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# No. 10: New Geographies of Infrastructure Systems

Spatial Science Perspectives and
the Socio-Technical Change of Energy
and Water Supply Systems in Germany

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# Imprint

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## 1. Introduction[1]

The liberalisation of markets and the privatisation of state property and public services are among the most significant new developments in the political economy of many countries. These trends are particularly remarkable in the infrastructure supply and utility sector. Traditionally, it was assumed that these sectors were subject to market failure for a number of reasons (natural monopoly, public and merit goods, external effects). The provision of services by the state (or in close association with the state) and the organisation of those sectors in territorial monopolies was therefore long regarded as indispensable. Today, the far-reaching transformation process is being driven not only by the increasing commercialisation of services previously performed by public utilities, but also by ecological modernisation in various infrastructure sectors. This is particularly true for energy and water supply sectors, as well as for the sanitation and transport sector, which regulate a considerable part of the material metabolism between nature and society. These developments have led to decisive changes in the range of infrastructure services available, the economic organisation of infrastructure provision and the forms of state regulation in infrastructure systems.

It can be assumed that these developments cause considerable spatial changes. This affects, on the one hand, the utilities, which extend their radius of economic activity, aim at supra-regional, or even transnational markets and increasingly audit their investments according to competition criteria. Numerous questions arise from this which are of considerable importance for spatial development. In what spatial context do these companies act? Are investments now made only in those regions in which high profits are to be expected? Will structurally weak regions perhaps be at a disadvantage with regard to investments and supplies of services? On the other hand the spatial context of politics in energy and water supplies is also changing. Here, too, there are a multitude of uncertainties. Will there be a denationalisation of infrastructure policies? Will the spatial reference of infrastructure policy also change at the subnational level? After all, technical innovations change the structure of infrastructure supplies: will these lead to a change in the existing technological structure also in a spatial sense?

Even if in the political debate far-reaching spatial changes in the supply and regulation of infrastructure goods are postulated, this thesis has not been systematically examined by scientists. Both international and, above all, German spatial research have as yet scarcely provided any empirically based answers to these questions. At best, increasing Europeanisation and denationalisation of technical infrastructure systems has been a focus of attention of political scientists, lawyers and economists, while the local and regional transformation of infrastructure systems has until now remained underexposed. Similarly, the classical spatial sciences, such as geography, regional economics, and urban, regional and environmental planning, have paid scarcely any attention to the new developments in infrastructure provision. Only in the UK and the USA, where the processes of privatisation

1 For critical comments and helpful suggestions to an earlier version of this study, we thank Olivier Coutard, Simon Guy, Simon Marvin, Harald Rohracher, Harald Spehl and the colleagues, members of the advisory committee and field partners of our research network netWORKS! Furthermore we are very grateful to Irene Wilson and Jacqueline Chilton, who helped us to work out this English-language text.

and liberalisation began much earlier, has research already been done on the spatial distributional effects of the current economic transformation. The hypotheses presented there, however, can on the one hand not yet be regarded as empirically proven, and on the other hand the research theses cannot be directly applied to the particular situation in Germany.

In spite of these limitations various threads of the scientific discussion can provide important stimuli for infrastructural and spatial research in Germany. Firstly, the international debate on the transformation of large technical systems contributes to extending our understanding of the basic concept of infrastructure, which in Germany is still strongly shaped by the economic infrastructure theory of the 1970s. Secondly, the results and hypotheses of Anglo-American research on the spatial distribution effects of liberalisation and privatisation processes indicate possible trends in Germany. Last but not least, important ideas can be derived from the debate on politics and territoriality, even if this is related one-sidedly to Europeanisation and denationalisation and hardly pays any attention to the regional transformation of infrastructure systems.

The aim of this paper is to analyse the various aspects of the spatial transformation of German energy and water supplies against the background of these discussions. Different threads of the scientific discussion will be united, extended where necessary by important arguments and critically examined in terms of the situation in Germany. The study intends, above all, to develop an analytical framework for a new field of research in the spatial sciences. Although the spatial aspects of the transformation of infrastructure systems are illustrated in the present study with the example of German energy and water supplies, the questions raised and the hypotheses discussed can hardly be examined satisfactorily here. Rather, the following study represents only a first step towards an empirical examination of the current spatial transformation.[2]

The study begins with the social scientific concept of "large technical systems", which represents a comprehensive and systematic approach to the analysis of technical infrastructure systems. It describes the spatial extension and the characteristics of the systems and explains the variety of mutual effects among the social and the technical components of infrastructure systems (cf. section 2). On the basis of this the extension of the concept by a socio-ecological dimension is discussed (cf. section 2.2) and the most important mainsprings and characteristics of the institutional transformation of infrastructure systems are described (cf. sections 2.2 and 3). This is followed by a summary of the spatial dimensions of technical infrastructure systems (cf. section 4.1) and of recent research into the spatial transformation of infrastructure systems (cf. section 4.2). In order to illustrate the spatial effects in Germany, examples of the transformation of German energy and water supply systems are primarily used. The focus is on the socio-spatial changes in these large technical systems, in particular on the transformation of the economic spatial struc-

2 Partial aspects of the spatial transformation of the energy and water supply systems outlined in the following are currently being examined empirically using the example of four German case regions in the spatial science research project "Regionale Steuerung von Ver- und Entsorgungssystemen im Wandel" (Regional governance of energy and water supply systems in the process of transformation" within the project netWORKS funded by the German Federal Ministry of Education and Research (cf. www.networks-group.de).

ture and of the territoriality of politics. Based on this, the requirements for future research on the spatial transformation of those technical systems and the impacts involved for spatial development are outlined (cf. section 5).

## 2. The concept of large technical infrastructure systems as an analytical framework for infrastructure transformation

The development, structure and effects of many technical infrastructures cannot be adequately understood if they are analysed as isolated artefacts, if e.g. only the development, the diffusion or the application of individual energy technologies are examined. The technologies are normally part of a comprehensive system, which supports, maintains or obstructs them (Summerton 1994: 3). Nevertheless, for many years social and historical technology research was focused mainly on individual technical artefacts (for example the computer, the production line or the motor car). The invention and dissemination of new technologies was examined comprehensively, the technification processes which these artefacts initiated in social systems such as politics, the economy etc. were explained (cf. Joerges 1988: 11), and the determining effects of individual technologies on social welfare, but also their societal risks, were discussed in detail.

The infrastructure discussion by economists in Germany, too, has been able only to a limited degree to contribute to the explanation of the structural peculiarities and socio-political importance of technical infrastructure systems. It emphasises, among other things, the great relevance of material infrastructures, the most important of which are energy, transport and communication infrastructures, for (regional) economic growth and spatial development. This discussion – which today is still strongly influenced in essence by the infrastructure theory of the 1960s and 1970s[3] (cf. Jochimsen 1966; Jochimsen & Gustafson 1970) – does not adequately differentiate, however, between technical infrastructures and other infrastructures such as buildings and equipment, or the administration, education, research and health services sector. The technical infrastructure is regarded primarily as something concrete, and is strictly separated from the institutional infrastructure of modern societies (the totality of norms, institutions and procedures) and personnel infrastructure (human resources). The institutional structure and dynamics of energy and water supply, transport systems etc. is ignored, as is the shaping of technical infrastructure by specialists. The technical infrastructures are interesting primarily because of the positive effects on productivity which emanate from them, i.e. in their function as the "lubricating oil" (Jochimsen) for the development of the market economy.

Not until the second half of the 1980s was an international research network of historians, sociologists, political scientists, economists, planners and engineers established, which on

3 According to the understanding of this period infrastructure is "defined as the sum of the material, institutional and personal institutions and conditions which are available to the economic units and which contribute to making possible the equalisation of the payments to equal factor contributions with an efficient allocation of the resources, i.e. complete integration and the highest possible level of economic activity" (JOCHIMSEN 1966: 100, our translation).

the one hand provided a "systemic" approach to technology and on the other hand explained the peculiarities of technical infrastructure systems and their characterisation by certain technical artefacts. The resulting debate on "large technical systems" (or "large technological systems") (LTS) was based to a large extent on the comparative study of electrification in America, the United Kingdom and Germany up to the 1930s by the technology historian Thomas P. HUGHES. Hughes developed concepts which could be universally applied for understanding the dynamics, structural attributes and the persistence of these large technical systems (cf. Hughes 1983, 1987). No longer the individual technical artefacts and their consequences for the technification of functional systems (economy, science, politics etc.), or for economic productivity take centre-stage in research on technical infrastructures. Instead the focus is on the way that certain technical artefacts are embedded in a comprehensive system of complex functional, institutional and organisational structures.

In contrast to the economic theory of infrastructures, which is widely accepted in the German spatial sciences, this discussion can contribute to describing and explaining the innate logic of the infrastructure systems and their characterisation by both technical *and* social components. Infrastructure research will in this way become more sensitive to the particular conditions under which technical infrastructures come into being, to their characteristics and their particular requirements regarding political regulation. The concept of large technical infrastructure systems provides a theoretical framework for the examination of common development and structural characteristics of energy and water supplies, of rail traffic etc., for analysing their importance for the development of society, for comparing the peculiarites of individual infrastructure systems and for explaining the complex interactions between technical and social factors in the process of system development. It thus complements and extends previous social scientific technology research as well as economic research on infrastructure by essential aspects and provides an extended theoretical framework for the study of technical infrastructure systems.

## 2.1 Attributes and phases of development of large technical systems

Large technical systems refer not just to the provision of electricity but include network forms of gas supply and district heating, water supply, sanitation, telecommunications, the transportation system (in particular rail and air traffic systems), the internet and also specific military defence facilities. Since the boundary between large technical systems and other artefacts which are widely used but which do not form a network system cannot always be clearly drawn, the concept soon experienced an inflationary expansion. In order to make it as manageable as possible for this study, and to facilitate the differentiation from other technologies or technology systems, in the following the most important attributes of the systems (cf. section 2.1.1) and characteristic patterns of their spatial dissemination (cf. section 2.1.2) are outlined.

### 2.1.1 Characteristic attributes and the socio-political importance of large technical systems

Large technical systems for the provision of infrastructure services we understand to mean highly complex and heterogeneous technical systems which provide certain infrastructural services, and which are characterised by network structures, geographical dissemination and a considerable capital intensity. Large technical systems are social systems in which organisations or institutions group themselves around a certain technology (or a system of technical artefacts). This differentiates them from systems in which the theoretical removal of the technology does not necessarily imply that the remaining institutions are meaningless (Weingart 1989: 178f.)[4] They are characterised primarily by the following attributes (Hughes 1987; Joerges 1988; 1999; Mayntz/Schneider 1995; Monstadt 2004):

*a) Extensive networks*

The size of the technical systems as a defining feature does not refer to size in the sense of "big technologies" as discussed, for example, in the context of large power plants, but to the extensive networks of heterogenous technical and social system components. In industrial countries, in particular, large technical systems have spread spatially into the most peripheral regions. The infrastructural networks for energy, telecommunications, water and transport cover virtually one hundred per cent of the populated areas. At the same time the infrastructural supplies are available irrespective of the time of day or the season.

It is, however, not in every case the spatial dissemination and the range of the physical networks which constitute large technical systems. For example, the sanitation networks are as a rule not connected up over a large area, but nevertheless the sanitation sector can be classified as a large technical system. The same is partially true of public rail transport systems. Even if these are not physically networked by means of cables or rails, their immaterial, social system components such as general quality standards, specialised occupations, associations, research etc., are also characterised by intensive and extensive networks (cf. Chatzis 1999).

*b) Fulfilling specific infrastructure functions*

Large technical systems provide private and public services that are necessary and difficult to substitute by storing, converting and/or transporting specific products. The main function of large technical systems is to permit certain activities, such as the operation of electric motors, cooking, washing, lighting or overcoming space both physically and through communication (cf. Mayntz 1988: 233; 1997: 74). Large technical systems *fulfil an enabling function and provide advance services* for specific purposes which are, or have become, basic human requirements (air travel, the internet).

4 "The railway system without railways does not make much sense, while the banking system without computers may be difficult to imagine, but it nevertheless makes sense" (Weingart 1989: 179, our translation).

With regard to their function they thus share common features with other non-technical infrastructure sectors such as education, research and the health system (on this cf. Jochimsen 1966: 105-109). Together with the latter the large technical systems are responsible for overcoming "technological and practical" barriers to free economic, social and cultural exchange (cf. ibid.). From an economic point of view they are regarded as the decisive precondition for the creation of complete integration in the sense of a homogeneous economic area. Enterprises, public institutions and private households "have an equal access to the supply of energy and to transport and communication services, so that the economic units can use them independently of their specific location, the branches to which they belong or the size of the units and enterprises" (Jochimsen 1966: 114, our translation). Infrastructure systems can in this sense be seen as "support systems" for economic and social life in general. They are made up of material, institutional and human resources and are the basic precondition for social and economic life in general (Schneider 2001: 43).

*c) Institutionalisation as a socio-technical system*

Large technical systems are closely interrelated on the one hand to the use of specific technical artefacts and processes. In fact they result from particular technical innovations and evolve in line with the continuing development of technical innovation processes (Mayntz/Schneider 1995: 77). On the other hand they have evolved into circumscribable and organisationally and institutionally distinct, functional social systems. They have their own knowledge bases, particular norms, specialised occupations, large formal organisations, and a good measure of internal integration and networks. Technical infrastructure systems, finally, are established throughout society and are accessible to practically every member of that society (Mayntz 1988: 234).

Unlike other social systems, their institutional and organisational structures are shaped by certain technologies, e.g. power stations, turbines, transformers, grids etc. They can thus hardly be viewed as purely social systems, but are equally not just determined by technology, and therefore are described as socio-technical systems (cf. Joerges 1988; Mayntz 1988). Besides static physical components, technical processes and artefacts, socio-technical systems are formed by a specific institutional context and are socially designed (Bijker et al. 1987).

