Provision of resources for the city by the Hambach opencast mine: Egineering geological aspects

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Abstract: The Hambach opencast mine in Germany is the largest lignite mine on this planet. The mine is located in North Rhine-Westphalia (18 million inhabitants), one of the 15 most important economic regions in the world. The region is densely populated and there are multiple interactions between the mine and the cities. The Hambach mine is one of three opencast mines in the region operated by RWE Power. These three mines deliver many resources to the region. Lignite is used to produce more than 50% of the electrical energy required by the industries and cities in North Rhine-Westphalia. The lignite is of Tertiary age and was deposited in a basin between the North Sea and the Rhenish Slate Mountains. The sediments have not been cemented and the groundwater table is high. To enable a large-scale surface mining operation possible, the groundwater level is lowered. This water is delivered to the thermal power plants, as potable water to neighbouring cities and for ecological purposes in surrounding wetlands. A third resource is gravel, which is mined and used in the construction industry in the region. A fourth resource is clay, which is used as barrier material in landfills. Gypsum, generated by the desulphurisation installations of the thermal power plants, is also used in the construction industry. In addition to all these resources, recreational activity is provided as well. The outside dump of the mine, called the Sophienhöhe, has been recultivated and is open to the public. In a region which is relatively level, the Sophienhöhe with its hiking paths, mountain bike trails and reforested areas, offers ideal recreational possibilities. The Hambach opencast mine can provide all these resources only through a thorough mining and geological engineering understanding, thus contributing to a sustainable urbanisation, today and in the future.

Résumé: La mine à ciel ouvert de Hambach est la plus grande mine de lignite sur cette planète. La mine est située en Rhénanie-du-Nord-Westphalie (18 millions d'habitants), sur le plan économique la Rhénanie-du-Nord-Westphalie est entre les premiers 15 régions du monde. La région a une densité de population très élevé et les interactions entre la mine et les villes sont multiples. La mine de Hambach est une des trois mines à ciel ouvert dans cette région exploiter par RWE. Un grand nombre des ressources dont les villes ont besoin, sont fournis par ces mines. Sur la base de lignite 50% de l'énergie électrique utilisé par les industries et les villes en Rhénanie-du-Nord-Westphalie, est produit. Ce lignite a été sédimenté pendant le Tertiaire dans un bassin entre la mer du Nord et le massif Ardennais-Rhénan. Les sédiments n'ont pas été cimentés et la nappe phréatique est très élevée. Pour l'opération minière à ciel ouvert les niveaux de la nappe phréatique ont été rabattus. L'eau est délivrée aux centrales d'électricité et aux villes et est utilisée dans la forme de l'eau écologique pour les zones humides dans les environs. Une troisième ressource du sous-sol exploité par la mine est le gravier. Ce gravier est utilisé dans les constructions de génie civil. L'argile, utilisé comme barrière d'étanchéité dans les centres d'enfouissement technique, est une quatrième ressource. Le gypse, produit par des unités de désulfuration dans les centrales d'électricité au lignite, est utilisé dans la construction des bâtiments. Détente et recréation est fournie en suppléant de toutes autres ressources. Le terril extérieur, portant le nom de Sophienhöhe, a été réaménagé et est ouvert aux citoyens. Dans une région plate, le Sophienhöhe, avec ces routes de randonnée, les chemins pour le "vélo tout terrain" et son bois, est une vraie colline de récréation. Uniquement par une maîtrise de tous aspects de génie minier et de la géologie de l'ingénieur, la mine à ciel ouvert de Hambach peut contribuer à un développement durable de la vie urbaine en fournissant toutes ses ressources du sous-sol, non seulement à l'heur actuel, mais aussi dans l'avenir.

Keywords: Surface mining, excavations, overburden, mining geology, coal mines

INTRODUCTION

Hambach opencast mine is one of the largest surface mines in the world. The mine follows a long tradition of lignite mining in the area to the west of Cologne. In order to understand why the mine is here, why this type of mining is performed and what resources are delivered for the city one must have a look at the geological picture and the urban development of the region.

