GREECO
Territorial Potentials for a Greener Economy

Applied Research 2013/1/20

Final Report | Version 28/02/2014

Case Study

Vol 4.5. Ruhr Area (Germany)

EUROPEAN UNION
Part-financed by the European Regional Development Fund
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This report presents the final results of an Applied Research Project conducted within the framework of the ESPON 2013 Programme, partly financed by the European Regional Development Fund.

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Executive Summary

The Ruhr Area serves as an example for an ongoing regional transition from an old and heavy industrial base (coal, steel, etc.) to a modern high-tech and service oriented region with some potentials for green economic development. The regional structure ranges from high-density core cities of the agglomeration to rather rural counties forming the hinterland of the region. The region is endowed with some "natural" territorial capital, mainly in the rural parts (forests, agricultural land), but also in the high-density cores (open space, Ruhr landscape park). Also the numerous brownfields can be understood as territorial assets for development of green economic activities. Multiple forms of agglomeration economies and existence of several eco-innovation clusters do exist as well, with a strong university base with high-tech orientation and attached technology centres and parks. These assets are backed by a high awareness among political and economic actors for the potential of green economic activities for the development of the region. Several political initiatives and programmes at different governance levels have been established for green transition of the economy. Two green economic sectors are analysed in detail in the case study, the water and the energy sector.

Regards the water sector, a relic of the coal mining times, the Emscher River System, was still in place. This is an up to 3 meters deep open sewer system with concrete shells. The renewal of the Emscher River system is one of the largest infrastructure projects in Germany with an investment of about 4.5 billion Euro and lasting for about 30 years up to 2020. The renewal includes the construction or modernisation of four decentralised wastewater treatment plants, the construction of more than 400 km of large scale underground sewers along the Emscher River and its tributaries to collect the wastewater of 2.2 million people and the reconversion of the rivers as such. This results in a green belt crossing the Ruhr area which is a "new green engine for regional development" with new open space quality, leisure activities, new attractive residential areas and economic activities. Eventually, the renewal of the Emscher System contributes to a new green image of the region gradually replacing the old grey one.

Regards the energy sector, it was analysed to what extent a conversion to renewable energies is possible in high-density urban agglomerations and what specific potentials old-industrialised regions have for this. It is demonstrated that the uptake of renewable energies has also happen in such an agglomeration and that there are huge potentials, in the densest parts of the region particular in electricity production from solar panels. Specific recourses of the Ruhr area for renewable energy production are the availability of brownfields and mine heaps for wind parks or solar power plants, the energy production from mine gas, landfill and sewage gas or even former coal pits that might be converted into underground pumped-storage stations.

1 General description of the Ruhr area

1.1 Geography

The Ruhr area in North Rhine-Westphalia is located in the western part of Germany in North Rhine-Westphalia. It covers an area of 4,435 square kilometres. The population in the Ruhr area is 5.135 million, i.e. a population density of 1,157 inhabitants per square kilometre. The Ruhr region is the largest agglomeration in Germany and together with the metropolises Île-de-France, Moscow, Greater London and Istanbul one of the five largest urban areas in Europe (Metropole Ruhr, 2013). From an economic geography perspective the Ruhr area is one of the most important economic regions of north-west European due to its central European location, its close links with the centres of Europe and its large heavy industrial importance based on coal and steel industries The Ruhr region has got this importance because of the coal reserves and its long-standing know-how since industrialisation until today and became energy site no. 1 in Europe.

The historical spatial development of the Ruhr area from a rural and predominantly agricultural area into one of the densely populated areas of Europe with very different spatial structures and qualities inside was essentially dominated by the spatial logic of the industrialisation processes. The Ruhr region is crossed by three east-west flowing rivers, Ruhr, Emscher and Lippe (Figure 1.1). In addition, the medieval trade route of the Hellweg crosses the region also from east to west. Each of the four linear elements is forming the central corridor of four very different zones, the Ruhr zone, the Hellweg zone, the Emscher zone and the Lippe zone.

Two centuries ago, the industrialisation process of the Ruhr area began along the river Ruhr which constituted the name of the area. Here, the stone coal was almost at the surface and could be easily extracted. Further north, the coal was deeper in the earth. With the evolving technological progress, the mining industry was able to follow the coal northwards. Steam engines, later replaced by electricity driven engines and pumps allowed ablating the coal from several hundred meters below the earth's surface. The mining industry went north to the Hellweg zone and since the early 20th century to the Emscher zone and exploited the coal fields. Nowadays, the last remaining coal mines are in the Lippe zone outside the high-density core area of the Ruhr. Due to the availability of cheap coal-based energy and the development of inland waterways and railways, other industries were attracted to settle down in the Ruhr area, in particular iron and steel works.

With the spatial expansion and north-movement of the mining industry and the establishment of other heavy industries, many new settlements were built for miners, iron and steel workers etc. However, the spatial logic of the new residential areas did not follow the existing spatial structures with town and villages, but was strictly driven by the needs of the industries and legal aspects of land ownership. So, new housing areas were built near the places of work, mostly on former agricultural land without a close relationship to existing urban functions. This created a relatively uniform dispersed settlement pattern of large "industrial villages" which can be seen in the urban landscape of today. In addition, the cities of the Ruhr area have experienced also the common growth and suburbanisation processes comparable to other cities.

This very unique settlement development did not consume all open space. Even in the Emscher zone which experienced the biggest industrialisation process within the Ruhr area, agricultural land and other open space has survived. These green patches and corridors are forming together with the recreation areas of the Ruhr zone in the south and the Lippe zone in the north the backbone of a regional green space system, and thus positively influence the image of the "urban landscape" (Ruhrgebiet Regionalkunde, 2013). Although the Ruhr region is one of the most densely populated areas in Europe with very compact settlement structures in the Hellweg and Emscher zones, it has also rather rural structures at its edges. Because of these natural assets in its hinterland, the Ruhr area has open space adding up to about 60 percent of the total area.

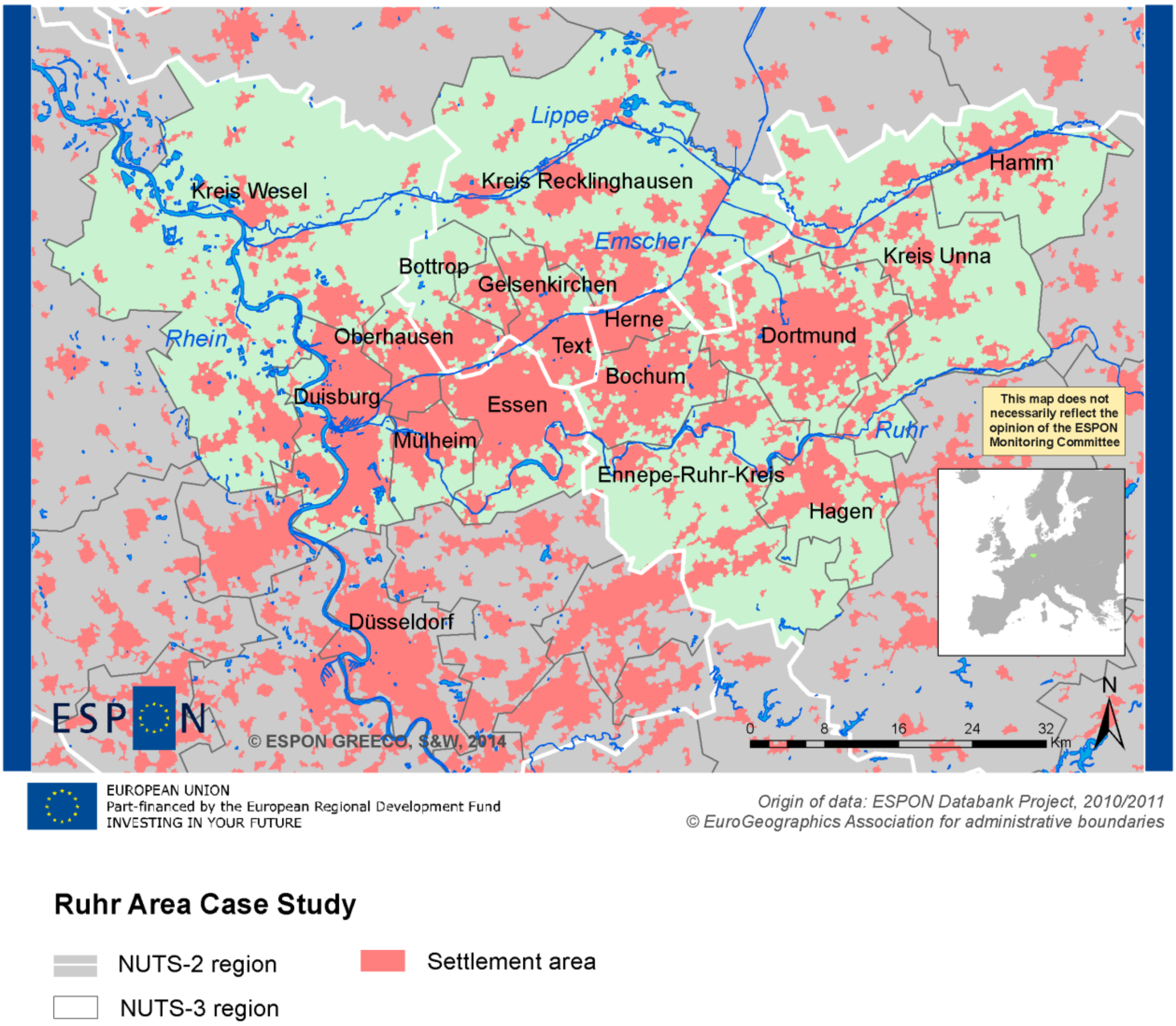


Figure 1.1. Settlement structure of the Ruhr area.

Already beginning in the 1960s the industrial base of the Ruhr underwent several economic crisis. Through the opening of the coal markets in the 1960s and widespread availability of other forms of energy such as oil and gas, but also cheap coal from other continents and negligible transport costs, prices fell on the energy markets. The outcome was that the number of mines and workers were reduced within a decade by half. A similar development happened from the 1970s onwards in the steel industry. Increasing international competition and lack of competitiveness on the global markets lead to concentration processes and the close-down of production sites. Consequently, the Ruhr has gradually lost its heavy industrial base and many of the former industrial sites were taken out of industrial use and developed into brownfields.

These economic structural changes enforced the necessity of the Ruhr area to depart from the "brown" industries towards an information and knowledge-oriented economy with future-oriented professions (Metropole Ruhr, 2013). One of the most successful policies for this was already implemented in the 1960s, the establishment of higher educational facilities which were almost not present in the area before. Nowadays, there are five universities, 13 universities of Applied Sciences and several other research institutions and technology centres which converted the Ruhr area into one of Europe's densest education and research region (Mercator Stiftung, 2010).

Later, during the 1990s, the new face of the Ruhr region was heavily transformed by the International Building Exhibition Emscher Park (IBA Emscher Park). In fact, the IBA was less a traditional building exhibition but a regional strategy to deal with the industrial relicts and heritage by using this as a starting point for future economic and social development. As part of the IBA Emscher Park, the number of brownfield sites and the water and wastewater industry with their wastewater streams on surface were renaturalised and thousands of houses were rehabilitated. Moreover, the old industrial sites were upgraded and used for arts, culture, leisure and sport, or as office space. The IBA Emscher Park is being considered as a project of the century and one of the major structural projects in the history of Germany. It has shown how industry and culture can be fused together to forms an industrial culture. In addition, the Ruhr area was elected European Capital of Culture RUHR.2010 which highlights the massive structural change in the past decade (Metropole Ruhr, 2013).

To communicate the structural and image change of the Ruhr in Germany and in Europe there was an intensive discourse since the mid-1990s to establish a new and modern label for the region. Since, the region was called "Ruhr Metropolis" to communicate an urban and regional science-oriented understanding of metropolitan regions (Ruhrgebiet Regionalkunde, 2013).

The structural change in the Ruhr area is far from being complete. However, it is facing constantly new challenges and tasks. In future, it is crucial how the region can compensate the decision from the Federal government to completely abandon the coal extraction in the Ruhr area by 2018 and to develop new local structures by using renewable energies.

1.2 State of infrastructure

The Ruhr area is covered by a narrow grid-like motorway and trunk road network formed by tree main east-west corridors and several north-south links. In consequence, a very high portion of 12.9 percent of the region's road network length is constituted by motorways and trunk roads. However, the proportion is only 7.4 percent in North Rhine-Westphalia and only 5 percent in Germany (Ruhrgebiet Regionalkunde, 2013). The Ruhr area is well connected by road infrastructure to other agglomerations in Germany as well as to the Netherlands.

There is also a dense network of rail infrastructure. Rail transport of bulk goods was one of the backbones of industrialisation of the area from the second half of the 19th century onwards. The outcome was a dense mixture of rail infrastructure for freight transport including a lot of industry-owned private lines and terminals and for passenger services. In terms of rail freight volumes, the Ruhr area used to be the region in Europe with highest transport volumes as origin and destination for general and bulk cargo. Many of the freight tracks were taken out of operation during deindustrialisation and partly converted into walking and cycling tracks. Current rail passenger services in the Ruhr are a mixture of regional and long-distance passenger services. However, because of capacity constraints, IC and ICE trains cannot be run with higher speeds than regional trains. The Ruhr area is fairly good connected to other agglomerations in Germany and abroad such as Amsterdam, Brussels or Paris.

The Ruhr area does not have an important international airport. There is one regional airport located in Dortmund which has some importance for serving touristic destinations and some connections to eastern Europe. However, air traffic for the Ruhr area is mainly handled by the international airports Dusseldorf and Cologne/Bonn. Good accessibility of the two airports by road and rail links is a crucial factor for the Ruhr region.

In the wake of industrialisation, the Ruhr area also got a very dense inland waterway system with a huge number of ports. The ports of Duisburg and Dortmund have most central functions and are in terms of transport volumes the largest inland port (Duisburg) and largest channel port (Dortmund) in Europe. The Ruhr area has along its four inland waterways (Wesel-Datteln, Datteln-Hamm, the Rhine-Herne and Dortmund-Ems canals) and the river Rhine direct connections to the North Sea and the ports of Amsterdam, Rotterdam and Antwerp.

1.3 Demography

Since its peak in the early 1960s population has decreased in the Ruhr region from 5.72 million at that time to 5.14 million people nowadays, i.e. a population loss of more than half a million people during the last 50 years. Further population decline is forecast for the next decades (Figure 1.2). The base variant of the population forecast shows, that population will go down to 4.97 in 2020 and to 4.75 million in 2030 (RVR, 2009).

The negative development of the Ruhr area until the mid-1980s is partly a result of the long-lasting structural changes which has influenced the migration rates and partly the generative behaviour. Since the 1970s, birth rates decreased by the improved contraception, the so-called "baby bust". Population development was very distinct in core cities and the rural areas. While the effects of structural change were strongly affecting the core cities, population of the rural district even increased through suburbanisation processes until the turn of the century, but has started to shrink since. Population has increased in the rural parts from 1961 to 2011. Compared with North Rhine-Westphalia, the population development in the Ruhr was much more negative than for the whole NUTS-1 region.

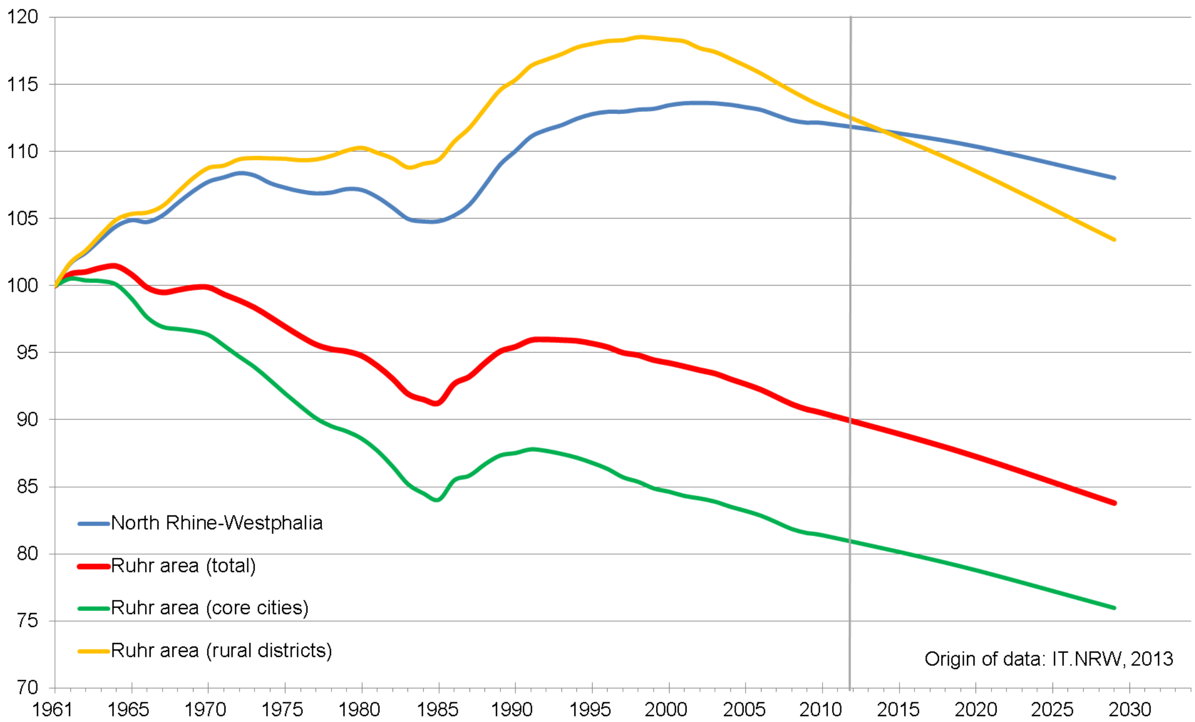


Figure 1.2. Population development, 1961 – 2011, forecasts for 2020/2030

During most times of the last fifty years, the Ruhr area had a negative migration balance, mainly because of the large losses of the core areas (Figure 1.3). The only major exception was between the mid-1980s and the mid-1990s in which the Ruhr area experienced strong inflows. This was caused by high migration flows from East Germany and eastern Europe and refugees which fled from crises and wars in their home countries such as former Yugoslavia. However, the latter migration flows were significantly reduced through a revision of German asylum legislation in 1993 (RVR, 2009). Since the mid-1990s, the migration balance became negative again for the whole Ruhr region. Also rural areas had to experience a negative balance.

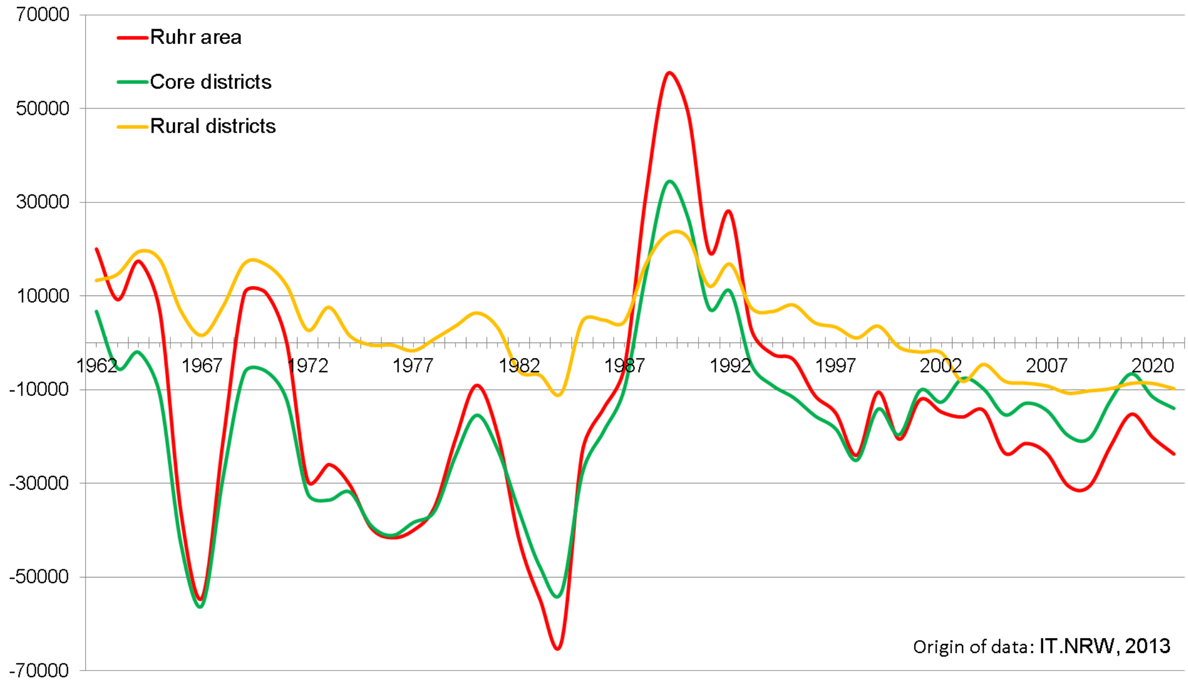


Figure 1.3. Migration balance in the Ruhr area, 1962-2011, forecasts for 2020/2030

The negative natural population development is also decisive. Since the early 1990s, the negative natural population development has increased continuously and accelerated the overall decline. But here, rural districts and the core cities had similar negative trends.

The Ruhr belongs to the most densely populated regions in Europe. Average population density is about 1,160 inhabitants per km², but is between 2,000 and 3,000 Inhabitants per km² in the core areas and goes sharply down in the rural parts to almost 100 persons per km² only (Figure 1.4).

Almost each municipality of the Ruhr area had population losses during the last decade Figure 1.5). Only a few municipalities, mainly in the north-western rather rural part of the region still had population increases. Largest losses were up to ten percent, happening in some core cities such as Gelsenkirchen, but also in suburban or rural municipalities in the districts of Ennepe-Ruhr and Unna. Losses in other core cities, in particular in Dortmund, were rather modest, mainly due to an active economic policy in combination with availability of land for residential development, partly on former industrial or military sites.

1.4 Administrative structure and governance

The development of the Ruhr region is determined largely by a complex governance structure with a variety of private and public/political actors and institutions. This section provides an overview about the competences and responsibilities of the various levels in the federal government system in Germany and about the governance structures in the Ruhr area with the interaction of the major public or institutional and private stakeholders who are crucial for a sustainable urban and regional development will be presented below.

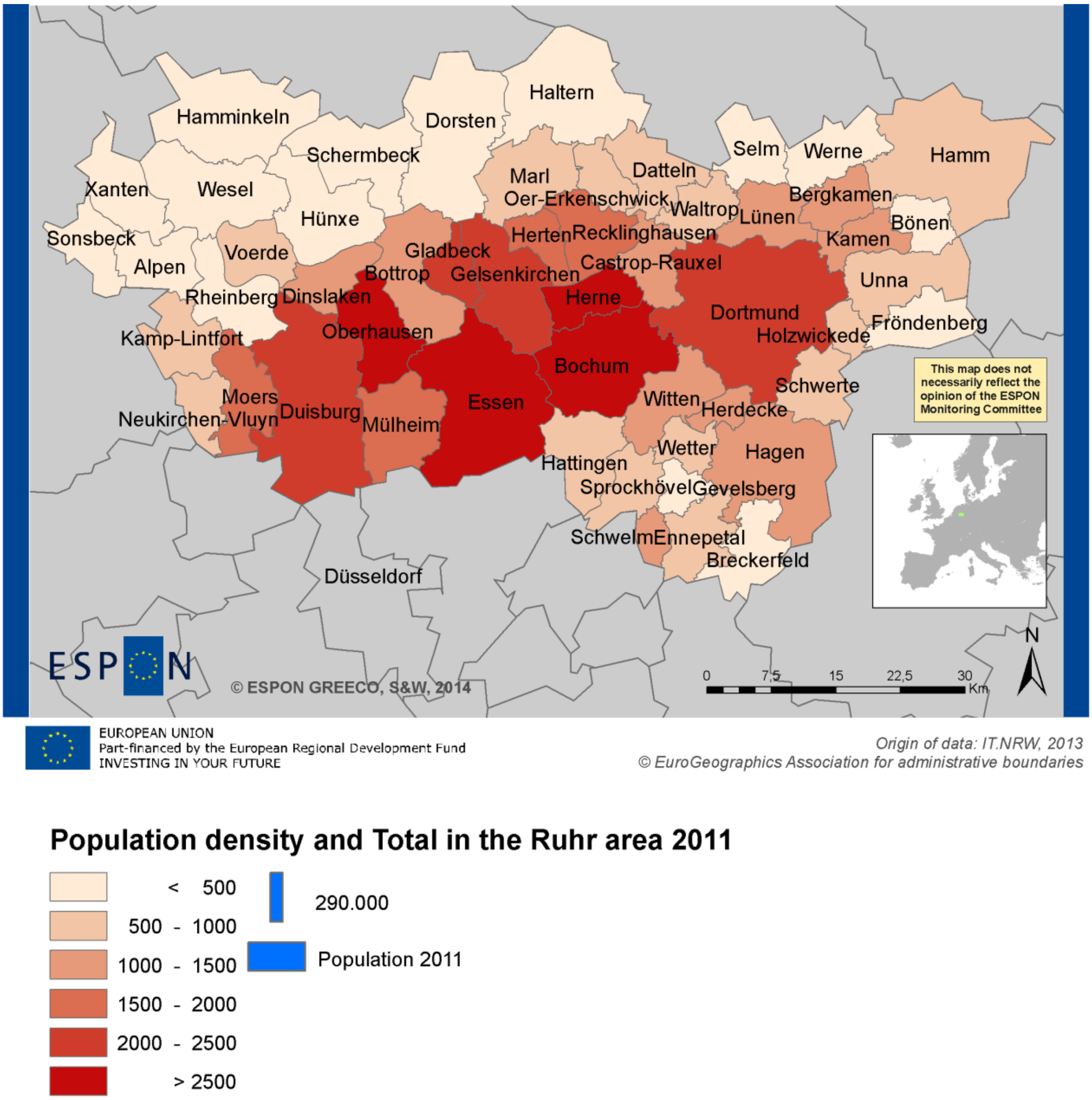
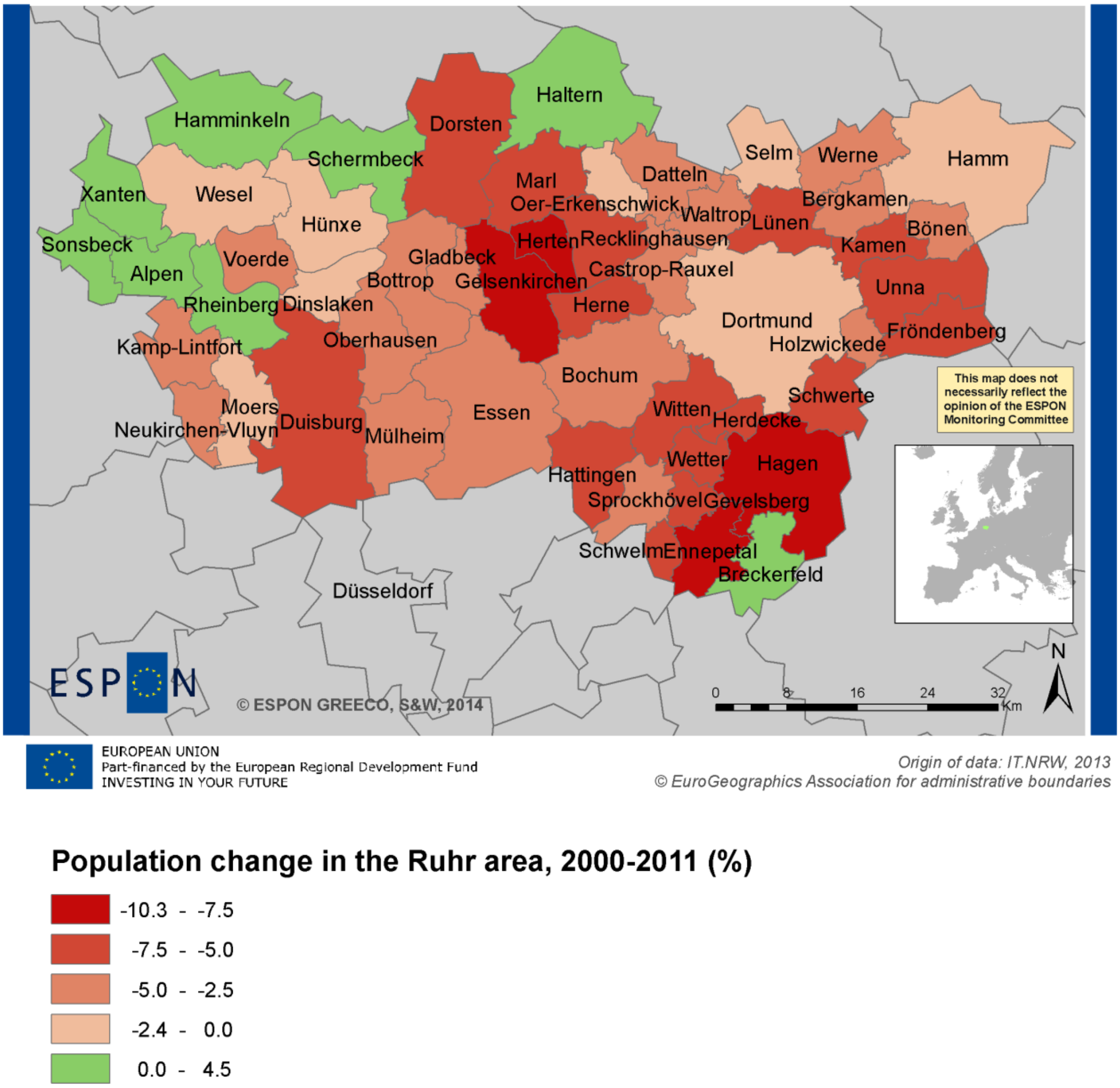


Figure 1.4. Population 2011



Map 1.5. Population change in the municipalities of the Ruhr area, 2000 – 2011

The basic principle of the federal system is the three-level system consisting of the Federal State (NUTS-0), the Länder (NUTS-1) and the municipalities (LAU-2). On the one hand, the allocation of authority and responsibilities to the three levels is clearly defined by legal, organisational and content. On the other hand the different levels are simultaneously interconnected by the so-called counter current principle.