Thus, technical systems are strongly linked on the one hand to social production and use; in other words they are socially constructed and their use is socially organised. On the other hand technical system components are increasingly being incorporated into social contexts, i.e. the technical artefacts of the infrastructure systems have a formative influence on the structure and dynamics of social interactions (Mayntz 1988: 236). The essential feature of the systems is thus their interaction between being "socially constructed and society shaping", between the social construction of technology and the power of technology to shape societies (Hughes 1987: 51). In other words, (socio-) technical systems and (technisised) societies co-evolve. "This basically means nothing more than that although technology is created socially, i.e. according to the needs, safety standards, efficiency criteria, economic calculations and other considerations, it then, as an artefact or a system of artefacts, shows a certain degree of resistance to social 'demands': artefact systems cannot be linked up to one another infinitely, and paths of development, once taken, cannot be reversed, or even abandoned without difficulty" (Weingart 1989: 178, our translation).

*d) Criticality and disruption potential*

Large technical systems have played, and continue to play, a key role in the modernisation and industrialisation of society. To some extent the systems have had an even greater influence in certain areas of society such as politics, the economy and science, than the latter's internal technification (Mayntz 1997: 78; Mayntz/Schneider 1995: 82). It was modern infrastructure systems that paved the way for the industrial revolution and for the economic growth of the last century. Even recent structural change in the economy, i.e. the globalisation of goods and capital markets, the formation of multinational enterprises and the spatial division of labour would not have been possible without the services of large technical systems (cf. ibid.). Moreover, their artefacts have long since been integrated into social contexts of communication and reproduction, and they have contributed to a significant transformation of life-styles.

However, as well as being of great benefit to society, the growing differentiation and complexity of these systems entails considerable risks. Infrastructure systems create intensive and *asymmetrical relationships of dependency* as the functioning of state and society is reliant on their continuous availabity and faultless operation. They thus possess a considerable *disruption potential and criticality*, as breakdowns, technical faults, accidents and attacks can lead to significant disruptions to the entire sphere of production and reproduction. The restriction or loss of performance and the temporal interruption of supply are key factors of public concern; the more efficient the systems, the greater the concerns with respect to the likely ramifications of breakdowns in operation (La Porte 1988: 240). As their failure or impairment could result in detrimental supply shortages, substantial disturbance to public order or similar dramatic impact they are often characterised as "critical infrastructures".

*e) High capital intensity and longevity*

Investments in technical infrastructures are frequently associated with high capital intensity, long payback periods and a high share of sunk costs (cf. Hughes 1987: 77; Mai 2001: 8). Investments once made in power plants, trains or in energy, telecommunication or railway-networks amortise often after a long period of operation of the assets. Additionally investments in the construction or modernisation of technical assets usually require long and complex authorisation procedures. The formal operating authorisation guarantees the utility a certain planning reliability for its costly investment project and warrants an enforceable residual term. As a consequence of the long planning and payback periods, the introduction of new technical infrastructures is decided by different economic and political decision makers to those responsible for their further utilisation (Mai 2001: 8). Due to those long-term commitments of infrastructure planning, the long-lasting operating permits and payback periods of several decades a rapid adjustment to new knowledge (e.g. the impacts of coal-fired power plants on climate change) or to new social constellations (e.g. change of government or market situation, civil protests) is nearly impossible.

*f) Inertia and path dependency*

From a certain point onwards large technical systems acquire *"momentum"* (Hughes 1987: 76-80), i.e. changes require long periods of time as the sheer mass of technological and organisational system components inhibits its flexibility and adaptability. The reasons for this inertia are to be found not only in the capital intensity and the long amortisation periods of the technical infrastructure equipment. The momentum arises especially from the organisations and people committed by various interests to the system (ibid: 76). Once a certain technical system has established, the system's established culture of expert communities, who developed, supported and operated the system and benefited from it, have vested interests in the growth and durability of a system. Those inventors, engineers, managers, financiers, user groups and politicians "use a variety of tactics to promote and defend their system. They can be expected to block attempts at reconfiguration that threaten their control" (Summerton 1994: 4).

This tendency to institutional inertia is reinforced by the enormous momentum and longevity of the material-physical system components. Once a technical network is implemented, it is complicated and time-consuming to substitute it by other technical options and it defines a development path for the future. "The durability of artifacts and of knowledge in a system suggests the notion of trajectory (...). Modern capital-intensive systems possess a multitude of durable physical artefacts. (...) Durable physical artifacts project into the future the socially constructed characteristics acquired in the past when they were designed" (Hughes 1987: 77). The decision for a certain structure of electricity supply (nuclear techniques, wind power plants etc.) is as a rule a commitment for several decades (cf. Mai 2001: 7). The problem is not only that alternative technological options – e.g. the substitution of large scale power plants by decentral energy technologies – have to be introduced against powerful actor groups and often require new forms of social organisation. In many cases it is not easy for technical reasons to implement them into the existing system, as they make high demands on the technical coordination of the network, the compatibility with other technical system components is not yet achieved, or the present technical staff are not qualified for the application of the new technology.

It is therefore for institutional and technical reasons that, once a technological concept is introduced and established, the associated shaping of the whole system can only be reversed rudimentarily or over longer periods. Coherent patterns between technological artefacts, institutional structures and use patterns (so called *technological regimes)* often obstruct radical and system innovations. Thus, innovations in infrastructure systems tend to be incremental in nature. Existing technological regimes undergo processes of slight, continuous improvement within established paths rather than radical change and deviation from approved paths. In many cases those path dependencies result in a "closure process" against alternative technological concepts during which even superior socio-technical concepts have difficulty in gaining acceptance.

*g) Proximity to state authorities and high degree of self-organisation*

As technical infrastructures play a key role in the development of a country and are comparatively susceptible to failure, they have evolved (in Europe at least) into economic sectors that in the past have been closely associated with the state and have generally not been open to market competition. In these sectors public institutions took on responsibilities for structural policy and regulation that go beyond consumer and environmental interests, much more so than in other sectors of the free market economy (Mayntz/Scharpf 1995: 13f.). The technical infrastructure systems were mostly organised into state-licensed and state-controlled monopolies. Infrastructure services were generally provided by the government or local authorities themselves through public utilities. Due to both their intrinsic benefits as well as their criticality and disruption potential, technical infrastructure systems have on the whole been highly regulated and subject to strong state intervention (Hermes 1998: 327). Only in this way did it seem possible to guarantee the safety and quality of the infrastructure and specific objectives of what are today termed "public services" or "services of general interest", such as the reduction of spatial disparities.

It only *seems* contradictory that the large technical infrastructure systems have as a rule evolved a high degree of self-organisation in spite of their proximity to state authorities and their considerable levels of bureaucracy. Mostly they are operated by a few large utilities, and have at their disposal highly organised pressure groups and professional associations, trades unions and their own knowledge base and are characterised by a high degree of integration in sectoral networks. Despite their proximity to the state, in many cases the utilities are able – partly due to their knowledge advantage and their financial and human resources – to avoid being directly influenced by the state.

### 2.1.2 Phases of the spatial dissemination of large technical systems

The spatial dissemination and structural development of the existing large technical systems usually takes place in phases which are similar in all systems.[5] Numerous "system builders" are involved in their evolution, i.e. individual actors (inventors, developers, managers, lawyers, politicians, users) or organisations (companies, banks, government authorities). Each phase of development has its own special predicaments which can only be resolved through specific competencies and the respective system builders (Hughes 1983: 14-17). The different phases of development are dominated by processes of invention, development, innovation, technology transfer, competition and system growth, as well as by universalisation and consolidation (cf. Hughes 1987; Coutard/Pflieger 2002). These processes cannot, however, be clearly divided into strictly sequential phases. They overlap, take place simultaneously and even change direction.

5 An exception in many respects is the construction of modern water and sanitation networks. Whereas the existence of large technical systems is something new, historically speaking, hydraulic engineering systems already existed in the advanced civilisations of antiquity (cf. Radkau 1994: 56-58). In contrast to other infrastructure systems, the water supply and sanitation networks were organised from the beginning with the exclusion of competition. Due to the relevance of public interests such as health protection and protection from epidemics, the provision of water for extinguishing fires and the cleanliness of the streets, competition between different suppliers remained the exception from the very beginning. Instead, the construction of modern water supply and sanitation networks in settled areas was driven by political initiatives and was characterised by far-reaching political intervention (Coutard/Pflieger 2002: 6, 8f.).

*a) Invention, development and innovation*

The first phase ranges from the invention which leads to new technological systems (e.g. the electric light-bulb) through its development, in which individual technology entrepreneurs provide the necessary economic resources and political support, to innovation in which the system is put to efficient application. This first phase is shaped above all by inventor-entrepreneurs who – together with engineers, designers and investors – influence the development process of the system until it is capable of application and ready for the market. Spatial dissemination at first remains limited to individual urban centres or urban sub-spaces with favourable demand conditions (e.g. industrial areas).

*b) Technology transfer*

In the second phase, that of technology transfer, the technical systems are employed in other urban regions. For this, the technologies and the organisational system components are transferred to other regions, where they are adapted to suit the corresponding geographical, political and social conditions. Aside from the existing technical structure of infrastructure networks national, regional and local regulatory institutions, the dominant technology entrepreneurs, the specific geographical pattern of demand, the settlement structure and the natural geographical conditions lead to the formation of specific "*regional technological styles*".

*c) Competition and system growth*

In this phase the market shares of the new technical systems grow and their profitability therefore increases. System growth is driven primarily by private entrepreneurs, who push forward the development and dissemination of the technologies. These entrepreneurs compete strongly with one another to supply lucrative user groups and profitable areas. In addition, they also compete with the "system builders" of traditional technologies. Thus, gas lighting was at first cheaper than electrical lighting, telecommunication was cheaper per telegraph than by telephone, a telefax cheaper than an email etc. The entrepreneurs therefore often first have to create a demand for their infrastructure products and to convince the customers of the advantages of using them.

During the spatial dissemination of the infrastructure networks socio-technical obstacles innate to the system must be overcome. Hughes (1987: 73) used the military metaphor "*reverse salients*" to describe those system components which lag behind the innovation process of the system as a whole and slow down its growth and progress. This lag can be related to technical, economic, organisational or political aspects of the system which inhibit further system growth. The system builders must thus be able to identify the system components which are lagging behind and convert them into resolvable issues (cf. Hughes 1987: 73). Moreover, the evolution of the system is continually obstructed by socio-technical problems which remain innately insuperable within the system and which in the long term can only be resolved through alternative system variants. These problems can only be overcome through a "*battle of the systems*", in other words through competition between different technical systems. The outcome of this substitutional competition is not only governed by technical rationality or practical constraints. Equally important are the institutional interests of the system builders that desire a specific technical solution, their power constellations, and also external factors such as public awareness.

The at first small and decentralised technical systems (insular systems) are relatively expensive to construct and run. At the same time their individual usefulness remains relatively small due to their low spatial range and repeated breakdowns. Only when the technical systems have spread do individual connection costs fall and the useful effects which can be realised can be maximised by smaller networks being connected into larger ones. Economies of scale arise, in which for example the costs of processing one cubic metre of drinking water fall with increasing size of the water treatment plant, so that low prices become possible. As individual connecting costs fall and the quality of the services can be improved, the positive network externalities can be maximised by the growing connection of smaller networks into larger ones. Due to longer term infrastructure interests, but also to their own commercial interests, state or municipal authorities advance the construction and the connecting-up of the networks and are themselves active in the supply of infrastructure through the founding of public utilities. Above all in the structurally advanced, urban regions with a high density of use and low connection costs, demand-pull arises and clear growth of the system in a spatial sense begins.

Despite this system growth the technical systems, due to the high initial costs for their construction and operation, are profitable above all in urban regions and their use remains at first confined to a highly solvent urban élite. Above all the poorer sections of the population and users in rural regions remains dependent on technological alternatives or is not connected to infrastructure networks.

*d) Universalisation and consolidation*

Even although competition among private utilities or between public and private utilities at first clearly stimulates and accelerates dissemination in the towns, this does not immediately lead to their spreading to every corner of the settlement areas and to the supply of the entire population with infrastructure services. Only with political intervention, the introduction of regional or national supply monopolies, public subsidies and the founding of public utilities does a universalisation of the infrastructure services take place in which the poorer sections of the urban population and, finally, rural regions are connected up to the networks. Supplying all strata of the population and the entire populated area increasingly becomes a political task. In all the industrial countries, a social norm for public services or for "services of general interest" becomes established, i.e. public responsibility for the secure and inexpensive supply of infrastructure services to the entire population, which is largely independent of income and of geographical conditions (Coutard/Pflieger 2002: 9).

From a certain point onwards increasing *consolidation* occurs. In this phase those economic forces which had driven the growth of the systems in the expansion phase become increasingly weaker. Economies of scale reach the point of saturation, economies of scope have largely been exhausted and the demand for the traditional infrastructure services also shows saturation effects (Hiessl et al. 2003: 132). Basic course corrections and path variances become increasingly difficult to implement, and are feasible at best only in the long term. The technological system develops a "*momentum*" (Hughes 1987: 76-80), i.e. changes are implemented over longer periods of time as the sheer mass of technological and organisational system components inhibits its flexibility and adaptability (cf. section 2.1.1 "inertia and path dependency"). Once such a consolidation phase has been reached, it is difficult to establish radical innovations or alternative system variants. When problems arise, the actors' technical and institutional efforts concentrate on incremental innovations which are compatible with the existing technological regime. Radically new technological variants or institutional system innovations evolve in this phase at best in niches in the system, and thus have a complementary rather than a substitutive character (Mayntz 1988: 254).

*e) Current trends towards a system transformation*

From the 1980s onward a fifth phase of system development became apparent which radically changes existing socio-technical structures. Competition was introduced – or, to be more precise, was reintroduced – and the monopoly areas were removed in those fields in which competition was possible. In addition, the provision of infrastructure services was (again) increasingly delegated to private utilities, and there was a partial disentanglement of state institutions and the utilities industry (cf. section 2.3). Technical networks have been expanding through ever stronger links across national borders and a growing internationalisation of the utility companies and of state regulation can be observed. Furthermore, technical innovations are being made fit for application and for the market which have the potential to effect structural changes to the existing technical system.

