INTRODUCTION

Most of the existing urban infrastructures can be typified as 'end-of-pipe' planning strategies. We transport waste, wastewater and even relatively clean rainwater outside urban districts to centralised treatment plants. We attempt to generate electricity or gas in centralised gas plants. The upshot of this is much more than the transport requirement and the use of extra material and energy. The inevitable mixing of different elements and/or qualities is detrimental to the overall quality. The majority of the transported flows undergo qualitative and quantitativie losses during transport, which also has serious impacts on the immediate environment. The way to permanent urban development appears to be elusive. In modern town planning new inventions and the introduction of intelligent reduced (or light) infrastructures are required. In the long term only closed cycles for processes and use of material could result in a permanent urban environment.

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ABSTRACT: The technical infrastructure (networks) of the essential flows (energy and sanitation, i.e. water, waste) is determinative to what degree a project, varying in scale from a (part of a) building to a city or conurbation, will or can be sustainable or even self-sustaining. This is due to its 'path-dependency', long term- and endogenous character and the existence of a limited number of dominant actors per network or flow, which have interest in little change of the 'ruling' paradigms. The physical and formal distance to users and the complexity for them to understand the processes and possible (sustainable) alternatives result in an increasing dependence (heteronomy) and a declining overall involvement. To be able to change the built environment in accordance with the principles of sustainable development there is a need to turn around the inter-relationship between the infrastructure and the suprastructure. Decisive aspects in a continuing urbanizing, and connected world with crucial dependency on integrated computer networks, will be the flexibility of the concept of generation, treatment and transport of the critical flows; the adaptability to passive- and natural technologies; the seize of space; and the overall resiliency to failure, inaccurate use and sabotage. The paper focuses on rethinking the urban planning as a whole, with emphasis on a changing attitude towards the relationship between the technical infrastructures of especially the energy flow related networks and the 'suprastructure'. Basis forms the application of the power-law concept, also known as Pareto or Zipf to the technical infrastructures concerning the essential flows in the built environment. Not only the (known) dependency of decentralized concepts on central networks, but also the reverse will be argued: the needed aggregation of decentralized micro-networks, or clusters and systems to the complex and continuously growing centralized networks. Main objective is to cope with the risks of rising complexity and continuing unity, apart from the rising need of resilience of the overall network in case of loss of parts. This, for our economy is increasingly reliant upon inter-dependent and cyber-supported technical infrastructures and information systems.

1 INTRODUCTIO

Most of the existing urban infrastructures can be typified as 'end-of-pipe' planning strategies. We transport waste, wastewater and even relatively clean rainwater outside urban districts to centralised treatment plants. We attempt to generate electricity or gas in centralised gas plants. The upshot of this is much more than the transport requirement and the use of extra material and energy. The inevitable mixing of different elements and/or qualities is detrimental to the overall quality. The majority of the transported flows undergo qualitative and quantitativie losses during transport, which also has serious impacts on the immediate environment. The way to permanent urban development appears to be elusive. In modern town planning new inventions and the introduction of intelligent reduced (or light) infrastructures are required. In the long term only closed cycles for processes and use of material could result in a permanent urban environment.

Building infrastructure almost always implies slow and large-scale processes. For a structural solution and preservation, the technical infrastructure should be considered because it will be
leading for the design and the allocation of the faster dynamics of the overlying layers: the layer of the overground “networks” and that of “occupation”. The infrastructure strongly correlates with production (supply as well as drainage). A change desired in the infrastructure, e.g. a bottleneck with respect to capacity, can be solved by investing in extending the infrastructure (now often accepted), but often also by adapting the “production” or “treatment” in strategic spots of the (central) grid.

This is the background for the presented research (Timmeren, 2006). It tries to demonstrate the need to include interdisciplinary approaches to the essential flows (energy, water and waste) and belonging infrastructures, integration of strategies for raising public awareness and improved use of the different qualities of water and energy (cascading qualities, or so-called low-exergy design). It is argued that for a lasting sustainable urban development and a necessary improved network geometry (Watts & Strogatz, 1998; Banavar et al., 1999) with respect to these essential ‘flows’, further development based on the future path of scaling-up of different networks and users will have to be combined with decentralised sub networks, or clusters, aiming at autonomy.