The federal level has extensive legislative, organizational and financial power as well as a framework legislative power, which defines the objectives, guiding principles and policies for the subordinated levels. At the Länder level the legal requirements of the federal level are taken up but might be made more precise. For certain subjects, the Länder have their own legislative power. At both levels, in addition to the formal legal regulations several informal policy initiatives and programs are possible which can also be used for a green transition of the economic, in particularly for energy savings and renewable energy development. Within the framework given by the upper governmental levels, the municipalities have territorial sovereignity, are responsible for land use planning and thus are decisive for certain territorial aspects in implementing green economic development.

An intermediate level between the Land and the municipalities are the regional districts (Regierungsbezirke) that form the NUTS-2 level in Germany. North Rhine-Westphalia has five regional districts. Their main tasks are to take over administrative tasks of the Land in the districts. Besides that the regional districts are responsible for regional land use planning.

The Ruhr area consists of 15 NUTS-3 regions. Out of these, 11 regions are large independent municipalities with widespread decision power, in particular on spatial development issues: Duisburg, Bottrop, Oberhausen, Mülheim, Essen, Gelsenkirchen, Herne, Bochum, Dortmund, Hagen und Hamm. More than half of the population of the entire Ruhr area is living in these 11 cities which make up the core zone of the region. In addition, there are four districts each consisting of a number of LAU-2 municipalities, 42 in total.

However, the Ruhr area is not a NUTS-2 region and no formal administrative unit, but spread over three different regional administrative districts (NUTS-2) (Regierungsbezirke). On top of this, the State of North Rhine-Westphalia (NUTS-1) has extensive legislative and financial power as well as the Federal State (NUTS-0).

The 11 independent municipalities and the four districts of the Ruhr region are together institutionally bound into the Regional Association Ruhr (RVR). The Ruhr Parliament is the democratically elected regional chamber of the metropolis Ruhr and reflects the counter current principle. The members of the parliament are elected by the councils of the independent municipalities and the district assemblies.

The first regional plan in Germany was developed for the Ruhr area in 1912 which led to the establishment of a predecessor of the RVR in 1920. One of the main elements of tnat plan was the introduction of green corridors to separate the different settlement areas which still exist today. The predecessor of the RVR kept the responsibility for regional planning until the mid-1970s. By then it was transferred to the authorities of the NUTS-2 regions leading to a situation in which the regional planning for the Ruhr area was done by three different authorities all located outside the region. However, in 2009 he Land North Rhine-Westphalia transferred this function back to the Regional Association Ruhr. Since, the RVR is the regional planning authority and coordinates and controllis the competing spatial requirements and thus encourages the sustainable urban and regional development (Metropole Ruhr, 201g).

Regional planning respectively the formal regional plan is one of the major statutory responsibilities to enable sustainable spatial development. The regional plan includes binding statements and other framework conditions which must be considered by municipalities when drafting local land use plans. The establishment or amendment of local land use plans is only possible with the approval of the RVR (Metropole Ruhr, 2013). By today, the three regional plans of the three NUTS-2 regional administrations are still in place, but the RVR is working on a new and territorially integrated regional plan for the Ruhr area. The making of the new regional plan is organised as an inter-communal and participatory planning procedure in which all stakeholders such as cities, government agencies, associations and municipalities are involved (Metropole Ruhr, 2013).

Besides formal and informal regional planning, the RVR is developing infrastructure projects such as the Industrial Trail and the Emscher Landscape Park. Other fields of responsibility are in tourism promotion and business development for the Ruhr, development of open space and public relation for the Metropolis Ruhr. In addition, the RVR supports its municipal members in various planning projects by providing basic information such as geo and climate data (Metropole Ruhr, 2013).

In addition, the municipalities of the Ruhr area are belonging to two municipal associations; the Rhineland and the Westphalia-Lippe Assembly of Municipalities. The role of the Assembly of

Municipalities is to relieve its members by taking on, for example, leaderships on local social, disability and youth services issues or for important social institutions as well as for the culture and the preservation of historical monuments (Metropole Ruhr, 2013).

Other important stakeholders for urban and regional development, especially in terms of structural change in the Ruhr region, are the economic development agencies of the 53 municipalities and the regional economic development agency (metropoleruhr GmBH) for the whole region. The regional economic development agency metropoleruhr GmBH combines local community interests and developes the economic profile of the Metropolis Ruhr jointly with local economic development agencies. It is the responsibility of economic development agencies to strengthen the business location and to develop overall strategies for national and international marketing of the location Ruhr (Wirtschaftsförderung Metropole Ruhr, 2013).

The local or (sub) regional agencies are to be distinguished from the Chambers of Commerce and Industry which are independent public-law entities of economic self-government. They represent the interests of their member companies against municipalities, Länder governments and politicians and the public (Wirtschaftsförderung Metropole Ruhr, 2013).

Another important actor in the Ruhr area is the Emscher Association. Its main responsibility is in the regional sewage system, i.e. river maintenance, flood control, wastewater disposal, rain and ground water management and, most important from a green economic perspective, the renaturation of the Emscher system, the "Emscher project". Plans, goals and measures have been developed in a reciprocal coordination with the RVR and are summarised in an independent informal document so-called "Masterplan Emscher future" (Emschergenossenschaft, 2013a; BBSR, 2009). Additional responsibilities in the Emscher project are with the lower water authorities of the counties Ennepe-Ruhr, Recklinghausen and Wesel and with the cities of Bochum, Bottrop, Dortmund, Duisburg, Essen, Gelsenkirchen, Herne, Mülheim / Ruhr and Oberhausen. All in all, 12 authorities are responsible in the Emscher region for the project (Emschergenossenschaft, 2013b).

A relevant, non-governmental stakeholder in the Ruhr region is the RAG Aktiengesellschaft (formerly Ruhrkohle "AG"; Ruhrcoal stock company). The RAG concentrates many activities of the coal industry and is one of the main employer in the region. Furthermore, the RAG Montan Immobilie belongs to the corporate group. They have developed the immovable assets of the RAG group for over 30 years. The immovable assets such as former industrial sites or brownfield sites are revitalised to modern residential areas, industrial of service parks or green, leisure and recreational areas, but have also a potential as locations for solar and wind energy sites,. Therefore, the RAG AG in particular the RAG Montan Immobilie provides a major contribution to a successful structural change (RAG, 2013). However, many former industrial sites do not have a real market value because of too many problems with the site. The state of North Rhine-Westphalia has developed the instrument of the "Grundstücksfond NRW" managed by a state agency. With this instrument, the former industrial land is taken over by the state agency and is developed for new use.

The Ruhr area has also a long-standing tradition of large-scale project based organisations. Task-force like agencies are created to manage the transformation of the Ruhr area based on a large group of individual projects, most of them taking the industrial heritage into account. The first outstanding example for this is the International Building Exhibition Ruhr during the 1990s which has transformed dozens of sites all over the area into new residential areas, industrial parks, landscape parks, museums, industrial landmarks etc. A second example is the RUHR.2010, the European Capital of Culture. Again, a huge number of projects all over the region were developed and social and cultural infrastructures were put in place that last long beyond the year of events. The coming "decade project" is the so-called climate expo in which local and regional strategies to improve energy efficiency and to reduce greenhouse gas emissions are promoted and implemented.

2 Regional economy

The steady decline of the coal and steel industry during the last decades induced a substantial transformation of the economic structure and economic power of the Ruhr area. Because of the losses of the industrial base, employment structures, purchasing power and the production of total value of goods and services has changed dramatically.

Gross domestic product per capita as key indicator of economic performance has an average of 28,600 Euro in the Ruhr area for the year 2010 which is less than in NRW (31,000 Euro) and Germany (30,500 Euro).

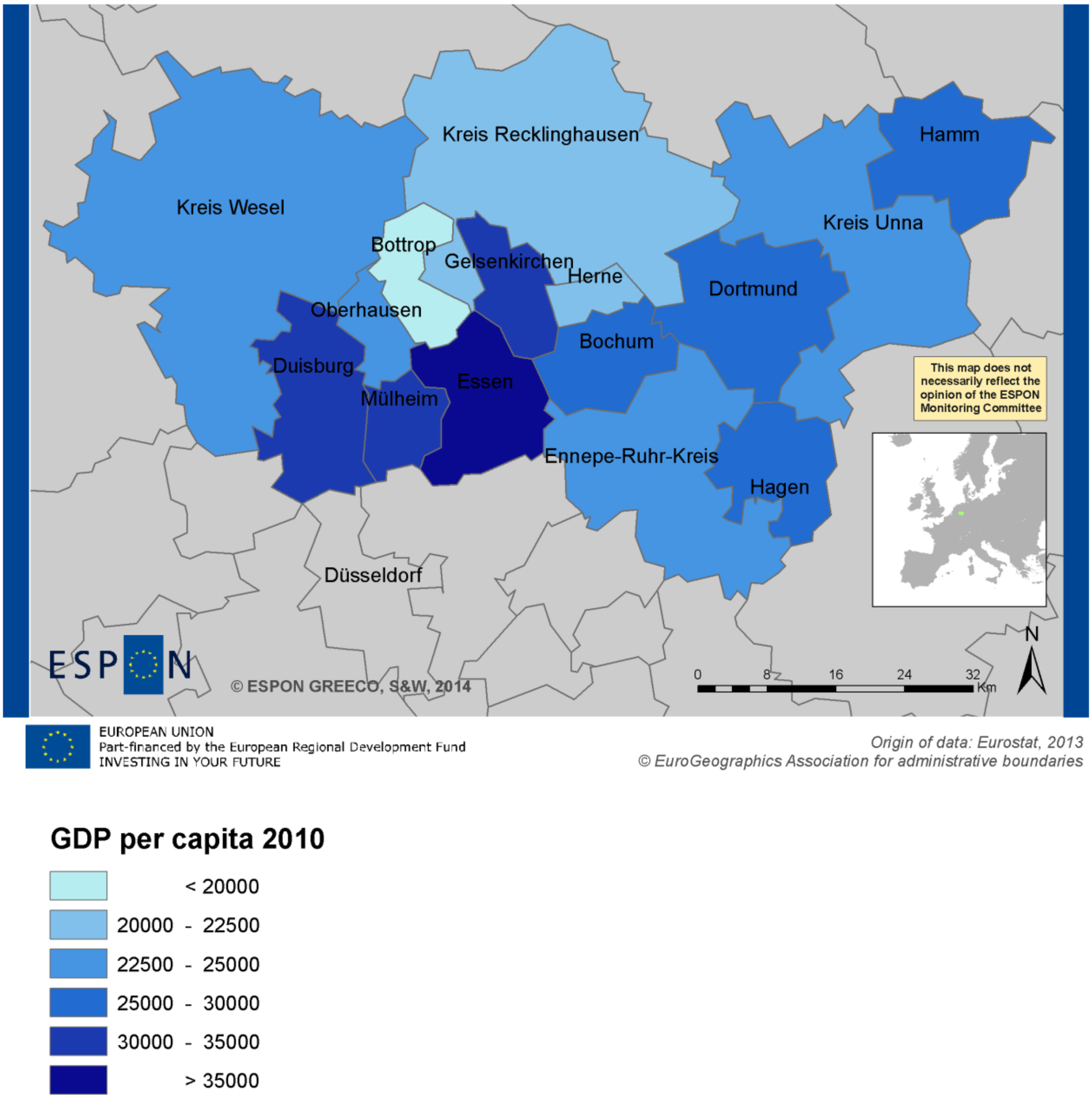


Figure 2.1. GDP per capita in the Ruhr area, 2010

However, the intraregional differences in the Ruhr area are apparent regardless the bias induced by commuting (Figure 2.1). The core cities of Essen (44,900 Euro), Mülheim (34,700 Euro) and Duisburg (34,100 Euro) have the highest GDP per capita and are also above the averages of NRW and Germany. In contrast, the lowest GDP per capita figures are in the core cities of

Bottrop (19,600 Euro), Herne (20,300 Euro), Oberhausen (23,000 Euro) and in the rural district of Recklinghausen (21,200 Euro).

Economic structural change is visible by the development of sectoral gross value added (GVA) for the period 1991 to 2010 (Figure 2.2). GVA is continuously increasing over the entire period with a downturn in the crisis years of 2008 and 2009. GVA increased from 105.730 billion Euro to 130.944 billion Euro in the period from 2000 to 2010, an increase of around 25%. The development of GVA in the Ruhr area is similar to that of NRW. In 2010, GVA of the Ruhr region accounts for about 27% of total GVA in NRW.

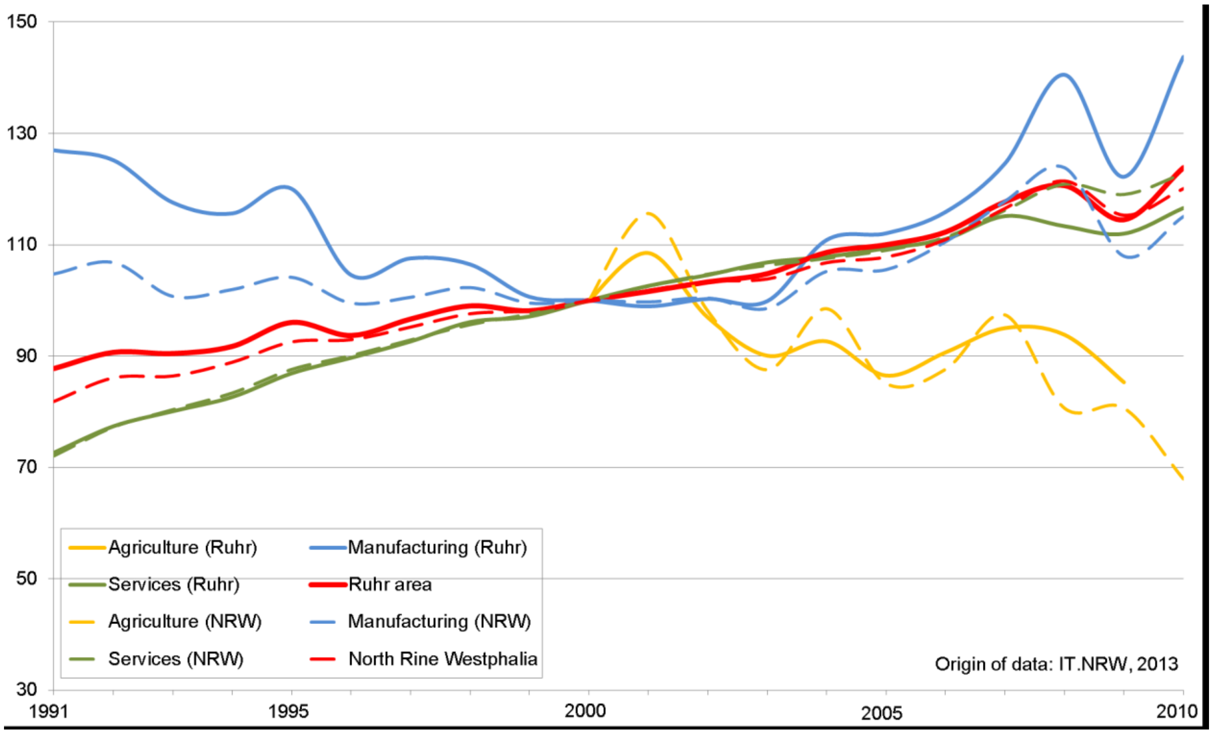


Figure 2.2. Gross value added in the Ruhr area by main economic sector, 1991-2010

GVA in the manufacturing sector fell from 1991 to 2000 by almost 30%. Remarkably, the development of the manufacturing sector since the turn of the century was better than that of the service sector. Manufacturing reached its peak with 42.652 billion Euro in 2010 after a strong loss during the crisis. The constant increase of the service sector from 54.899 billion Euro in 1991 to about 88.000 billion Euro in 2010 shows the progressive tertiarisation in the Ruhr. The expansion of the service sector is mainly responsible for the postive economic development in the Ruhr area.

However, the increase of GVA was very different in different parts of the Ruhr area (Figure 2.3). With the exception of the city of Bochum that had a decline of about 9 percent, all NUTS-3 regions gained in GVA. Lowest growth was recorded in the cities and counties around Bochum, whereas the western parts had higher growth rates. On average, the four rural counties had a growth of 27 % and was slightly more positive than in the core cities with an increase of 23 %.

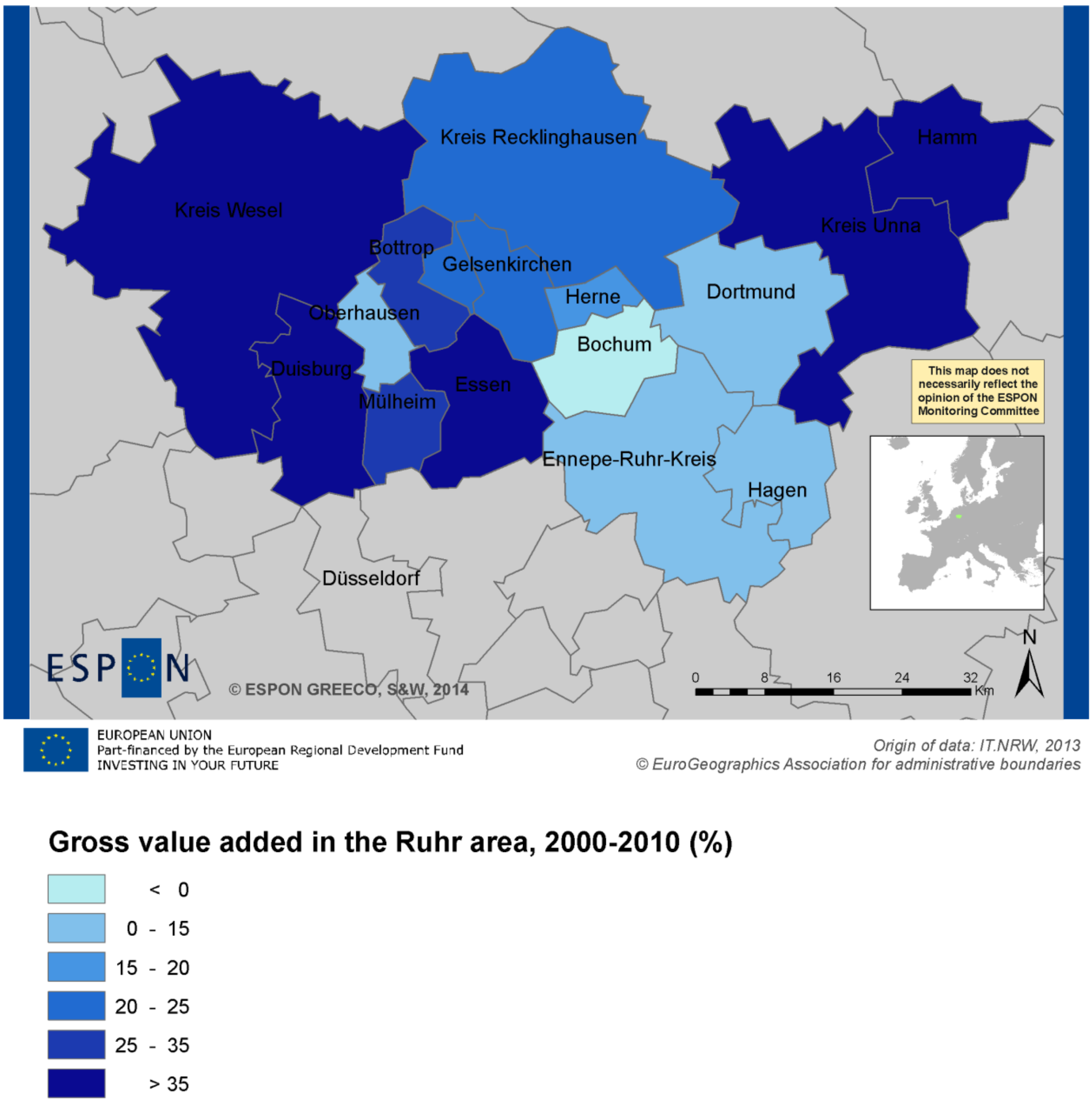


Figure 2.3. Change of gross value added in the Ruhr area, 2000-2010

Although the increase of gross value is indicating a positive economic development in the Ruhr area, the evolution of long-term unemployment rate is unfavourable. Whereas in the 1970s there was still full employment, the unemployment rate steadily increased afterwards and is around 11 percent nowadays. Core cities have higher rates than the counties.

The total number of employees in the Ruhr went down, in the long-term period 1976-2012 by 13 percent, whereas North Rhine-Westphalia as a whole had a gain of 8 percent (Figure 2.4). This is due to the more pronounced structural change in the Ruhr area. Due to the decline of the coal and steel industry and other supplying industries from the manufacturing sector the main employers broke away and employment numbers declined in this sector. From 1976 to 2012, the number of employees in the manufacturing sector decreased from 1,046,836 to 423,893 in the Ruhr area, a decline in employment of about 60 percent and of even 65 percent in the core cities. The overall trend in North Rhine Westphalia was similar trend. but less sharp with a loss of about 40 percent,

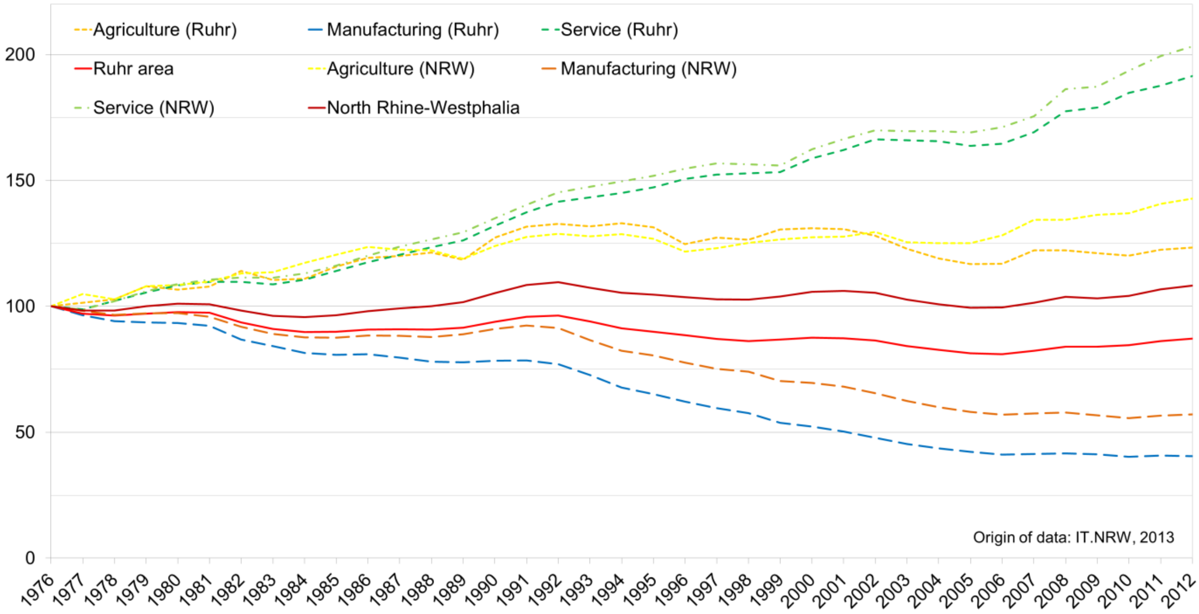


Figure 2.4. Development of employees in the Ruhr area by main economic sector, 1991-2010.

On the other hand, the service sector clearly expanded. Employment of the services sector in the Ruhr area has increased from 405,048 employees in 1975 to 775,287 employees in 2012, an increase of more than 90 percent. However, in NRW the number of employees in the service sector doubled. The stronger losses of industrial employment in the Ruhr area than in NRW combined with somewhat slower growth in the service sector explain why the Ruhr had experienced employment loss whereas NRW gained.

The main losses of employment due to structural change happened during the 1980s and 1990s. The situation since then has stabilised. The overall employment trend in the Ruhr area was only slightly negative since the turn of the century. Between 2000 and 2012 a decline in employment of 0.5 percent has been noted, however, a growth of 2.4 percent was recorded for NRW. But the development within the Ruhr area is rather uneven (Figure 2.5). A couple of cities, mainly located in a north-south corridor in the eastern middle part and in the south-eastern parts of the Ruhr are responsible for the overall losses. On the other hand, several municipalities which are mainly located in the western parts of the Ruhr and around Dortmund had clear employment growth. Employment growth in particular happened in the largest and economically important cities such as Essen, Dortmund and Duisburg which had an employment growth of up to 15 percent. Those cities have also the highest shares of employment in the service sector (Figure 2.5).

A more detailed breakdown of recent employment change by NACE sectors shows which branches are responsible for the employment gain and which for the losses (Figure 2.6). Strong absolute employment growth is related to branches such as human health and social work activities, education, administrative and support service activities, professional, scientific and technical activities and to trade. That means job growth is based on social services, in particular services of general interest such as health care and education, and on technological development. Strong absolute losses happened in manufacturing industries and mining and also in the energy sector.

A decomposition of recent employment change (2008-2012) by the sectors treated in more detail in GREECO shows that research is doing best in absolute numbers with an increase of nearly 12,000 jobs followed by tourism with plus 5,000 jobs (Figure 2.8). In relative term, also water management (+13 %) and waste management (+15 %) are doing well. On the other hand, the energy sector lost 10 percent of jobs which are almost 3,000 employees.