## 2.2 Broadening the concept to encompass the socio-ecological dimension

Ecological aspects have hitherto played at best a minor role in the literature on the concept of large technical systems and in analyses of their risks, disruption potential and accidents (cf. Joerges 1999: 265). At most, the direct material system components – i.e. the machines, grids, equipment, power stations etc. which affect every sphere of society – and the natural conditions to which their artefacts and processes are subject are taken into consideration (cf. Joerges/Braun 1994: 42).The traditional analytical categories of a socio-technical system are unsuitable for portraying adequately the metabolism between nature and society structured by large technical systems or the socio-ecological ramifications of this.

The problem is not just that the construction of infrastructure networks often has a major negative impact on local ecosystems leading to the disruption and industrialisation of natural landscapes, and that it requires considerable areas of land. In fact, large technical systems give structure to the entire process of industrial metabolism and its associated environmental risks. They constitute a – and perhaps *the* – central interface between nature and modern societies. The functioning of every technical infrastructure system depends to varying degrees on the availability of natural resources as the central production factor. This includes the resources for the production of the technical artefacts, the areas for the abstraction of resources and for the operation of those infrastructure facilities, and in particular the material flows which flow through the technical systems (energy resources, water, sewage). The socio-technical structures of the systems thus have a direct effect on the current problems regarding shortage of natural resources. Their "socio-ecological disruption potential or criticality", however, lies mainly in the production of waste, which causes considerable environmental problems (pollution of water, air and ground, global climate change). Last but not least, due to their infrastructure function, the systems impact on technification processes in every field of social life and stimulate industrial processes of material transformation. In this way they have an indirect but significant effect on the "industrial metabolism" of modern societies.

In this broadened perspective the large technical systems do not just have a technical and social dimension but also a "natural" or material one. Seen thus, they are a *hybrid of natural, technical and social system components*, which co-exist in a complex relationship of interdependency and are becoming increasingly difficult to distinguish due to reciprocal overlapping. The creation of the technical artefacts *and* the material flows within the large technical systems occur through the actions of individuals and organisations, the influence of institutions and a specific knowledge base. However, these contexts of social interaction are also affected by the technical system components, even if they cannot be accredited with a determining impact. Similarly, the ecological dimension of the technical systems considerably influences modes of social interaction in the technical systems. The availability of energy and water resources and the resulting ecological problems influence the choice of technology and the social (socio-spatial) organisation of the systems, and the geographical structure has an influence on the planning of the networks and infrastructure plants. The ecological system components also have a substantial, though not determining, influence on social actions and communications in technical systems. In contrast to the way technical systems are influenced by the artefact, the results of the "material system effects" on the socio-technical structure in particular are much more indirect because in many cases cause and effect are greatly separated in spatial, temporal and social terms.

### 2.3 Institutional change to large technical systems as an emerging field of research

Studies of large technical systems have contributed to our understanding of the evolution of modern technology not just as a process of advances in engineering but also as a socio-technical process. Despite great variation in the scientific discourse, structural similarities of relatively heterogenous technical systems have been established which explain – and permit comparisons of – institutional differences, the technical systems' internal modes of functioning, their high degree of inclusivity and their specific functions for the modernisation of societies. Not only social scientific research on technology but also modern infrastructure research can gain from this knowledge. In addition, the theoretical discussion on governance has been stimulated by the fact that the considerable persistence of the systems – explained in terms of their technical and institutional path dependency and the permanence of their technical artefacts – was elaborated, which helps account for their resilience to attempts at political regulation.

Since previous research focused on the historical emergence and dynamics of the systems and on the resulting forms of social order, however, current problems and developments have been partially neglected. In particular, the fifth phase of the evolution of large technical systems (cf. section 2.1.1), which began worldwide in the 1970s and 1980s, has thus far received only rudimentary attention (exceptions: see Summerton 1994; Coutard 1999).

In the current transformation process decisive components for operating the systems, such as political control and technological, institutional and spatial structures, have undergone marked transition. A number of questions still remain open or inadequately answered by the research on large technical systems. For instance, which components of a system are changing? What are the (new) requirements for the political regulation of technical systems? More fundamentally, what factors trigger institutional change? Here, four main drivers for change can be identified, which are strongly interconnected (for details on electricity cf. Monstadt 2004):

*a) Ecological modernisation*

Firstly, a process of ecological modernisation began in the 1970s in some infrastructure systems, especially in energy and water supply systems, in the sanitation system and to a limited degree also in the transport system, shaped largely by a number of incremental political reforms and technical innovations. This process is driven by the pressure of growing ecological and economic problems facing large technical systems, by their politicisation via the ecology movement and the mass media, by scientific findings and risk analyses, and finally by the gradual extension of the institutional and technical capacities to solve environmental problems. Since this time the political, administrative and legal capacities in the field of state environmental protection have been extended constantly at every political level. For example, in Germany the regulations concerning environmental standards in the fields of immission protection, drinking water and sewage management were continually tightened. In addition the efforts of environmental policy are increasingly directed towards the ecological management of material flows, e.g. support for energy efficiency, water saving, renewable energy etc. Besides the state environmental policy institutions and the environmental groups the processes of ecological modernisation are increasingly driven by innovative enterprises in the environmental industry. Those "ecopreneurs" become increasingly promotors of industrial transformation and build up a pressure group policy supporting environmental legislation.

*b) Privatisation*

Secondly, since the 1980s, and more so from the mid-1990s onwards, a process of privatisation of public utilities and infrastructure services has emerged in almost every industrialised country. The observable "neoliberal renaissance" (Ambrosius 1994) has rolled back state economic functions, including even infrastructure sectors that used to be very closely associated with the state. By reducing state economic activity and public involvement in infrastructure supply, an attempt is being made in virtually every western industrial society to create new openings for the private sector and achieve greater cost efficiency. As a result of the selling off of numerous former public utilities and the delegation of services of general interest to the private sector we can observe a growing trend towards the disentanglement of the traditional relationship between public institutions and utilities. While privatisation in Germany is far advanced in most technical infrastructure sectors, German water supplies and sanitation are largely in public hands, and private or mixed-economy water supply and sewerage utilities are the exception.

*c) Liberalisation and commercialisation*

Thirdly, reforms advancing competition since the mid-1980s have brought about radical change to the institutional structures of large technical systems. Traditionally, it was assumed that infrastructure and utility services were condemned to market failure for a number of reasons (natural monopoly, public and merit goods, external effects), and that the provision of services by the state and the exclusion of competition were therefore essential. Triggered by problematic economic developments in monopolistic infrastructure systems, by recent technological innovations and also by the growing proliferation of neo-liberal ideas a paradigm shift has taken place in all of the western OECD countries. Drawing on the experiences of individual trailblazing countries like the UK, the European Commission has been actively encouraging a common internal market since the late 1980s, including all technical infrastructure systems. The liberalisation of infrastructure services has brought about great changes in institutional constellations with respect to state control, the structure of the industry, consumer rights and the orientation of professional associations and interest groups in the affected sectors. Only water supply and sewerage have been exempted so far from the European single market project. In Germany these two branches continue to be organised in local monopolies and only an institutionalised comparison of performance between the utilities ("benchmarking") is being discussed.

*d) Technical innovations*

Finally, technical innovations are further prime movers in the transformation of infrastructure systems. Technical developments are enabling "competition between rival technologies" (Guy et al. 2001: 198) and the reconfiguration of technical networks. Decentralised systems of power generation and network supply are increasingly supplementing the already existing centralised electricity supply structures. In water supplies, too, technical system alternatives are revealing themselves through progress in membrane technology and decentralised plants for the treatment of local drinking water sources and of rainwater and grey water. The inclusion of new electronic measurement, monitoring and communication technology in the control, accounting and organisation of infrastructure provision considerably extends the range of possibilities for infrastructure services.

## 3. The characteristics of the institutional transformation of infrastructure services

Since the 1980s all large technical systems have been undergoing dynamic transformation. Taken individually these changes and political reforms may only affect small segments and functional layers of a system and do not always alter its path dependency or affect its persistency. Taken together, however, they are having the cumulative effect of stimulating deep-seated structural change. There is talk of a "new logic of infrastructure provision" (Marvin/Guy 1997: 2027), which is causing considerable changes to key social components of system operation such as market structure and corporate strategies, the role of the consumer, and political control and regulation (for details cf. Monstadt 2004).

*a) Changing corporate strategies and market structure*

The liberalisation of the infrastructure markets has opened up former regional or national monopolies for infrastructure provision to competition. Consequently, the utilities are rethinking their corporate policies, making full use of the scope for rationalisation through staff redundancies and more efficient management, and reassessing their infrastructure services and investments increasingly according to the needs of a more competitive market. The pressure to establish effective corporate management strategies has grown as a response not only to liberalisation but also to the privatisation of many public utilities, because private shareholders generally expect greater returns than municipal or state shareholders. Companies previously restricted to their own supply areas are tapping into new national and sometimes international markets by attracting new customers with professional marketing strategies, but mainly by expanding their radius of activity through mergers and takeovers.

Companies are still under legal obligation to safeguard minimum standards of supply and other objectives associated with services of general interest. However, the previous ethic of public services – the model of cheap, reliable and universal utility services for all, irrespective of income or location – is increasingly being replaced by the goal of profitability (Guy et al. 1997). The former "build-and-supply logic", whereby the physical infrastructure was optimised according to technical criteria and investments were designed to meet maximum loads plus a security reserve (Moss 1998: 216f.), is increasingly being replaced by principles of competitive corporate management.

Changes in market structure are a result not just of established companies becoming more competitive, but also of the emergence of new market players. On the one hand, environmental regulation and socio-technical innovations have encouraged greater specialisation of the environmental market. This includes manufacturers and users of innovative environmental technologies (e.g. producers and operators of micro- or regenerative power plants and small-scale sewage works, technologies for more efficient end-use of water or energy, resource saving vehicles), and providers of new environmental services (e.g. environmental consultants, energy and water-saving contracting, environmental financial services, car-sharing providers). Even though these innovative ecopreneurs have thus far only been able to tap niche markets, growing turnovers and employment levels demonstrate considerable market potential. On the other hand, competition has encouraged the emergence of new services. In electricity provision, for example, independent power producers, traders, brokers and other service providers are extending the traditional infrastructure market with a wide range of new, competitive products and services.

*b) Changing role of the consumer*

In the course of liberalisation the traditional relationship between providers and users has dramatically altered (cf. Summerton 2000). Traditionally users were "captive customers" dependent on the services of their local provider, but the present market enables them to choose between a variety of products and tariffs.[6] Just being able to change provider has forced the utilities to give greater consideration to what their customers want. However, the impacts of competition are very different depending on the type of customer. While large – and lucrative – industrial customers profit disproportionately from price reductions and improved services, the benefits for household customers and small businesses often remain small.[7]

*c) Changing the functions and structure of state involvement*

A regulatory regime based on public ownership and state monopolies was traditionally typical for technical infrastructure sectors in Western Europe. Public interests connected with the provision of infrastructure were mostly served by state or municipal companies and by state controls over prices and investments. In the course of liberalisation and privatisation infrastructure services provided by the state are increasingly being replaced by private sector provision, and the traditional close linkage between utilities and the public sector is being eroded.

Contrary to the expectations of the advocates of neoliberalism, these market reforms have not led to deregulation in terms of rolling back the state or weakening state regulation, but to the reform of state institutions and the drafting of new regulations (Majone 1994). On the one hand intense competition and economically more efficient structures can only be expected where state regulation guarantees discrimination-free access to the network monopoly for all, prevents price-fixing agreements, and stops the emergence of cartels through the concentration of infrastructure markets. Only such "market-making regulation" (Héritier 1998: 4f.) can create the conditions which allow particular qualities of the market, such as efficiency of allocation and innovation, to take effect. New regulatory authorities must be created, therefore, which enable and sustain competition in the long term.[8] On the other hand, it must be assumed that even efficient markets cannot optimally fulfil the social and ecological objectives of infrastructure provision. One of the key tasks of the state is therefore to fulfil public objectives and prevent or correct the undesirable effects of market activities in the interest of the politically defined public welfare. Such "market-correcting regulation" (ibid.) addresses objectives of public welfare (safeguarding supply, universal provision and access of infrastructure services for all citizens) as well as objectives of environmental protection.

6 An exception is water supply, where competition among the utilities is only evident when inviting tenders ("competition for the market"), but not for customers in a region ("competition in the market").

7 In electricity provision, in particular, consumers are becoming better organised. Individual consumer groups, especially small and medium-sized companies, are forming buyers' groups and public authorities are centralising the purchase of infrastructure services so they can negotiate better prices as large customers.

8 In the course of liberalisation in the United Kingdom several new state authorities were created to regulate competition (e.g. OFWAT, OFGEM, OFCOM, OFRAIL).

The state thus does not withdraw; it merely changes its appearance from that of a *"positive state"* to that of a *"regulatory state"* (cf. Majone 1994; Benz/König 1997; Grande/Eberlein 1999; Monstadt 2004). The regulatory state is characterised by its adherence to protecting common goods and public welfare, and by safeguarding not just economic efficiency but also social justice and environmental protection (cf. Haughton 2002; Slingerland/de Jong 1998). However, it provides public infrastructure services ("services of general interest") itself only in exceptional cases. In many sectors the state's role is limited to regulating production processes and markets, organising and facilitating negotiations between social actors and ensuring agreements are honoured. It oversees, essentially, the general framework within which public goods are distributed in the market. The strategic role of the state has shifted from that of producer to regulator, a role that protects the public interest through increased coordination and regulation. What has changed fundamentally is the way in which state responsibilities for infrastructure provision are (or must be) exercised, whereby the state shapes private infrastructure provision through specific forms of state supervision, control, funding and strategic management.

## 4. Spatial transformation of infrastructure provision

The spatiality and the spatial impacts of technical infrastructure systems seem, at first sight, obvious. This is particularly the case for the spatial dimension and spatial impacts of technical artefacts such as transportation and energy networks, water pipelines, power stations, waterworks etc. Their construction and operation require a considerable area and they have become a key element of modern cultural landscapes. Further spatial effects arise when infrastructure systems extract natural resources, transform them and then deposit them as waste. Technical infrastructure systems are thus implicated in dramatically transforming the natural environment and in causing local, regional and global environmental problems. In addition, technical infrastructure systems affect socio-spatial structures considerably by influencing the spatial dimensions of mobility behaviour, communication, technical applications and consumer behaviour, and by directing the location of investments with far-reaching direct and indirect effects on regional incomes and employment. After all, the spatial expansion of technical infrastructure systems has traditionally been strongly linked to the territories of politics. Its spatial dissemination beyond territorial boundaries therefore has implications for state activity.