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2 THE ESSENTIAL ROLE OF TECHNICAL INFRASTRUCTURES

2.1 The relation infrastructure - suprastructure

During the contemplation of the different flows and the several belonging energy- or water-concepts and belonging forms of technical infrastructure one needs to pose the question: what is the real exigency of this specific infrastructure and which is the best physical form of appearance? Additionally one should think about the relation between (technical) infrastructure and the social goals that are aimed at, doing this as much as possible independently from the existing ways of thinking and existing arrangements.

In case of the stated question, one has to reflect newly upon which social needs exist, and which (technical) infrastructures belong to these needs. There is a common consensus in society about the necessity of fundamental facilities for meeting the most fundamental needs in the own living environment (support, protection, affection, understanding, participation, relaxation, expression, identity, freedom). Support, or maintenance, includes the availability of energy and food, including clean drinking water, and the removal of waste (water).

The different standards of societal needs and goals, which form the basis of all physical networks of logistical chains, including the (technical) infrastructures, are defined as the ‘suprastructure’ (Ruis, 1996). It is no use trying to introduce sustainability measures that harm the previous stated fundamental need. Many relevant participants however do not seem to realise that other, more sustainable alternatives can be found by abandoning the specific characteristics of the traditional paradigms rather than following them. The dominant participants have an interest in using existing structures as efficiently (economical) as possible and in developing them further with as few risky investments as possible. Looked on from the aim of “sustainable development”, the common path of expansion selected (centralisation) is not necessarily the optimum as perceived subjectively.

The ‘Development Alternatives Centre’ (CEPAUR) together with the ‘Dag Hammarskjöld Foundation’ were the first in formulating the suprastructure of a society. The developed theory is based on two suppositions: First of all, fundamental human needs are not unlimited but restricted in number, moreover can be classified. Secondly, fundamental needs of different cultures and historical periods are the same (Max-Neef, 1991). In the decision processes concerning changes or extensions of the technical infrastructure the decision-making will be optimal if the suprastructure (strongly related to planning) and the infrastructure (maintenance of the planned) are tuned in well to each other. This is easier said than done since there is a matter of a ‘centralisation paradigm’ in case of technical systems (concepts) and belonging infrastructures. This goes especially for the essential energy- and waste- and (waste)water flows.
It has turned out that the ongoing processes of liberalization have put pressure on the importance of the certainty of supply of energy, and also removal of waste and waste water. Working certainty of supply and independence out in further detail seems necessary, or even essential. A possibility is connecting or disconnecting (decentralised) sustainable sub production (generation or processing capacity). This may be realised by including sustainability, via reliability, as an added value at relatively little cost, e.g. in the form of a decentralised utility and backup, possibly even aiming at autonomy. Too little advantage is taken of this aspect of sustainability. It may involve short-term interventions for long-term guarantees (sustainability, guarantees for supply/processing and in the end affordability). Such a principle may be useful as a kind of fallback scenario for, for example, a serious and unforeseen dysfunction of the current process of further scaling up and liberalization of sectors.

So essentially two future paths for the development of (sustainable) technologies and concepts concerning the energy and sanitation (water and waste) flows are distinguished: further development based on the future of scaling-up and heteronomy of different networks and users, and decentralisation with the aim of local autonomy (or even autarky). In short concepts based on the “economies of scale” versus concepts based on the “scale economy” (Timmeren, 2006).

With respect to both extremes, globalization (heteronomy by interconnection) and striving to complete (ecological) autarky cannot be seen as an optimal development for the so-called ‘structure’, or, in other words, a good, democratic basis for societies. And what is more, neither of them (in their specific pure form) is to be considered a good basis for further, sustainable development of the structures for those societies. For the essential ‘technical infrastructure’ (i.e. energy, waste- and water infrastructure), the dynamics of non-simultaneous, slow transformation necessary for attuning the complex structures of society, the ‘flows’ and nature (or natural processes) implies that it is wrong to still think in separate systems within integral development processes. That is, since there is an increasing interconnection and interdependence in the technical infrastructure of the essential flows. Although an increasing interdependence and heteronomy between people and their institutions can be noticed, Goudsblom (Vries and Goudsblom, 2002) claims that the dependence on natural forces has become less direct. The technical and social chains between the production of objects and their use (“source and service”) are longer and more forked (complex).