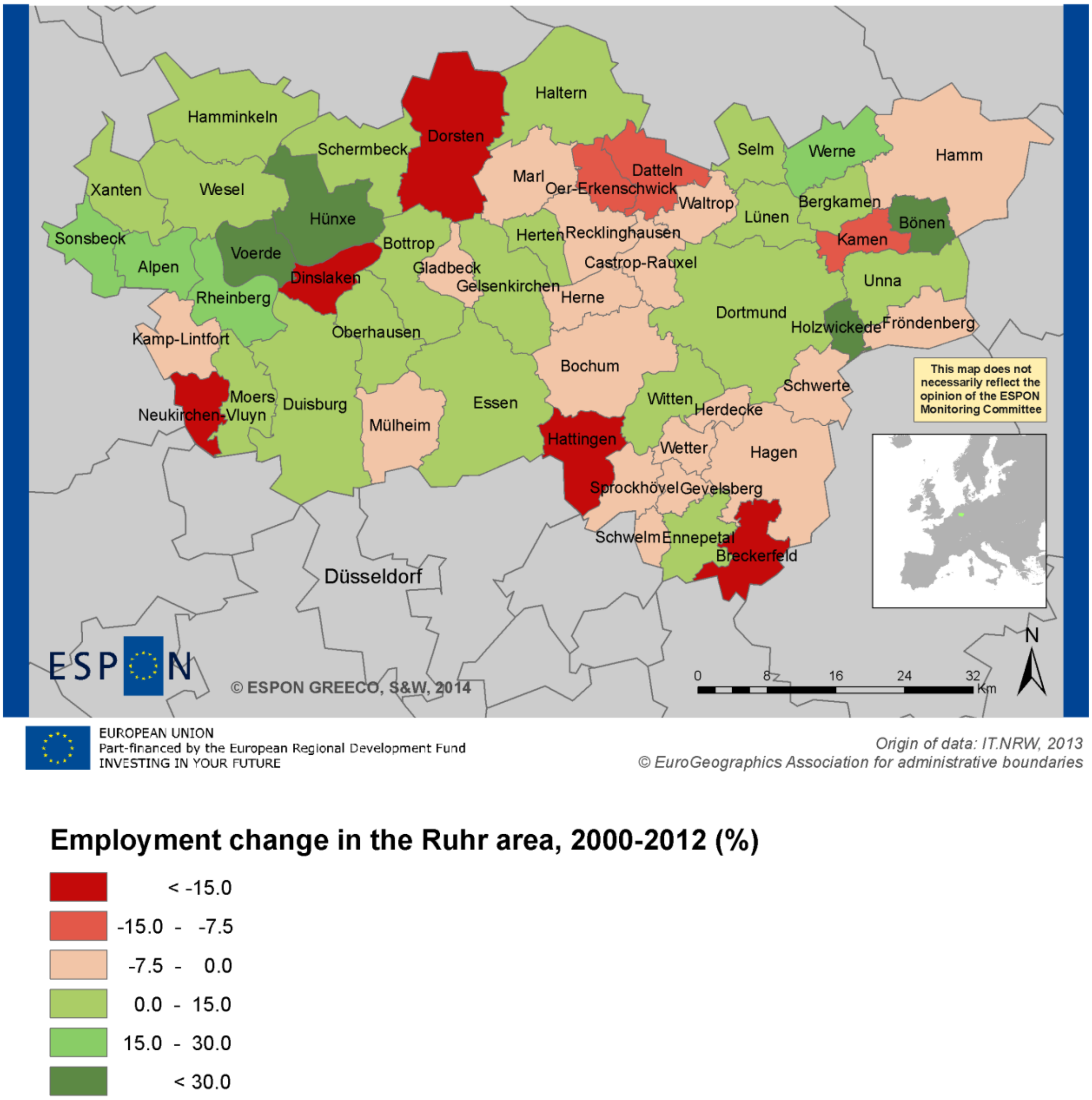
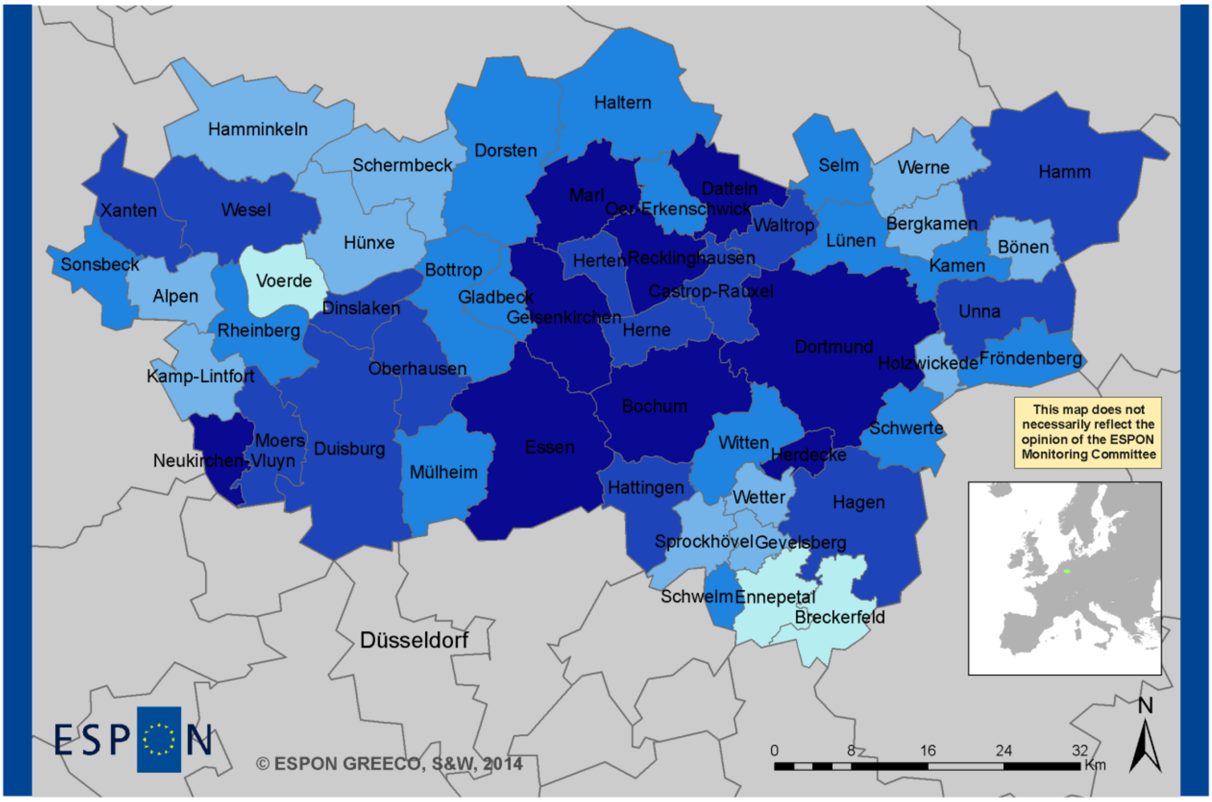


Figure 2.5. Employment change in the Ruhr area, 2000-2012



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Share of employees in the other services sector in the Ruhr area (%) 2012

- < 25
- 25 - 35
- 35 - 45
- 45 - 50
- > 50

Figure 2.6. Share of employees in the sector "Other Services" in the Ruhr area, 2012

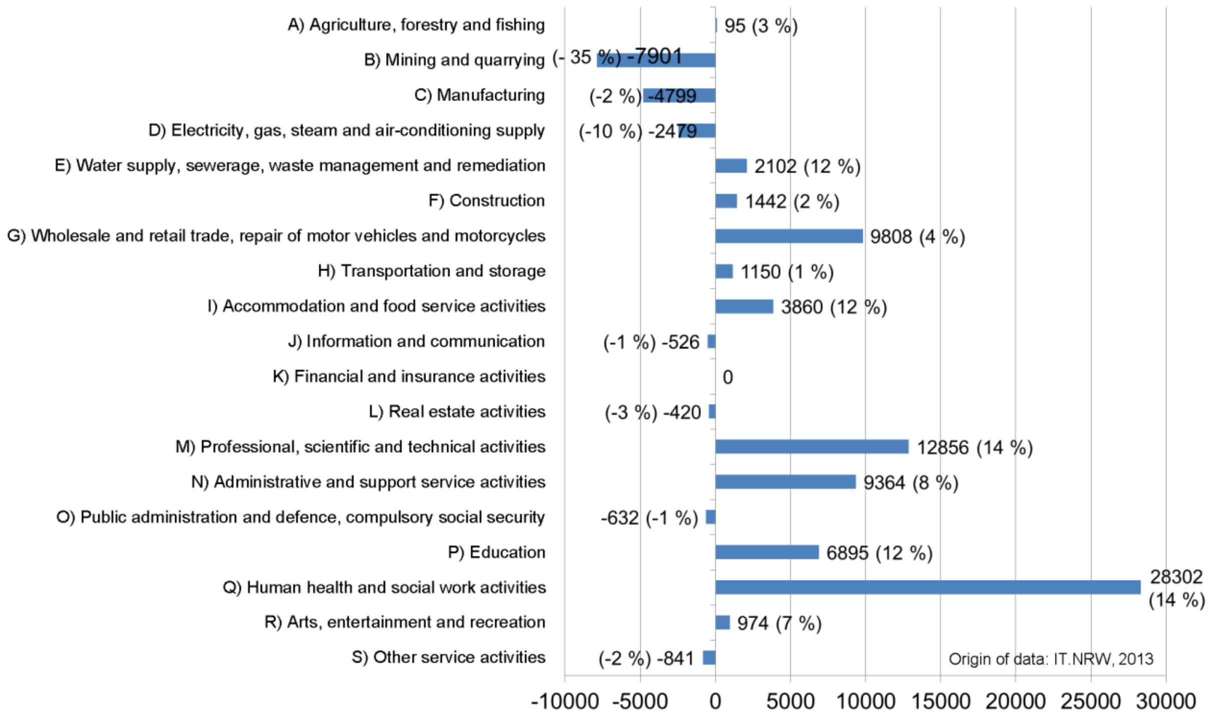


Figure 2.7. Employment change in the Ruhr area by NACE Rev. 2 sectors, 2008-2012

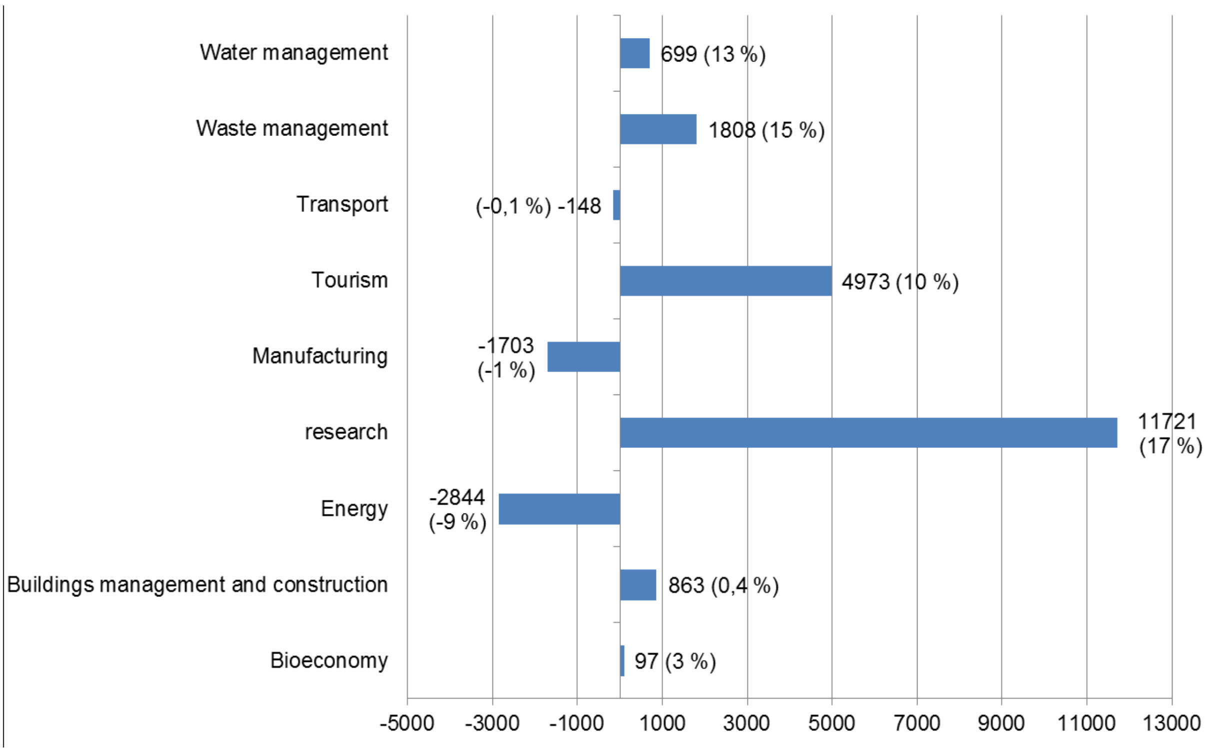


Figure 2.8. Employment change in the Ruhr area by GREECO sectors, 2008-2012

3 Water as key sector for the green economy in the Ruhr area

The provision of clean drinking water and the treatment of waste water is always a challenge for metropolitan areas. In the Ruhr area this challenge was even larger because of the specific circumstances related to the coal mining industry. A good functioning water sector can be seen as a key requirement for green econonomic development in metropolitan areas. This chapter reports about the water sector in the Ruhr area in general, but concentrates then on the current rebuilding of the waste water treatment system.

3.1 Performance of the water sector:

The basic element for the functioning of the water sector in the Ruhr area is the functional division of tasks between the rivers of the region which is in place for more than a century. There are three main east-west flowing rivers which all end in the river Rhine in the western part of the region, the Ruhr, the Emscher and the Lippe.

Ruhr

In the south, there is the Ruhr. Along this river, the coal mining industry started operation first because the coal was almost at the survace and could easiliy been digged out. As the main industrialisatioin processes started here, the Ruhr gave its name to the region. When the coal fields were exploited, the coal mining industry had to follow the coal northwards. However, the coal layers are not any longer at the surface but are gradually going deeper into the earth in northwards direction.

The task of the Ruhr in the water system is to provide clean drinking water and water for the industrial processes. In essence, the Ruhr with its approximately 300 waterworks provides clean water for most parts of the metropolitan area. Because of its favourable soil conditions, especially by the powerful gravel layers that have a natural filter for the clean water production function the Ruhr is ideal for drinking water supply. However, due to fluctuating natural water flows and water losses through over-pumping in adjacent river systems, the water supply could not rely alone on the Ruhr. The water supply of the Ruhr area is only possible with the operation of dammed lakes along the tributaries of the Ruhr River. The dams of the Sauerland located south-east of the Ruhr area take an important function as water reservoirs. This clean water system as well as the main sewer system along the Ruhr is managed by the Ruhrverband in cooperation with the municipalities.

Emscher

The Emscher River is located in the center of the Ruhr area and traverses the core cities of Dortmund, Herne, Bochum, Gelsenkirchen, Essen, Bottrop, Oberhausen, Duisburg and the rural districts of Unna and Recklinghausen. It is situated in a predominantly industrial agglomeration.

Before industrialisation, the Emscher River and its tributary streams were winding rivers in a sparsely populated region which was mainly agricultural. But during rainy periods the Emscher River came over its banks and turned large parts of the country under water. This flooding already caused often diseases, epidemic plague or tuberculosis. In the 19th century the Emscher system took also over the burden from industrialisation. The waste water from industry and population were discharged into the Emscher River without any filtering and from there into the Rhine. The formerly clear Emscher water became increasingly cloudy and groundwater burdened always stronger. These contaminants destroyed the ecosystem to a large degree. In addition, the risk of disease increased - particularly during floods - throughout the Emscher area to. The Emscher River gained an inglorious fame as "water engineering disaster area" or "cloaca maxima" (WI, 2013, 25). This situation was for the settlement areas with thousands of miners and other industrial workers not acceptable. To remedy these serious deficits the Emschergenossenschaft (Emscher Association) was founded in 1899. Already at that time there were first considerations or plans to straighten out the Emscher to prevent flooding.

The onset of industrialisation and the underground coal mining had significant impacts on the Emscher River system. Caused by coal mining a permanent, large area ground subsidence happened which accumulated in some areas to more than 20 meters sinking of the surface. This did not allow the construction of underground sewerage systems as in other urban areas and on the other hand resulted in frequent floodings of the area. With the aim to eliminate the hygienic deficiencies, the Emschergenossenschaft decided to rebuild the waste water management fundamentally. The Emscher River was straightened, put up to three meters deep and fixed in an open sewer by concrete shells. This was the only feasible solution due to the permanent, large-scale subsidence. The numerous tributaries were redesigned in a similar way. In addition, new dykes were built to counteract subsidence and protect the region from flooding. From the late 1950s onwards the peak of coal mining walked slowly to the end. Less wastewater from mining was discharged into the channelised Emscher. However, population and domestic wastewater increased significantly. In 1977, the Emschergenossenschaft put the largest wastewater treatment ever plant in Europe at that time in the estuary of the river in Dinslaken into operation to protect the water of the Rhine.

There have been always problems with subsidence. Areas emerged of which the surface is below the Emscher system. In consequence those areas had to be drained by pumping stations. This is still to be done today and will be so in the future. The number of pumping stations increased between 1949 and 1985 from 40 to 92. Almost 40 percent of the territory of the Emschergenossenschaft has to be drained.

In summary, the function of the Emscher system is to be an open sewer system in the predominantly industrial heart of the agglomeration.

Lippe

The most northern river in the Ruhr area is the Lippe. Due to the high salt concentration the Lippe is not suitable as provider of drinking water. In the Ruhr area, it has the function to provide water for industrial processes, as cooling water for the power plants along the river and to feed the sewer system of the Emscher River as well as the Dortmund-Ems canal with water at times of water shortage. The Lippe system including the sewer system in that area is managed by the Lippeverband in cooperation with the municipalities.

The water quality of the flowing rivers in North Rhine-Westphalia and in the Ruhr area is fairly good. However, because of its specific function the water quality of the Emscher system is very poor. Figure 3.1 shows good water quality in green colours, poor in red.

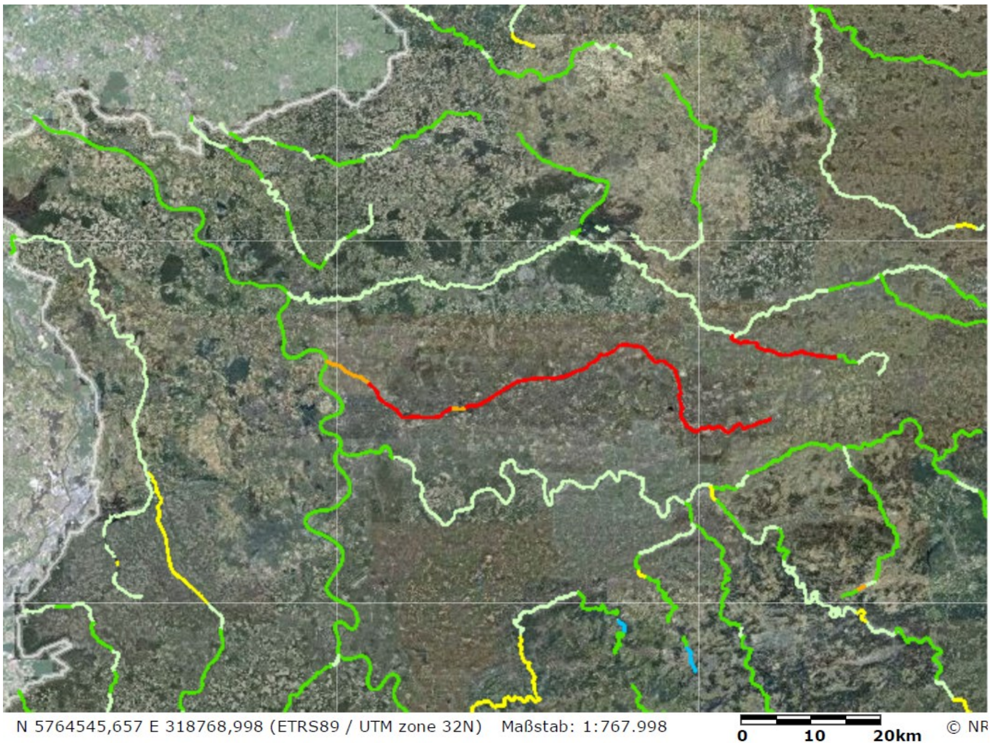


Figure 3.1. Water quality of flowing rivers in NRW (MKULNV, 2013)

3.2 Key milestones of the development of the water sector

The importance of water management in the Ruhr area is particularly evident by the renewal of the Emscher River system. The renewal of the Emscher river system is one of the largest infrastructure projects in Germany - perhaps even in Europe - and is called the infrastructure project of the century. The Emscher renewal project illustrates the Green Economy with many of its fields of action in the Ruhr region.

A necessary pre-condition for the renewal of the Emscher system which can also be interpreted as part of a conversion to a green economy in the Ruhr area is the end of the brown economy, i.e. the closure of the coal mining activities in this part of the Ruhr area. Only since the risk of further ground subsidence is minimal, the open sewer system could be replaced by "normal" large scale underground sewer canals.

To understand the specific radiance of the Emscher River conversion and its challenges for water management in the Ruhr region a glimpse into history is helpful as done in the previous section. The development of the Emscher River can be classified into three main phases (WI, 2013): before the industrial period (Emscher 1.0), during industrialisation (Emscher 2.0) and the renewal of the Emscher River system after industrialisation (Emscher 3.0).

Emscher 3.0

After the peak of industrialisation in the early 1970s numerous coal mines were closed in the Ruhr area, the total mining industry declined and the process of ground subsidence was slowed down clearly. Thus, the risks of an underground sewage system decreased. At the same time, environmental consciousness among the population increased. The people in the Emscher region felt impaired in their quality of life by the constant sight and odor nuisances from the open sewers.

In a tributary stream of the Emscher River in Dortmund the Emschergenossenschaft implemented a pilot project to put waste water in an underground sewer and initiated also a first attempt of renaturation in the 1980s. After the concrete shells were removed and the tributary stream was fed with spring water and rainwater, a natural landscape developed rapidly.

This pilot project prompted the Emschergenossenschaft in 1991 to the decision to rebuild the entire Emscher River system and the large-sclae wastewater network in underground. The Emscher that previously served solely the needs of the industry should become a "symbol and element of structural change" in the Ruhr. But the challenge of the Emscher conversion could not be solved in a day, but sees itself rather as a "generational mission" (WI, 2013, 27) to be implemented over a period of about 30 years.

The basic requirement for the conversion of the wastewater system was initially the construction or modernisation of four decentralised wastewater treatment plants (WWTP Dortmund-Deusen, Bottrop sewage treatment plant, sewage treatment plant and the Emscher River estuary Duisburg Old Emscher). In addition, the construction of more than 420 km large underground sewers along the Emscher River and its tributaries was part of the conversion. This is one of the biggest technical challenges. This system is planned to take the wastewater of 2.2 million people as well as of commerce and industry in the Emscher region.

More than half of the sewer network is already built, by 2017 about 400 km will be constructed. The water quality of the Emscher will be improved. Up to now, about 120 km of the former open sewer are already recultivated, by the year 2020 this will be around 350 km of water streams that are ecologically reconverted.

Overall, the technical complexity of the Emscher River conversion is associated with considerable financial efforts. By 2020, the expected completion year, in total 4.5 billion Euro will be invested (WI, 2013). However, the Emscher River conversion is much more than a pure technical infrastructure project. The new Emscher River system with underground sewage systems provides multiple changes and options in many fields of life and economic activities for the population in the Ruhr region as well as the appreciation of the entire region.

Economic impulses of the Emscher conversion

In addition to the extensive environmental, social and cultural effects to be expected or already observed for the Ruhr area as a result of the Emscher conversion economic effects will also happen. Although the Emschergenossenschaft assumes that these economic effects will happen in a long-time perspective only and mostly after the completion of the project, however, positive economic effects are felt even today.

First preliminary results can be taken from the ongoing research project "Regional economic effects of the Emscher conversion" conducted by the Rheinisch-Westälisches Institut für Wirtschaftsforschung. Impressive employment effects can be recorded. The Emscher conversion project created about 5,500 jobs in Germany of which about 3,400 jobs were created in NRW. This employment development can be expressed as the generation of about 100,000 person-years. However, the job growth is not restricted to the water sector but happens primarily in the construction industry and related service jobs. In 2012, the number of work contracts awarded increased to 250 with a total volume of 540 million Euro. 200 contracts of which were awarded to companies from NRW. Many contracts were again with a relatively low volume. 90 percent of the orders are under 1 million Euro; 50 percent are below 125,000 Euro. The biggest contracts had a volume of 20 million Euro and 14 million Euro. There was no contractor outside Germany in the Europe-wide tendering process for 13 contracts (Stemplewski, 2011).

Employment statistics indicate a growth of the number of employees in the water management sector of the Ruhr area. Between 2008 and 2012 the number of jobs increased by 13 percent, a total surplus of 699 employees (Figure 3.2). The growth was almost identical in the sub-sectors "Sewerage" with a plus of 345 employees (15 percent) and in the sub-sector "Water collection" with an increase of 354 employees (11 percent).

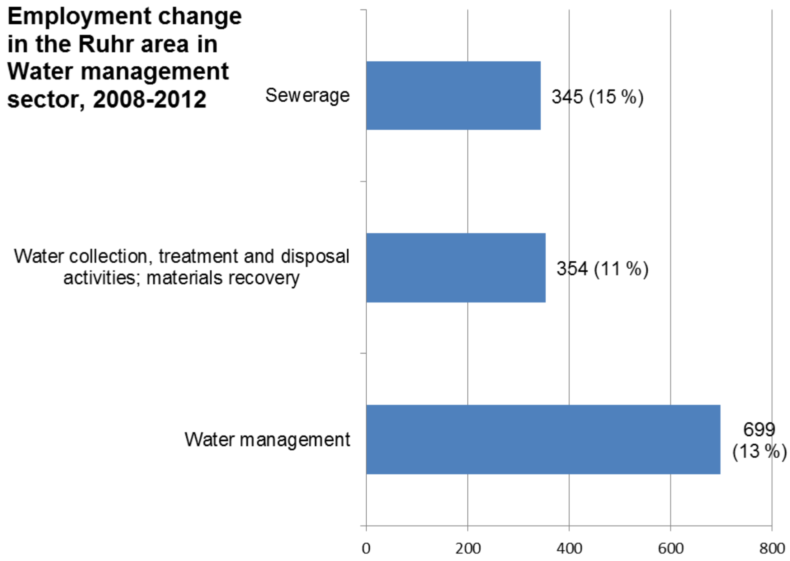


Figure 3.2: Employment change in the Ruhr area in the sector water management, 2008-2012

3.3 Drivers, barriers and enabling conditions

Drivers, barriers and enabling conditions are crucial for the development of key sectors of the green economy. This section tries to analyse the most important aspects of these for the Emscher system renewal.

External drivers

External drivers are in most cases more general developments which provide enabling or hindering conditions for changes towards a green economy. There are a couple of such external drivers responsible for the decision to tackle the Emscher system renewal.

First of all, economic structural change provided the technical pre-conditions. Only with the decline of the coal mining industry and therefore with the reduced risk of further ground subsidence which did not allow for large underground sewer tubes alternatives for the open sewer canals were feasible.

A growing awareness for the environmental quality was another driver. Population, politicians and other stakeholder got conscious that an open sewer system in which the waste water was transported over dozens of kilometres is not an environmental asset, but a problem of urban hygiene and maybe even a health problem. Related to this, it was evident that a recultivated Emscher system could form green corridors with high environmental quality through the middle of one of the formerly most industrialised regions in Europe and could fulfil the increasing demand for highly attractive living environments.

Finally, the not very positive image of the Ruhr area in the outer world was determined not only by coal and steel and related environmental pollution, but also by the open sewer. Any attempts to improve the Ruhr image would fail if this major issue would not been tackled appropriately.

Policies as internal driver

With the *EU-Water Framework Directive (*WFD) "Directive establishing a framework for Community action in the field of water policy" and the *EU Flood Directive* "Directive on the assessment and management of flood risks," the European Union has provided a basis for sustainable management of water resources. Thus, the European Union has created a framework of rules for Europe, and formulated objectives for an integrated water protection.

These two key guidelines for a comprehensive water and flood protection have been taken up in the German water law *(Water Resources Act - WHG).* In North Rhine-Westphalia, the EU Water Framework Directive is implemented through the program *"Living Water"*. Accordingly, all waters should reach the environmental targets of the WFD not later than by 2027.

In addition, the Emschergenossenschaft has agreed upon the *"future agreement rainwater"* to avoid the discharge of rainwater to the sewer system through the decoupling of space from the sewer system. From 2006 to 2010, the Ministry of Environment introduced for this purpose seven million euros for central wastewater discharge.

The Emscher Master Plan, which was published in 2006, is considered a milestone for the improved integration and generation of knowledge and enables an efficient coordination between the municipalities.

Institutions as internal drivers

The central actor of the Emscher River system renewal is the Emschergenossenschaft. Its major responsibilities include wastewater treatment, securing of the effluent, flood protection and water maintenance. The Emscher River Association has 193 members and is responsible for the disposal of sewage of about 2.2 million people in an area of 865 km ^{2}. Together with the Lippeverband the Emschergenossenschaft has had more than 1550 permanent employees in 2011.

With the aim to offer citizens, communities and the economy continuously improving and more cost-effective services the Emschergenossenschaft cumulated an extensive knowledge. There are many practitioners and experts in the key areas of water, aquatic ecology and infrastructure reconstruction. In addition, the Emschergenossenschaft has the entitlement beyond their core competence to improve the habitat along the Emscher River and Lippe River and to develop vibrant and diverse river landscapes for people and nature. In this direction goes also the entitlement to put impulses for urban development and to promote the structural change in the region by an attractive and ecological river system.

Essential for the Emscher conversion is the organisational structure of the Emschergenossenschaft as a corporation under public law. In addition, the target and decision-making within the Emschergenossenschaft is done by the customers who are at the same time financing members of the association. This allows for an integrated approach and a further pool of knowledge in the cooperative. Therefore, the member municipalities and counties as well as the commercial and industrial companies and the owners of the coal mining sites are critically involved in the definition of objectives and implementation of activities.

However, the Emscher Association cannot manage the extensive tasks or the required multidimensional planning and design tasks by themself, but rather need further knowledge about theory and practice of planning processes. In such complex infrastructure projects like the renewal of the Emscher system the different areas of knowledge and actors cannot be considered independently of each other, they must be integrated and networked. The networking of stakeholders from the fields of technology, economics, ecology, social and water management, and the implementation of common activities, targets and solutions increases the quality of the project and the entire project gaining a higher viability and acceptance (WI, 2013).

For example, scientific institutes are commissioned by the Emschergenossenschaft to analyse the social structure or the tourism potential which are very differentiated in the Ruhr area and in the Emscher region. This study will then be used for further steps. Similarly, the Fraunhofer Institute for Factory Operation and Automation was commissioned by the Emschergenossenschaft to solve technical questions. Therefore, for already finished canal systems the Fraunhofer Institute has developed special robots and monitoring systems for maintenance and repairs of the Emscher canal systems (WI, 2013, 73).

The networking and pooling of different actors in the Emscher river project is on several levels and is essential for the success of the project. The Master Plan Emscher future *(Emscher-Zukunft)* was developed in an intensive dialogue over a period of one and a half year by many professionals, practitioners and researchers from different disciplines such as architecture, spatial planners, landscape architects and the housing industry. Based on this plan, the Working Group "New Emscher Valley" *(Neues Emschertal)* worked as a partnership between the Emschergenossenschaft and the Regionalverband Ruhr and with all other members, citizens, communities, government and industry for the vision of an attractive city, culture and water landscape. Also, the master plan Emscher future as an informal instrument without legally binding is created in a participatory and communicative process.

Especially in complex projects such as the Emscher river renewal, informal planning offers new opportunities to gain and to process information and to integrate the fields of water management, environmental, economic, social, urban planning and design aspects in an overall plan simultaneously.

The Master Plan Emscher future offers the opportunity to coordinate and bring the interests of the actors such as the Ministry of Environment of North Rhine-Westphalia, the district governments Arnsberg, Dusseldorf and Munster, the former state environmental agencies Duisburg, Herten, Hagen and Lippstadt, the lower water and landscape administrations, local civil engineering, environmental and urban planning offices, the sectoral planning (Road Authority or Water Administration) and other stakeholders of economic development together. Thus, the master plan has managed to coordinate all stakeholders towards to a common goal which shared by all actors.