Technical infrastructure systems are thus never "neutral" in spatial terms, but have a spatial impact in a multitude of ways: "(…) those public goods that derive from large technical infrastructural networks also become elements of the social construction of public space" (Rochlin 2001: 68). The relationship between infrastructure and space is thus reciprocal: infrastructure systems shape space and are themselves shaped by spatial conditions and developments.

Despite the considerable spatial relevance of technical infrastructure systems this was for a long time virtually ignored by the spatial sciences in Germany. Only in spatial planning debates did infrastructure systems remain on the agenda, and were discussed even then only with respect to land use and the spatial viability of new pipelines, power stations, water abstraction zones or other infrastructure facilities, the spatial integration of these facilities and acceptance within the local or regional population. Aside from that, they were taken for granted in discussions on urban and regional development and to a large extent ignored. Only recently has interest in the socio-spatial transformation of infrastructure systems been growing, and neglect of this theme is increasingly being perceived as a shortfall in spatial research.[9]

Current studies are beginning to take up the spatial relevance of infrastructure systems and attempt to indicate how the transformation of infrastructure systems also comprises spatial dimensions (cf. work by Coutard, Graham, Guy, Marvin and Offner). However, a review of the international literature runs up against the problem that – unlike in other research fields in urban and regional development – there exists hardly any broad, problem-oriented discussion which can deliver results with an empirical basis and takes account of current developments in this field. The explicit spatial research debate on the transformation of infrastructure systems is still in its early days.

The following summary of the current debate on spatial aspects of the transformation of infrastructure systems must thus first derive and define the spatial dimension or the spatial relevance of these systems in a fundamental way. Particularly when it is a question of describing the spatial effects of transformation, very diverse and loosely related discourses on regional economics, economic geography, the politics and governance of space and the privatisation and liberalisation of public infrastructure systems (a debate largely lacking in spatial sensitivity), must be taken into account and – as far as possible – brought together.

## 4.1 Spatial dimensions of technical infrastructure systems

When analysing the spatial transformation of infrastructure systems it is important to clarify in greater detail the term space and the spatial relevance of technical infrastructure systems. In the following space is understood as a social construction, the basis of which is material and physical spatial structures, the organisation and importance of which are created, however, only through social translation, transformation and experience.[10] Space is thus shaped by physical as well as social factors. On the one hand space is constituted as the result of societal activity and is characterised by social, economic and cultural factors (cf. Blotevogel 1995: 739). On the other hand, physical space itself also shapes social activities in a way which sometimes has far-reaching effects on organisations and social activities. According to this interpretation, space is characterised not only by the physical-material form it takes, but also by the structuring regulation in and of space, by the historical construction of space and cultural expression in and of space (Sturm 2000: 200).

Accordingly, the spatial structure and spatial relevance of technical infrastructure systems are determined not only by physical-material structures such as technical artefacts and

9 "Study a city and neglect its sewers and power supplies (as many have), and you miss essential aspects of distributional justice and planning power" (Star 1999: 379).

10 "Space in itself may be primordially given, but the organization, and meaning of space is a product of social translation, transformation and experience" (Soja 1989: 80).

resource flows. Just as important are socio-spatial factors such as the spatial organisation and regulation and the economic geography of the systems.

### 4.1.1 Physical spatial dimensions

Urban and regional studies on infrastructure systems generally relate to the physical structures of technical infrastructure systems, which in turn are of particular importance for spatial planning as a whole and for the technical planning of supplies and disposal. The focus is on the interdependencies between technical artefacts (infrastructure plants, transport and distribution systems) and spatial structure. In more recent times the interaction between resource flows transported by the technical systems and the environmental quality of spaces is being paid more attention.

*a) Infrastructure plant, transport and distribution systems*

A significant characteristic of technical infrastructure systems is the extent of their networks (cf. section 2.1.1). Infrastructure networks connect different spaces and serve to overcome space both physically and through communication. Here, the visible parts of transport and distribution networks of technical infrastructure systems are only the tip of the iceberg. At least as important are the underground, and thus invisible, electricity, telecommunication, water supply, sanitation and transport networks. Basically, we can distinguish between "local networks working in an isolated way in an urban area and being confounded with this territory" (e.g. local water supply and sanitation systems) and "large interconnected networks which cross these territories and put them into relationship with each other" (e.g. telecommunications or the European electricity grid) (Lorrain 1995: 51).
The interaction between technical infrastructures and physical space is also apparent in, for one thing, the spatial distribution of their physical components and networks, the locations of which depend on physical conditions. For example, terrain relief is a significant factor in pipeline construction. Power stations, transmission masts, waterworks etc. are dependent on natural conditions to a certain extent, and not every location is equally suitable for infrastructure facilities. In many cases the spatial availability of resources is also a key criterion for location. This is especially true for water supply, but to a limited extent also for energy supply, which can be illustrated by major locations of power plants such as the Ruhr Region, the Eastern German Lausitz or the North German wind energy locations.

Technical infrastructure systems are not just shaped by physical spatial structures. As a rule their construction and operation have considerable impacts on physical space, depending in many cases on their size or degree of centrality and decentrality. The construction and operation of large technical systems usually require a large area, cut through the countryside, and adversely affect the ecosystem and the landscape. A large share of the strongly politicised conflicts over land use are triggered by the construction of infrastructure facilities. In addition, they can greatly increase local emissions (air pollutants, radiation, sewerage) or require restrictions of land use (e.g. in water protection areas).

The physical requirements and effects of building and operating technical infrastructure networks and to a certain extent the spatial impacts of the physical infrastructure are why they have been of key interest to spatial research and spatial planning. To safeguard the spatial integration of the installations and minimise negative spatial impacts spatial concepts, plans and measures have been prepared and planning procedures and other spatial coordination processes implemented in order to

- coordinate spatially the region-wide and secure provision of energy and water and the disposal of waste water,
- assess the spatial viability of networks and other technical installations for energy and water provision, sanitation etc.,
- determine and designate suitable locations and routes for supply and disposal systems depending on the physical conditions and the structure and density of resource demand,
- and to balance competing claims with regard to land use.

*b) Resource consumption and environmental damage*

Technical infrastructure systems for supply and disposal intrude, on the one hand, on the natural environment and consume natural resources. On the other hand they convert these resources and produce material and energy waste, which they return to the environment. In this way they contribute substantially to the environmental problems of modern societies by exacerbating shortages of finite resources (especially fossil fuels) and polluting the environment with harmful emissions.

In the past three decades the impacts on the local and regional environment of the technical artefacts of infrastructure systems such as power stations, sewage treatment plants, transmitting stations and the technical networks of energy and water supply, sewerage, transport or telecommunication have advanced to one of the major subjects of spatial planning and spatial research. This is reflected not only in the strengthening of the legal instruments of environmental impact assessment for the construction of infrastructure facilities, but also in the requirement to systematically consider ecological aspects in spatial planning procedures and regional planning programmes. Initial steps are being taken by regional planning to explore all available options to save resources and protect the environment by designating locations for decentralised facilities and priority areas for local heating systems and decentralised water supply and sanitation.

### 4.1.2 Socio-spatial dimension

Technical infrastructure systems do not only interact closely with physical space. At least as important are the interactions between socio-spatial structures and technical infrastructure systems. Technical infrastructure systems create a specific social space and a specific territoriality, to a certain extent they "format" market areas and political territories (Offner 2000: 165) and they exert considerable influence over the socio-spatial development of modern societies:

> "At the urban level (...) the networks contribute to the construction and operation of territorial systems. The history of local institutions is identical to that of urban services, whether for drinking water networks (...) or public transport networks. The metro is to Paris what the RER (regional express network) is to the Île de France Region. The functional space of the transport flows (...) legitimizes the political territory. In short, infrastructures create the matrixes (...). Their development increases the available stock of geographical levels from which the various social, political and economic players can draw their supplies, according to their own rationale and strategy" (Offner 2000: 171).

Notwithstanding this, the socio-spatial dimension of technical infrastructure systems has been sorely neglected in the German spatial research discussion. The current transformation of infrastructure systems with its far-reaching impacts on socio-spatial structures has so far barely been investigated. Two aspects seem particularly important here: first, socio-spatial organisation and spatial regulation, and second, the significance of technical infrastructure systems for the regional economy.[11]

*a) Spatial organisation and regulation of infrastructure systems*

Up until the 1980s or 1990s the spatial organisation and regulation of technical infrastructure systems had been largely unaltered for many decades in every industrial country. In the past the dissemination and integration of technical infrastructure systems have made an essential contribution to the construction and legitimisation of nation states (cf. Graham 2000: 184), and vice versa the territorial state structure has often predefined the borders for the infrastructure systems. In other words, the territories of nation states and of technical infrastructure systems have to a certain extent co-evolved and interacted in their spatial dissemination. Local, regional or national monopolies – which are in many cases congruent with the political territories – characterised the spatial organisation of infrastructure provision in just about every infrastructure system in every country. Transnational ownership and trading were the exception and infrastructure services were provided almost exclusively by the corresponding national, regional or local monopolists. Just as the economic activities of the companies were restricted to the territory of nation states, so was state regulation of infrastructure provision characterised by the high degree of autonomy of nation states.

The spatial structure of infrastructure provision within the state borders was highly diverse among countries and across sectors with respect to both the spatial radius of activities of the utilities and the territorial organisation of state regulation. Whilst the German energy industry was characterised by a comparatively decentralised and pluralistic structure of provision, in the UK and France it was much more centralised and in the hands of one or just a few large utilities. The same is true in principle of water services, which in Germany are provided almost exclusively by a multitude of municipal utilities, whereas in France and the UK just a handful of large companies dominate the market. Analogous to Germany's federal structure, the energy and water sectors were traditionally regulated by the *Länder* (federal states) and local authorities and many utilities were owned by the communal authorities or Länder. By contrast, in the UK and France the central state level was

11 Questions on how the spatial structures of technical infrastructures systems were historically constituted are also relevant to the socio-spatial dimension (cf. section 2.1.2).

traditionally more important. Even if the pattern of the territorial monopolies of the infrastructure companies was not always congruent to the administrative territories of the country, there was generally a high degree of overlap between political territories and the spatial structure of infrastructure provision.

Due to the decade-long stability of the economic spatial structures of infrastructure provision as well as the far-reaching congruence between economic spaces and political territories, the spatial organisation and regulation of infrastructure systems was an issue that was all but ignored by spatial research. In the social science debate on regulation there are casual references to how infrastructure provision is spatially organised, but it has not been the subject of explicit research. However, against the background of the current process of institutional change (cf. section 3) signs can be seen of an extension and reconfiguration of the economic spaces of infrastructure provision and a shift in regulative powers across political levels.

*b) The significance of technical infrastructure systems for the regional economy*

Technical infrastructure systems exert considerable influence on the spatial structures of a regional economy. On the one hand, the energy and water industries in many regions are among the most important employers and investors. Through their investment in infrastructure both branches have a significant influence on the volume of investment in a region as well as on incomes and employment. On the other hand, infrastructure systems affect the regional economy indirectly, since technical infrastructure facilities are among the key factors in interregional competition to attract business and investment. For the energy and water industries this is less a question of the provision of basic services, which at least in the industrialised countries has reached a high level in just about every area. More important are regional price variations for infrastructure provision and the quality of regional infrastructure services (e.g. consulting, contracting and financial services, energy saving and facility management), where regional differences can be substantial.

The interdependencies between technical infrastructure and the economic development of localities have consequently played a prominent role in the regional economic and economic geography discussion for some time. The common argument in this debate is that technical infrastructure systems (together with other non-technical public infrastructures (e.g. educational and health facilities) constitute an important basis for all economic activities. Good infrastructure facilities promote productivity and lower costs and thus have a positive effect on the economic development of a region (cf. Seitz 2000: 267).[12] Regional infrastructure can be the determining factor for a company's choice of location as well as for the competitiveness of local companies (cf. also Abegg/Thierstein 2003; Thierstein et al. 2004). Upgrading and improving existing infrastructure can thus help raise the quality of locations and competitiveness of economic regions (Nijkamp 2000: 89).[13]

12 Seitz argues that: "(…) differences in regional infrastructure supply explain up to 20 percent of the observed interregional disparities in employment growth across West German cities" (Seitz 2000: 278).

13 The quantifiable extent of this impact is the subject of (regional) econometric investigation which, however, cannot be elaborated here. David Aschauer is a prominent proponent of this. The Aschauer hypothesis assumes that investment in public infrastructure has direct and indirect positive effects on private-sector productivity (cf. Aschauer 1989).

However, the relationship is not a one-dimensional, causal one since technical infrastructure facilities are a necessary but, on their own, not a sufficient condition for economic growth (cf. Fox/Porca 2001). Despite the close interdependence of technical infrastructure and spatial development a deterministic linkage cannot be assumed. Rather, infrastructure facilities tend to amplify the existing benefits or drawbacks of a location (cf. Offner 2000: 168).

What is conspicuous about the theoretical discussion on infrastructure and regional economic development is that, at least in Germany, it was largely concluded at the beginning of the 1970s (Wilkes 1992: 20) and there have been virtually no conceptual developments since then. Even current contributions draw on the classical concepts of infrastructure theory from the 1960s and 1970s (cf. Jochimsen 1966). This is particularly astonishing given that recent institutional change in infrastructure provision has meant that the corporate policies and investment programmes of utilities are being revised along market criteria. This is resulting in the commercial interests of the companies being given a new weight vis-à-vis policy objectives for spatial development, and in particular the reduction of regional disparities. Considerable cumulative effects for regional economies can be expected in view of the fact that not just some, but almost all sectors of technical infrastructure provision are coming under liberalisation and commercialisation pressures (cf. Thierstein/Abegg 2000). So far there has been no systematic examination of the extent to which this change is increasing spatial disparities in infrastructure services and investments, and how far the existing strengths and weaknesses of a regional economy may be reinforced as a result of changes in various infrastructure sectors.