GEOLOGICAL PICTURE

The area is located in between two 'branches' of the Rhenish Slate Mountains (Figure 1) to the south and the east, the Cretaceous deposits of Limburg (the Netherlands - NL) to the west, and the western European coal belt which stretches from the Borinage (Belgium - B) over Liège (B) and Limburg (B&NL) via Aachen towards the Ruhr area located near the northern rim of the Rhenish Slate Mountains and the Tertiary North Sea in the north. During the Tertiary the Rhenish Slate Mountains where eroded down. The sediments where transported and deposited by rivers traversing the plane area - which was subjected to tectonic subsidence - towards the North Sea. Lush vegetation developed in the subtropical climate on this plane and along the coastline. During trans- and regressions, processes promoting the development of marshes (Pohl 1992), the dying organic material turned into peat. Due to subsidence of the plane thick (400 m) peat layers accumulated (Walter 1995). This peat was transformed into 100 m thick lignite deposits. Sand, clay and gravel accumulated during the remainder of the Tertiary and the Quaternary, resulting in a several hundred metre thick overburden. Loess was deposited on top of these layers. (ENB 2005). The drainage pattern is directed to the North Sea. The major transport route is the River Rhine. Today's climate is a sea climate.

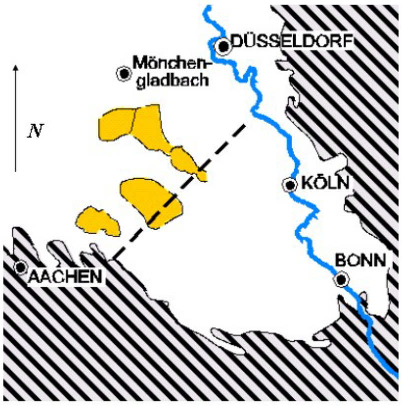

Figure 1. The old cities Aachen, Cologne (distance ~ 50 km) and the RWE Power mines in North Rhine-Westphalia (yellow patches), the River Rhine and the branches of the Rhenish Slate Mountains (hatched area) are indicated on this map. Limburg (NL) and Liège (B) are located in the west. The Ruhr area is located towards the north-east and the North Sea towards the north and west.

URBAN AND INDUSTRIAL DEVELOPMENT IN RELATION

The geological setting of the region allowed for a long tradition in mining. Depending on the technical requirements and development of civilisation, different types of natural resources were mined throughout the ages. The mining of flint was one of the oldest forms of mining and still persists in the region today (Schmitz, Polo-Chiapolini & Schroeder 2005). Large surface mines (Aachen: Lousberg) (Felder 1998) and subsurface mines (Limburg: Rijkholt) were producing flint during the Stone Age. In this time the region was a large mining district. Combined with the presence of the fertile loessic, plain terrain, an ideal starting position for agricultural development, the area was densely populated.

During later ages the metal deposits in the Eifel-Ardennes metallogenic province (DMNF 1972) and other regions of the Rhenish Slate Mountains were mined. At that time there were many ore deposits but they were very small compared to the size of those exploited today in the world. However, this does not lessen, by any means, the influence these deposits had on the economic and cultural development of these regions (DMNF 1972) and thereby the world. This mining activity in the Rhenish Slate Mountains became part of the culture (Ring des Nibelungen). In Roman times the infrastructure was developed further and transportation routes existed between the rivers Meuse and Rhine from Cologne to Boulogne sur Mer linking the different mining districts. The importance of industry increased even more. For metal processing, fuels were needed and therefore the forest of the Eifel, the Ardennes and those in the Rhenish lowland were used. In the Hambach region glass production flourished. Cologne developed into one of the most important cities of the Roman Empire. Later the thermal springs of Aachen were one of the reasons that Charlemagne built his palace in Aachen (Einhard ~830) and made Aachen the capital of his empire.

Industrial evolution continued and the population density increased and wood as fuel for industry was replaced by coal. From the Middle Ages Carboniferous coal was mined (possibly on a small scale even in Roman times). This Carboniferous coal, initially close to the surface was mined in the region north of Aachen (Raedts 1974) and in the Liège region. Due to political turbulences in the 16th century the highly developed metal industry in the Prince-Bishopric of Liège moved (amongst other) to Aachen (DMNF 1972). The river Rhine remained one of the most important transport routes in Europe. In the Cologne area Tertiary coal was mined from the 16th century as fuel. From the 20th century this lignite was used to generate electrical power. Today, the region is one of the most densely populated regions in the world. There is a close link between urban development and mining activity, not only following other processes in the world, but leading in development. Important impulses were given by mining to urban development and the other way round by using the potential of the people in the region and those who immigrated to the region. Mining depended on urbanisation and urbanisation on mining. The part of the region described above, which is located in Germany, is the federal state of North Rhine-Westphalia (NRW). NRW is one of the 15 most important regions of the world. Chemical industry, machine manufacturing, electric/electronic industry, metal manufacturing and metalworking, nutrition industry and vehicle manufacturing are the most important economic branches (NRW 2005). The largest self-contained lignite reserves can be found (initial $55 \cdot 10^9$ ton on 3000 km²) in NRW (Walter 1995). With an annual production of $100 \cdot 10^6$ ton per annum, NRW is one of world's largest lignite producer. Besides lignite, the largest reserves of sand and gravel (Braus & Pahl 2004) in Germany are located in NRW.