Financing as an internal driver

The Emscher conversion as one of the largest infrastructure projects in Europe has an implementation period of approximately 30 years (1992 - 2020). The Emscher system renewal requires investments of about 4.5 billion Euro, a very cost intensive project that cannot be financed solely by the main actor, the Emschergenossenschaft. Only in 2013, the Emschergenossenschaft invested about 250 million Euro. This represents an investment of approximately 1 million Euro per working day. By 2020, the total investment of the Emschergenossenschaft will amount to 2.5 billion Euro.

The financing of the reconverson of the Emscher system is based on two main pillars, the state of North Rhine-Westphalia on the one hand, and loans of the European Investment Bank on the other. A framework agreement between the government of North Rhine-Westphalia and the Emschergenossenschaft assures a long-term funding by the state. Of the total investment of 4.5 billion Euros still 2 billion Euro are to be invested. The state of North Rhine Westphalia will take over another 400 billion Euro. Low-interest loans from the European Investment Bank (EIB) will be the second main source for future funding. In a first step, a 450 million euro loan was approved by the EIB for 2011-2013.

As already mentioned, the Emschergenossenschaft is financed by contributions from its members, the contributions of the Emscher municipalities and therefore also the contributions of households. The Emschergenossenschaft has the objective to charge a fair price for wastewater management. Their fees for the Emscher municipalities are 18 percent below the average NRW.

As the causer for this specific form of water and wastewater management is the mining industry, the mining foundation as legal successor is also involved in a reasonable amount of renaturation of the Emscher river system.

The renaturation of the Emscher system is also done with the support of EU Structural Funds. Here, the EU promotes as part of the ERDF program, the ecological transformation of individual sections of the river. For instance, a sub-project in Essen with a total amount of 6.3 million euros got the amount of 2.3 million from the EU.

3.4 Spatial dimensions of the development of the water sector

A functioning sewage management is a basic requirement for urban, regional and open space development. The Emscher conversion is considered an "engine of regional development". The transfer of waste water in a closed, underground canal system gives new impulses and new innovation spaces with environmental, social, urban planning and economic facets (WI, 2013, 102). The former non-accessible zones along the rivers and streams are converted into new recreational areas for cyclists and pedestrians. More than 450 individual projects will be implemented in the framework of the so-called Emscher Landscape Park. The increased amenity values provide an increase in the quality of life, however, which is difficult to quantify. Figure 3.3 gives an overview on the Emscher River as centrepiece of the Emscher landscape park to be further developed.

Figure 3.3. Emscher Landscape Park (http://www.metropoleruhr.de/regionalverband-ruhr/emscher-landschaftspark.html)

People, animals and plants are obtaining the remodelled waters back as new habitats. Studies show that by the conversion of the Emscher system many species have returned to the region. The project is also a contribution to the preservation and promotion of biodiversity and ecosystems. In addition the newly created open spaces as well as the wetlands contribute to filter air pollutants and improvet the urban micro climate. Also, the newly created open spaces fulfill an important function for natural flood protection, which avoides costs for additional flood protection measures.

This is a significant part of a successful rainwater management. The rainwater can seep better on the slightly impervious surfaces and recharges groundwater which provides also major cost savings. By this decoupling of rainwater from the sewers, additional constructions with an investmet of around 70 million Euro don't have to be built. The urban drainage system can be clearly relieved by good rainwater management which avoids costs in the urban sewer networks of about 200 million Euro (WI, 2013, 112).

It is difficult to evaluate the economic impacts of the conversion of the Emscher system by the rising ecosystem performance in terms of education, leisure and recreation. Besides direct economic benefits, the recultivation of the system contributes to further value added chains for instance in the field of ecosystem services, however, which are difficult to quantify.

The improved environmental qualities along the Emscher system give new options to match the desire for living near the water and in green residential housing projects. Also the environment of the existing settlement areas has been upgraded, which was evaluated by the residents as very positive. In the field of the real estate sector economic effects of the Emscher region regeneration should be easier to grasp than the economic effects of ecosystem services. However, an overall increase of land values could not been determined in the Emscher region so far, but rather selective, over the average rent increases are observed.

In general, the ecological enhancement of the Emscher region and the increased attractiveness for residents and for economic locations performs an enlarging motivation for public sector investments and private investors.

One of the examples in which the Emscher system is an enabler for large-scale private investment and thus for the spatial development of the Ruhr area, is the Phoenix Project in Dortmund. In former times, the huge Phoenix areal was the site of heavy industries in form of iron works, steel mills and related activities. It is located in Dortmund along the Emscher River. After closure of the industries in the late 1990s, the area was turned into one of the largest urban redevelopment projects in Germany. The western part is converted into a new technology park for innovative companies embedded in a landscape park along the recultivated Emscher.

In the eastern part, an artificial lake has been developed along the Emscher with a size of 25 hectares. The lake is now a popular recreational area with high quality recreational area for the whole Ruhr region and for tourists. Around the lake high-quality housing areas as well as a variety of gastronomical options are under development. Part of the lake area is designated for office and commercial buildings. The lake serves also as flood retention basin for the Emscher River.

The development of the Phoenix areal emphasises the increased attractiveness of the business and residential location of Dortmund as a symbol for the increased attractivity of the entire Ruhr region. It shows a development path from a brown, dirty industrial district to a highly attractive place of living, working and for leisure activities. These wider effects were enabled by embedding the development of a key sector of the green economy into broader urban and regional development strategies.

3.5 Links with other sectors

As presented before, the reconversion of the Emscher system is in a narrow sense a project of the water management sector. However, because of the magnitude of the strategy and the investment it is a project with links to numerous other sectors. The investment itself creates jobs in the construction and related industries. More indirect links are to the housing and tourism sector. In general, the reconversion of the Emscher system is a new enabler for economig growth in all sectors.

One specific and innovative link is with the energy sector. The Emschergenossenschaft is doing a model project to enlarge the functioning of a wastewater treatment plant to that of a hybrid power plant. Energy in form of heat and electricity is produced from the sewage sludge. Solar and wind energy are also used for the energy demand of the treatment plant. Energy can be stored as sewage gas, hydrogen and beomethane.

3.6 Potential for development of the sector

Once the Emscher reconversion programme will be finalised at the beginning of the next decade, the aspiring targets will be achieved. By then, the water management sector will be based on high standards and latest technology. The main tasks will be the maintenance of the system and gradual improvements in local contexts. The potential for further GVA increase and job creation will probably not within the sector, but in other economic sectors. As described the Emscher reconversion as centrepiece of the conversion of the Ruhr area has huge effects on other sectors. Here are the main potentials for further economic development induced by the water sector.

4. Energy as key sector for the green economy in the Ruhr area

North Rhine-Westphalia sees itself in particular with its industrial heartland, the Ruhr area, as energy region no. 1 in Germany. However, this status is mainly based on traditional ways of energy production, predominantly by burning brown and coal. Energy provision in Germany is not a public task, but done by private corporations. For reasons of energy security and social care for the mining workers, the coal mining industry received large amounts of state aid to be cost-competitive with imports from other parts of the world. However, in the wake of liberalisation, the amount of state aid went down and it is agreed to close the last coal pit by the end of this decade and to use only imported coal for the coal-fired power plants. However, with German's plans to exit from nuclear energy and drastically reduce fussil-fuel energy as consequence of the nuclear desaster in Japan and the responsibility for climate mitigation, the energy sector is heavily challenged. This chapter looks at the performance of the traditional energy sector (4.1) and presents the development of the renewable energy sector (4.2), its main drivers (4.3), its spatial dimension (4.4), links with other sectors (4.5) and future potentials (4.6).

4.1 Performance of the traditional energy sector

The huge hard coal deposits in the Ruhr area and brown coal deposits in neighbouring territories of the Rhineland were the base for the industrial development of the Ruhr area and the state of North Rhine Westphalia. The coal was mainly burned for energy production in power stations and was also processed into coke. The Ruhr region was and still is one of the most important energy production sites in Europe. Despite many crises in the coal and steel production, about 30 percent of the current gross power generation in Germany is produced in North Rhine-Westphalia (vgl. Agentur für Erneuerbare Energien, 2013, 13). Therefore, North Rhine-Westphalia makes use of the term "energy state no. 1”.

However, coal production in the Ruhr has taken a dramatic downturn development (Figure 4.1). Until the late 1950s, the hard coal was besides brown lignite the main energy source. The energy sources of coal were considered without alternative and inexhaustible, and were one of the cornerstones of the economic upswing of the post-war period in the Ruhr area, North Rhine-Westphalia and in the entire Federal Republic of Germany. The coal production reached its boom phase in mid-1950s. In 1957, 123.2 million tons of hard coal were extracted in the Ruhr area. This corresponds to a daily amount of almost 425,000 tons. The large demand for coal from the Ruhr coal deposits had positive employment and population effects for the region. In 1957 almost 500,000 people were working in the coal mining industry. More than 80 percent of coal production and related employment of the Federal Republic took place in the Ruhr.

The boom phase of coal mining with its peak in 1957 is only of short duration. Already in the following year there was the first major coal crisis, the self-evident growth of the coal mining industry ended. One major reason for the decline of hard coal mining is the high price of Ruhr coal. At the beginning of coal mining, coal could be mined economically more or less at the surface, but as those areas are exploited, today the mining has to be done in depths of up to 1500 meters. This makes the Ruhr coal a very expensive commodity. On the other hand by the increasing liberalisation of international electricity markets and the decreasing transport costs, it was possible to import cheaper coal from abroad. Furthermore, the Gulf States pushed with dumping oil prices to the European energy markets so that the expensive coal mining in the Ruhr area lost more and more competitiveness and was successively substituted by the fossil fuels oil and gas. Therefore, potential outlets of the Ruhr coal or coal conveying other German hard coal locations were more difficult and required a continuous reduction of unprofitable shafts, capacity, funding and employees as well as the closure and amalgamation of mines.

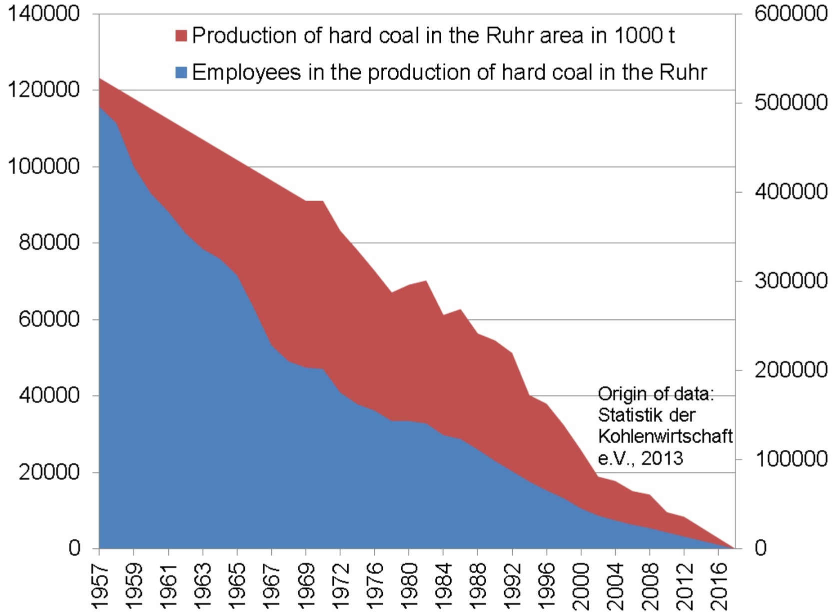


Figure 4.1: Hard coal in the Ruhr area, production and employees, 1957-2018

Thus, the total production of hard coal in Germany fell from 149 million tons in 1957 to 69.8 million tons in 1990, reaching nowadays only 8.5 million tons in 2012 which were almost entirely used in power plants (vgl. Statistik der Kohlenwirtschaft e.V. und BBSR 2013: 10).

As a result of these developments, the share of coal in primary energy consumption of the Federal Republic of Germany decreased from 70 percent in 1955 to 20.9 percent in 1981. The conditions for the German hard coal industry have changed largelyy, especially in the last 20 years. To "slow down" these negative developments or to equalise the German mining cost compared to the cheap imports, it was decided by judgment of the Federal Constitutional Court to subsidise the Ruhr coal used in power plants from 1994 onwards. The Ruhr coal is subsidised by the state of North Rhine-Westphalia up to 2015 and subsequently taken over by the federal government to the finally decided end of coal mining in 2018.

Despite the dramatically changing conditions such as the declining world market prices or the German "Energy transition policy", coal-fired electricity generation remains very important. With a share of 12.4 percent of the German energy mix for 2012 the hard coal is still a very important component for the German energy supply. According to the energy scenarios from the German authorities, coal stays important for the German energy supply for the next 15 to 20 years at least. The share of hard coal in primary energy consumption can vary between 6.4 percent and 11.7 percent depending on the scenario. However, the coal with the closure of the coal pits in Germany, the coal will be importet coal only.

Parallel to the decrease in coal production in Germany the coal imports from abroad increased. In 2001, it was the first time that imports were higher than the production of hard coal in Germany. In 2011, 41.6 million tons of hard coal were imported from abroad, probably with increasing tendency. The share of imported coal was already 76.7 percent in 2011. Hard coal mainly stems from Colombia (10.5 million tons), Russia (9.7 million tons), the United States and Canada (each with about 9.4 million tons) and Australia (4.1 million tons). From other EU countries only 4.1 million tons hard coal was imported. Despite the large distances between the source of imported coal and and the power plants, the coal from the Ruhr has disadvantages in cost, the close spatial relationship between coal extraction site and power plant is lost. .

The Ruhr area has been critically affected by this development. Between 1957 and 2012 the coal industry has lost about 480,000 jobs. Today there are still nearly 14,000 employees in the coal industry.

The strong changes in hard coal production and the amount of German imports are to be seen in the context of a relatively constant demand of the coal-fired power plants of between 40 and 50 million tons since the 1990s with some fluctuations due to economic changes and crisis.

Energy production

North Rhine-Westphalia has a gross electricity generation of 180.8 million kWh which is the largest amounts of all Länder in Germany followed by Bavaria with 89.2 million kWh. The gross electricity generated in NRW has a 30 percent share of Germany's total production. This high percentage underlines the importance of a reliable energy supply. The energy production using hard coal contributes significantly to the stability of energy supply in Germany. An indication of the security of supply are the low power failure times. In 2011, German end consumers were on average only 15.3 minutes without electricity. In contrast, the Netherlands and France had to accept significantly higher power failure times of 33.7 minutes and 62.9 minutes in 2011 (BMWi 2012, 2).

In Germany, 26,292 MWel are installed in 50 power plants with a capacity of over 100 MW in 2012. The power plants are located in 11 federal states. Hard coal-fired power plants are principal mostly located along waterways and near major industrial plants and as expected in the coal mining areas Ruhr and Saar. In NRW, in 19 coal-fired power plants 12,000 MW are installed plants which is 45 percent of German hard coal based power generation (BBR 2013: 9). 15 large power plants with an installed capacity of more than 10 MW are located in the Ruhr area; 11 of these power plants are operated with hard coal (Figure 4.2)

With the power plant “Scholven” in Gelsenkirchen the Ruhr area has one of the most efficient hard coal-fired power plants in Europe. The power plant “Scholven” is operated by the electricity company EON and has a total capacity of 2,200 Mwel. This power plant can cover three percent of Germany's electricity demand. There are plans for new coal-fired power plants in Lünen and Datteln that should replace older ones, however, as there are opponents this will be finally decided by the courts.

Greenhouse gas emission

Gross electricity generated in NRW is based to a high proportion of 94.2 percent on fossil and nuclear energy, however the proportion of nuclear power must be regarded as very low Mainly because energy production is based on fossil fuels and hard coal NRW as one of the leading industrial Länder in Germany is a very energy- and the most CO_2-intensive region in Germany. There was a reduction of CO_2 emissions at the end of the 1990s, but since it was always around 300 million tons; little less during the crisis, but up to 305 million tons again in 2012. This is around one third of total CO_2 emissions in Germany. More than half of the CO_2 emission is generated by the energy sector.

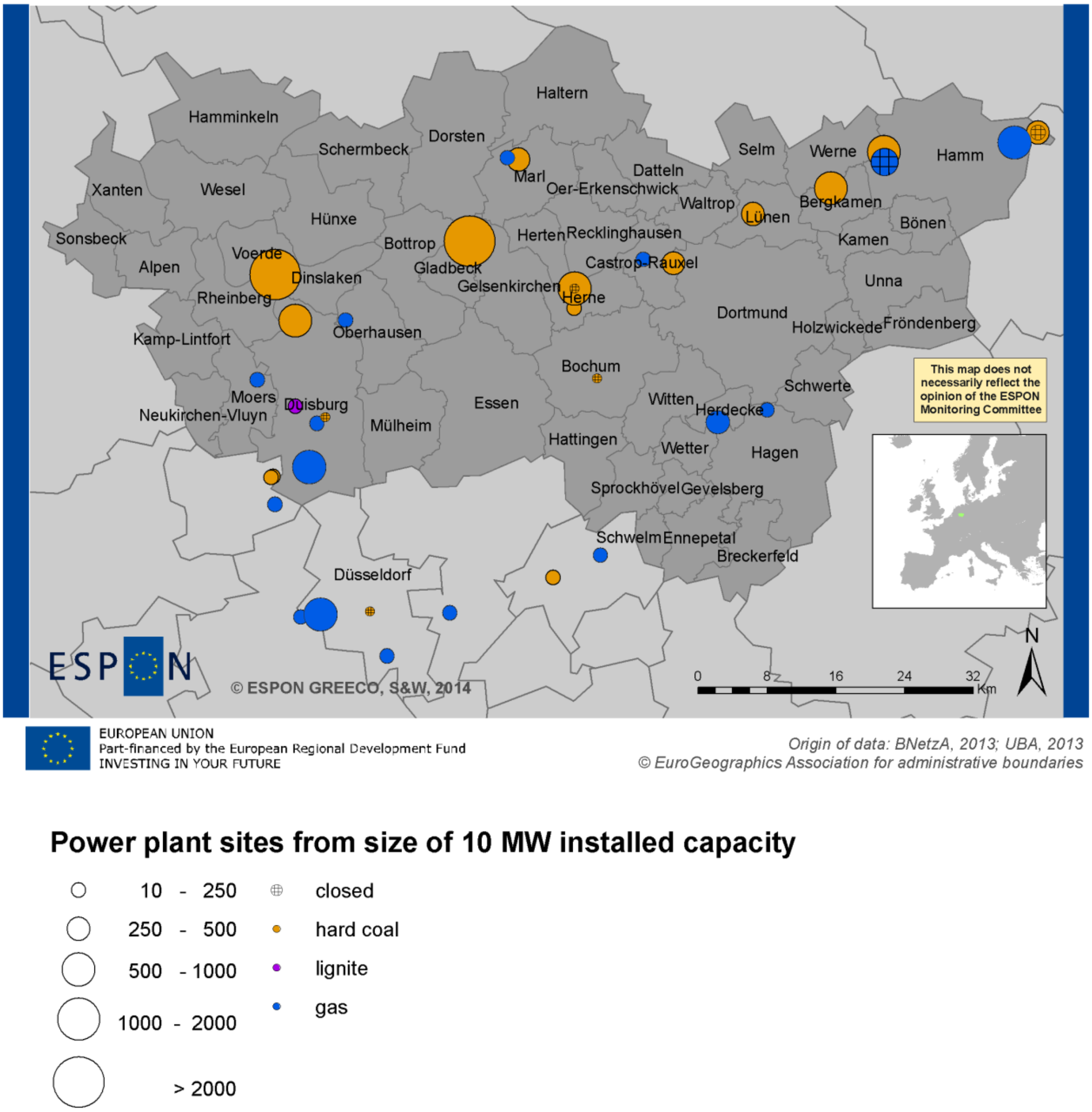


Figure 4.2: Power plant sites in the Ruhr area

Electricity consumption

The high CO_2 emissions in NRW are the logical consequence of the high fossil electricity production and on the other the result of high power consumption in an industrial embossed and highly populated region. There is a high total amount of electricity consumed in the Ruhr (about 46 million MWh) and in NRW (about 138 million MWh). About half of the electricity is used by industry in NRW; in the Ruhr region the industrial share is as high as 58 percent. Accordingly, the trade and industry has a huge impact on the demand for electricity and the resulting CO_2 emissions. The power consumption of the Ruhr area represents approximately 8 percent, NRW about 25 percent of the total power consumption of Germany.

Despite some fluctuaton caused by economic up and downs, industrial energy consumption is rising in Germany, NRW and the Ruhr area. In the latter, there is a tendency that the electricity demand of core cities goes up, whereas rural areas require less energy (Figures 4.3 and 4.4).

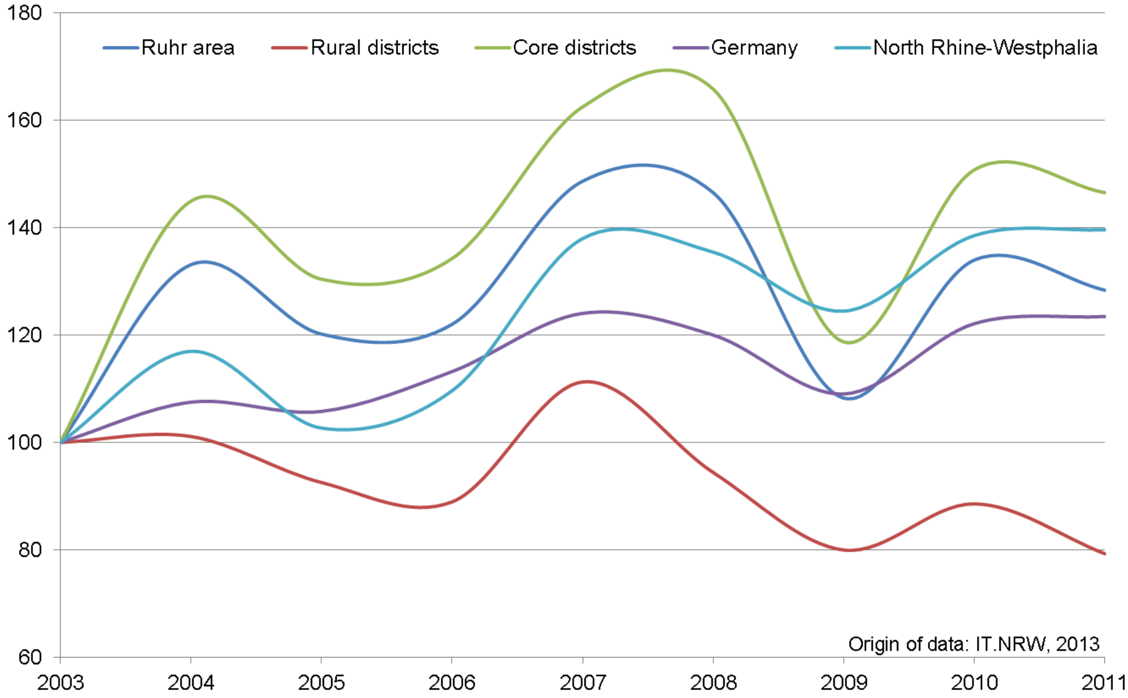


Figure 4.3: Energy consumption of the mining and quarrying sector and the manufacturing sector, 2003-2011(Index: 2003))

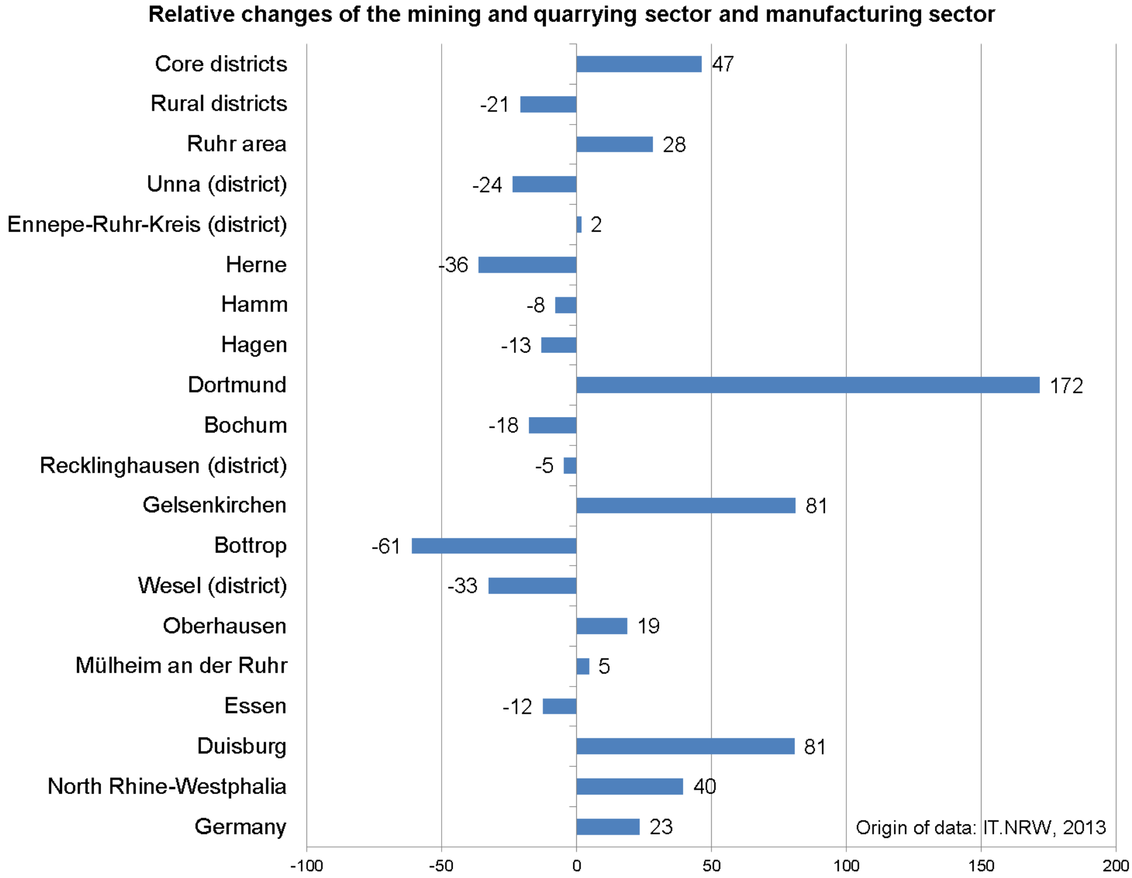


Figure 4.4: Energy consumption in the Ruhr area, 2003-2011

4.2 Key milestones of the development of renewable energy sector

The decrease in CO_2 emissions is attributable to a certain degree to climate protection measures such as the expansion of renewable energies. However, the decisive impulses for the development of renewable energies are not primarily coming from environmental considerations, but is a result of political and social decisions maybe even social constraints. Because after the nuclear disaster at Fukushima in 2011, nuclear power generation was reconsidered by the federal government with the outcome that nuclear energy production in Germany will be ended by 2022. This was certainly a key milestone in the development towards a new, sustainable, safe and "green" energy supply in Germany. This step was accompanied by the agreed end of coal mining in 2018. The federal state of Germany and the state government of NRW have set ambitious goals to cover the electricity demand largely through the use of renewable energy and at the same time to contribute to climate protection. In this context, the expansion of renewable energy is the core element of Germany's energy supply.

Therefore, new strategies for sustainable ("green") electricity production must be found also in the Ruhr area. Especially against the background of the tradition in the hard coal production of about 150 years, the Ruhr area and in particular the key provider of electricity are now facing a massive restructuring of the energy supply and a huge challenge to do the energy transition and the development of renewable energy in an active and successful way. However, this means that the electricity generation and the electricity distribution will change through the break with the nuclear energy and the gradual decline of the coal industry as of now and in the coming years. In traditional power generation large amounts of energy was produced at in rather centralised structure in a few places.

Natural assets suitable for RES generation

Renewable energy production, however, has other, more diverse and more complex demands for space. In general RES are considered as land-intensive. In contrast to traditional power generation, generally RES require to use a larger area for the same amount of electricity. They are usually distributed decentralised in space. In addition, renewable energies and especially wind energy are not free of land use conflicts with competing demand for the same plot of land. In particular wind energy can affect human life and its surroundings negatively. Similarly, the RES expansion targets may be in conflict with the interests of nature conservation and species protection as well as aspects of the landscape. Therefore, in a metropolitan area such as the Ruhr area, a natural and environmentally friendly planning of RES is an important challenge, because there is only limited space for the development of renewable energy available.

Because of the climatological preconditions, the construction of renewable energy plants is not possible in each available location. For wind energy plants a suitable wind speed is crucial for the efficient generation of electricity. Since the produced power increases with the cube of the wind speed, i.e., the wind speed increases by 5-fold, a 125-fold amount of energy can be generated (Theiss, 2008). In the Ruhr area the location factors for wind energy are not ideal. However, the technical progress makes it possible to build higher plants and therefore to use the higher wind speeds at higher altitudes. Through this technical progress there are locations available, which could not be used for wind energy before. In contrast to the northern coastal areas in Germany where average wind speed of more than 10 m/s exist in an elevation of 120 m, wind speeds in the Ruhr area are primarily at 5-6 m/s at a hub height of 120 meters. In rural areas occasionally wind speeds of up to 7 m/s are possible. These wind speeds are sufficient for the technical and partly for economic operation.

Regarding photovoltaic, regions in southern Germany have substantially better location advantages compared to the Ruhr region because of higher radiation intensity and duration of radiation. However, photovoltaic can be efficiently used in the Ruhr area, but it should be avoided to locate photovoltaic ground-mounted systems in close proximity to relevant shadowing objects such as forest areas or buildings.

In the sections below it is shown for different renewable energies that although the locational conditions are not ideal, a successful expansion with positive environmental and economic effects is possible in NRW and the Ruhr area is possible.