In practice, we see far-reaching semi-autarkic projects being connected to central infrastructures. What still is unknown is that, to be able to connect to the electricity infrastructure, to a larger extent than approximately 30% of the network capacity, projects (subsystems) based on autonomy and/or renewable (discontinuous) sources new network philosophies (or network geometry) and use of these centralized grids should be introduced. Within the existing electricity network it is not possible to replace existing generation by generation through (variable) renewable sources for a larger extent than this 30%. For the sanitation infrastructures alternative use of existing networks offers possibilities to cope with increasing costs due to aging and shortages on capacity due to expansion(s) and introduction of higher densities (Timmeren, 2006).

2.2 Increasing ‘heteronomy’

There are clear differences between the characteristics of the various central networks, in the energy and sanitation sub flows each as well as between the energy and sanitation supply as a whole. They are caused by different “central scales” of application and different extents of visibility, but also by the management structure and the presence or absence of liberalization processes. For sectors that are left to market forces, positive effects are to be expected on the efficient use of the infrastructures, and in Europe, by oligopolistic market types and on the affordability of the accompanying services. However, market participants have no interest in overcapacity, which puts pressure on the reliability of supply (by a maximum bid on the available capacity). Pressure can also be put on the other long-term interests, including maintenance of grids and investments in, research into or application of innovations, e.g. those that aim at sustainable development (Künneke et al., 2001). At the same time, main aspects for users are sustainability, a guarantee on supply and processing and affordability (Quist et al., 1999).

Where the essential infrastructures are concerned, the liberalization of the markets shows that the goals set concerning sustainability cannot always be accomplished in an integral way. At a national level, there is too little grip on the developments. The demand for supervision or rules
at a supra-national level is being heard, and this causes one of the reasons for liberalization with respect to essential services to be surpassed. The “dilemmas of progress” and the so-called “prisoner’s dilemma” force themselves upon us: the deviation from this specific unsustainable (end-of-pipe) type of solution(s) is so expensive and will involve such far-reaching social consequences that there seems to be no other choice than continuing with these relatively expensive infrastructures and systems. Besides of that, the distance created between the (environmental) problem and its solution leads to more and more complexity. The process of changing the inter-related public and private services, systems and infrastructures is becoming more complicated and less predictable. Together with the increased scaling, the convergence of utilities and the growing number of parties and techniques involved have increased the end users’ (consumers’) subjective dependence, or heteronomy.

3 NEW PLANNING APPROACH AS A BASIS FOR SUSTAINABLE DEVELOPMENT

3.1 Autonomy through interconnection and heteronomy or through decentralisation

There are two development processes concerning use of technology for the purpose of autonomy with respect to the essential flows (energy & sanitation): viz. first, the efficiency and improvements in the integration of sub techniques and co-ordinated, connected concepts, and, second, a better harmony between supply (input) and demand of the (different) sub flows. Additionally, there are two more general underlying development processes. The first is the environment-technical, environmental and, to some degree, also social optimization of decentralized systems within semi-autonomous projects. The second underlying development process concerns the link to economic applications related to the surroundings, often determined by soil or users, including taking nutrients back to agriculture and other lateral applications or possibilities, mostly concerning ‘services’ such as car-sharing systems. In addition to the possibility of other types of use of (agricultural) grounds, the link to agriculture (i.e. ‘urban agriculture’) may not only lead to a structurally different infrastructure (aboveground and underground), but also to different country planning as a whole, when applied on a larger scale (Röling and Timmeren, 2005). Some authors claim that this also implies a different (economic) organization: dependent on the scale of application, which amounts to incorporating decentralized participatory democracy or types of federation and confederation on different scale levels (Timmeren, 2006).

This also offers points of departure for interrelating “red” and “green” functions in environmental planning. Here, the aspects of vicinity and comfort are leading. In this situation, the search for an optimum scale of autarky or autonomy of the various essential sub flows in the built-up environment gains higher importance. The critical upper and/or lower limit set by the technology solving one of the sub flows will actually become indicative of the integrated system, and, consequently, of the other sub flows. However, it would be too easy to summarize the need for further-reaching sustainability and sustainable development, with autarky as their ultimate goal, with a plea for nature and natural processes in the city. The new structures should be found in larger freedoms, to be accomplished by closing circles on different levels than the ones belonging to current paradigms, so that a maximum variety of solutions becomes (or stays) possible.