### 4.2 Spatial effects of the current transformation of infrastructure provision

Changes to technical infrastructure systems are not just transforming actor-specific modes of action, incentive structures and the institutional constellation of infrastructure provision (cf. section 3 on this). Also in spatial terms we can observe deep-seated changes which so far – at least in the German-speaking part of the world – have not been specified in any great detail by theoretical and empirical research. The examples of electricity supply and, to a limited extent, of water supply show that corporate spatial strategies for infrastructure provision are changing and the radius of economic activities is increasing; in addition, the spatial distribution of services and investments in utility sectors is becoming more differentiated (cf. section 4.2.1). Furthermore, the creation of a single European market for various infrastructure services as well as new constellations of environmental problems have changed the spatial structure of state regulation. While water policy has until now only been marginally affected by the common market project, in the case of energy politics, we can observe a partial shifting of specific regulatory competencies among political levels (cf. section 4.2.2). Finally, the institutional transformation of infrastructure systems has had an impact on the physical spatial structure of infrastructure provision and its use of resources (cf. section 4.2.3).

### 4.2.1 The transformation of the spatial-economic structures of infrastructure systems

In the current transformation process spatial-economic structures, particularly in the electricity industry, are conforming more and more to those of sectors organised around the market economy. On the one hand the clearly defined spatial boundaries of infrastructure provision are becoming blurred and the companies are loosening their spatial ties and extending the areas of their economic activity. On the other hand the degree of spatial differentiation in infrastructure services and investments is partially on the increase and new forms of spatial division of labour are gaining in importance.

*a) Extending and reconfiguring corporate spatial dimensions*

The spatial economic structure of technical infrastructure systems has traditionally been characterised by the division into closed-area supply monopolies at a local, regional or national level.[14] As in other infrastructure sectors, the radius of the energy and water utilities' economic activities was defined by national boundaries. International trade relations played only a minor role. At most, cooperative agreements existed among the European Transmission System Operators for the compensation of peak loads in electricity supplies. Beyond that, transnational utilities were a rare exception until a few years ago. Domestically, German energy and water utilities secured their economic monopoly within the boundaries of the supply district through a network of contracts under private law.

While in neighbouring European countries an institutional and spatial restructuring of water supply systems has begun, in Germany the spatial structure of water supply has scarcely changed so far. In many EU member states water supplies are characterised by increased private sector participation, the growing importance of new stakeholders such as consumer organisations, water service suppliers etc., the introduction of new tendering models or other models for competition, but also by the concentration of the water industry (cf. Euromarket 2003). While these developments have triggered regionalisation- and internationalisation processes of the water supply sector in many European countries (ibid.), the situation in Germany is almost constant. In contrast to neighbouring countries the economic structure of the water industry in Germany continues to be dominated by a large number of municipal companies (approx. 7000) and local supply districts. Indeed, some municipal utilities have extended the area they supply in recent years and they now deliver to neighbouring municipalities (e.g. the Stadtwerke Hanover (Hanover utilities) and the Berliner Wasserbetriebe (Berlin water works). Additionally regional cooperation between water companies is gaining in importance and is increasingly demanded by politicians (cf. Bundestags-Drucksache 14/7177). However, due to the lack of competitive elements, to the low market share of large utilities and to the low measure of private sector participation economic pressure to reconfigure the companies' areas of operation is relatively low (cf. Euromarket 2003: 62). Rather, close interlinkage between the German water industry and the municipalities can be observed, and the spatial-economic structure of wa-

14 While telecommunications and the railways were national monopolies, electricity provision in Germany was divided into regional and local supply areas (and continues to be so for network management), whereas water services are mostly organised around local district monopolies.

ter supply continues to be strongly associated with the territorial structures of water politics.

By contrast, German electricity supplies are affected by far-reaching changes. Although the spatial-economic structure of transmission and distribution networks will continue in future to be defined by territorial monopolies, competition has been introduced to the territorial monopolies of the electricity generating and electricity retail markets, eroding the established spatial-economic boundaries of electricity provision. Electricity can be sold to end-users, brokers and distributors in the entire federal territory and – to a certain extent – to customers in neighbouring European countries,[15] and can in principle be generated anywhere. Today trans-regional trade in electricity on stock markets or via online markets has become an attractive economic option for many utilities. Large utilities in particular have established their own electricity trading departments which procure or sell electricity not just throughout Germany but also (although this is still in its infancy) throughout Europe, for example on stock exchanges. All in all liberalisation has enabled companies to extend their radius of action, facilitating territorial penetration of hitherto strictly separated economic spaces and thereby acquiring customers in the supply areas of their competitors.

A significant expansion of the corporate spatial dimensions of European energy and water companies is also due to ownership changes (cf. Hoare 1997: 258). The ongoing privatisation of formerly public utilities together with liberalisation and commercialisation have dramatically fuelled the trend towards greater concentration of German and European energy and water markets since the 1990s. Especially large utilities such as EdF, Vattenfall, E.ON and RWE Energy, RWE Thames Water, Suez/Ondeo and Vivendi/Veolia have tapped new markets and radically extended their supply areas through mergers and takeovers. The national basis of infrastructure utilities is gradually being eroded as the utilities increasingly develop into global players in water and energy supply (cf. McGowan 1999). At the sub-national level similar processes are emerging. Here, too, small and medium-sized utilities are attempting to expand their radius of activities by forming strategic alliances or through mergers and takeovers. All in all, the former regional monopolists are increasingly becoming less attached to their former territories, and the spatial structure of the European energy and water industries, once characterised by national industries and decentralised supply areas, is eroding. In Germany these trends remain almost exclusively confined to energy supplies, however. While the concentration of the German energy market has dramatically increased in recent years (cf. Monstadt 2004: 200-204) and a large number of energy utilities have been privatised (ibid. 165-177) German water companies remain, with only a few exceptions, municipal property. Nevertheless, foreign water utilities and large German water utilities such as RWE and Gelsenwasser AG have increased their efforts in recent years to expand spatially in the German water market by means of takeovers.

15 Network capacities are still inadequate, however, for a functioning international trade in electricity. Various initiatives by the European Commission are aimed at improving the network access conditions for international trade in electricity (Monstadt 2004: 190f.)

New market entrants in infrastructure provision are also contributing to this erosion of traditional economic spaces defined around territorial monopolies. New entrants in the energy industry, such as independent power producers (e.g. independent operators of combined gas and steam turbine power plants, combined heat and power plants, green electricity producers), energy traders and energy services companies (e.g. energy saving agencies, consultants and contractors, energy brokers, aggregates) are generally not focused spatially on traditional supply areas. Their spatial ties are not (yet) stabilised and they focus on the spatial structure of demand. In the urban water industry, too, an institutional differentiation can be observed, and new market participants and public–private partnerships are gaining in importance.[16]

All in all, an erosion of the spatial dimensions can be observed of the German energy utilities and to a lesser extent also of the German water utilities – shaped for decades by state boundaries and territorial monopolies. The traditional spatial settings of infrastructure provision are transforming as new markets are being tapped in the cause of competition, as ownership changes, but also as new market entrants emerge in the course of commercialisation and ecological modernisation processes. New functional economic territories and networked spaces of infrastructure provision are emerging that are not shaped primarily by clearly defined boundaries but by economic interactions (cf. Monstadt 2004: 241-246).

However, contrary to simplified assumptions it seems unlikely that there will be continued expansion of the spaces of infrastructure provision and complete abandonment of spatial embeddedness. This is true above all for the (German) water industry, which because of its institutional interlinking with municipal authorities, but also for physical, material reasons, remains locally tied (among other things due to the limited possibilities of transport and of connections to third party networks). But also in electricity supply, as in other sectors of the economy, we cannot expect increasing competition on international markets and the spatial expansion of economic relations to result in economic actors abandoning their regional and local roots completely.[17] Indeed, growing competition between utilities and between locations on the one hand and the re-embedding of economic interactions in socially manageable, regional structures on the other, are not a contradiction but two sides of the same coin. Even transnational companies depend on developing specific strategies for regional and local markets.

For example, the RWE Energy concern founded six regional energy companies, each of which combines sales, certain cross-sectional functions and customer services, the operation of distribution networks and network services, and the operation and maintenance of electricity and gas supplies as well as the regional water industry under one roof. This

16 The function, institutional structure and significance for water policy of such new "intermediary" organisations is the subject of research by a European research network (cf. www.irs-net.de/intermediaries).

17 Regional studies literature maintains that economic actors view the extension of spatial contexts not just as an opportunity for greater benefits, but also as a source of new uncertainties and risks. They lack secure information, sufficient capacity to process information etc. We can observe here the emergence of regional networks which contribute to the social (re-)embedding of economic relationships, coordinate the activities of public and private actors, reduce transaction costs for everybody, build confidence and minimise social conflicts (cf. Benz et al. 2000).

new structure is intended to guarantee the greatest possible proximity to the customer and improve cooperation with municipal utilities. Also interviews with representatives of municipal utilities have shown that regional proximity to the customer, local presence and co-operation with neighbouring municipal utilities are among the key elements of success for the utilities (Ernst et al. 2003). Initial studies testify to such a tandem between regionalisation and internationalisation processes in infrastructure provision that is characterised by increasing spatial expansion of the markets for infrastructure services and, at the same time, by the strengthening of regional economic relations (cf. Graham/Marvin 1997: 115; Monstadt 2004: 241-246).

However, so far there has been virtually no study of the expansion and reconfiguration of the spatial relations of utilities in Germany, especially at a sub-national level. While the internationalisation and Europeanisation of utilities are increasingly being analysed and subjected to critical appraisal (cf. e.g. McGowan 1999), the regionalisation of infrastructure provision has to date rarely been addressed by the urban and regional studies literature.

*b) Regional differentiation in infrastructure supply and investments*

Spatial differences in infrastructure provision are by no means a new phenomenon. The observation that "behind the universality of services a great disparity in the quality of service lies hidden" (Offner 2000: 168) may well always have been applicable to the development of energy and water supply systems. It has not been possible at any point in time to completely overcome spatial disparities with respect to prices, the quality of infrastructural services and social and geographical access (cf. Graham 2000: 184f.; Coutard 2002; Button 1998: 152). However, studies in the UK indicate that under the present transformation of infrastructure systems the extent of spatial differentiation and division of labour is increasing rather than decreasing: "Networked infrastructures, far from somehow equalising geography as so often portrayed in the business press, are actually being organised to exploit differences between places within ever-more sophisticated spatial divisions of labour" (Graham 2002: 4).

As utilities increasingly operate according to free-market principles in response to liberalisation or commercialisation, supply areas are no longer seen as homogenous spaces supplied evenly with the same basic services, but as spaces comprising diverse customer groups with varied requirements and sub-systems with different capacities (Moss 1998: 231). In the competition to serve territories with the highest returns – according to several studies in the UK (cf. Graham 2000, Graham/Marvin 1997; 2001) – the utilities focus their marketing and investments not only socially on particularly lucrative customer groups but also spatially on lucrative sales regions or structurally advanced sub-regions (e.g. industrial areas).[18] Such regional or sub-regional "hot spots" are characterised by high density of use (e.g. due to lucrative business and commercial users or dense settlement structures) and are thus favoured by the utilities ("cherry picking"). Consequently customers in these areas benefit more than average from competition. The users enjoy low prices, greater security and reliability of supply and innovative products. They have better negoti-

18 An extreme form of socio-spatial differentiation is posed by "gated communities", in which high-grade infrastructure is provided to wealthy clients within clearly defined boundaries (cf. Graham 2000).

ating powers because of the higher level of competition between rival providers (Graham/Marvin 1997: 116). Graham refers to these hot spots as "premium network spaces" in which tailor-made infrastructure services are offered to wealthy customers (Graham 2000).

The corollary is structurally weak areas with low consumption densities and high network operation costs[19] which are less attractive to the competing utilities. Contrary to cherry picking, peripheral or disadvantaged regions face a possible decline in the quality and quantity of infrastructure supplies and services and a reduction in investment levels (cf. Graham 2000; Offner 2000; Bakker 2002; Guy et al. 1997; Thierstein/Abegg 2000). Various studies indicate that with the commercialisation of infrastructure services the previous cross-subsidisation between regions decreases (cf. Bakker 2001). For peripheral areas this poses the question how certain minimum standards for the provision of infrastructure services can be guaranteed if the costs of this provision cannot be financed by the small population (Wagner 1996: 271). It is feared that "(...) it makes geographical barriers more important and leads to polarisation between regions based on the degree to which they are attractive to the cherry pickers" (Graham/Marvin 1997: 117). Similar trends are forecast for sub-regions in which infrastructure of the highest quality has been set up for lucrative customers while less prosperous customers are confronted with a simpler supply under worse conditions or are even illicitly excluded from the network (cf. Bakker 2001; Graham 2001; 2002; Speak/Graham 1999; 1987). As a whole it is feared that in a market-oriented supply system the competitiveness of peripheral, structurally weak regions will continue to decline and the regional disadvantages of peripheral locations will be aggravated. Structurally weak, peripheral regions are thus in danger of becoming the losers in the liberalisation and commercialisation of the utility sectors (cf. Graham 2000; Thierstein/Abegg 2000).[20]

This trend towards regional differentiation in the provision of infrastructure is fuelled by the current trend towards the concentration of utilities. As a result of corporate mergers and takeovers as well as rationalisation measures among German energy suppliers many regions are left with only skeletal the customer services. The large, post-merger companies (in particular the transmission system operators) concentrate their strategic corporate functions in a single location and remove them from others. In this process of spatial-economic restructuring there is, in all probability, considerable regional disparity in terms of job losses and the relocation and concentration of corporate operations (Pfaffenberger 1999: 79). Presumably the same applies to the increase in jobs in the new, emergent market segments of energy and water provision, which is not evenly distributed spatially. Innovative service and technology companies in the energy and water industries are relocating primarily to profitable regions. The economic attractiveness of regions depends on factors like the spatial proximity to demand markets, to science and research, to other up-

19 Transport and distribution costs in the energy and water sectors correlate not only with spatial consumption densities but also with the physical geography of a region. In rural areas low population densities and a lack of large industrial users has led to higher specific costs for the construction, operation and maintenance of the physical networks.