Wind energy

The spatial distribution of wind energy sites in the Ruhr region and in neighboring regions is clearly linked to the structural conditions of space. The locations of wind power plants are situated mainly in the rural areas such as the northern Münsterland, in the eastern Sauerland and in the west in the direction of the Dutch border.

About 170 wind energy plants have been realised in the Ruhr area so far, which are mainly located in less dense locations at the boundaries of the region. A concentration of wind power plants is to be found in the rural districts of Wesel and Recklinghausen. In the core zone of the Ruhr the number of wind turbines is low. If at all, individual plants are located in the border area of the independent cities.

The upturn of wind energy production in the Ruhr area started at the turn of the century (Figure 4.5). Before, only about 20 GWh per year were produced. The production steeply increased up to more than 400 GWh in the year 2012. The spatial distribution of wind energy production in NRW is shown in Figure 4.6 by municipality. It can be seen that municipalities in the Ruhr produce wind energy, but that this is much less than the municipalities in the other parts of NRW do. In most of the municipalities of the Ruhr area, wind energy contributes currently to less than 5 % of energy consumption (Figure 4.7). It can also be seen that some municipalities in rural areas with high wind energy productoin can cover almost their total electricity demand by wind energy; some even have a surplus.

The development of wind energy also shows economic benefits after initial difficulties. From 1997 with about 1,000 employees, the number of employees increased steadily. In 2011, about 10,000 people from NRW were already employed in wind energy technology (BWE, 2014). Especially the medium sized engineering companies in the Rhine area and the Ruhr area have developed a new business pillar and export their products such as gearboxes, generators, steel towers, bearings or major components for wind turbines. A similar development is reflected in revenues from the equipment and system construction of wind power in NRW. Here the revenues sharply increase from about 900 million Euro in 2005 to more than 2,000 million Euro in 2011. Consequently, sales have more than doubled in six years.

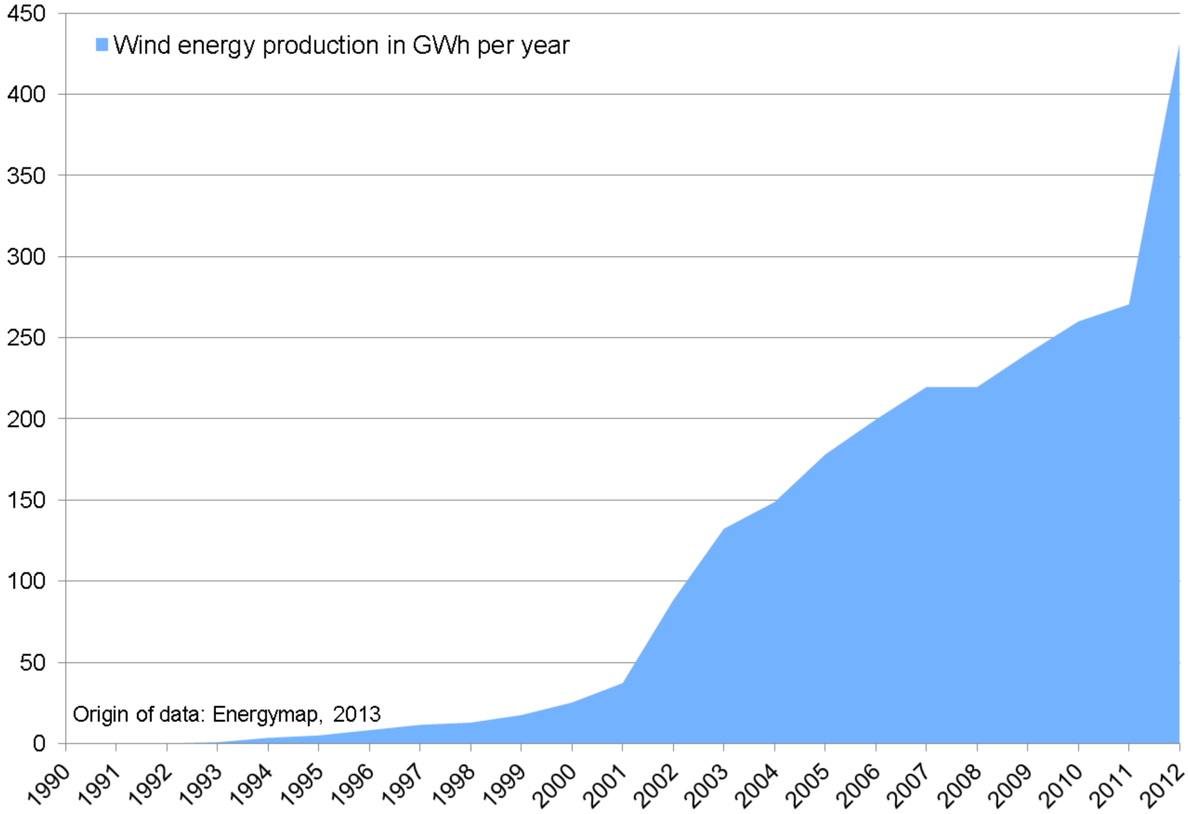
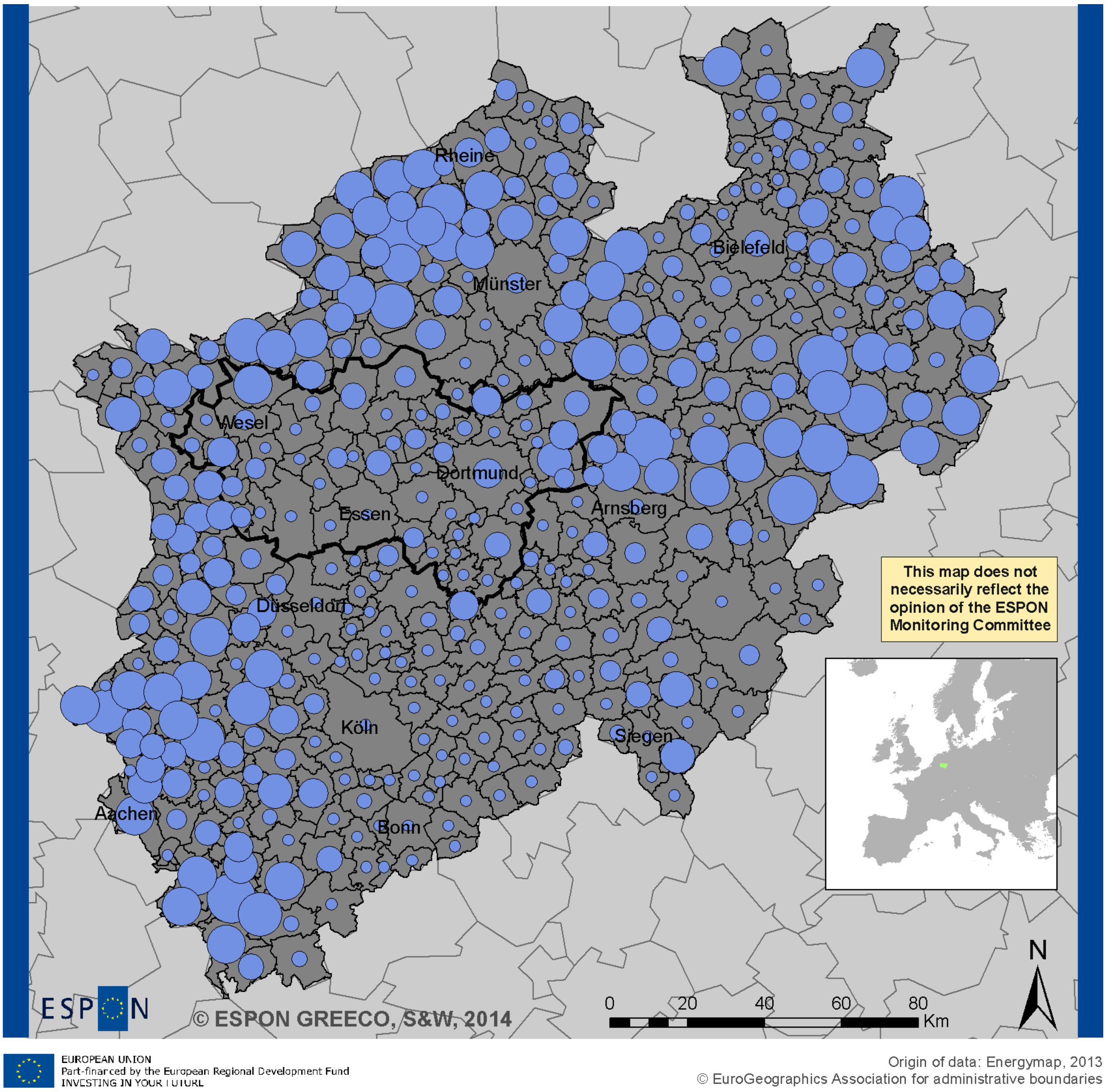


Figure 4.5: Electricity production from wind energy in the Ruhr area, 1990-2012



Electricity production from wind energy 2012 (GWh)

< 2	25 - 50
2 - 5	50 - 80
5 - 10	< 80
10 - 15	Ruhr area
15 - 20	
20 - 25	

Figure 4.6: Electricity production from wind energy 2012

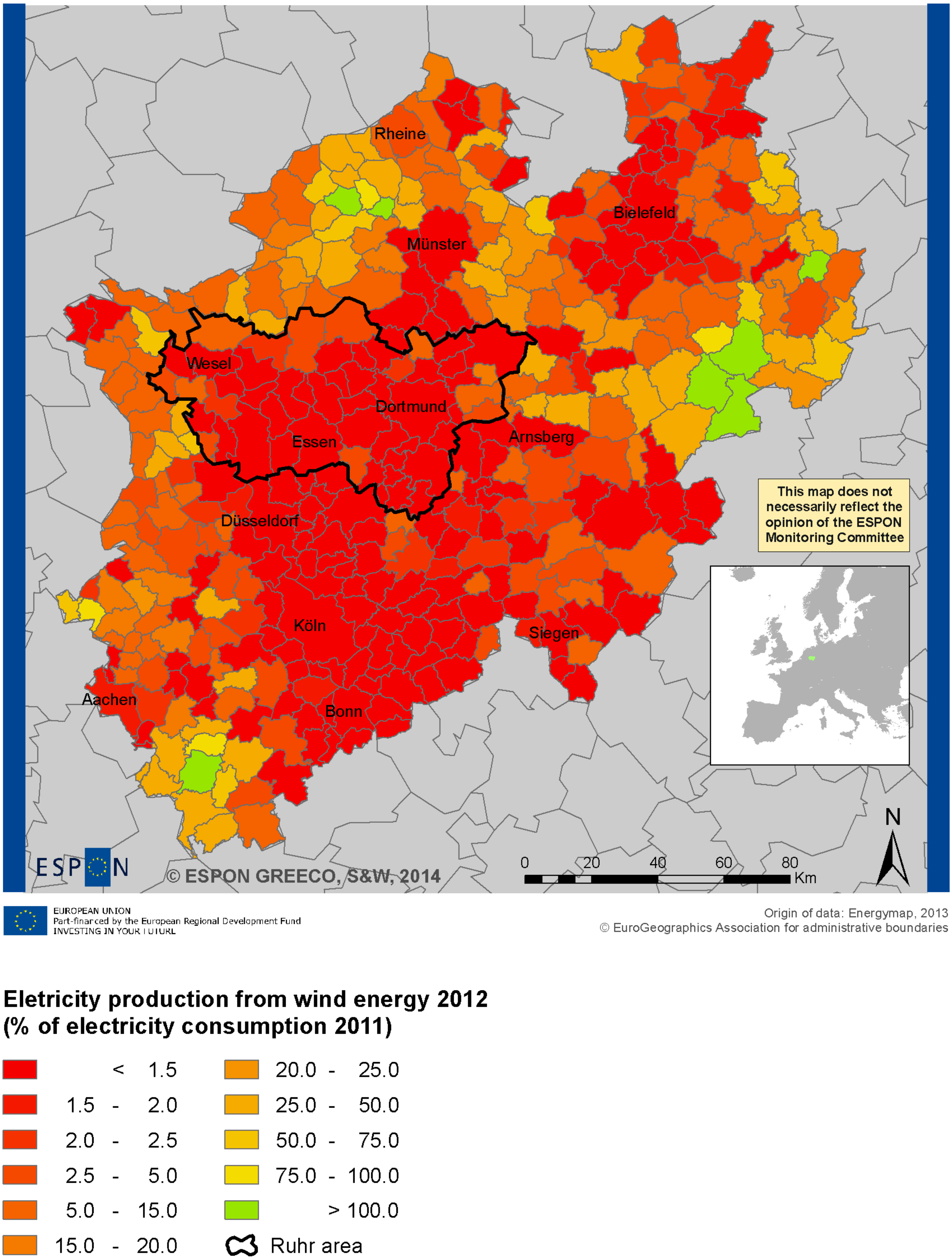


Figure 4.7: Electricity production from wind energy 2012 in percent of electricity consumption 2011

Solar energy

Photovoltaic has experienced a boom during the last 15 years in all parts of Germany as well as in NRW and in the Ruhr area. At the beginning of the century, about 3,000 devices had an installed electric power of 13 MWp in NRW, this rose to 160,000 sites with an installed power of almost 2,900 MWp. Solar energy is after wind energy and biomass the third important source of renewable energy. In the Ruhr area, in wich 15 years ago almost no electricity from photovoltaic was produced, about 380 GWh per year were generated in 2012 (Figure 4.8).

Figure 4.10 shows the spatial distribution of solar energy generation by municipality for the year 2011. The spatial pattern is different than for wind energy. Now, also the large cities in the Ruhr area produce as much as electricity as many rural municipalilties. The reasons for the concentration of solor energy production in the major cities lies in part in the high population number and the corresponding high number of suitable roof surfaces. However, Figure 4.11 shows that the producton of electricity from solar energy in the Ruhr area covers only up to five percent of energy consumption.

The importance of solar energy in terms of economic effects is large in NRW and took a comparable impressive development during the last 10 years. The number of employees in the regenerative system and plant construction for the photovoltaic increased from 862 employees in 1997 to 7,894 employees in 2011. As well, revenues have more than doubled in the previous six years. 2008, the construction for plant and system in the photovoltaic had a turnover of 4,141 billion euros, while 1,225.1 million euros were generated in 2010. Between 2010 and 2011, revenues decreased by 71.5 million euros to 4,069.5 million euros, which is probably justified by the change of the EEG feed-in tariff for ground-mounted photovoltaic systems.

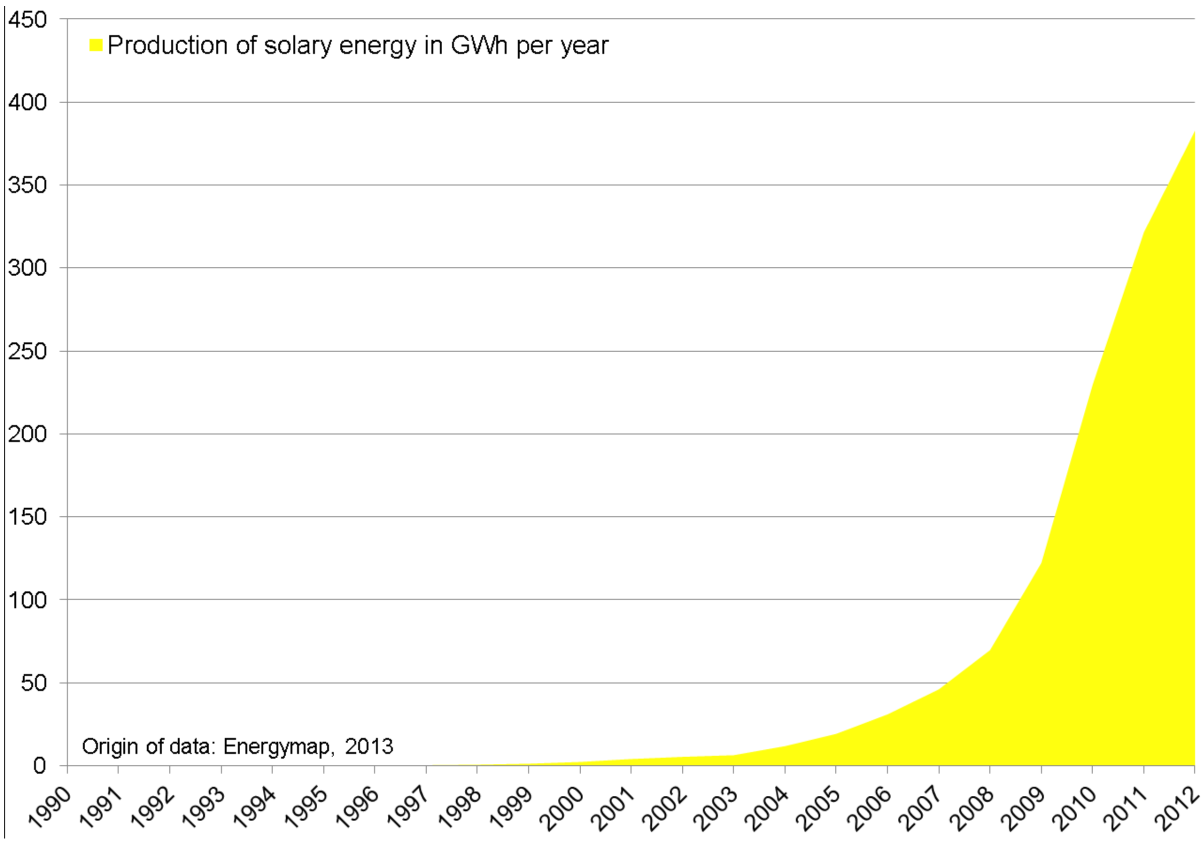


Figure 4.8: Electricity production from solar energy in the Ruhr area, 1990-2012

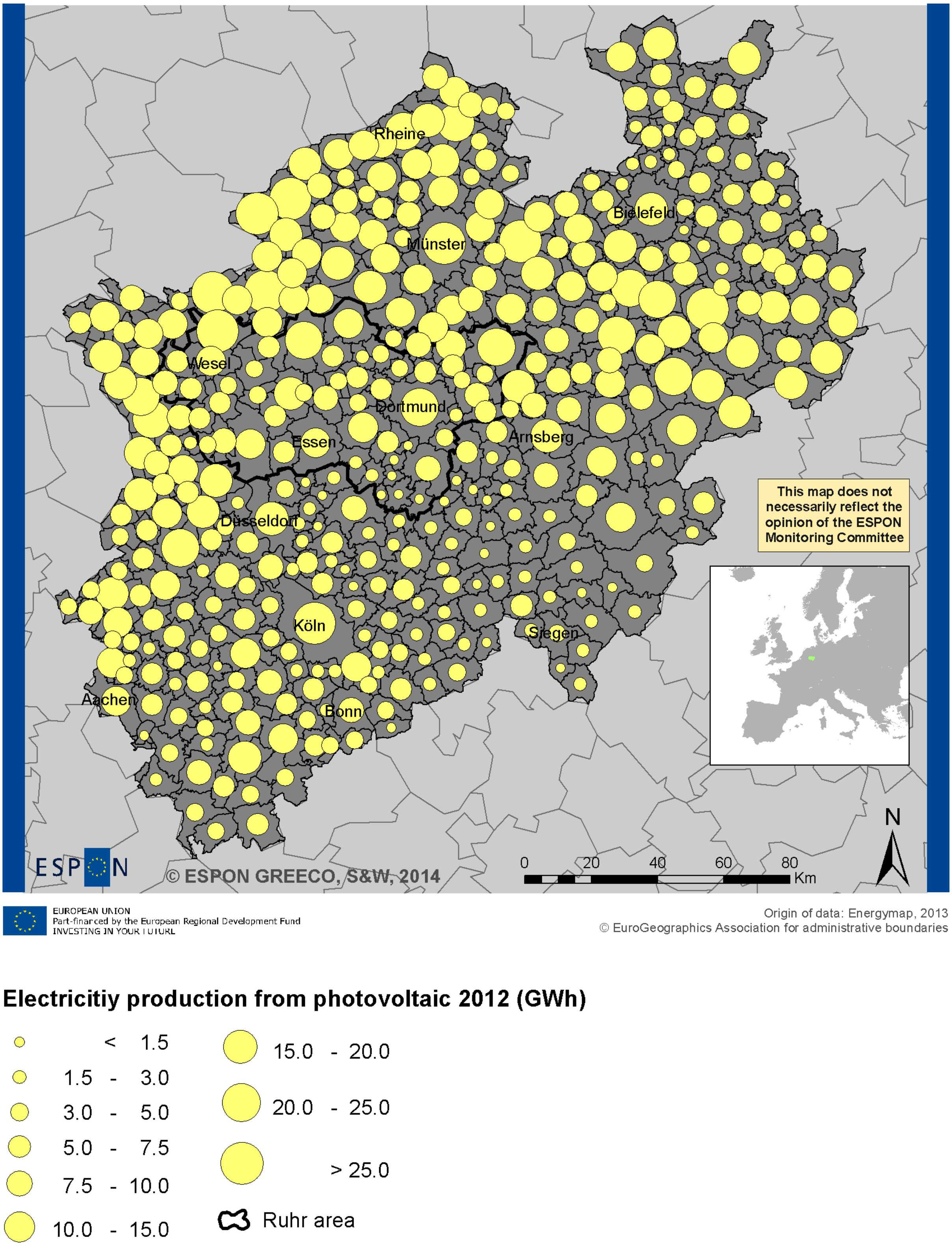


Figure 4.9: Electricity production from photovoltaic 2012

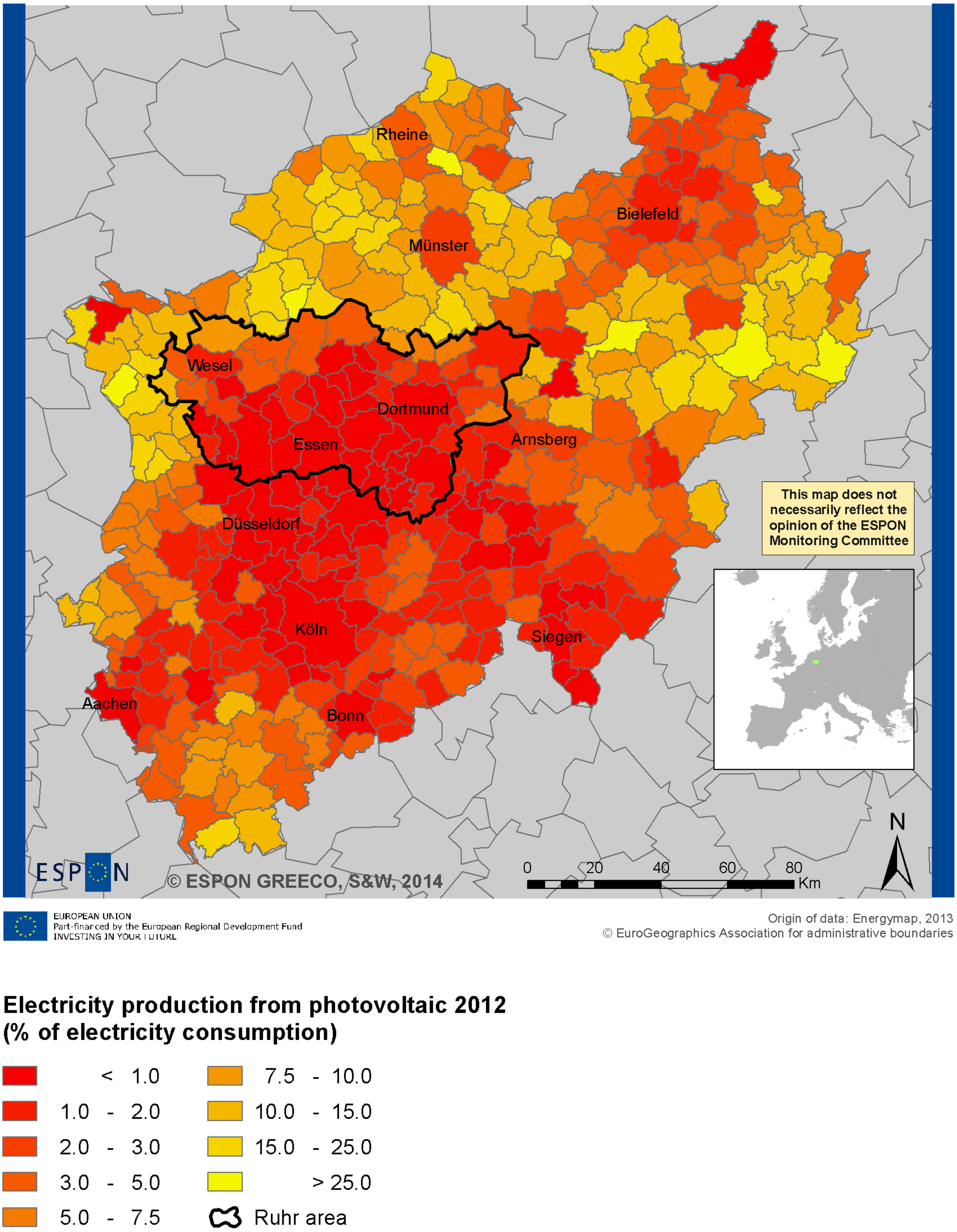


Figure 4.10: Electricity production from photovoltaic 2012 in percent of electricity consumption 2011

Biomass

Biomass gain in importance in North Rhine-Westphalia and the Ruhr area a little bit later than wind and solar energy. However, the upturn during the last ten years is impressive. In 2012, energy production based on biomass was 970 GWh per year (Figure 4.11). Despite its urban character, the Ruhr area is an important location for this form of renewal energy production. However, the more rural municipalities show the highest amounts (Figure 4.12) whereas the production in the core cities are neglectable.

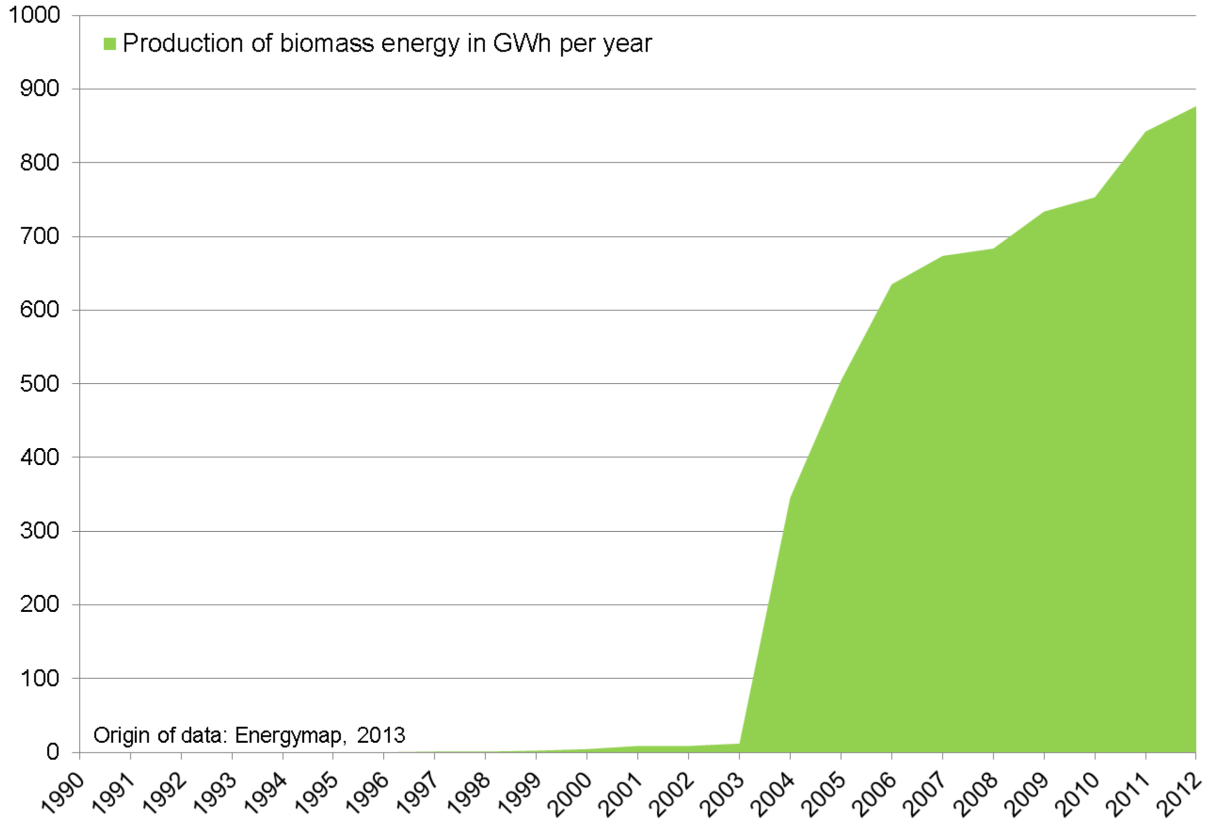


Figure 4.11: Electricity production from biomass in the Ruhr area, 1990-2012

Other alternative energy sources

The gases mine gas, landfill and sewage gas produced as a result of coal mining, in degradation processes in landfills and in the purification of wastewater are used for energy production in NRW and in particular in the Ruhr area. All of these gases consist of the greenhouse gases methane and CO_2, which makes them a source of energy. The yearly energy production from these sources is nowadays about 900 GWh per year (Figure 4.14). For this energy source, the municpalities of the Ruhr area are the top location within North Rhine-Westphalia (Figure 4.16).#

A minor role in the Ruhr area is related to water power. The total amount produced in 2012 is about 150 GWh per year (Figure 4.15). In the Ruhr area, the hydro-electric power plants are mostly located at the river Ruhr in the south of the region (Figure 4.17). The map shows in addition that the dammed lakes securing the water supply of the Ruhr region in the Sauerland south-east of the Ruhr are also used for electricity generation.