In spite of the potential of the underlying optimization principle of the “scale economy” claimed in much of the literature and projects, and in spite of its importance, which was also proven, it has only been applied to a small extent. Consequently, there still are not many “economies of scale” in this area. However, the sub aspects concerning the application freedom and environmental integration (smaller sizes, fewer secondary demands, etc.) and user-related demands (comfort, ease of use, costs, etc.) do improve noticeably. In projects with a clear organization (or organizational structure) and with responsibilities clearly agreed on the often foreseen ‘problem’ of larger complexity often occurring in integrated systems is not necessarily perceived as only a disadvantage. For users and participants, it emphasizes the additional or ‘lateral’ fundamental needs of “identity”, “participation”, “relaxation”, “freedom” and “self-expression”.

The critical limits that are set for parts of the integrated system, together with changing conditions regarding environment, use, technique or market, imply that such semi-autarkic systems should be considered unstable by definition. Because of the fundamental need of protection of
maintenance, semi-autarkic projects should be able to meet such changes, either by means of a connection to a “backup” system (often on higher scale levels), or by means of parallel solutions (hence over dimensioning) within the system itself.

3.2 Changed network philosophy

In energy supply, there should be more emphasis on increasing the flexibility in the current (infra)structures, including Town and Country Planning in its entirety. The more so since it can be expected that there will not be only one decisive future technology to solve the coming problem(s) concerning security of supply and sustainable development. Especially with respect to energy this asks for a simplification of the processes, products (or rather: services) and parties involved. A larger concentration on integral provision of services, or, in other words, the supply and management of integral packages, offers possibilities. This seems to be reinforced by the (ongoing) liberalization processes. Another solution is having the level of application attune better to the lifestyle and direct surroundings of the users.

The desired changed philosophy described has far-reaching consequences for the way in which infrastructures are designed and integrated. It is important to realize that the stability or resilience of networks is directly related to the their complexity. It is not the components of the various structures that matter, but the way they are organized together as intelligent structures. It is important to learn from the organization structure and topology of other existing adaptive, complex structures. Recognizing the structures of each network is needed for combining their optimally ongoing development, possible decline and damage done to them, whether desired or not, with constant or increasing sustainability and certainty guarantees for user. Random networks with complex topologies often occur in nature, but also in culture. The complexity of many social, biological, communication and transport systems finds its basis in a network that is rather interrelated and that is defined by the system components and their mutual interactions.

The mathematician Alexander (1966) was one of the first to recognize the importance of the underlying structure as the basis for the possible notion of spatial planning and the accompanying physical and social networks. He distinguishes two scale-dependent opponent structures: the tree axiom and the semi-grid axiom. Later research (Watts & Strogatz, 1998) shows that even the smallest addition of random connections to a well-ordered network leads to advantages known from social networks (Granovetter, 1983; Granovetter, 1973), also known as the “small-world” principle (Milgram, 1967).

As opposed to the social networks, the so-called “in-between distance” is relatively large. Within large-scale, aristocratic “small-world” networks, it turns out that a limited number of nodes has considerably more connections than the other nodes. These nodes are called “hubs” and can be considered as the pivots of a cluster. Well-ordered networks often consist of clusters, as do social networks. The importance of clustering is that the loss of one element will not result in any dramatic fragmentation of the network in disconnected subsystems (Barabási et al., 1999; Banavar et al., 1999). The ‘power law’ implies that there is a fixed relationship between the total number of connections and the total number of nodes. This ‘power law’ is also known as “Pareto”, “Zipf” or the principle of “self-organization”, and may be considered as the main generic effect of the increasing networks or complex structures. Moreover, together with the principle of “self-repair” it is the main characteristic looked for in the possible application of “natural technology” for the facilities for the essential flows within sustainable urban development.

Two regimes can be distinguished in complex networks: an exponential regime, leading to homogeneous, egalitarian networks; and a “scale-free”, aristocratic network, characterized by a clear difference in the number of connections per node. The aristocratic network structure approaches Alexander’s semi-grid axiom, but has a structure more complicated and subtle, which make complex structures more easily to be included into the notion of the semi-grid. It turns out that the largest networks with known topological data in the aristocratic network structure show the same characteristics because of further-reaching interconnection (be it on world-scale or not): scale-free characteristics and a distribution of the transport connections according to the principle of the power law.