20 Spatial differentiation is not just significant for the economy but also for "regional-cultural identity" (Abegg/Thierstein 2003: 5). There are fears that the dismantling of former public services will turn peripheral areas into “forgotten regions“.

stream or downstream stages of production and to other favourable production conditions. In the course of the current processes of commercialisation and the emergence of new market actors competition has increased not just between utilities but also between regions. Economic locations are increasingly competing with one another for direct investment even in the energy and water supply industries which were previously far removed from competition and in order to attract and retain lucrative supply and service sectors.

However, the extent to which the liberalisation, privatisation and commercialisation of infrastructure provision not only leads to spatial differentiation but also substantially exacerbates spatial disparities has not yet been clearly proven. Authors such as Offner (2000), Coutard (2002) and Holmes (2000) view present spatial differentiations in infrastructure provision much less pessimistically. It is argued that recent reforms in utility industries have not significantly challenged existing universal services in developed countries (Coutard 2002). Besides, recent market reforms do not inevitably lead to spatial polarisation, since it can be very attractive for the utilities to present themselves as universal providers, and thus also to supply peripheral regions (cf. Offner 2000). If spatial disparities increase, the causes cannot always be attributed to the liberalisation and privatisation of infrastructure provision, but might also lie in other political, technical, cultural or environmental circumstances in the region (cf. Holmes 2000; Borenstein/Bushnell 2001) or the increasing social and functional specialisation of spaces in general.

Moreover, disparities between spaces in the provision of, access to, and use of network infrastructures are not necessarily socially undesirable: "'Cheap service for all' policies often end up as bad service for many and no service at all for many more" (Coutard 2002: 170). On no account do spatial differentiations in infrastructure provision equate automatically with social polarisation; indeed, the social and functional specialisation of spaces can have positive social impacts (ibid.: 173). Spatial division of labour and specialisation can also stimulate the emergence of regionally more adapted and economically more efficient spatial structures of infrastructure provision. One possible option is that in rural areas insular systems of decentralised electricity production, water provision and wastewater disposal emerge due to the high cost of the networks which are possibly more efficient and better for the environment. Moreover, a positive effect of the spatial division of labour could be that otherwise economically disadvantaged rural regions could use their economic potential to produce renewable energies or that the locational advantages of urban regions could increasingly be used to develop innovative technologies and services.

Taken as a whole, hardly any certain conclusions concerning the regional differentiation of infrastructure provision and its impacts on the spatial division of labour in Germany can be drawn on the basis of the existing studies. There is scarcely any empirical evidence as to how far regional disparities in German energy and water supplies are deepening and spatial cohesion objectives being undermined by the current transformation process, or as to which spatially adjusted strategies of infrastructure provision could maintain or improve the competitiveness of regions.

### 4.2.2 The transformation of the spatial organisation of state infrastructure policy

For a long time technical infrastructure systems were one of the last bastions of national industries and policy. The economic spaces of infrastructure provision were externally constrained by the territorial boundaries of the nation state. Furthermore, the territorial monopolies of German energy and water utilities were often – and in many cases still are particularly in the water sector – identical with the territories of regional and local authorities. In the course of the present transformation of infrastructure provision the spatial structures of utility industries and their regulation are also changing. Brenner describes this as a process of "reterritorialisation, (…) re-configuration and re-scaling of forms of territorial organisation" (Brenner 1999: 431), which leads to a new geography of infrastructure systems.[21]

Spatial reorganisation is a process long observed in other sectors of society. Global flows of capital and goods or new technologies for overcoming space physically or via communications have radically changed the significance of space in the past few decades and generated new spatial structures. At the same time new spatial levels can be added (such as the global arena in many areas of society) and the importance of specific levels or the relationships among them can alter. These changes to the spatial organisation of societies have – and this is nothing new – considerable implications for political regulation. Political regulatory powers shift across the different levels; today numerous regulatory tasks can only be carried out effectively beyond the nation state. This results in a spatial reorganisation of state regulation which is often paraphrased in the Anglo-American human geography debates with terms such as "shifting geometries of power" or the "jump of scale" (cf. Swyngedouw et al. 2002).

What is new about this phenomenon of spatial reorganisation is that today even infrastructure systems, which have been so far closely linked to the nation state or its territorial bodies, have also been affected by this process. This applies not just to the expansion of economic spaces; the previous spatial organisation of infrastructure policy is also subjected to radical changes. "The traditional boundaries of political space have become obsolete and the economic rationale now predominates in the extension of public services" (Offner 2000: 167).

*a) The Europeanisation and internationalisation of infrastructure policy*

Unlike the majority of industrial sectors that are heavily involved in international trade and influenced by transnational companies, infrastructure provision for a long time was only indirectly affected by internationalisation or globalisation, through its links with the global markets for energy resources and technology, or through the effects of globalisation on the demand for infrastructure services. The economic functional spaces of infrastructure provision existed largely within the territorial boundaries of nation states. Up to the end of the 1980s infrastructure policy was characterised by a high degree of national autonomy and a general abstinence on the part of European policy. Not until the 1990s did the ex-

21 Reterritorialisation encompasses "the continual production and reconfiguration of relatively fixed spatial configuration - for example the territorial infrastructures of urban-regional agglomerations and states" (Brenner 1999: 435). It therefore represents the counterpart to deterritorialisation through globalisation.

clusively national contexts gradually become more permeable. Today, the extent of activities of infrastructure policy that require regulation and that can no longer be effectively regulated by the nation states has clearly increased. The causes lie in the combination of several factors (cf. Monstadt 2004: 217-223):

- Since the 1990s European policy has increasingly laid claim to the regulation of network industries, and the European Commission has become a key actor in liberalisation policy. Single Market regulations have been successively extended to all systems of infrastructure provision, the only exceptions being water supplies and sanitation. Decisions concerning market-making regulation are made less and less in the national context. Regulations enabling discrimination-free network access, preventing price-fixing agreements and cutting off cartelisation processes have been shifted substantially to the European level. The European Union also plays an active role in establishing and funding trans-European networks in the field of transport, energy and telecommunication.[22] This trend towards the Europeanisation of infrastructure policy has altered the powers and formal decision-making processes of the nation states. Today no member state is able to pursue autonomous policies independent of the European level. National interests in infrastructure provision can only be formulated, agreed and implemented within a multi-level system. Nation states are increasingly required to negotiate their territorial interests with the Commission and other member states at a European level.
- The economic integration and harmonisation of national supply systems in European and global markets has been accelerated by the liberalisation and commercialisation of infrastructure provision (cf. section 4.2.1). There has been substantial growth in the interdependencies of national policy as international infrastructure markets tend towards oligopolies, multinational utilities expand and international strategic alliances are formed. Trans-nationally oriented energy and water companies are increasingly distancing themselves from the influence of nationally oriented infrastructure policy not only in a spatial sense but also by virtue of their growing market power and organisational capacities (McGowan 1999). While a European Single Market in infrastructure is being created and transnational capital involvement within the utilities sectors continues to strengthen, the effectiveness and efficiency of nationally oriented policies declines and the demand for effective institutions for European or even global regulation increases.
- Besides the internationalisation of markets, the transnational or global reach of the numerous environmental problems associated with infrastructure provision reduces the effectiveness of nationally oriented policy. Environmental problems concerning cross-border watercourses, cross-border air pollution or global climate change have necessitated shifts in responsibilities to the level of supranational institutions and transnational negotiation systems. Many environmental problems can now only be resolved in interrelated multi-level systems. In those systems nation states do exercise an important link between international and sub-national policy. However, specific decision-making

22 For an overview compare the summaries of European Union legislation (http://europa.eu.int/scadplus/leg/en/s06019.htm, 1.11.2004).

powers and regulatory tasks must be transferred to international and supranational policy, and nation states are increasingly bound into negotiation systems at European and international levels. Here institutional precautions are taken to prevent individual states from free riding, and also to amalgamate environmental policy strategies internationally and harmonise them through regulative market guidelines (e.g. the Kyoto protocol, European emissions trading, European wastewater standards, the European Water Framework Directive).

The globalisation of environmental problems and the internationalisation of economic interdependencies in large technical systems create a need for regulation that can no longer be satisfied at the national level. We can observe the gradual emergence of international organisations and regimes, as the growing number of agreements and organisations in global trade, climate protection and water policy illustrate. However, numerous empirical findings testify to the fact that the establishment of effective regulatory institutions at the global level lags far behind the growing economic-ecological interdependencies of nation states. An "institutional void" (Hajer 2003:175) arises, in which both clear regulations and norms to guide which measures should be taken and organisations with the power to ensure that effective measures are implemented are missing.[23]

At the same time we can observe a distinct increase in regulatory activities in infrastructure provision at the European level which has prompted some authors to herald the rise of a regulatory state in Europe (cf. Majone 1994; 1997; McGowan/Wallace 1996). However, this assumption has been challenged and assessed differently in recent studies. It is conceded that European regulation with respect to the opening-up of markets is comparatively advanced, since simplified decision-making rules apply to Single Market legislation, resulting in fewer objections from member states. By contrast, European regulation in the fields of environmental policy, public services or the security of supply are subject to typical decision-making log jams (cf. Eberlein 2000: 102). Effective regulations on environmental protection, for example stipulations concerning taxes or rules which affect a member state's choice between different energy sources or the general economic structure of its energy and water supplies, require a unanimous decision in the European Council. The dilemma is that, especially in the case of regulations relevant to structural policy in the field of energy and water supplies, because of the huge economic differences between the member states "the diverging interests are typically so predominant that either common standards are blocked or a consensus can only be achieved by means of expensive compensatory payments or package deals" (Scharpf 1996: 117, our translation).[24] In view of the difficulty in reaching agreement at the European level over the regulation of social

23 For example the ratification of the "United Nations Framework Convention on Climate Change" (1992) and its specification in the Kyoto protocol had still not been completed twelve years later. It was only confirmed when Russia joined in autumn 2004. Whether the ratification will also lead to the effective implementation of the agreements, and beyond that to an improvement in the environment, depends on the coming negotiations on effective control mechanisms and procedures.

24 European climate policy regulations thus remain confined to the definition of objectives, reporting obligations etc., despite the increase in greenhouse gas emissions in most member states. Effective environmental policy within market regulation is still the exception, and the task of defining regulatory frameworks is deferred to the member states. The same applies to other policies for safeguarding public interests in the provision of infrastructure (such as spatial cohesion objectives, security of supply etc.), for which, at a European level, only vague objectives and reporting requirements have been formulated.

or environmental aspects of infrastructure provision, it can be expected that a considerable share of the responsibilities will continue to be located at the national level (cf. Eberlein 2000: 103; Czada/Lütz 2003: 30). This can no longer take place under the condition of national autarchy, however, but only in conjunction with other states.

Within the last decade a broad research community has focused on the political problems of regulation as a result of the growing international interlinking of markets, global (environmental) problems and the multilevel interrelationship of state regulation. Particularly for infrastructure provision, however, where internationalisation is a relatively new phenomenon, only a few studies exist which deal with the new distribution of responsibilities between nation states and the supranational political level.

*b) Enhancing regional spaces for the functioning of infrastructure policy*

Although numerous questions regarding the division of labour between the national and supranational levels remain unresolved in the current debate it is above all the consequences of these changes for the sub-national level to which not enough attention is being paid. The initial question is whether addressing the sub-national political level is anachronistic given that even nation states are regarded as too small a territorial unit of governance to be capable of meeting the needs posed by the growing Europeanisation and internationalisation of economic space and the globalisation of environmental problems. This impression is confirmed when we consider market-making regulation, to which regional and local policies can at best make a marginal contribution. The regulation of competition, including defining the conditions for opening up markets in the energy industry or for competitive tenders or benchmarking in the water industry, supervising company mergers and takeovers and ensuring discrimination-free access to the energy networks or a discrimination-free invitation of tenders for water supplies, can hardly be dealt with at a decentralised level but are much more efficient when subject to national and European regulation.

However, the sub-national political level continues to bear responsibility within the framework of market-correcting regulation, i.e. regulation aimed at correcting markets in order to achieve ecological objectives and welfare objectives such as security of supply, the universal provision of infrastructure services and equal rights of access to those services. This responsibility rests not solely on the formal obligations arising from the principle of subsidiarity or the decentrality of the historically rooted utility structures in Germany. The argument that greater attention needs to be paid to the sub-national political level is based above all on functional considerations: conditions for improving innovation in the provision of infrastructure cannot be planned and implemented solely by the central level of the nation state or the EU. Processes of economic restructuring and innovation vary from region to region. Conditions specific to particular regions[25] substantially determine the capacity of regional infrastructure systems to innovate and the direction of such innovation. Regional research emphasises that decentralised policies are more suited to activating and

25 These include the skills of the regional labour force, infrastructure for communications, technical and network infrastructures, the economic and technical specialisation of a region's infrastructure provision and the scale and nature of regional demand for infrastructure services (cf. Heeg 2000: 47).

developing this endogenous potential than policies at other levels (cf. for example Benz et al. 2000; Heeg 2000; Cooke et al. 2004). They can make a greater contribution to establishing connections with traditional economic domains and technical infrastructures and to mobilising regional expertise and advantages related to specialised infrastructure provision. Local proximity enables policy-makers not only to gain a more precise impression of regional strengths and weaknesses but also to recognise deficits and problems at an early stage, allowing them to react with greater flexibility. Local or regional political bodies are able to disburden policy-making at national and European level and to provide support in gaining acceptance locally. Their task is not so much to influence markets by means of prices or legislation but to compensate for gaps in national and European regulation, to facilitate compliance with regulations, to counter the avoidance strategies of those affected by regulatory policies and to take adequate account of local specificities, problems and endogenous development potential as well as to combine solutions to environmental problems with economic benefits.

Although the basic significance of the sub-national political level is largely undisputed, new challenges have arisen regarding its spatial organisation. Recently, trends in energy and water provision can be observed that are comparable to those in other sectors organised along the market economy. Neither liberalisation and commercialisation nor new environmental policy regulations have resulted in space losing its significance. Economic processes and large-scale networks continue to be embedded in regional structures that are socially "manageable" (cf. section 4.2.1 a). However, these links to specific regions correspond only to a limited extent to the boundaries of traditional administrative units or supply districts, which is also true of other economic sectors that are organised along the principles of competition. Although the supply areas which have developed historically and the territorial organisation of the federal states and the municipalities continue to affect the spatial economic structure of energy and water provision, the influence of regional and local authorities and of historical supply districts on spatial structures is diminishing with regard to both energy and water provision, although for different reasons.