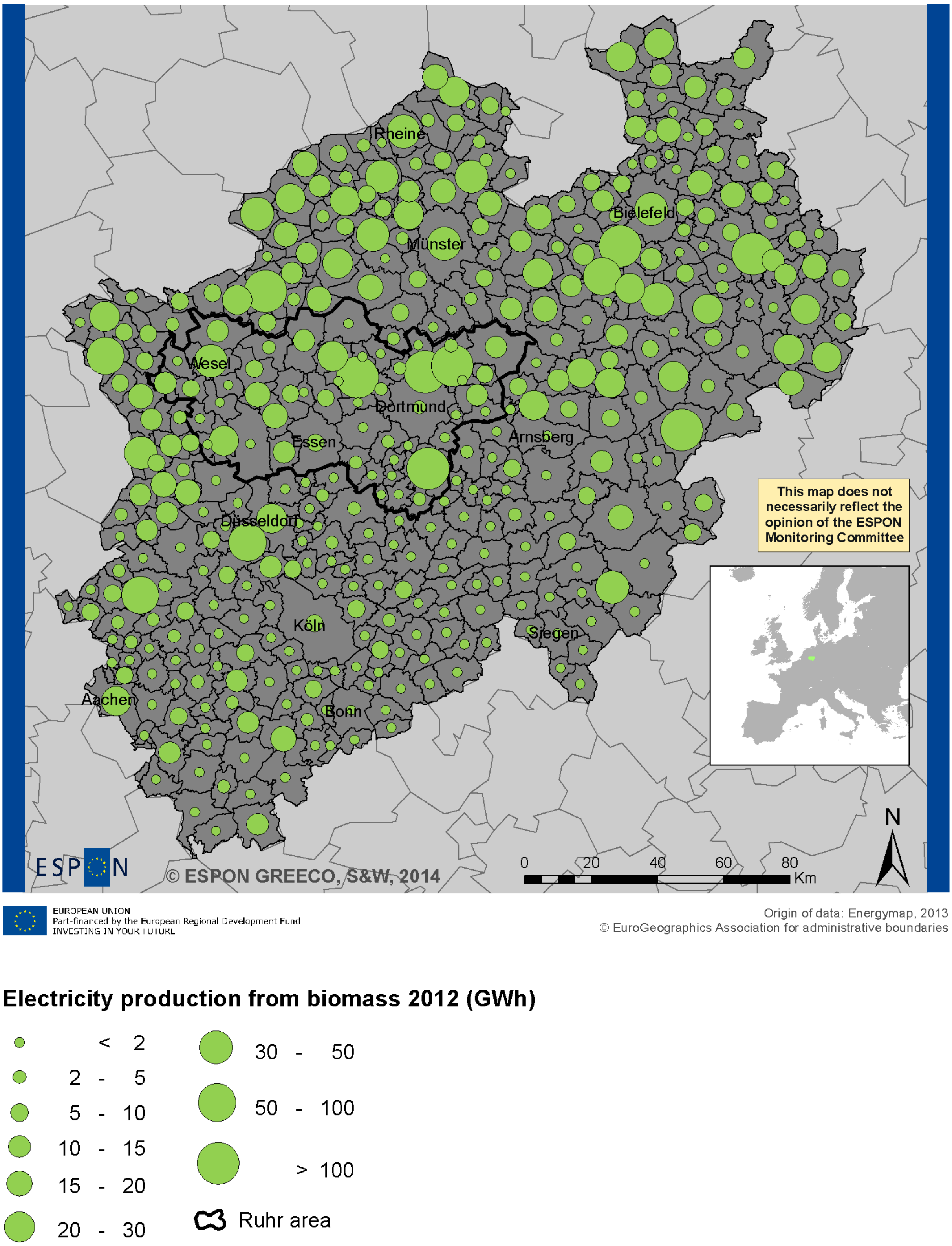


Figure 4.12: Electricity production from biomass 2012

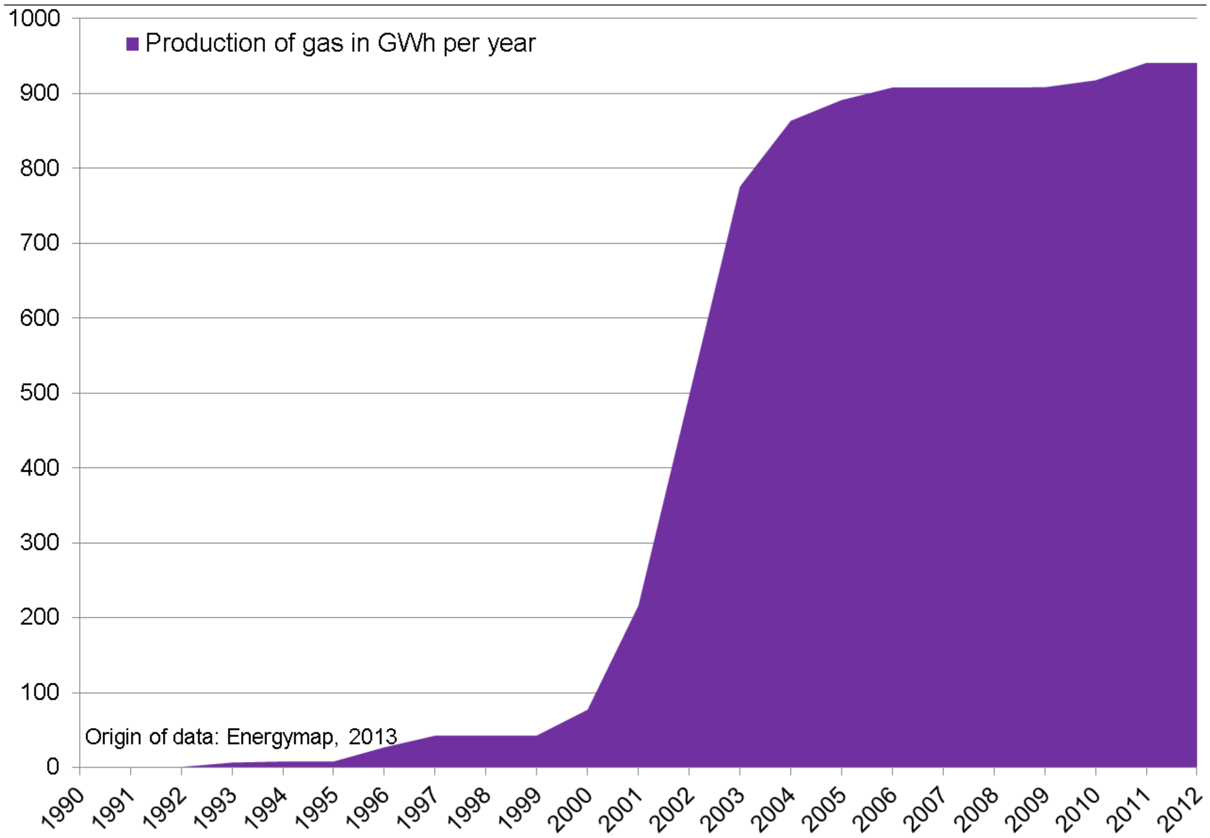


Figure 4.13: Electricity production from mine gas, landfill gas and sewage gas in the Ruhr area, 1990-2012

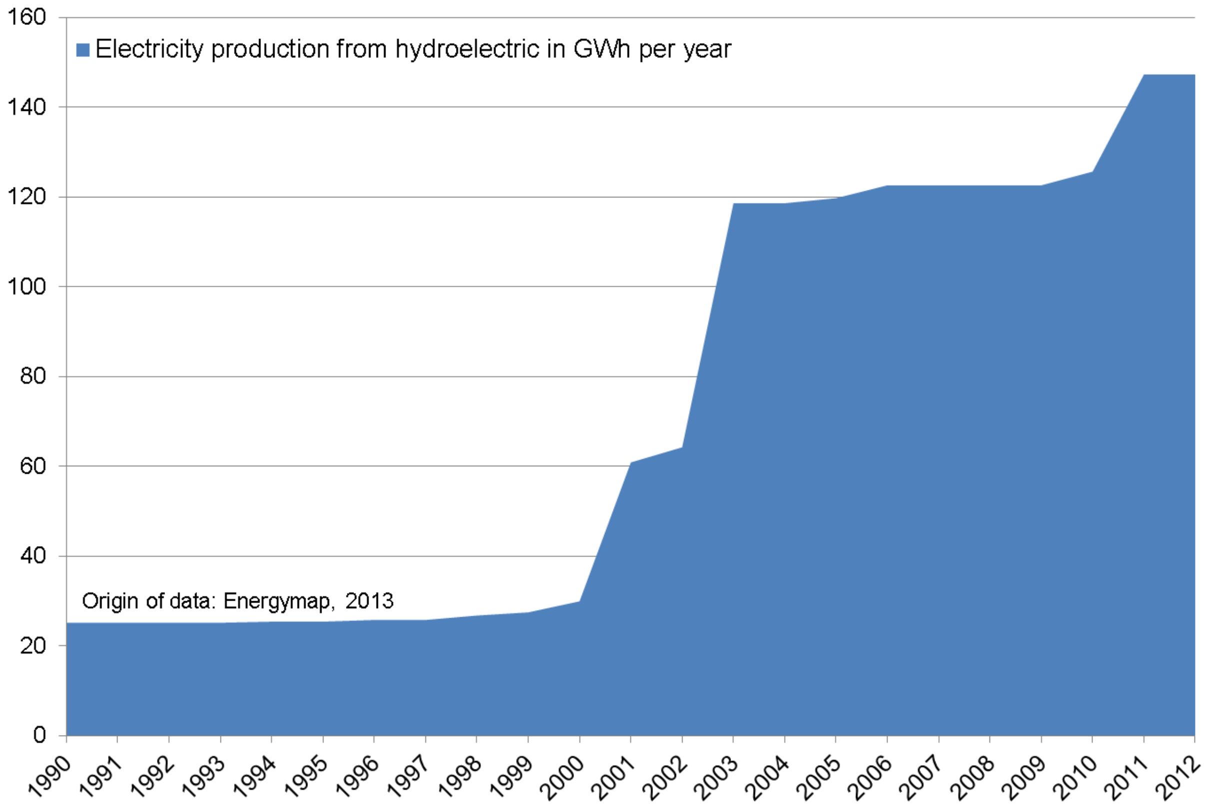


Figure 4.14: Electricity production from hydroelectric in the Ruhr area, 1990-2012

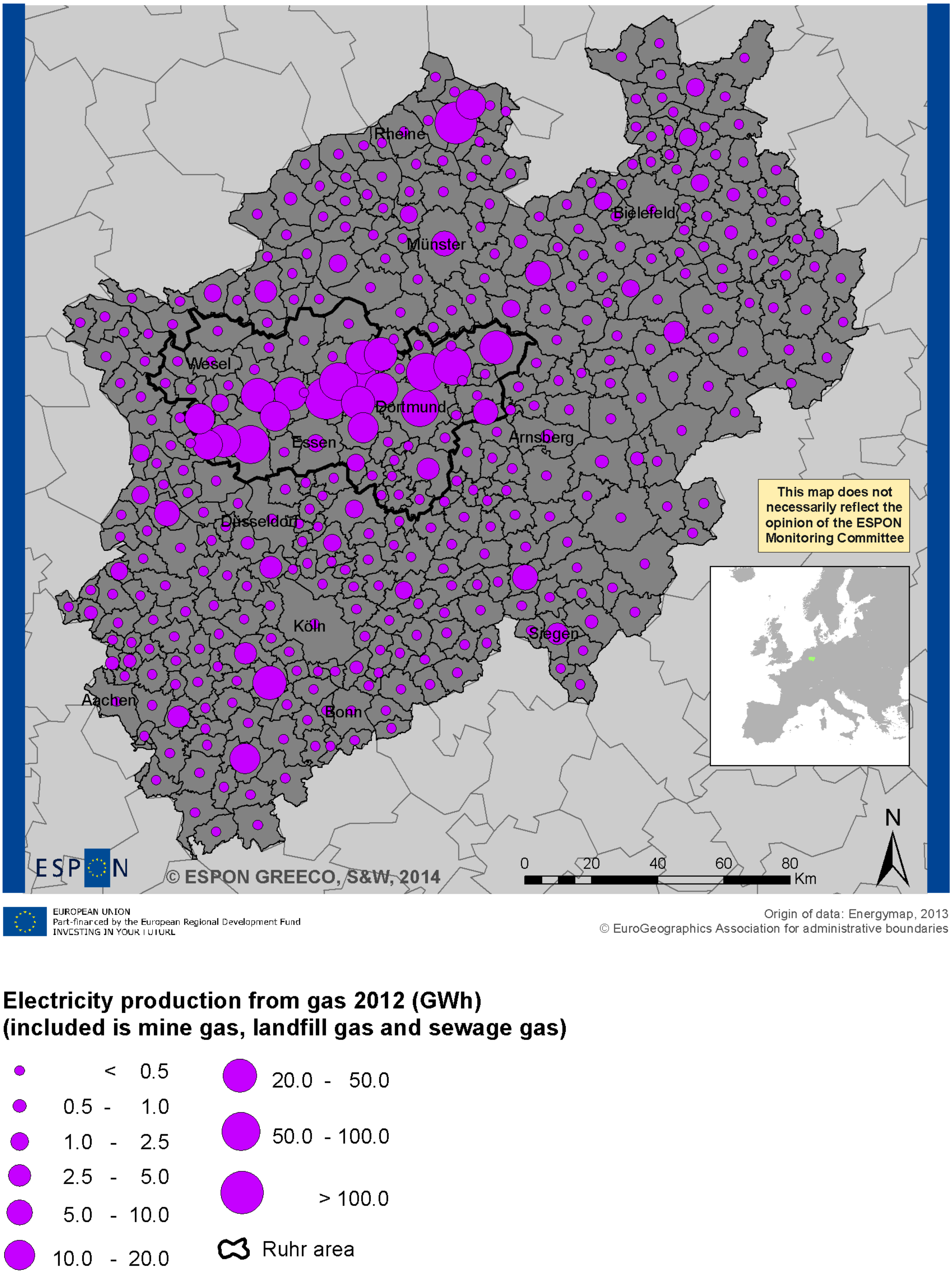


Figure 4.15: Electricity production from mine gas, landfill gas and sewage gas 2012

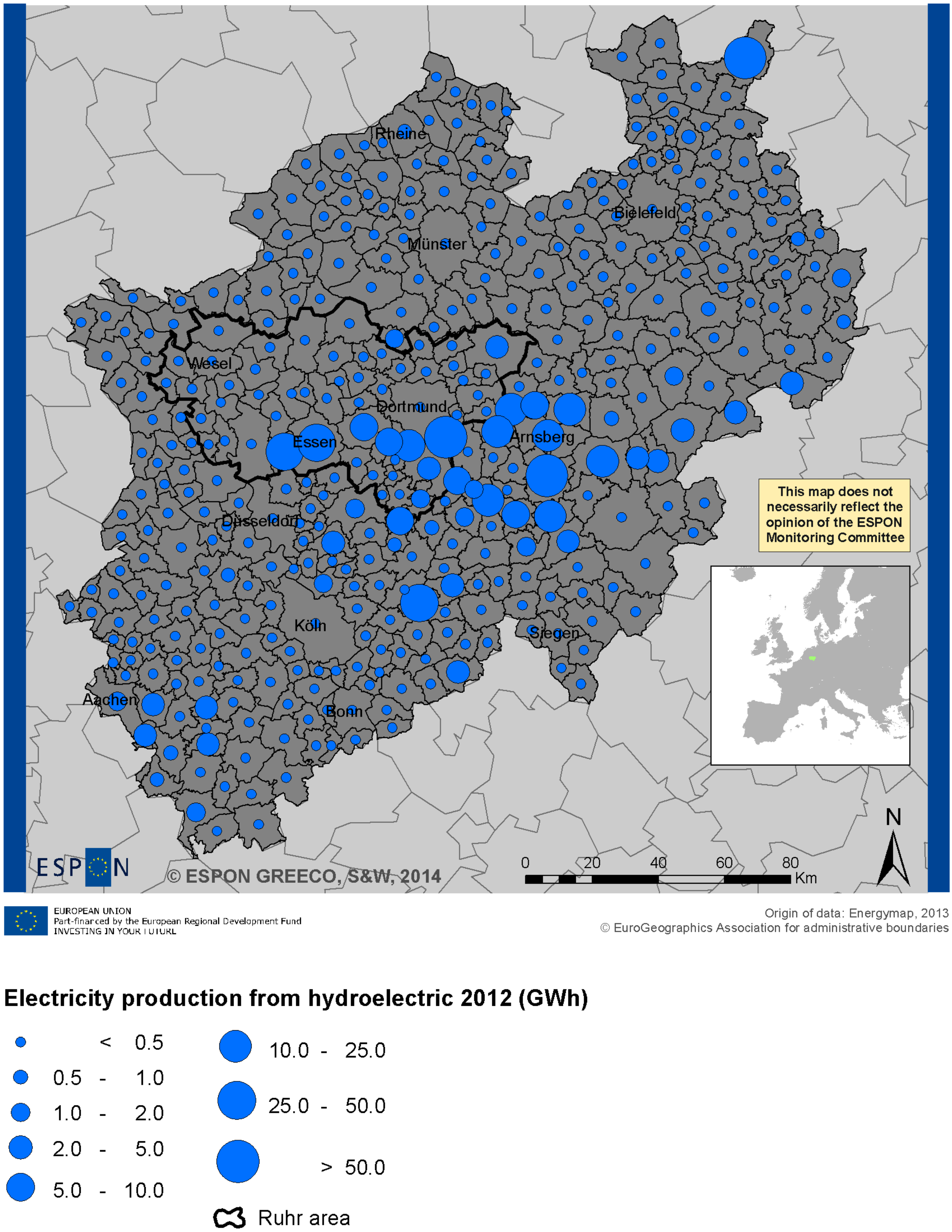


Figure 4.16: Electricity production from hydroelectric 2012

Aggregate effects

The last 15 years have seen a tremendous increase in the energy production from renewable sources. Whereas the production in the 1990s was almost neglectable, by today (2012) renewable energies located in the Ruhr area have a yearly energy production of about 2,800 GWh (Figure 4.17). Biomass and gas from mining or sewer treatment have the largest shares, but wind energy and solor energy do also make important contributions. Renewable energy production in the municipalities is as high as in other municipalities of NRW (Figure 4.18). The core cities of the Ruhr do even produce more renewable energy than other large cities in NRW such as Köln or Düsseldorf. Figure 4.18 demonstrates that there is still a long way to go to achieve sufficient shares of renewable energies in total energy production. Whereas many municipalilties in rural area produce more than 20 percent, partly between 50 and 100 percent, partly even more of their energy consumption by renewable energy sources, those figures are much lower in the municipalities of the Ruhr area. A few municipalities have shares between 10 and 20 percent, three municipalities even more. But the majority of municipalities is clearly below 10 percent of even below 5 percent. However, compared with the urban regions along the river Rhine, i.e. Düsseldorf and Köln and their suburbs, the shares of renewable energy production in the Ruhr area is much higher than there.

CO_2 reduction due to renewable energies and other alternative forms of energies is estimated to be about 17.6 million tons in 2011.

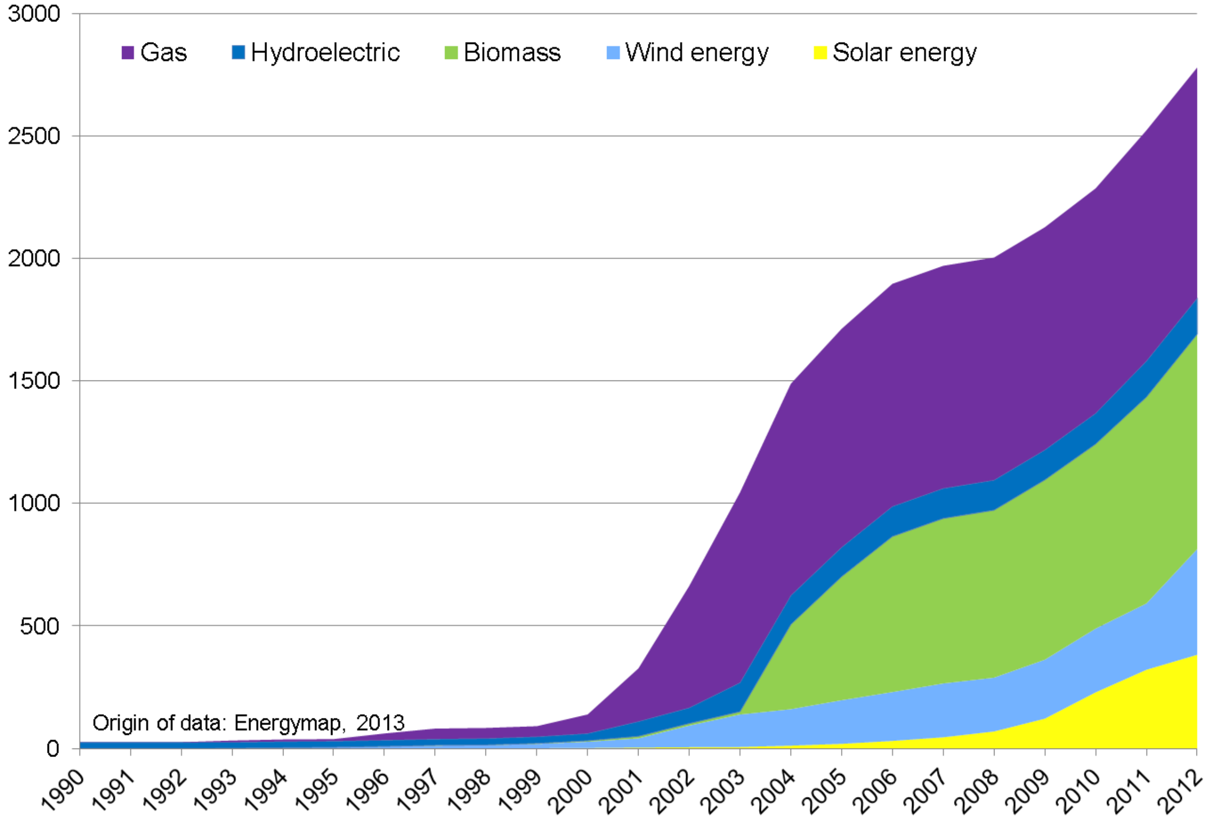


Figure 4.17: Electricity production from renewable energy in the Ruhr area, 1990-2012

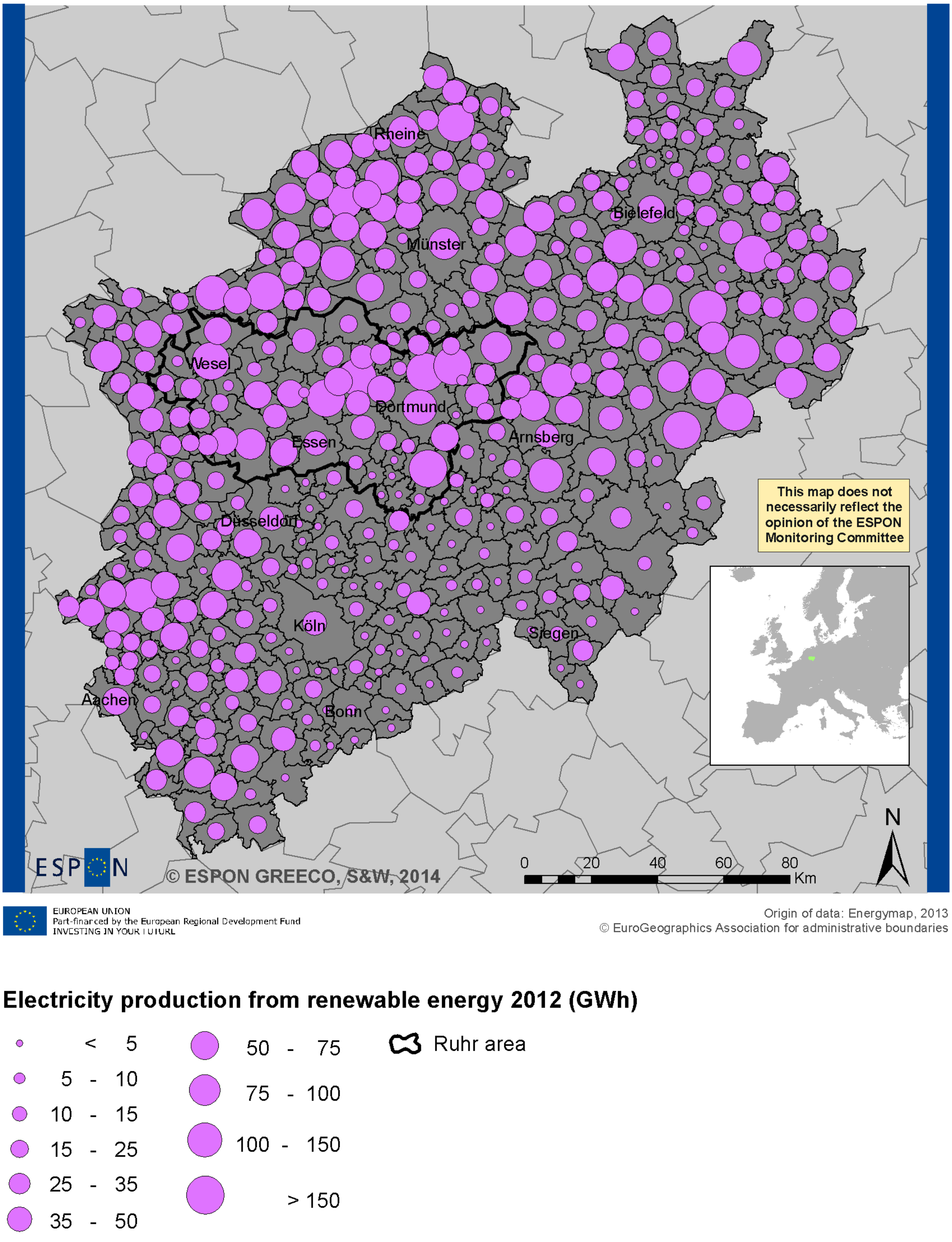


Figure 4.18: Electricity production from renewable energy 2012

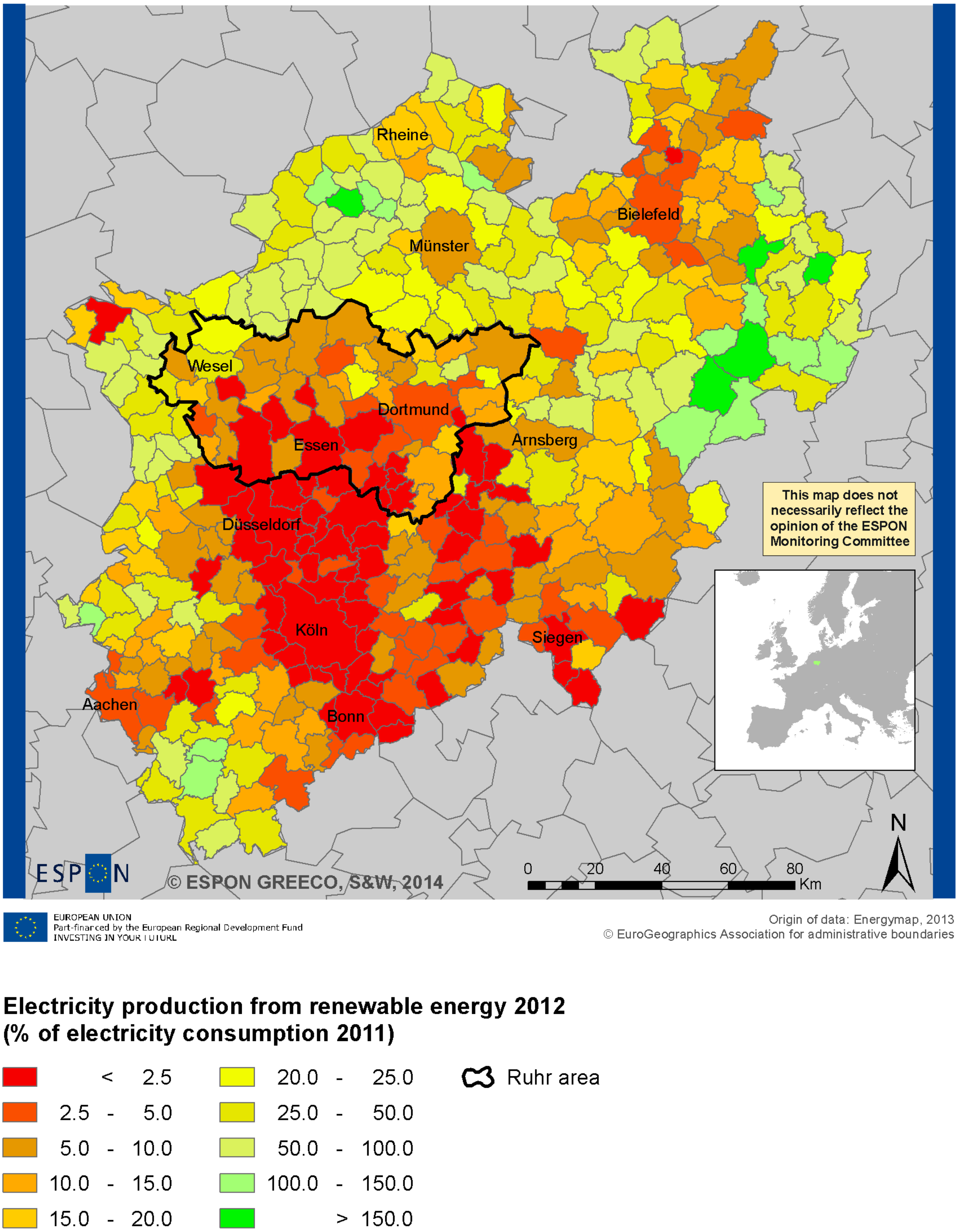


Figure 4.19: Electricity production from renewable energy 2012 in percent of electricity consumption 2011

In addition to the positive environmental effects of renewable energies in NRW, the development of renewable energy has quite positive economic impulses as well. Considering the direct and indirect employees from the production, operation and maintenance of renewable energy plants, there is to observe an increase from about 3,200 employees in 1997 up to 28,200 employees in 2011 (Figure 4.20). Highest total employment is in the fields of wind energy (8,150 employees) and solar energy (7,900 employees), followed by biomass production (3,850 employees). Wind energy and solar energy had the largest growth in the renewable energy sector during that fifteen-year period. The number of employees has risen steadily regardless of the development of renewable energy since 1997. Fluctuations due to the global economic crisis, as is known from the development of other sectors of the economy, are not to be found here.