Almost all structures and networks designed or “ordered” may be put on a par with the tree axiom and have egalitarian characters. In addition to the urban development structures of most (newly) planned cities and city districts, the North American electricity grid is also a relevant...
example. The interdependence of communication networks that are relatively simply accessible and connected to or integrated into the essential infrastructures becomes larger and larger; they are almost always characterized by the aristocratic structure as described above. Because of the desired guarantees for operational safety and sustainability to users at lower scale levels, it is of importance to consider the effects of change (expansion, disturbance, breakdown) at higher scale levels. Research into the resilience or safety of simplified networks, particularly distribution networks, shows that the aristocratic and egalitarian networks are very different from each other. When an uncoordinated breakdown occurs, e.g. because of incorrect use or age, egalitarian structures fall apart rather quickly whereas aristocratic structures allow for more than half of the nodes to be removed for the remaining parts of the network to perform well as a whole. When intentional breakdown occurs, e.g. in case of sabotage, the aristocratic structures turn out to be more sensitive, but it is relatively simple to secure the critical nodes in this type of network (in advance) or to isolate them (afterwards) without influencing the performance of the remaining network. The recent (2006) collapse (blackout) of extensive parts of the electricity grid throughout entire Europe after a relative small accident in Germany subscribes the previous, as does the Asian fall-out of internet and other communication means after the December 2006 earthquake near Taiwan.

It can be argued that the best ultimate goal, when elaborating on the principles of the “economies of scale”, is a complex, adaptive aristocratic structure of each of the networks, or perhaps of the whole that they form together (on regional, national or ‘Euregional’ and even global scale). It implies “scale invariance” and “self-organization”, which are desirable aspects. A precondition is that the network grows continuously by new connections and (decentralized) clusters, and that new connections are connected to the network following the power law, with so-called “multi-connected” connections according to the principle of “preferential attachment”. With respect to this, and in order to be able to understand the necessary process of clustering it is of importance to know the underlying “powers” of the principle of “preferential attachment”, the principle of “the rich-get-richer”. As to this principle, Bianconi & Barabási (2001) argue that the aspect of “fitness” plays a role in competitive networks, or as they state: the principle of “fitter-get-richer”. The aspect of “competitiveness” implies competition within networks rather than market competition between networks. The aspect of “fitness” should be defined differently for the various networks. For the essential flows and their infrastructures within urban development this implies a combination of the extent to which generation, collection and transport are flexible, uniform, consistent and technically & spatially optimized. Supply guarantee together with sustainability is the key word, and this can be reached by tuning and adjustment of quality, optimizing rotation time and smart network design. If the connections between weak nodes are made stronger, by the simultaneous introduction of more “weak connections” between the important nodes in the system, the whole infrastructure can acquire more robustness and, eventually, more perseverance. This is when the necessary mutual connection between operability and sustainability is taken as a basis.

3.3 Decentralised solutions as a basis for sustainability and innovation

The application and fitting in of new decentralized techniques and/or alternative network structures, does not suffice for the accomplishment of “sustainable development”. Too often there is tension between the mechanisms and the institutions that regulate motivation on behalf of individual or joint wishes. In following the conventional centralization paradigm, this type of “ritualism” stands in the way of a development into a society with more opportunities for changes according to the principle of “conformity” (Merton, 2000). It creates niches of “sustainable development” of all alternatives that do not comply with the centralization paradigm (Kemp et al., 1998). This occurs in the shape of concepts that can be placed under “rebellion” and even “separation”. Examples are to be found in some of the Eco-villages, co-housing projects and Eco-districts, started by private – sometimes collective – initiatives and in some instances as individual projects. Although fargoing projects such as the Eco-villages are to be considered as the application typology of “conformity” according to Merton’s definition, they are often placed under the application typology of “rebellion” or even “retreatism” by the dominant institutionalized authorities, looking at them from their own context on the basis of the current paradigm.
Opportunities for a widely supported need for innovation are neglected here, and so is the chance of more significant “sustainable development”, for example through scale invariance.