Marked regionalisation can be observed particularly in energy provision (on the energy industry cf. Monstadt 2004: 241-246). Many utilities, particularly regional suppliers and municipal utilities, concentrate primarily on customers in close proximity to their previous sales districts and their marketing strategy emphasises their regional competency and embeddedness (Ernst et al. 2003). Even conglomerates which are active throughout Germany and internationally such as RWE Energy AG set up regional companies and develop specific regional marketing strategies. In order to concentrate their interests and market power and to utilise the existing infrastructure in an optimal fashion, municipal utilities and regional suppliers form strategic alliances in their neighbourhood. Municipal authorities and certain end-user groups also organise themselves into regional procurement cooperatives. The aim of these alliances, some of which are organised by associations, chambers of trade and commerce or specialised energy service suppliers, is to negotiate more favourable economic conditions, and in some cases ecological standards, for energy purchases. Most energy agencies, energy service suppliers and associations of engineers also operate in a regional context. Proximity to the customers and the use of existing regional communication structures represent a competitive advantage. Certain decentralised electricity producers also organise regional networks (wind energy producers, for example) and in some regions technology clusters are formed among different technology companies, service providers, research institutions etc.

Parallel to these regionalisation processes it can be observed, particularly in energy provision, that the traditional regulative power of the federal states and the municipalities is being eroded. Three factors are decisive for this. Firstly, utility companies are undermining the influence of regional authorities by increasing their activities beyond the boundaries of the established regional or local territories. Secondly, the former regulatory agencies of the federal states responsible for the control of infrastructure investments and energy prices have been abolished and the regulatory influence of the municipalities via concession contracts and utility ownership has been diminishing. Thirdly, the fiscal crisis of many municipal authorities and federal states makes it increasingly difficult to meet the objectives of services of general interest and of environmental protection via public subsidies or investments. The regulatory influence of local and regional authorities on spatial structure is thus diminishing (cf. Monstadt 2004: 223-228). Offner (2000: 173) speaks of "the limitation of the power of local governments [which] is shared by many recent analyses on territorial governance which place the accent on the complexity of modern public policy-making as well as on the diversity of the public and private players involved in local decision-making". This loss of political influence in the area of regulation and in the direct provision of services by public companies can only be compensated for if there are increased cooperative and market-oriented forms of governance and new forms of interactions among state, municipal and social actors. Structural policy strategies for the promotion of innovation and business development play a role here, as do strategies for informing, convincing and negotiating with the addressees of political interventions and for activating their willingness to cooperate.

New economic functional spaces and regional networks are gaining in importance due to the economic regionalisation processes described above, but also due to the decline of the regulatory power of the federal states and municipalities. However, the boundaries of such functional spaces, determined above all by the scope of the economic relationships of the utilities and service industries and the reach of regional networks, are becoming more and more blurred. As a result, regional interrelations in the provision of infrastructure services are emerging, the spatial structure of which is defined primarily not by the boundaries of political territories but increasingly by economic and socio-cultural networks at a regional level (Monstadt 2004: 241-246).

In the German water industry, too, first signs can be seen of stronger regional cooperation among utilities. In addition to the already existing inter-communal water associations, in recent years numerous communes have begun to use synergy effects in the utilisation of infrastructure and to achieve cost savings through regional cooperation. In its modernisation strategy the federal government calls for support for regional cooperation, or mergers of neighbouring water supply systems and the creation of larger regional operative units (Bundestags-Drucksache 12/7177). The pressure for economic efficiency in water provision and sanitation compared with other utility sectors has until now been low, however, and market-driven regionalisation processes are still exceptional. Instead, the new legislative framework for water policy promotes the creation of new regional functional spaces and leads to a reconfiguration of the spatial context of water management, which was previously based on the territories of the federal states and municipal authorities. The introduction of the European Water Framework Directive in the field of water policy has thus created new political and economic spaces in which the management of water resources in future is to be based on river basins (for more details cf. Moss 2003).

These processes of economic and political regionalisation in energy and water provision, it is argued, pose new challenges to the spatial organisation of state regulation and political governance. Generally speaking, it can be assumed that the effectiveness of political regulation depends largely on the extent to which its spatial organisation is compatible with the spatial dimensions of economic relations or other functional contexts. The efficiency of political intervention can be enhanced the more regulative concepts and processes anticipate the spatial context of the networks of economic actors and other addressees of political steering and the more the spatial context permits appropriate problem-solving strategies (cf. Benz et al. 2000; Holzinger 2002). In terms of infrastructure provision the territorial organisation of political and administrative responsibilities – in Germany primarily along the territories of the federal states and the municipalities – is becoming increasingly problematic. The territorial institutions of energy and water policy correspond less and less to the network spaces of the economic actors who are the addressees of political intervention or to the newly created functional spaces for river basin management. The misfit between economic or ecological functional spaces and administrative territories is growing and creating new problems for the compatibility and efficiency of political regulation. Public interests relating to infrastructure provision can now only be asserted to a limited extent within the territorial boundaries of the federal states and the municipalities.

Given the limitations of policy exclusively organised within the territorial boundaries of the federal states and municipalities attention is turning increasingly to regions as arenas for planning and decision-making.[26] This does not mean that federal and municipal policies are becoming less important for the provision of infrastructure services.[27] However, the effectiveness of decentralised governance can be increased if account is taken of current processes of regionalisation and the extent of socio-economic interaction or newly created political spaces of activity. It does not follow that new territorial units need to be created and defined along new boundaries or – at least primarily – that new formal organisations should be established at a regional level. Rather, regional policy should enrol the new economic relationships of a region in problem-solving processes and seek greater integra-

26 The *region* is defined here as a spatial context of action located between the nation state and municipalities. Regions are interpreted in the following as spaces in the sense of an area of social interactions which are shaped by the various economic, social and political actors and organisations within a physical, geographical space (cf. Benz et al. 2000). River basins can be regions in this sense, as can regional network spaces in the energy industry.

27 Numerous government tasks – such as the drafting and implementation of plans and programmes (e.g. land utilisation plans, urban and regional planning, infrastructure planning), awarding grants, implementing legal regulations, supervising municipal companies – remain in the hands of the formal institutions of the federal states and municipalities, and remain tied to parliamentary decision-making and the creation of political legitimacy.

tion with the activities of regional actors in research, chambers of trade and commerce, business associations and other economic actors. This includes the development of co-operation between municipalities and strategic forms of cooperation between the various state actors (EU, nation state, federal states) as well as municipal actors, utilities, service and technology firms, associations, consumer groups etc. in a regional context (cf. Heinze et al. 1997: 320). Such new forms of regional cooperation and governance can serve the further economic development of a region and the growth of its competitiveness as well as supporting social and ecological innovations.

Even although the existence of processes of regionalisation in energy and water supplies can be proven empirically and the increasing importance of regional policies therefore appears plausible theoretically, this does not imply that such a reconfiguration of the spaces of political activity is in fact taking place. The beginnings of a revaluation of the regional level can be illustrated in the field of policies relevant to energy and water, however. For one thing, this is the case for the prevention of water pollution, where local and regional authorities are beginning, as a result of their legal obligations, to coordinate their policies and develop common policies with regard to river basins. In contrast to this, regional co-operation between, or the interconnection of, neighbouring water and sewerage systems is still in its infancy despite political support, and public investments in infrastructure have so far been little coordinated among local and regional authorities. In the field of energy policy the first regional models and institutionalised forms of cooperation have been developed in recent years, for example in the "climate protection regions" Elbe-Elster, Hessisches Ried, Kiel and Hanover, the "solar capital" Berlin and the "solar regions" Freiburg and Rhein-Neckar, the "energy regions" Nuremberg and Emscher-Lippe and the "energy states" North Rhine-Westphalia (NRW) and Brandenburg. Further attempts are being made, via the founding of regional energy agencies, to support environmentally friendly and efficient forms of energy supply and use through public private partnerships or similar organisation models in a regional context. Finally, by setting up and supporting regional centres of competence and regional innovation networks political authorities are attempting to link technological and environmental policy innovations with the economic development of the regions. Networks such as the Energy Forum of Bavaria, North Rhine-Westphalia's "State Initiative on Future Energies", the "Energy Network NRW" and "Water Management Initiative NRW", the "Berlin Energy Forum" and the "Berlin Centre of Competence for Water", the "State Energy Foundation of Schleswig-Holstein" and the "Centre for Energy Technology" in Brandenburg all attempt in their own specific way to strengthen regional competitiveness and innovative capacity, to support state promotion of technology and to tie innovative energy, water and technology companies to the region. In spite of these regional approaches the larger share of political initiatives in support of energy supplies, and more particularly of water supplies, continues to be territorially focused and scarcely reflects economic and functional interdependencies in space.

Although the problem of multi-level governance is stressed in the literature, the transformation of infrastructure policies at sub-national level have, paradoxically, been ignored in studies of statehood by social scientists (cf . Coen et al. 2002; Eberlein 2000; Eising 2000; Grande/Eberlein 1999; Sturm et al. 2002). Apart from initial empirical research on the impacts on urban infrastructure management (cf. the studies by Graham, Guy, Marvin, Monstadt and Moss), there are virtually no empirical case studies of the transformation of sub-national infrastructure policy and its spatial organisation.

#### 4.2.3 The transformation of the spatial structures of technology and resource use

The current transformation affects not only the socio-spatial organisation of technical infrastructure systems. In view of the close linkage between the specific institutional context of infrastructure systems and their technical components the institutional transformation currently taking place also affects technical structures. The new forms of social organisation can lead to certain technical artefacts or structures being favoured or disadvantaged to a greater extent than in traditional systems of infrastructure provision. Such changes have a profound effect on the spatial dissemination and structure of technical artefacts and the spatial dimensions of resource use. A distinction can be made between the following aspects:

*a) Changes in the spatial structure of infrastructure facilities and networks*

The liberalisation process in the energy sector (and in other infrastructure systems) increases incentives for the *spatial expansion* and *growth of technical components*. Technical networks are expanding as the scale of cross-border interconnections increases.[28] An earlier growth pattern at the national level is thus being repeated at the transnational level as (supra-) state institutions participate actively in transnational expansion of technical systems and promote convergence between them (Mayntz/Schneider 1995). This can be illustrated by the trans-European network project, the rise of European regimes for the economic regulation of network industries or for environmental protection. The boundaries of what used to be clearly defined supply areas are also becoming blurred at sub-national level, and individual connection lines are being laid to lucrative customers in neighbouring areas. In the water sector in Germany, by contrast, the spatial structure of the supply networks remains closely linked to the established territorial monopolies, except in a few cases.

A further significant innovation is the *emergence of decentralised technical networks and insular supply systems*. Technical innovations, but also environmental policies have resulted in existing technical systems for energy and water supply being supplemented by decentralised energy generation and water treatment technologies. Technical innovations in energy and water supplies, together with new information and communication technologies (ICTs), make completely new supply solutions possible. In the energy sector electricity generation technologies that can be applied on a decentralised basis, in small units and (partly) with limited capital investment have become quite competitive (e.g. modern steam and gas turbines, combined heat and power plants, small-scale fuel cells and renewable energy generating plants). The decentralised generation of electricity and its transfer to the grid have been advanced with the help of innovative transmission tech-

28 Water provision is an exception. In this sector there is very little transnational trade in water at least in Europe, where any water transfers are limited largely to a regional context. However, we can expect some measure of convergence in technical structures and forms of social organisation in response to European regulations, the globalisation of technology markets and growing corporate linkage.

nologies which reduce energy losses from the grid and improvements in electricity metering technology and in the monitoring of cables, which enable the supply by decentralised micro-power stations to be coordinated with the aid of information technology. These developments have led to changes in the classic topology of the networks and the locations of power stations. For example, power stations are in some cases now being located in coastal areas instead of coal-mining regions. At the same time, an increasing number of decentralised power stations, some of which generate electricity from renewable energy sources, must be integrated into the existing technical system (for details cf. Monstadt 2003: 50-63).

For water supplies new technological developments like membrane technology or information and communication technologies may bring about radically different system concepts and higher quality decentralised solutions. For example, membrane technology enables the construction of extremely small, high-powered but also inexpensive plants for decentralised water treatment (Hiessl et al. 2003: 136). In addition, innovations in the utilisation of rainwater, the treatment and utilisation of grey water and disinfection, as well as innovations in the field of water-saving household appliances and fittings, offer completely new options for water provision. Particularly the combination of decentralised plants with the modern automation of buildings and remote monitoring enable radical innovations in water supplies, which can also have considerable spatial effects.

Altogether, on the one hand a trend towards spatial expansion and the networking of technical systems over great distances can be identified, due to the growing convergence of technologies through trans-nationally valid norms, international companies etc. and to the physical linking of the networks. On the other hand, the technical innovations described have the potential to complement the existing centralised supply structures in the energy and water industries or even, in the long term, to replace them. Given the local specificities of most infrastructure systems and the increased range of technological alternatives, preferable technical solutions are likely to become locally and regionally more differentiated than today. Technological innovations make possible the spatial diversification of technological structures and the emergence of innovative regional technological styles. This combination of spatial expansion and diversification of the technical systems has until now, however, not been the subject of much scientific investigation.

*b) The transformation of the spatial dimensions of resource use and technical modernisation*

Gradual changes are also occurring in the spatial dimensions of resource use and the technical modernisation of infrastructure facilities both in electricity supplies and to a certain extent in water supplies as a result of changes to economic incentives. Increasing pressure to be competitive and to rationalise has prompted infrastructure providers to reappraise existing technical structures and possible capital expenditure on modernisation according to commercial and competitiveness criteria. Capital expenditure on the construction and operation of power stations, water treatment plants, distribution networks and other technical components can no longer be evaluated almost solely on the basis of the extent to which they fulfil the criteria of engineering excellence and security of provision. Instead, low investment and operational costs as well as short amortisation periods are gaining in importance as criteria for determining capital expenditure.