The total number of employees in the entire field of renewable energies will exceed this figures as the data set does not include employees in research and development. These are estimated to be around 10,000 jobs in Germany. In Germany in 2010 more than 367,000 people were employed in the fiels of manufacturing of renewable energy plants, their operation and maintenance, provision of biomass fuels as well as in research, consulting and management. The number of employees has more than doubled between 2004 and 2010. In 2010, 1 out of 100 jobs is depending on renewable energies in Germany.

Even if the current expansion of renewable energies is accompanied by positive employment effects, there are further job losses probably in the traditional energy sector. According to estimates by the Ministry of Economics of North Rhine Westphalia, about 240,000 jobs are affected by the energy transition in NRW.

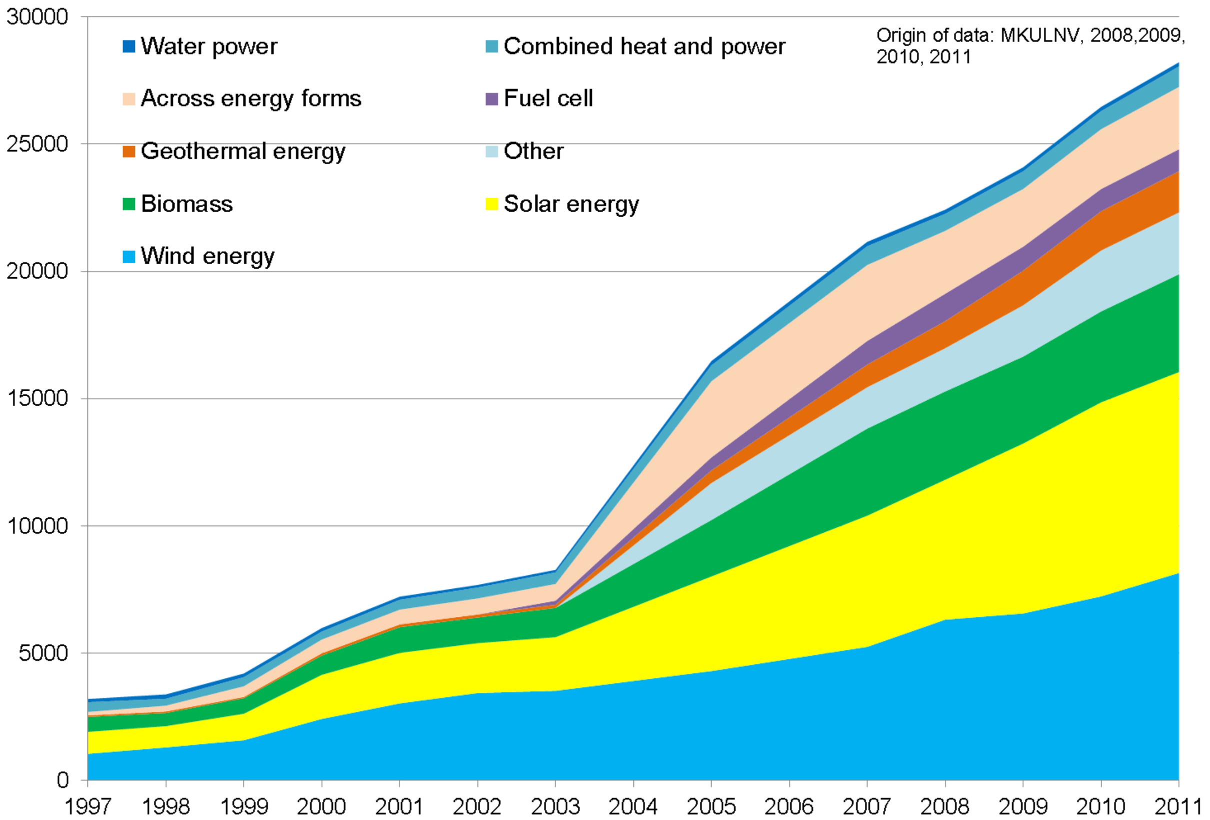


Figure 4.20. Employees in renewable energy plants and system construction in NRW

Parallel to the described development of employees, the direct and indirect turnover from the production, operation and maintenance of renewable energy plants show a positive development. Since 2005, the turnover of 4,200 million Euro has continuously increased to 8,700 million Euro in 2011. Largest gains are with solar energy. However, between 2010 and 2011 the turnover growth slowed down, which is due to a change in the EEG feed-in tariff. In particular, the reduction in the activity of turnover can be observed in photovoltaics, which also led to a reduced number of new photovoltaic systems installed.

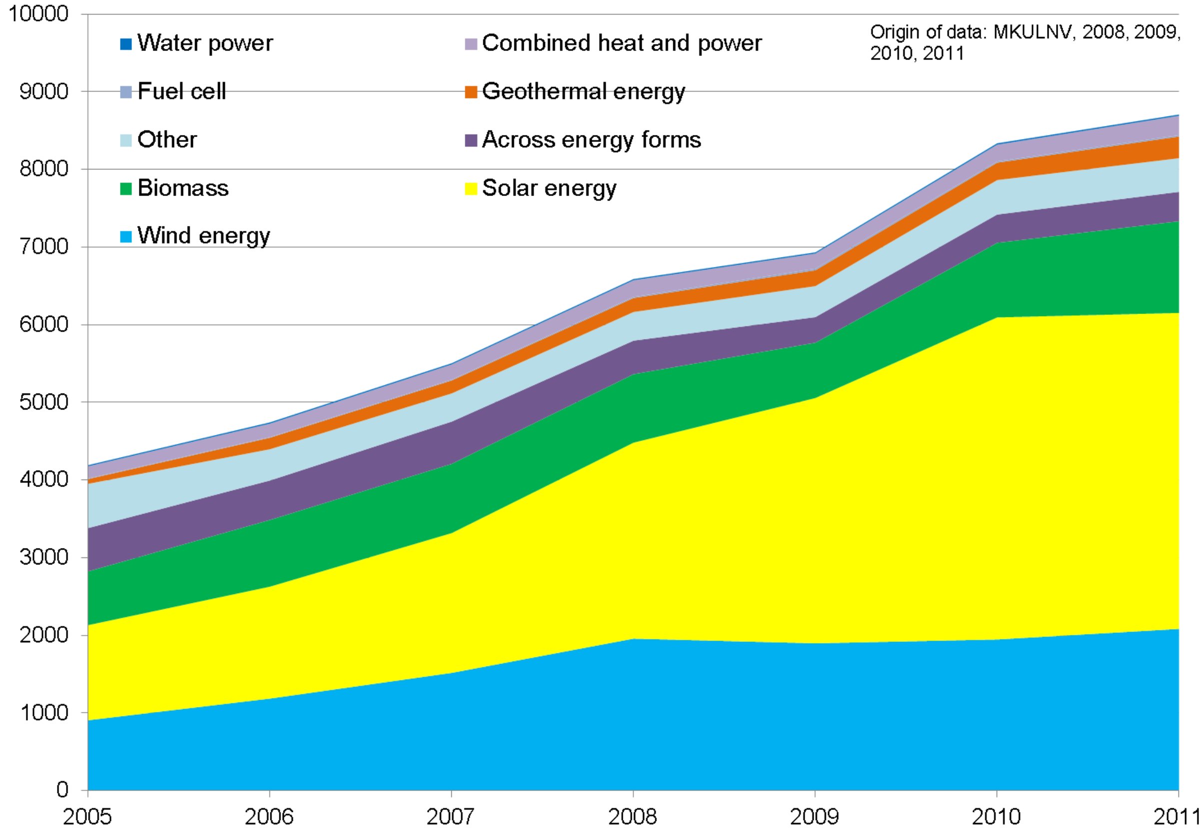


Figure 4.21: Turnover in renewable energy plants and system construction in NRW (in millions of euros)

4.3 Drivers, barriers and enabling conditions

Identification and description of external drivers

One important external driver for the increase of renewable energies is the environmental conciousness of large parts of the population and policy makers. This was already in place before the nuclear disaster in Fukushima in 2011 driven by aspects such as air pollution and climate mitigation. In consequence, renewable energies are highly accepted by the population.

Another potential external driver is the increasing availability of land even in core areas of the Ruhr area. Structural change and deindustrialisation have taken former industrial land out of use.

One specific land use category in the Ruhr area are slag heaps which are being recultivated. Possible new users are renewable energy plants.

Policies as an internal driver

Energy Concept 2050

Germany has opted for a fundamental transformation of its energy supply. After the nuclear disaster at Fukushima in 2011, nuclear energy production was re-evaluated with the result that all nuclear power plants in Germany go offline by 2022 at the latest. Already in 2010, but then reinforced and accelerated, the federal government adopted a long-term comprehensivel energy concept. The "Energy Concept 2050" contains long-term development paths, guidance and targets for a reliable, secure and affordable energy supply. The federal government aimed to implement national and international objectives with a cross-sectoral energy concept with an overall strategy by 2050. At the core of the energy concept is the expansion of renewable energy, the reduction of greenhouse gas emissions and increased energy efficiency. Ambitious climate protection targets were defined for short, medium and long-term development.

One of the objectives defined is to reach a share of renewable energies in electricity consumption of 18 percent by 2020 and to gradually increase this to 30 percent by 2030 and 60 percent by 2050. Another key element of the energy concept is the reduction of greenhouse gas emissions. For this, the Federal Government is pursuing high targets. Greenhouse gas emissions must be reduced compared to the base year 1990 by 40 percent by the year 2020, by 55 percent by 2030, by 70 percent by 2040 and by 80-95 percent 2050. These objectives also meet the international climate protection agreements. The third major component is energy efficiency. Primary energy consumption is expected to decline by about 20 percent in 2020 and by 50 percent in 2050 in relation to 2008.

Renewable Energy Sources Act - EEG

The main policy instrument for the expansion of renewable energies is the Act on Granting Priority to Renewable Energy Sources (Renewable Energy Sources Act - EEG). The EEG was adopted in 2000 as a further development of the former electricity feed law of 1991. Since then it has been amended several times. The EEG is mainly responsible for the rapid expansion of renewable energies, especially in the electricity sector. It serves in over 50 other countries as a template for similar arrangements.

The concept of the EEG is basically to guarantee a constant price for a period of twenty years for the renewable energy provider. The EEG provides that green electricity has to be fed to the electricity grids with clear priority over conventionally produced electricity. The network operators have to take over the renewable electricity at a fixed feed-in tariff which is determined by the EEG. The operators of renewable generating capacity may be recordable companies, cities or private individuals. In the development of the EEG, it was especially important during the early phase of the energy turnaround, to develop technologies to reduce costs, accelerate the construction of green power plants and to provide incentive structures for the production of renewable energies.

The effects of this instrument for the expansion of renewable energies in Germany are already measurable today. About 25 percent of electricity is covered by renewable energy sources such as wind, solar, biomass or water. Between 2010 and 2012 the share of renewables increased from 17 to 23 percent of gross electricity generation. A continuation of this development path would mean that the objectives defined by the Federal Government for 2020 could be achieved already in 2016. Accordingly at least 35 percent of the total electricity demand can be met by renewable sources. In the year 2012, 146 million tons of greenhouse gas emissions were avoided in Germany, of which 81 million tons are directly attributable to the EEG power tempered.

However, the EEG was developed for the early phase of the energy turnaround, in which the share of renewable energy was low. The EEG has been constantly revised to provide adequate support to the energy transition. A problem is the burden for citizens and businesses by additional costs of the disproportionate increase in the EEG surcharge. On the functional principle is that consumers pay the difference to the current market price of electricity and the fixed price of the EEG apportionment. In case market prices are low and the amount of green electricity fed-in high, the cost of electricity for consumers increase. For 2013, the EEG provides an increase in the feed-in tariff to 0.5277 Euro per kWh; the end user will probably have to pay 20.36 billion Euro for electricity from renewable energy sources. However, there are also many excemptions for several industrial branches and other to pay the EEG fee when using electricity. A fact, which is heavily disputed under aspects of solidarity on the one hand and competitiveness of those industries at the other.

Another problem from an economic point of view, which is directly reflected for in the energy companies and the local authorities in the Ruhr area, is the feed-in priority of green electricity before using power from coal and gas. Because due to the current high share of renewable energy the coal-fired power plants work only to a limited extent in the Ruhr area. In 2012, many power plants of the energy company STEAG produced electricity only for 1,000 to 2,000 hours from a total of 8,760 yearly hours. However 4,000 to 4,500 operating hours per year are required for the economic efficiency of a power plant. In 2011, Steag had with a turnover of 3.1 billion Euro a profit of 5 million Euro, only. However, this sum is not sufficient to cover the credits of the owner. In this case the owners are the public utility provides of Bochum, Dortmund, Essen, Oberhausen, Duisburg and Dinslaken in form of a holding with 51 percent of the shares.

Another criticism is that the EEG is directed only to a quantitative expansion of renewable energies, and a coherent view on temporal and spatial aspects and the effects on conventional energy and the expansion of the networks is lacking. Although the EEG has exceeded previous expectations, a fundamental reform is required by many stakeholders for the reasons mentioned above.

Climate protection law of NRW

An engaged climate protection legislation is implemented also at the Länder level of North Rhine-Westphalia with the core aim to push forward the expansion of renewable energy. In 2013, the state of NRW adopted the “Law for the Promotion of climate protection in North Rhine-Westphalia" (Climate Protection Law). By this the Land is playing a pioneering role in climate protection in Germany. For the first time in Germany a political authority formulated binding reduction targets for greenhouse gas emissions in a law taking account of international and national climate agreements and objectives. Greenhouse gas emissions should be reduced by at least 25 percent by 2020 and by at least 80 percent by 2050 compared to the base year 1990. Especially against the background that in NRW approximately one third of all greenhouse gases from Germany are emitted, nearly 30 percent of the German energy consumption is generated and almost a quarter of the German final energy and 40 percent of German industrial electricity is used in NRW, climate protection in NRW has a special responsibility.

The key instrument of the state government to implement the Climate Protection Act is the Climate Protection Plan, which is under development with broad participation of different stakeholders. There will be a broad range of measures for climate mitigation and climate adaption.

But even before the completion of the first climate protection plan the country government published first central climate protection measures that are bundled in the program "Climate Protection Start Program" ("KlimaschutzStartProgramm“). The measures addressed to a variety of actors are ranging from an initial voluntary commitment of the state government through to climate neutrality for the provision of low-interest loans to promote the energy performance of buildings up to a power-saving initiative for low-income households.

In addition to that, the state of NRW enables the extension of wind energy by a wind energy edict (Windenergie-Erlass 2011) and enables with some limitations wind energy plants even in forests ("Framework for Wind Energy on forest land in NRW"). Specific targets are set for the expansion of wind energy. Accordingly, the share of wind energy in electricity generation should increase from currently 3 percent up to 15 percent. This will require that about two percent of the territory of NRW will be used primarily for wind energy.

Other

In addition to these instruments of energy transition, energy and resource efficiency or the expansion of renewable energies in Germany there are numerous other formal laws and informal programs or guidelines.

To the formal laws that are applied in the context of its energy transition, include the Energy Development Act (EnWG), Power Grid Expansion Act (EnLAG) and the Grid Expansion Acceleration Act (NABEG). These laws contribute to the expansion of transmission networks for integration of renewable electricity or thermal generated for a "highly secure, low-cost, consumer-friendly, efficient and environmentally compatible" energy supply. The planning process should be accelerated by uniform and simplified authorisation procedures and should contribute by increasing transparency and participation to more acceptance in the population.

Similarly there are in Germany and at the state level of NRW different informal programs as the "Integrated Energy and Climate program", ”Renewable Energy Directive”, “Directives and targets for climate and energy package of the EU (20-20-20 Aim)”, "100 percent climate change", the "10-point immediate action program", “progress.nrw” and projects such as "100 percent renewable energy regions" and more energy and climate change policies and strategies, which all have the aim to support the objectives established by the Energy Concept 2050. The mostly informal programs are aimed at a variety of stakeholders such as private households, municipalities, and educational or research institutions. Furthermore, different companies can be addressed in the areas of the economy through the programs. These programs cover a broad range of climate protection activities, for instance an energy saving household or implementation of projects by municipalities or firms.

Institutions as an internal driver

The EnergyAgentur.NRW works on behalf of the state government and supports it in the implementation of the energy and climate protection targets. The EnergieAgentur.NRW has a variety of tasks ranging from energy research, technological development, demonstration and market introduction, energy consultancy to vocational training.

The NRW Ministry for climate protection established an information and advisory platform, the dialogue platform Energiedialog.NRW to support stakeholders with knowledge and consultations. The main objective is to mitigate in cases of conflict and to help as a neutral advisor in the early phase of planning process regarding renewable energies.

Belonging to the Ministry of Environment the "State Agency for Nature, Environment and Consumer Protection" (LANUV) is one of the most important agencies for the implementation of climate protection and the development of renewable energy. The LANUV has a comprehensive and detailed database that covers climate change aspects and changes in natural and environmental quality. Among other this information is used to assess land suitability for wind energy, thus implementing the edicts listed above for the expansion of wind energy. The LANUV has also identified in the potential studies for wind energy and photovoltaic possible potentials for renewable energies in NRW (see Section 4.6). By this, the local and regional planning agencies, municipalities and counties, energy companies, investors and site seekers are supported by the state of NRW with essential spatial information for climate protection and the expansion of renewable energies.

The Ruhr Regional Association can take over a central role and responsibility for the development of renewable energy in the Ruhr area. The RVR can materially influence the development of renewable energy through its formal regional planning competence as well as by informal control instruments. Particular to achieve the objectives of the state government of NRW in the Ruhr area, a positive planning management for wind energy is required to define regional development areas, i.e. priority areas for the development of wind energy. To increase photovoltaic on roof surfaces, informal planning strategies and concepts are necessary to motivate the homeowners for such use. Since especially the housing associations have a long tradition in the Ruhr area owning a large housing stock, this actor can play an important role in the expansion of photovoltaic on rooftops.

The actual implementation of the expansion of renewable energies and climate protection and resource efficiency takes place in the municipalities. Here, local governments are eventually fixing the wind energy in land use plans with a binding effect for authorities and citizens. In addition, cities can be engaged as owners of the potential energy surfaces on which the construction of renewable energy systems might be realised. This would speed up the implementation process and would also avoid additional rent costs. Some cities of the Ruhr area have developed an Internet based solar cadaster in which for each roof of the city area the radiation intensity is shown. This shold motivate home owners to invest in solar energy on their own roofs.

One of the key actors in the energy transition and the development of renewable energy is the RAG AG which since 1998 incorporates all German coal mining and related activities. The RAG AG is responsible for implementing the requirements of the decision of the federal government to terminate subsidised coal mining in Germany by the end of 2018. On the other hand, the RAG AG operates also in shaping the structural change in the Ruhr area. The RAG Montan Immobilien GmbH develops former mining areas to modern residential and commercial areas or to ecologically upgraded recreational areas. In terms of energy, the RAG AG has not only the resources, but can also contribute the specialised know-how of traditional electricity generation development of innovative technologies to make extraction of geothermal energy or for the storage of energy. As an example, the former mine heaps of RAG form a particular potential for photovoltaic use due to their exposed locations.

Similarly, energy companies and power plant operators such as RWE, E.ON and STEAG which are located in the Ruhr area are among the key players in the energy sector. In the Ruhr area the communal authorities are very closely intertwined with the energy industry. The cities in NRW including the cities Dortmund, Essen, Duisburg and Gelsenkirchen of the Ruhr area own 25 percent of the shares of the energy company RWE Also the Essen-based energy company STEAG has a communal ownership of 51 % realised by the public utilities of Bochum, Dortmund, Essen, Oberhausen, Duisburg and Dinslaken. As described above, the energy companies are obliged to give priority to feed electricity from renewable energies into the grid prior to electricity from other sources. Since renewable energy has grown increasingly, this is positive for ecological reasons, but has strong negative financial consequences for the energy companies and its local shareholders leading even to budget problems in some municipalities.

The very big energy-related know-how in the Ruhr area is enhanced by the two Transmission System Operators for Electricity (TSO), Amprion and Tennet. The TSOs have the great challenge of incorporating decentralised renewable energy facilities in the transmission network. To transport the electricity produced using renewable energy to the consumption centres, an extensive expansion of the electricity net is required.

The required expansion of transmission networks will be monitored and supported at the federal level by the Federal Network Agency (Bundesnetzagentur – BNetzA). In addition, the Federal Network Agency shall perform a variety of tasks according to the Renewable Energy Sources Act (EEG). It monitors, among other things, the EEG compensatory mechanisms between the distribution system operators, transmission system operators and electricity suppliers. In addition, the Agency determines the fixed tariffs for photovoltaic systems.

Financing as an internal driver

The main financial instrument for the extension of renewable energies is the price guarantee for a period of twenty years as dinfed in the Renewable Energy Sources Act (EEG). As described above, the EEG has really boosted the upturn swing of renewable energy production during the last decade.

In addition, there are some financial incentives provided. The state of NRW supports the energy change in NRW by a number of conveyed projects – especially in the area of energy and resource efficiency, the promotion of combined heat and power as well as the exploration of new technologies in the energy transition. In order to achieve the goal of the NRW state government to decrease the share of electricity from combined heat and power plants by at least 25 percent, the state government has started the power-generation impulse program (KWK-Impulsprogramm). The program with a budget of 250 million Euro bundles advisory tools, promotion and financing options and especially an accelerated development of new technologies. The NRW.Bank helps commercial enterprises and households to invest in energy or resource efficient measures with long-term low-interest loans. T

4.4 Spatial dimensions of the development of the sector

The successful development of renewable energies is a major challenge for spatial planning in Germany, especially in a metropolitan area such as the Ruhr area. Against the background of the successive decline of traditional energy production in power plants which require relatively small areas, this transformation requires the creation of new structures. Renewable energy sources as opposed to conventional energy supply are usually space-intensive and conflict-ridden in a decentralised spatial distribution system.

The development of renewable energies as a core element of climate protection is a major challenge and an opportunity for regional planning in terms of achieving a harmonious spatial development by acknowledging the different demans to open space. Therefore, the policy objectives can only be achieved with an efficient land use. The development of renewable energy, climate protection measures and adaptation to climate change must be implemented in a space-efficient manner. Energy and space efficiency act together and thereby make a contribution to climate protection.

In the context of expansion of renewable energies, the regional and local land use planning authorities have the task to coordinate the conflicting and competing needs and to secure by the legal underpinning adequate spatial potentials. Without appropriate areas that can be used for renewal energy production, the ambitious development goals cannot be achieved. On the other hand, spatial planning has the necessity to protect valuable and sensitive areas from being used for renewable energy.

Particularly for wind power, land use conflicts are getting bigger by the increasing size of the plant towers. Wind power plants are visible over long distances and thus have a negative impact on landscape. In part, this may even lead to a technical overprinting of nature and landscape. Similarly, wind turbines are a risk for certain bird and bat species. Especially, it is necessary to protect the species of the EU Birds Directive (Directive 79/409/EEC) for collision and bird strikes. In addition, large separating corridors towards residential areas are required to protect the people in their living environment from adverse impairments such as noise and visual effects. The additional fact that can be efficiently used from technical and economic points of view only beyond a certain wind speed contributes to the challenge for spatial planning to steer wind turbines on natural and environmentally friendly locations.

The problem is intensified in highly dense areas, such as a metropolitan area and an energy-intensive area like the Ruhr region. Especially in the Ruhr region it is a difficult task for spatial planning, caused by a lack of land, to secure sufficient land for wind energy in order to achieve the development goals of the state government of NRW. As shown before, rural municipalities in the Ruhr area have a significant importance for the development of wind energy. Rural counties have much largerr space potentials for wind energy than the core cities. In general, agricultural land is being claimed for wind poiwer plants. Repowering, i.e. the replacement of older and smaller plants by large multi-megawatt systems, is an additional option relatively easy to implement to achieve the development goals

Predominantly agricultural land is taken for the production of biomass. Whereas wind energy takes actually only a very small part of the surface, the production of biomass however requires larger areas of agricultural lands. The use of land occurs in competition with the traditional animal feed and food production. Therefore, agricultural land should be used for biomass production only, if the local and regional demand for agricultural products can be covered by the remaining agricultural land. And, only that amount of biomass should be used for energy producaton that can regrow in the same time. This guarantees also a corresponding CO_2 absorption. However, spatial planning usually has no instruments to control the type and intensity of agricultural and forestry use.

Photovoltaic systems can be installed on or at existing buildings. This is in small-scale only and does generally not produce significant spatial effect. Hoever, large-scale solar power plants are built on open space, where they can trigger a large spatial effect. Thereby landscape attractivity as well as the recreational value of the landscape for human use is adversely affected. Only when the "threshold of significant space" is exceeded, that is, if the photovoltaic system is classified as spatial relevant project with a certain size, the instruments of spatial planning can be applied for site control. This is similar to the control of wind turbines that backs up the land in spatial plans to treat the energy use of priority. Accordingly, in the ground mounted photovoltaic use, it is the task of spatial planning to avoid pressure on nature (particularly on soil and plants) and landscape by a positive control.

As in the case of wind energy such photovoltaic power plants are demanding certain types of space. These have, for example, a high solar radiation intensity and duration as well as minimal shading by nearby constructions or forests. Therefore, the concerns regarding nature and landscape have to be brought in line with the spatial requirements of photovoltaic power plants for efficient and environmental use. In addition, as renewable energy production from biomass and photovoltaic power plants can be in competition for the same area.

In planning practice formal and informal planning instruments can be combined for a successful and natural acceptable and environmentally sound development of renewable energy, either for the identification of suitable areas as well as in planning law implementation. Informal instruments are important as well that allow for early and substantial participation processes to increase acceptance.

For the decentralised production of renewable energies large areas are required. In the Ruhr area, those are mainly available in the rural districts only. But then the question arises whether it is fair to claim the rural areas for the expansion of renewable energies although the core cities are much more energy intensive and emit more CO_2? Therefore, the many old industrial and commercial sites as well as the dumps and landfills offer some options for renewable energy producton in the core cities of the Ruhr area. These areas have a relatively low risk of conflicts as there are already predisposed to surfaces. Therefore, only modest land use conflicts can be expected. The following examples show how former industrial areas of the Ruhr can be used as part of the energy revolution and as the same time as a symbol of structural change in the energy sector of the Ruhr.

Example 1: Underground pumped storage power plants

The vision of the pumped-storage power plants arose from the problem that electricity from the photovoltaic and wind energy is to a large extent available when the demand is low. Therefore, storage capacity for electricity is needed. The mining infrastructure in the Ruhr area could do a contribution to solve that problem. The technology of storing energy from pumped storage power plants exists for over 100 years. However, the new approach is to use the former mining pits for storage. Therefore, the traditional mining know-how has an important significance for the electricity storage technologies.

The technology of "underground pumped-storage plants" works in that water falls through the former mine shaft about 1000 feet in depth and is able to drive electricity turbines. If wind or photovoltaic systems produce more energy than needed, the water is pumped up again to an artificial lake. With raising demand of electricity in peak periods the water goes downwards again.

This technology is a predestined example of structural change in the energy sector in the Ruhr area. On the same time it is illustrated how former locations that produced inputs for traditional power supply become new functions through innovative, "green" technologies. However, the implementation of such a pump storage power plants raises many technical and economic questions still to be investigated.

Example 2: Renewable energy plants on mine heaps

As a relict of hard coal mining and the steel industry numerous mine heaps and landfills exist in the Ruhr area. The RVR is owner of 36 mine heaps and has already converted some to landscape dominant elements in the Ruhr. Their current use is not comparable to the former. Today, the mine heaps are used in many ways, especially for recreational or leisure purposes. For example, an indoor down-ski hall was built on one mine heap in Bottrop, others are used for Nordic walking and mountain bike trails or for air trend sports such as paragliding, hang gliding and model. Others are under nature protection. However, the mine heaps and landfills are suitable for the construction of wind energy plants due to their topography and for the construction of large-scale photovoltaic systems due to the exposed south facing also. So far, only the mine heap "Hoppenbruch" in Herten is used as a wind energy site.