When started as a niche, it can be taken as a method of allowing innovations to grow for the purpose of a more structural and large-scale use. The starting points of the restructuring processes from the industry, known as “Empowerment” and “Business Process Re-engineering”, are of interest for the (large-scale) systems and networks connected to the essential flows that they may form the onset of research into scale invariance in the crucial infrastructures and their innovations. On the one hand a more market-oriented attitude should be taken as its starting point, on the other a more local or surroundings-oriented way of organizing. The background for this is the global transformation of economies from being focused on “mass production” to a focus on “tailor-made for the masses”. Particularly inspired by liberalization processes, there is now almost only attention for the first aspect within the crucial flows and their infrastructures. The second aspect (surroundings-oriented attitude) implies a larger and more structural change, and offers better opportunities for innovation and further-reaching sustainability (at several scale levels). It is the result of the increasing demand for user-specific, “on-site” solutions.

In current central infrastructures of energy as well as wastewater flows, the possibilities of an alternative network layout are not or not sufficiently taken into account. More and more connections are made between the various networks in gas and electricity networks, but this occurs because of considerations of capacity and economic (business) perspectives, rather than on the basis of the principle of network geometry.

Consequently, there is a direct interest for large-scale central networks to have subsystems as a decentralized clusters included into the complex network. Because of the principle of self-organization, it also offers the possibility and the guarantees for being able to make local decisions with respect to, for example, further-reaching sustainability without abandoning the principle of scale size (“economies of scale”). Systems within decentralized planning concepts may lead to networks, complex or not, with a more strongly decentralized network structure with part of the networks performing relatively autonomously. These may support flexible planning concepts in town and country planning. Moreover, the issue of a more precise attribution of costs to specific customers or transactions (which becomes more and more important as complexity decreases with ongoing liberalization) may be solved or may easier be solved.

3.4 Low Exergy design

Another important approach related to a changed urban planning and related network philosophy is the cascading use of resources, where high-grade flows are used in high-grade processes and residual waste flows are used in lower-grade processes, thus making the most efficient use of the initial value of a resource. This so called low exergy approach taken here is inspired by natural ecosystems, where processes run on the available (usually low exergy) resource flows. This approach is thus in line with the Industrial Ecology thinking of taking nature as a role model. “Low exergy design” and ecological approaches can strengthen the systems, methods and tools used for organizing, operating and supervising the urban environment and will minimize the negative impacts of urban areas on ecological cycles at all levels, creating efficient urban systems and livable cities. A life-cycle approach is mandatory here in order to capture all relevant environmental effects to ensure an overall optimisation of resource use.

4 CONCLUSIONS

One could state that the infrastructure of the essential (or critical) flows, due to its ‘path-dependent’, long term character, importance of network geometry and the existence of a limited number of dominant actors per network or flow, is determinative to what degree a project - varying in scale from a (part of a) building to a city or region- will or can be sustainable. Especially the (waste)water infrastructure and the energy infrastructure can be characterised by transported flows which are not drawn up out of ongoing ‘ecologisation’ and dematerialisation but out of efficiency in central management and other economical factors. From the point of view of sustainability the technical infrastructure and with it urban development therefore seems to be insufficiently efficient.
Differentiation and urban flexibility (i.e. buildings and infrastructures) are pre-conditions for anticipating long-term uncertainties, due to actual liberalisation processes, rising complexities and even sabotage. Sustainable starting-points are suppressed more and more by these changes. However, at the same time especially the urban scale can start up the necessary process of transformation towards real sustainable development, for it takes the best of two worlds. At present however, technical infrastructures still are leading to urban development, often even to the suprastructure of society. There is rising concern for the complexity of structures, aging of existing (technical) infrastructures and even several places of congestion. The development can be qualified for being ‘path-dependent’: as for the essential flows this means a ‘centralisation paradigm’, resulting most of the times in solutions that still include mixing of different (sub) qualities (i.e. are not based on cascading- and exergy principles).

Within this process of path-dependent development, the existing infrastructures therefore can be considered as a growing restriction for sustainable interventions on lower scales, and therefore sustainable development. The strategically or even random integration of decentralised clusters (which preferably approach autonomy) in interconnected centralised networks will help to improve the resilience, flexibility, security and sustainability of the overall network. At present mostly only the dependence of decentralised systems on centralised systems -in general for reasons of storage and/or backup- have been put forward. However, the outcome of the underlying research shows that especially in case of ongoing interconnection, centralisation and liberalisation, both future paths for sustainable development, the ‘economies of scale’ and the ‘scale economy’ need one another mutually.

5 REFERENCES

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