The changes to cost and market structures tend to disadvantage capital-intensive technologies with long amortisation periods. As it can no longer be guaranteed that capital expenditure on the construction of plant for energy provision will be covered by "captive" consumers, and customers now are often bound only by short-term contracts with the suppliers, the utilities are becoming increasingly averse to taking risks on investment. Similar trends can be observed in the water industry, where tenders are invited for the provision of supplies or certain water services for limited time-periods (for details cf. Rothenberger/Truffer 2004). Investments in technical infrastructure which can only be amortised in the long run will only be made if the contracts are for a correspondingly long period. The chances of capital-intensive technologies (such as complex district heating systems, nuclear power stations and sewage treatment plants) being implemented decrease unless the state provides additional incentives or regulations for investment. Uncertainty regarding future market developments and increasing pressure to rationalise create substantial financial risks for the utilities, which may respond by choosing less capital-intensive technologies of by shelving or postponing necessary infrastructural investment.[29]

Above all in the remaining area of monopoly, the distribution networks, it is rational for companies to attempt to make monopoly profits, in other words to seek considerably higher profits than are justified by their capital expenditure and maintenance costs. As networks that are in a poor condition cannot be sanctioned readily by customers – owing to the lack of competition in the network monopoly – and are thus cost-effective for the companies concerned, there is a risk that the required capital expenditure on the modernisation of distribution networks will either be postponed or not carried out at all. The sub-standard water distribution networks in the UK, which contribute to large-scale water leakage, and the power cuts in North America, the UK and Italy in 2003 illustrate the dangers of inadequate levels of investment.

Increased pressure to be competitive and to rationalise affects not only the technical condition of infrastructure systems and investments in the security of provision. They also have a profound effect on the way resources are used, although it is still unclear whether the beneficial effects outweigh the detrimental ones or vice versa.

In the German electricity sector it can be observed that utilities which compete with one another have to make a greater effort to retain their customers. Consequently, we can observe an increase in their readiness to provide services to attractive major customers such

29 This trend can currently be observed in the German electricity sector. Although around half of the existing power stations will be decommissioned over the next two decades, requiring a high level of investment, capital expenditure has decreased considerably since the energy market was liberalised, falling by 50 per cent between 1998 and 2002 (Monstadt 2003: 41).

as regional and local authorities and large industrial and commercial users.[30] In addition to promoting the number of service activities offered by the utilities, liberalisation can also promote the emergence of environmentally oriented actors on the market (e.g. producers and traders of green electricity) who target environmentally aware domestic customers. The trend towards less capital-intensive technologies can also have beneficial effects. It has, for instance, supported the technological switch from coal-fired power stations to cheaper and less polluting combined gas and steam turbines for the production of electricity. Economic incentives to use fuel economically and reduce losses from distribution networks are increasing in response to the pressure to cut costs emanating from liberalisation and commercialisation. This can result in a higher efficiency of resources used and to a reduction in the emission of pollutants (Marvin/Guy 1997; Bakker 2003; Meredith 1992). In addition, pressure to be competitive can also lead to supply and demand being matched more effectively and any overcapacity being reduced in an environmentally sound manner, as the German electricity sector has demonstrated recently.[31]

At the same time, we can observe considerable negative environmental impacts. All investments in innovative environmental technologies and services aimed at conserving resources are being reappraised and only introduced if there are measurable economic or market advantages or at least an improvement in the company's image. Voluntary environmental programmes run by individual utilities (e.g. energy conservation campaigns, funding programmes for technology development) and consultancy targeted at household customers are being shelved. Owing to the uncertainty regarding market developments and the growing pressure to cut costs, investments in innovative environmental technologies and services are in many cases considered too risky and therefore axed (cf. Lofman et al. 2002). Many companies are investing their limited financial reserves – and their management resources – less than in the past in the development of innovative products or the opening up of new markets for environmental services and technologies. Instead, many of them are trying to increase profits by directing scarce financial and human resources at improving their market position by buying up, or merging with, other companies.

Overall it is virtually impossible to make any general assertions on the consequences of the transformation of infrastructure provision for the way resources are used spatially. It can generally be assumed that capital expenditure on the ecological modernisation of infrastructure plant and networks or the development of demand-side management is increasingly being examined from the point of view of economic efficiency. The ecological effects of increased competitive pressure and the privatisation and commercialisation of infrastructure provision must, however, be differentiated according to the very specific conditions in individual sectors and regions (Meyer-Renschhausen 1996) and depend to a

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30 Guy, Graham and Marvin in particular stress the growth of activities by the utilities in the field of demand side management and refer to the "environmental benefits of liberalisation" based on experience in the UK (IBID. 1997: 206). That experience can only be partially confirmed in the case of electricity supply in Germany. While major customers in Germany benefit from an increase in the range of services being offered to them, energy services for domestic customers and specific energy conservation programmes have been subject to drastic cutbacks.

31 For example, in the initial years following the liberalisation of the German electricity market huge power generation capacity was decommissioned without being replaced.

great extent on supplementary support by environmental policy. Consequently, it is difficult to generalise about the impacts on the spatial structure of resource use, especially as they have hitherto been subject to little scientific scrutiny.

## 5. Research Requirements

Political and economic reforms in infrastructure provision have, in the space of a few years, broken up the established spatial structures developed over past decades, and new spatial structures of technical infrastructure systems are emerging. Despite numerous reforms to environmental and competition policy the end of this spatial reconfiguration of infrastructure provision is not in sight. In the German water sector in particular political market reforms – e.g. the introduction of tendering procedures, benchmarking systems and/or other elements of competition – are to be expected in the medium term. The liberalisation of European water markets remains on the political agenda of the Directorate-General for Competition of the European Commission. Furthermore, in view of the desolate financial situation of many municipalities, the increased activities of transnational corporations in the German water sector and the increasing pressure for the creation of larger and more efficient production units it is very probable that privatisation and market concentration in the German water industry have only just begun. The transformation process in the German electricity industry is also far from complete. The EU's extensive energy reform initiatives, in particular to increase competition by restructuring the regulation of network access, the introduction of a European system of trade in emission rights and other climate policy market reforms will have far-reaching effects on German electricity markets in the medium and long term. Moreover, by 2020 almost half of German power generating capacity will be decommissioned, the phasing-out of ($CO_2$-free) nuclear power generation should be almost complete, and at the same time $CO_2$ emissions are to be reduced by 40% against 1990 levels. It is likely, therefore, that the speed and extent of transformation in both the energy and water sectors will increase rather than decrease in the future.

As illustrated in the previous sections, the existing and planned market reforms, technological developments and visible market trends have had a significant impact on the spatial structure of infrastructure provision. Not only the infrastructural preconditions for economic development and for social and spatial cohesion will be radically changed. The socio-spatial structures of infrastructure provision will also be re-arranged and even the character and spatial structure of the infrastructural networks and plants will be affected by the transformation. Precisely because energy and water supply systems are the driving forces of numerous production processes, because they have considerable direct and indirect impacts on economic-spatial differentiation, on regional employment and income and on resource use and environmental damage their influence on the spatial development of modern societies can hardly be overestimated. Hence the prospect of pursuing sustainable spatial development depends to a large extent on how technical infrastructure systems, such as energy and water supply systems, develop.

This study has been able to structure and to specify in some detail the various dimensions of spatial transformation and to discuss the possible opportunities and risks involved. The transformation of infrastructure systems and their individual spatial effects has still to be examined empirically, however. While the increased number of national comparative studies in recent years has been able to contribute to the considerable growth of knowledge on national policy styles, institutional conditions for the success of policies etc., only few regional comparative studies have been undertaken. Since existing studies of the current transformation of infrastructure systems and state infrastructure policy by political scientists, economists and legal experts all ignore the spatial contexts of action and the regional policy level, numerous open questions relating to the regional transformation of infrastructure provision need to be addressed. The questions which arise are how the transformation of infrastructure systems takes place in different spatial-institutional settings and what specific demands are placed on regional policies. Both depend not only on the general national conditions but also on the specific regional energy and water problems, on the technical infrastructure available, on the qualifications of the workforce, on geographical and settlement structures, on the demand for infrastructural services and on the institutional structure of politics and administration. For further spatial research the following hypotheses can therefore be formulated, which should be examined empirically in regional case studies.

*The present transformation of infrastructure systems is prompting the regionalisation of economic and political relationships in the energy and water sector*

The liberalisation and commercialisation of energy and water supplies, the emergence of new market actors in the energy and water industries and new requirements with regard to the prevention of water pollution are undermining the spatially structuring effect of municipal authorities and historically developed supply districts. There is considerable expansion of the areas of operation of many utilities, and particularly in the German energy industry the internationalisation of supplies can be observed. At the same time it is expected that spatial ties will certainly not disappear, but that companies will increasingly have a regional focus, that regional cooperation and new regional functional spaces will gain in importance. Particularly local authorities, whose regulative and financial control of energy and water supplies tends to decline with commercialisation, privatisation and the fiscal crisis, are confronting increasingly the limitations of a territorially oriented policy. They are increasingly dependent on cooperation in a regional context for influencing utilities and supporting innovators in the utility sectors.

*The supply of infrastructural services, the investment activity of utilities and their technological profile will become spatially more differentiated*

We can expect the transformation of infrastructure provision to exacerbate existing spatial disparities and strengthen the spatial division of labour since infrastructure investments allocated under conditions of competition will favour structurally strong, urban regions with high demand densities, while a reduction in infrastructural investments will be suffered in rural, structurally weak regions. For structurally weak regions or districts there is therefore a risk that previous standards for services of general interest will no longer be able to be guaranteed throughout, which could lead to (further) reductions in regional competitiveness and quality of life. Conversely, structurally advanced regions profit as "premium network spaces" from higher intensity of competition through lower prices, greater security and quality of supply and a high quality product range. They thus become preferred locations for the production of social and technical innovations in infrastructure provision. Depending on their individual locational situation and endogenous potential, regions are increasingly dependent on the development of region-specific strategies for infrastructure provision, on the use of spatially adapted technologies and the development of regional competency and specialisation profiles.

*New economic incentive structures for the environmental modernisation of energy and water supplies are emerging*

Privatisation, liberalisation and commercialisation processes are by no means neutral in terms of their environmental impacts. They alter economic incentives for resource use in that investments in the ecological modernisation of technical infrastructures or demand-side management are assessed according to the extent to which they increase a utility's competitiveness. Investment in the efficient use of resources, in an extended range of services etc. has in many cases proven to be economically rational, and specialised environmental businesses are proving to be competitive, at least in niche markets. Nevertheless, it is by no means probable that competition will lead to ecologically more efficient and environmentally sustainable use of resources without market-correcting regulation. Regional technological and environmental objectives in the field of energy and water provision can only be achieved if the investment activities of utilities are – inter alia – regulated at a regional level and if the competitive conditions for ecological innovators are improved by professional and market-conforming structural policy strategies.

*State responsibilities in infrastructure provision must be given a new direction at the level of the federal states and local authorities*

Given that the provision of both energy and water are subject to pronounced market failure when it comes to operating monopoly networks, using environmental public goods and securing specific public services, the debate on the deregulation of infrastructure provision is clearly nothing more than political rhetoric. The current transformation of infrastructure provision should therefore be interpreted not as a withdrawal of state responsibilities but as a complex adaptation of state functions and structures. This is particularly true of the water and energy policies of the federal states and the municipalities, in which the state's responsibilities must be defined anew.

Specific regulatory functions have emerged to meet this need, relating for example to sustainable resource management. Other functions are increasingly redundant under the conditions of a functioning market, for example the case-specific supervision of investments and prices (except for the network monopoly). Further infrastructure functions are being delegated to the private sector via privatisation or outsourcing, leaving state institutions with the task of controlling the outcomes of private-sector involvement. While until recently it was typical for the regulatory regime to be based on public ownership, state-controlled monopolies and end-of-pipe environmental protection and to operate within clearly defined spaces (nation state, supply districts, sub-national administrative territories), these traditional, territorially defined state mechanisms of control and regulation are becoming less effective.

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## Appendix

### netWORKS-Papers

The findings of the netWORKS Research Association are published in the series netWORKS Papers, the full text of which is published in the Internet and in a small edition. Local authorities may order these publications free of charge – as long as stocks are available – from the German Institute of Urban Affairs. Academic customers and the specialist community can download the texts free of charge from the project platform www.networks-group.de. The following Papers have appeared to date:

- Kluge, Thomas/Scheele, Ulrich
  **Transformationsprozesse in netzgebundenen Infrastruktursektoren. Neue Problemlagen und Regulationserfordernisse**
  Berlin 2003 (netWORKS-Papers, Nr. 1)

- Kluge, Thomas/Scheele, Ulrich
  **Transformation Processes in Network Industries. Regulatory Requirements**
  Berlin 2003 (netWORKS-Papers, No. 1)

- Kluge, Thomas/Koziol, Matthias/Lux, Alexandra/Schramm Engelbert/Veit, Antje
  **Netzgebundene Infrastrukturen unter Veränderungsdruck – Sektoranalyse Wasser**
  Berlin 2003 (netWORKS-Papers, Nr. 2)

- Bracher, Tilman/Trapp, Jan Hendrik
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  Berlin 2003 (netWORKS-Papers, Nr. 3)

- Bracher, Tilman/Trapp, Jan Hendrik
  **Network-Related Infrastructures under Pressure für Change – Sectoral Analysis Public Transport**
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  **Netzgebundene Infrastrukturen unter Veränderungsdruck – Sektoranalyse Telekommunikation**
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  Berlin 2004 (netWORKS-Papers, Nr. 8)

- Hummel, Diana/Kluge, Thomas
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- Monstadt, Jochen/Naumann, Matthias
  **Neue Räume technischer Infrastruktursysteme.** Forschungsstand und -perspektiven zu räumlichen Aspekten des Wandels der Strom- und Wasserversorgung in Deutschland.
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- Monstadt, Jochen/Naumann, Matthias
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  Berlin 2005 (netWORKS-Papers, No. 10)

- Rehbinder, Eckard
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  Berlin 2005 (netWORKS-Papers, Nr. 12)

Further publications of the netWORKS Research Association:

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