More of these projects are currently in the planning stage. The RAG plans three wind turbines on a mine heap in Marl. A capacity of about 10 MW shall be installed in an area of approximately 130 ha. Similarly, the city of Dortmund planned to lease two former landfills with nearly seven acres to an investor for photovoltaic use. However, the project is currently stopped for economic reasons. In the future, probably many of these projects might be created being also a symbol of structural change in the Ruhr area since the former mining infrastructure will be used for environmental friendly energy production.

Example 3: Geothermal energy

In general, the geothermal energy is extremely versatile and can be used either for heat supply as well as electricity generation. The geothermal energy has the distinct advantage compared to most other renewable energies that it is always available because geothermal energy is independent from time of day or night as well as from changing weather conditions. Germany has currently about 600 MW of installed capacity on the basis of geothermal energy.

In North Rhine-Westphalia, more and more buildings are supplied with near-surface geothermal energy. In a nationwide unique study of the Geologischer Dienst NRW the geological subsoil was analysed by taking the heat demand of a one and two-family house into account. The results of the study show that the Ruhr area and especially the Rhine axis has a very high geothermal spreading rate and are particularly suitable for the usage of geothermal energy. In an EU-funded geothermal study of the Ruhr area, numerous of available data will be re-summarised and interpreted and integrated into a geographic information system. Thereby it is possible in future, to forecast the geothermal potential at any location in the Ruhr area, on the basis of GIS-supported subsoil models.

Because of the large underground cavities and tunnels as a result of mining, the Ruhr area is also suitable for geothermal energy utilisation. There is a natural temperature range of about 40 degree Celsius which could be used for energy supply. Currently, there are some exemplary projects were geothermal energy is already used for heat and power supply, or to be used in the future.

Geothermal energy is not just an important element for the future of energy production in the Ruhr area, but is already an important economic factor for the region. Along the entire value chain of the geothermal energy a variety of stakeholders from the region are involved. These include plant engineers, experts in drilling technology or high performance pumps up to project planner. Careers of former mining industry are also represented, so that the know-how of the mining industry can also be used for geothermal projects and for the development of geothermal energy. This knowledge is already being exported to the world market.

In addition, the International Geothermal Center was founded in Bochum, as a research institution which seeks a close relationship between science and industry and between politics and government. Here, the research center has in addition to the research activities among other things the task to be available for public as a competence center, also. Likewise International Geothermal Center is offering retraining's for employees from the former coal and steel industry at a mining near future technology of geothermal energy.

4.5 Links with other sectors

The energy sector has links with all other economic sector because all economic activities consume electricity. Renewable energies do have specific links with specific sectors of green research and development. Here, new and advanced technologies for new forms and higher efficiency of renewable energy production are to be developed as well as technologies for increased energy efficiency.

4.6. Potential for development of the sector

The potentials for development of the renewable energy sector are huge in North Rhine-Westphalia and fairly good in the Ruhr area. To demonstrate this, results of studies analysing the future potential for wind energy and solar energy production are presented in this section.

Potentials for wind power

The State Agency for Nature, Environment and Consumer Protection (LANUV) has released a study analysing the potential for electricity production from "wind energy" in North Rhine-Westphalia at municipality level (LANUV, 2012). Three possible paths of wind energy expansion were analysed in a scenario setting, the so-called NRW_{old}-scenario, NRW_{lead-}scenario and NRW_{plus}-scenario.

Overall, the scenarios show large differences both regarding the identifiable suitable sites for wind energy as well as the resulting number of wind power plants and the amount of electricity production. The scenario NRW_{old} gives the lowest potential with 48 TWh/year in NRW of which only 2 TWh per year are produced in the Ruhr. The NRW_{lead} scenario and the NRW_{plus} scenario see significantly higher potentials with 71 TWh/year and 83 TWh/year, however, of which 3.4 TWh/year and 4 TWh/year are produced in the Ruhr area.

Reflecting the results of the $NRW\text{-}_{lead}$ scenario and the NRW_{plus}-scenario with the state's target to achieve from currently 4 percent a 15 percent share of wind power in electricity generation, it should be noted that the potential is much higher. Electricity consumption in 2011 was 138 TWh, i.e. the wind energy potential is about 50, respectively 60 percent of NRW's electricity demand (LANUV 2012).

The spatial distribution pattern of wind power potential of the NRW_{lead} scenario shows that in the core cities of the urban agglomerations including the Ruhr region the lowest potentials are to be identified (Figure 4.22). The wind energy potential of the core cities is below 50 GWh yearly; however, the rural districts of the Ruhr are within a range of 50 to 200 GWh. The Sauer- and Siegerland, southern Weserbergland, the rural district Steinfurt in the Münsterland and sub-regions of the Lower Rhine Basin have very great potential of more than 1 TWh per year per municipality.

Consequently, if potential wind energy generation is related to current electricity demand, the core cities of the Ruhr area might produce only up to 5 percent (Figure 4.23). But, this share is improving when going to the more rural parts, some municipalities might even generate more electricity by wind power plants than their current demand. This is also true for many rural municipalities in NRW.

Another study analysed the potentials for wind energy expansion in the Ruhr region on the basis of four scenarios (Dokter, 2013). The focus was on the identification of suitable sites for wind energy depending on land-use conflicts regarind nature and landscape as well as protection of population. The first scenario was very restrictive concerning protection of nature, landscape and population. An area of 26 hectares has been identified as suitable sites for wind energy plants in this scenario "Restrictive expansion". However, several of existing 175 wind turbines of the Ruhr area are located already at these sites. In the second and third scenario either the restrictions for nature protection or those for human protection became loose leading to potential wind energy sites of 329 ha and 624 ha respectively. In Scenario 4, in which all restrictions such as distances to protected nature or population were rather low, a suitable area of 5,515 ha was calculated. The identified suitable locations are concentrated in the more rural districts. The suitable areas of the fourth scenario make up a share of only 1.24 percent of the total Ruhr area. Therefore, this study questioned also whether the "2 percent of territory for wind energy target" of the state government is realistic for metropolitan areas or whether there has to be in place a functional division of labour between different parts of the state.

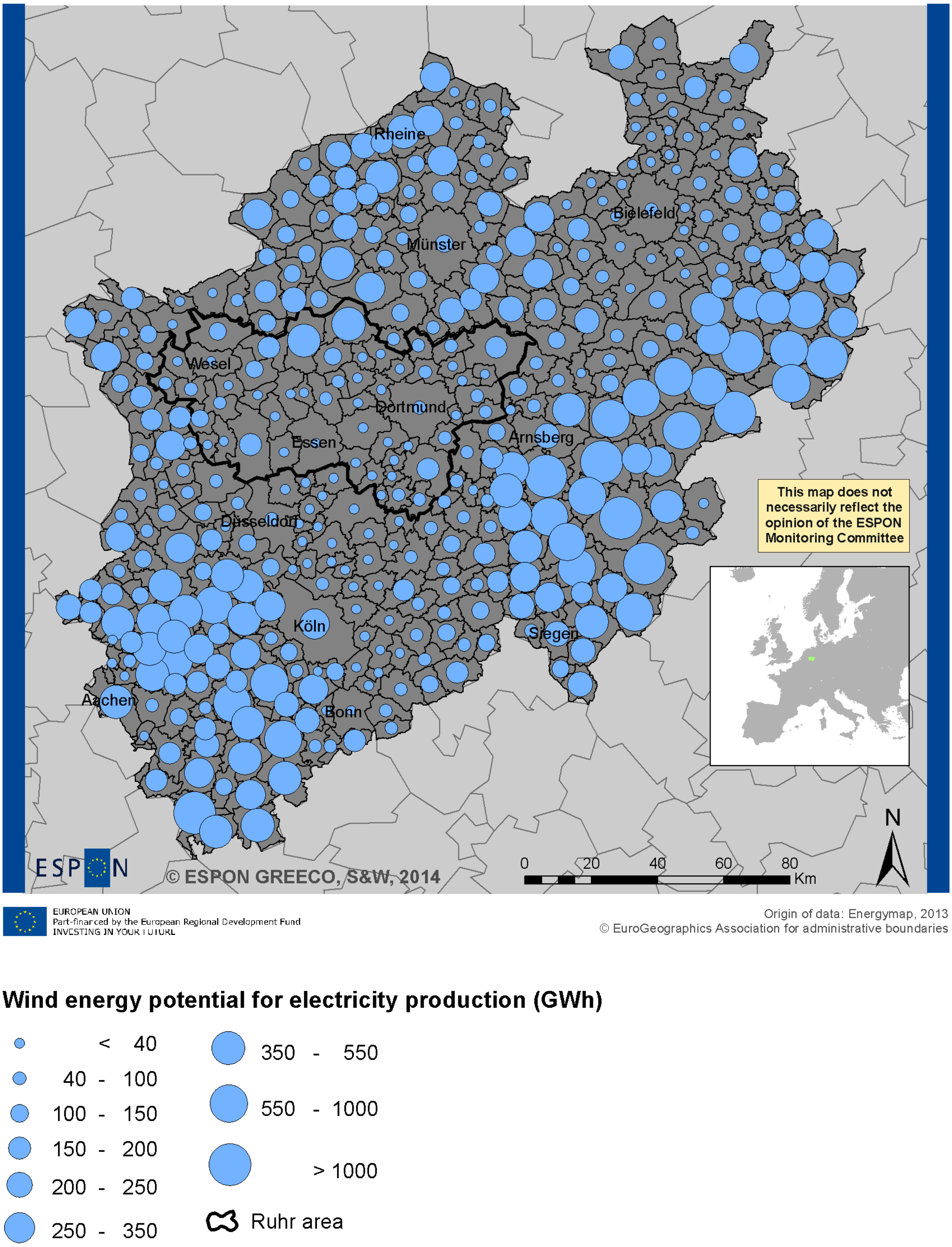


Figure 4.22: Wind energy potential for electricity production

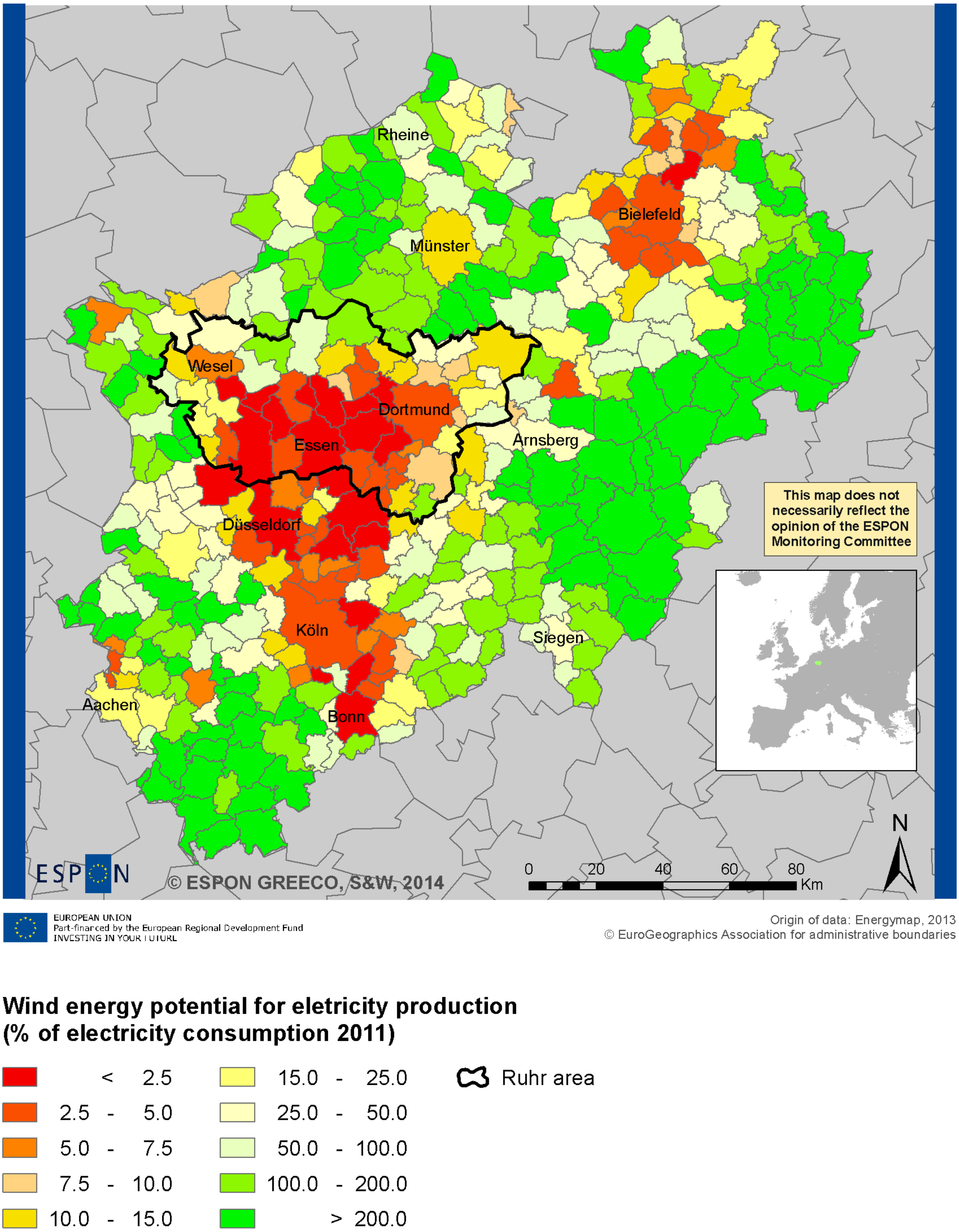


Figure 4.23: Wind energy potential related to electricity consumption 2011

Potentials for solar energy

In the second part of the "Study on the potential of renewable energy NRW" by the State Agency for Nature, Environment and Consumer Protection (LANUV, 2012), the potentials of solar energy were calculated for each municipality differentiated by photovoltaic and solar thermal systems. A distinction is made for photovoltaic between ground-mounted open space solar plants and the use of individual roof surfaces. Ground-mounted photovoltaic systems are systems that are not built in or on buildings. Potential sites for these solar power plants are expected not to have high-quality nature and landscape functions. Therefore, those areas were considered that are already preloaded by other interventions in the natural surroundings and landscape, as 110 m broad edge strips along highways and railways, dumps and landfills, mining sites, economic or military conversion areas, parking, noise barriers and bridges; areas that are existing in the Ruhr area to a very high degree.

There is a potential area of about 470 km^2 in NRW for photovoltaic installations. Of this amount, 53 percent are roof areas and 47 percent is open space. Based on an average efficiency of 18 percent it is possible to install a capacity of 84.4 GWp. At the end of 2011 the nominal installed power in NRW was approximately 2.9 GWp, which means that the potential ise realised by only 3.4 percent. A full exploration of the potential would realised about 72 TWh, which would mean that about 52 percent of the current annual electricity demand of 138 TWh in NRW could be generated by photovoltaic (LANUV PV, 2013).

For the Ruhr area, about 105 km^2 were identified for photovoltaic installations. Similar to NRW-'s shares, hereof are 53 percent at roofs and 47 percent in open space. A nominal capacity of about 35 GWp would be possible.

So, urban regions have a high potential for solar power (Figure 4.24). For the city of Cologne the highest potential electricity production with 2.5 TWh/year was identified, followed by the Ruhr cities of Dortmund (1.5 TWh/year), Duisburg (1.4 TWh/year) and the rural district of Wesel (2.6 TWh/year). Also the Ruhr cities of Essen and Bochum have large absolute potentials with 1 TWh/year each.

Theoretically it would be possible to generate about 35 percent of the current electricity demand of the Ruhr area (46 TWh) solely through the installation of photovoltaic. However, the spatial pattern shows a clear differentiation (Figure 4.25). It becomes clear that major cities which have high absolute numbers can cover smaller proportions of their own electricity consumption by photovoltaic than municipalities in rural areas. However, the share of electricity generateion by solar power on total current electricity demand goes up to 50 percent in some core citeis of the Ruhr.

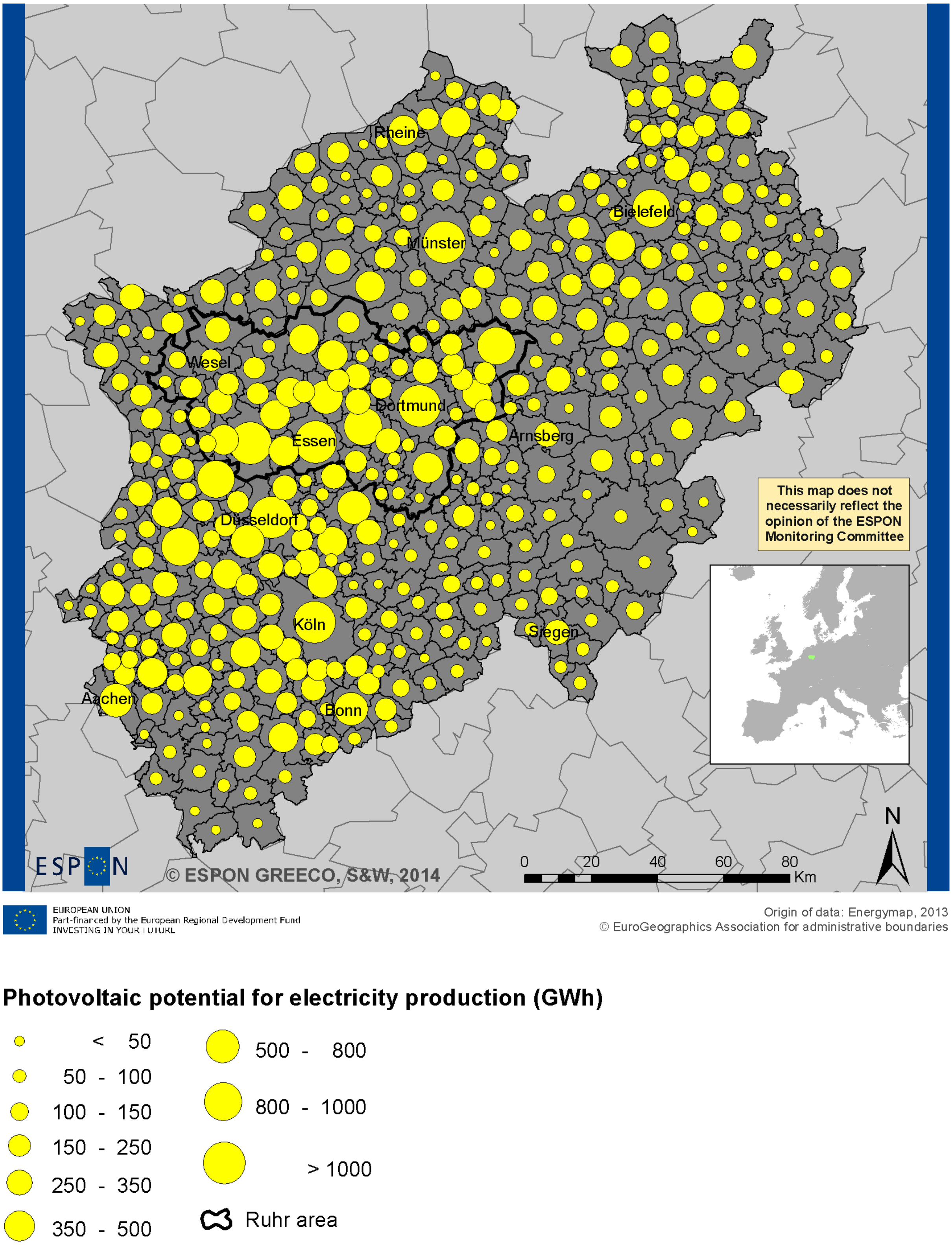
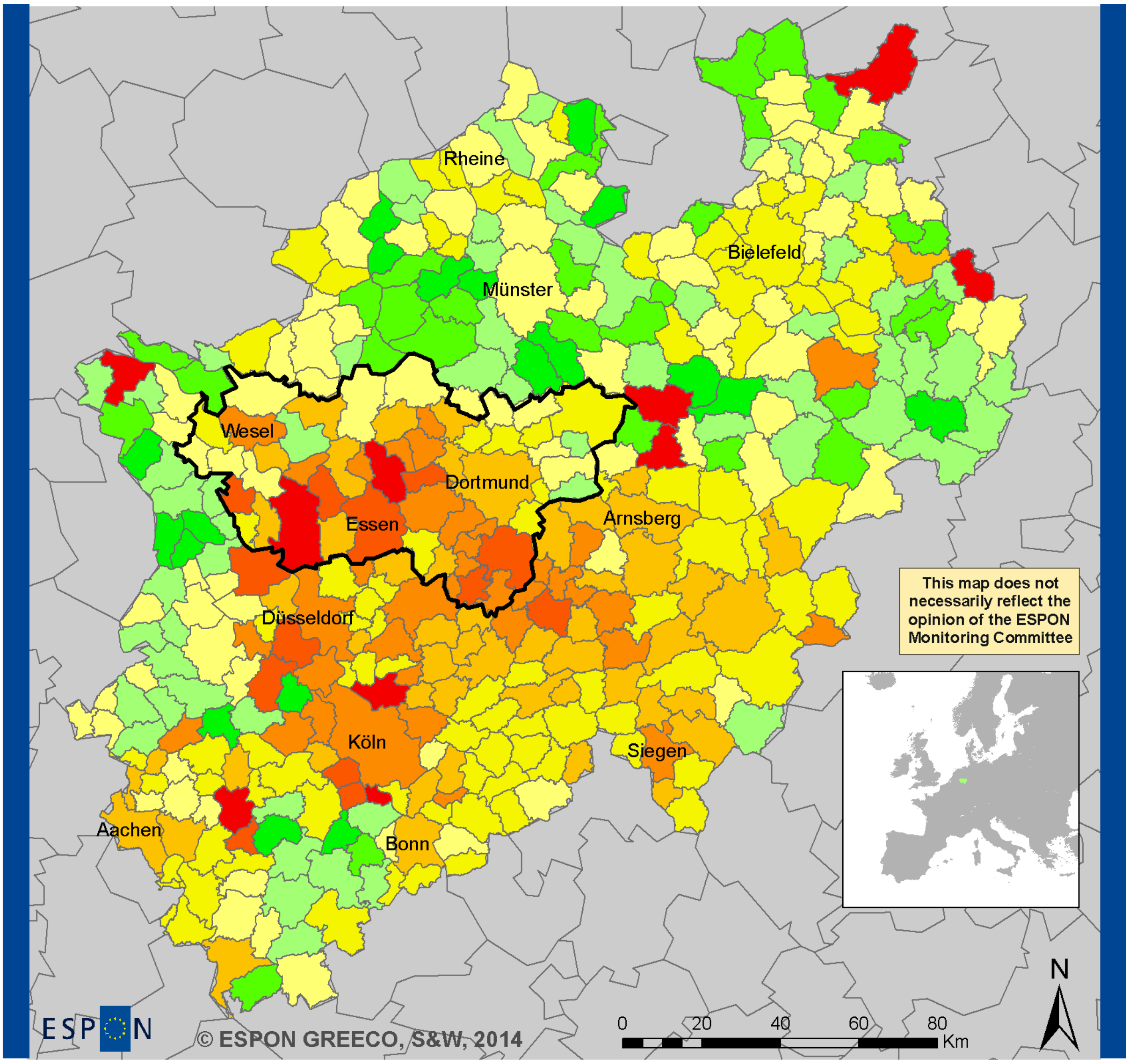


Figure 4.24: Photovoltaic potential for electricity production



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Photovoltaic potential for electricity production (% of electricity consumption 2011)

- > 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 75
- 75 - 100
- 100 - 150
- 150 - 200
- > 200
- Ruhr area

Figure 4.25: Photovoltaic potential for electricity production related to electricity consumption 2011

5 The road ahead

This case study report on selected aspects of the green economy has focussed on two specific sectors relevant for the Ruhr region, the water sector and the energy sector. The two sectors have very different tasks within the development of a green economy in the Ruhr area, and both are at very different stages of maturation.

The water sector with its central project, the reconversion of the Emscher system back from an open sewer network to a modern water treatment system which offers at the same time new ecological quality in green corridors to the people of the Ruhr area, has made extreme progress throughout the last decades and will reach its planned status in the next couple of years. This means that this sector will have reached a very mature status, something that has to be kept at the achieved quality level, but also something that cannot be substantially improved anymore. The key achievement of that sector by then will be as an enabler of sustainable development in other parts of economy and society. It has been demonstrated that the reconversion of the Emscher system already by today has initiated a fast number of attractive developments in the Ruhr area which will further contribute to the transformation of the Ruhr area from an old-industrialised region into an attractive and modern, technology-oriented region. Thus, the main future role of the water sector as a key element of the green economy will be its enabling function.

The renewable energy sector is in a different state. The upturn during the last fifteen years is breathtaking. The growth of energy production by different renewable energy sources has been extremely high. It was argued that mainly the financial incentives and guarantees provided by the EEG are responsible for that success. However, there are also extremely aspiring targets for shares of renewable energies within total energy consumption which are derived from the need and national and international targets in fighting against climate change. Despite the success story of the past years, there is a long way ahead to achieve those targets. However, there is also a large potential to do so. If one relates the impressive achievements of past renewable energy production, taking photovoltaic as example, whith the potentials estimated, it is obvious that currently only a small portion is realised (Figure 5.1). In particular the core cities of the Ruhr area which have a large potential for solar energy production are currently far away from that. Currently, only up to three percent of the potential energy production by photovoltaic is realised. This might be a disappointing figure at first glance, however, it gives tremendous hope for the future.

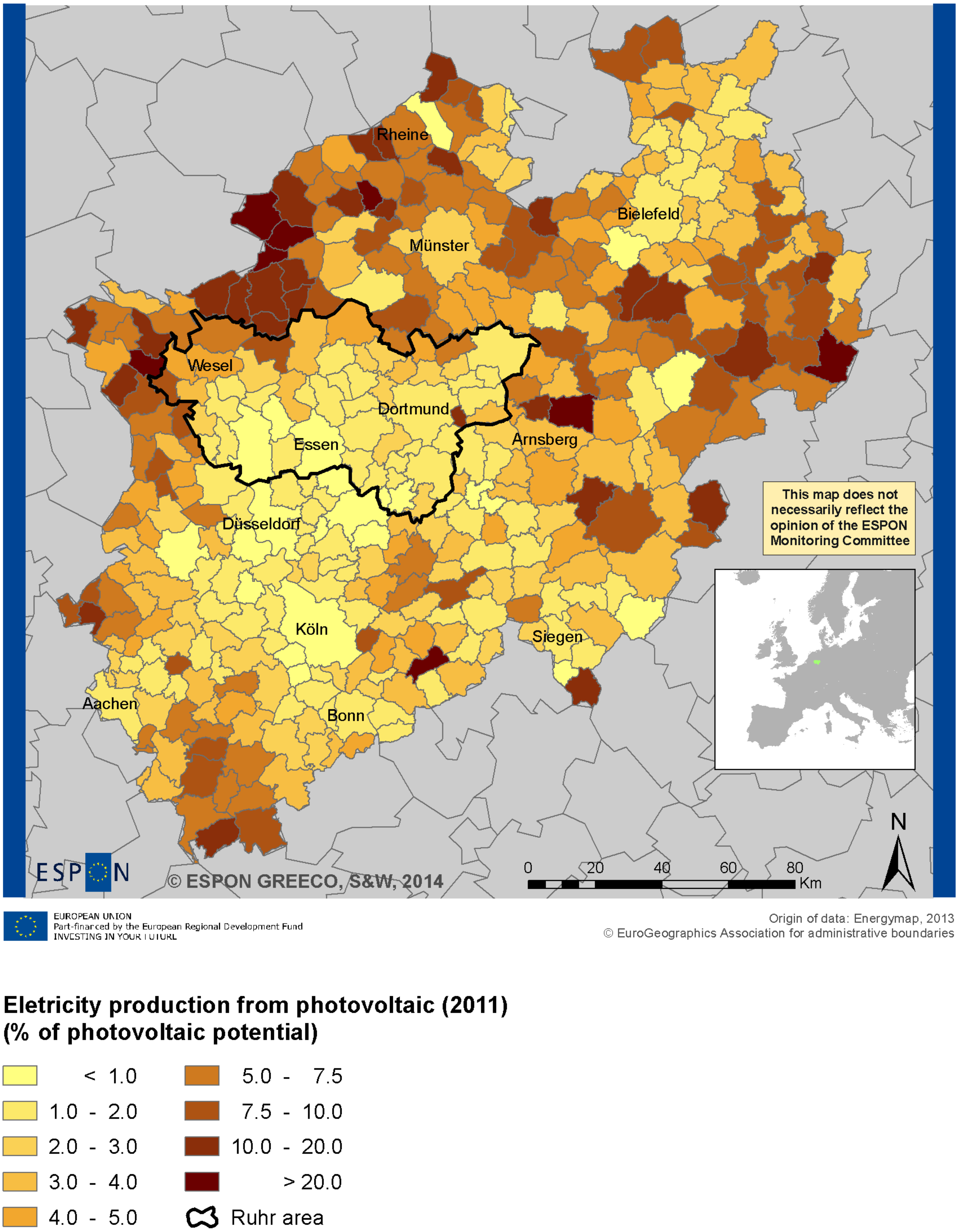

Figure 5.1: Already realised potentials from photovoltaic

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The ESPON 2013 Programme is part-financed by the European Regional Development Fund, the EU Member States and the Partner States Iceland, Liechtenstein, Norway and Switzerland. It shall support policy development in relation to the aim of territorial cohesion and a harmonious development of the European territory.

ISBN 978-2-919777-57-0