the investments. The capacity effect is also dependent on the type of IGOP, considering, for example, the difference between intermittent PV and industrial combined heat and power units.

There are no arguments why reliability of particular plants should change because of other ownership, e.g. PV wherever installed, is technically very reliable, presumably the most reliable power generation technology forever.

From table 1 follows that electricity forthcoming from IGOP scores a lower market value than electricity from commanded generation plants, the latter being exclusively dedicated to serve the market. Leftover to the established systems and institutions, it is unlikely that IGOP may win the uphill market battle against incumbent power generators that run ordered plants. Nykamp et al. (2012), and Gawel & Purkus (2013) reveal the difficulties in developing proper financial incentive mechanisms to overcome the prevailing market structures and rules. Moreover, the mechanisms must stay transparent and provide certainty for implying many millions more of small RE generators. There is no future in expecting that more than a small percentage of end-users ever can be engaged in the intricacies of electric power systems, a neither economic, nor social beneficial time passing for the vast majority of people. The corollary is high exigencies to regulations for bringing IGOP from its present non-competitive position to the default electric power generation option. Only effective, efficient, and fair, but also simple and transparent regulations may engage millions of building owners and small companies.

6. Policy implications of the proposed spread of liabilities

Before developing the detailed, and often tricky, regulations of electric power sector transition to 100% renewable energy supplies, an encompassing helicopter vision is recommended. Every modern power system is widely branched and multi-leveled, however continuously integrated by a single, common frequency control. Within the technical constraints there is ample choice on the degree of centralization of the power supply industry.

A first policy decision is to state explicitly the priority assigned either to centralized power supply plants, or to distributed IGOP (Independent Generators of Own Power). Priority to IGOP is the more sustainable option, but also the more distant one from inherited power sector systems and practices. Acting along the priority for IGOP implies innovative technical, financial, and regulatory approaches and mechanisms, which development and deployment necessitates further policy decisions.

The second policy decision is shifting the targeted benchmark or reference point, now anchored at past or present electric power sector structures and practices, to a reference reflecting the 100% renewable electric system as envisioned by the first policy decision. A clear view on the future vantage point is most helpful in backcasting the suitable steps for an effective, efficient, and fair transition.

The third policy decision is the application of the polluter pays principle in its advanced version of “extended polluter responsibility”, for allocating the expenses of the conversion of the power systems from fossil fueled and nuclear, to very low-carbon and low-risk power supplies. Once societies and their political representatives have recognized the significant economic value-price gaps in climate, fossil fuels, and renewable energy supplies, they opt for the full (and urgent) transition to 100%

renewable electricity systems. Realizing this principled choice in practice means significant reversals in ongoing activities and practices. In comparison to ordered power supplies that are dispatched on command by a system operator, IGOP power has a lower value due to weaker commitment to supply liability in meeting the intense and exigent demands by affluent electricity consumers in wealthy countries. Left over to thriving electricity trade practice, IGOP has little chance to fulfill its historical role in the 100% renewable energy transition. Public intervention for changing the trade rules is urgently on the agenda.

Germany is the industrialized country with the strongest commitment to turn over its electricity supply sector from a mainly fossil fuel and nuclear fission based one, to a 100% renewable electricity version. Integrating RE is mandated for grid operators in Germany, except when the connection exceeds 'reasonably economical' costs. Minimizing expenses is a justified efficiency goal, when all costs are fully identified, and measured from the proper future reference point.

The danger of volatile policies is real when the encompassing meta-vision on the transition is lacking. For example, the Flemish government and regulator are now taking back money from PV investors, after attributing too high subsidies as guaranteed certificate payments (in fact: guaranteed premiums on PV output) in the period 2008-2012. Since January 2013 onwards, household PV plants in Flanders are practically no longer subsidized. On the contrary, all PV owners pay a yearly fixed fee (per kWp installed inverter capacity: € 56 to € 83 in 2013, depending on the distribution utility), or they can install a smart meter to measure and bill their power exchanges with the grid (Eandis 2013, Infrax 2013). This policy U-turn has significantly retarded the transition to a low-carbon and low-risk electricity supply sector.

7. Conclusion: Opposite perspectives on integrating renewable supplies

Respecting the +2°limit of the Copenhagen Accord (in December 2015, reaffirmed in the Paris Agreement), implies that the world's electricity generation systems turn to zero or very low carbon sources (IPCC 2012). When accepting that RE, in particular RE built and operated by IGOP, have to become the default generation option in a 100% RE system, a comprehensive helicopter view on the transition and integration issues is requested. In case of direct short-term competition between established power systems and IGOP challengers, the latter will fail to develop (section 5). Two arguments for overcoming the fallacy of direct spot competition merit consideration. The minor argument is that today's power supply systems are distant from market competitive optima as hailed in the economics literature. Most economic analysis of power systems starts from the hypothesis that electricity companies obey competitive market rules. For example, it is assumed that most electricity is traded at power exchange prices, and that the spot prices at the exchanges reflect the true short run marginal supply costs of power. This way of pricing would approach the theoretical bliss under two conditions: all power is traded at the transient short-run marginal costs that include all the public and private costs of used economic resources, and the generation system is optimally composed (so that the equality of short-run and long-run marginal costs prevails, guaranteeing that short-run prices also cover the fixed expenses on the plants). In reality, both conditions are not fulfilled. Large quantities of electricity are traded under long-term contracts, mostly including substantial capacity payments. Consecutively, the national power supply systems in Europe (that together make up the European system) are far from textbook optimal composition, formerly targeted by vertically integrated monopolies. The long-living fixed assets systems have been perturbed, e.g., by the EU liberalization packages, and by unexpected growth of RE capacities. Public authorities and regulators deliberately acting to promote and support RE (like in Germany is the case) are molding the 100% RE systems of the future as the reference to construct. They base the policy on the other, major argument: today's power supply systems are completely grown adverse because of unpaid externalities and unpaid risks of its large-scale fossil fueled and nuclear plants. The energy systems of the industrialized world were driven in a non-sustainable direction by two major economic value-price gaps (section 2). Fossil fuels and the global climate have been and are still highly over-used (or abused) because their prices were and still are far below their value. The political target of a maximum global temperature rise of +2°C is set, implying the task of transiting to low carbon energy economies. The electricity sector is seen as the first major energy subsystem that can and should realize the transition. Understanding well the structure, composition, working, and participants in this sector is a prerequisite for finding the most effective and efficient solutions (section 3). The position and characteristics of IGOP are highlighted, without full dissection of the various cases and situations that one meets in practice. New mechanisms to support IGOP must stay transparent and provide certainty for implying many millions more of small RE generators. There is no future in expecting that more than a small percentage of end-users ever can be engaged in the intricacies of electric power systems, moreover neither economic, nor social beneficial. This condition challenges governments, and their regulatory authorities, to stay on top of the power sectors (figure 2) and of their evolution. For supporting IGOP, objective information is needed about asymmetries in supply liability, remuneration of IGOP surplus power supplies to the grid, pricing of back-up power from the grid to independent generators. The issues are often not well understood and generally contentious, but of high importance for the effective, efficient and fair transition from non-sustainable to 100% renewable power systems.

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