PRESENT DAY LIGNITE MINING IN NRW

As discussed above NRW is a "mining" state and a state that created an industry based on former and present day mining activity (Grabert 1998). In this contribution the focus will be on the resources for the city produced by the mining activities of the RWE Power in this region and the geoscientific and geoengineering aspects involved.

RWE Power operates three mines in this region: Hambach, Inden and Garzweiler opencast mines. The focus in this contribution will be directed towards mining operations in Hambach. The main mineral resource of interest is lignite. 90% of the lignite is processed in power plants of RWE Power producing herewith 50% of the electrical energy needed by NRW. 10% of the lignite is processed in RWE Power's factories. However, next to these resources many other resources are delivered to the city.

Natural outcrops of lignite were the first to be mined. Since then, the seam was followed to greater depths. At present in the Hambach opencast mine, lignite is mined at an incredible 370 m depth from the surface (Figure 2) and the artificial slopes are - from the top of the outer dump to the lowest excavator bench - more than 500 m high (Figure 3). Correspondingly, the amount of material moved on a daily basis is enormous.

Hustrulid (1999) reported that only the largest of the world's open pits remove one million tons of drilled and blasted rock per day. At present, Hambach surface mine tops this figure by excavating more than one million tons of coal and cubic metres of overburden a day. Because surface mines all over the world extend to ever increasing depths (currently, many mines worldwide are planning for pit depths exceeding 500 m, but few have yet reached such depths (Sjöberg 1999) and with the deepest of these opening now approaching 1000m, with plans being made for pits nearly one mile in depth (Hustrulid 1999)) the importance of geoscientific & geoengineering assistance given to mining engineers increases.

Although coal in Hambach is located very deep (Figure 4) mining operations are very efficient because of the thickness of the coal seam (Figure 5).

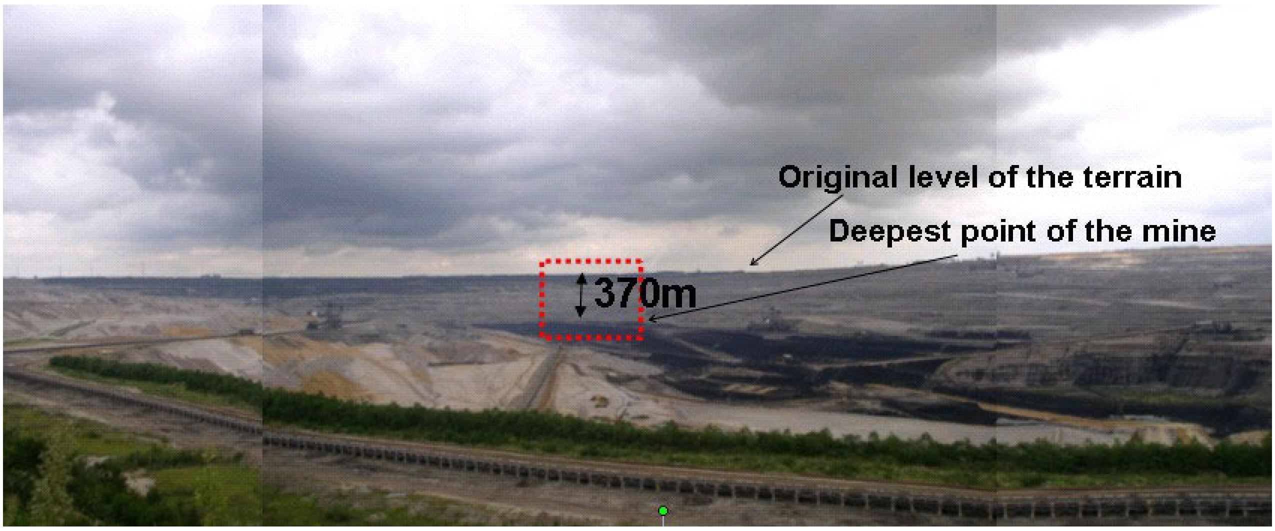

Figure 2. Looking north into the mine. At the far distance (4.5 km) the original surface can be seen. From here the mine extends to 370 m depth. At this depth the coal is located. On the right 6 bucket wheel excavators remove the clay, sand and gravel overburden. In the centre 2 bucket wheel excavator excavate lignite (Figure 5). On the left side 6 stackers deposit the overburden. A zoom into the area marked by the red square is given in Figure 7.

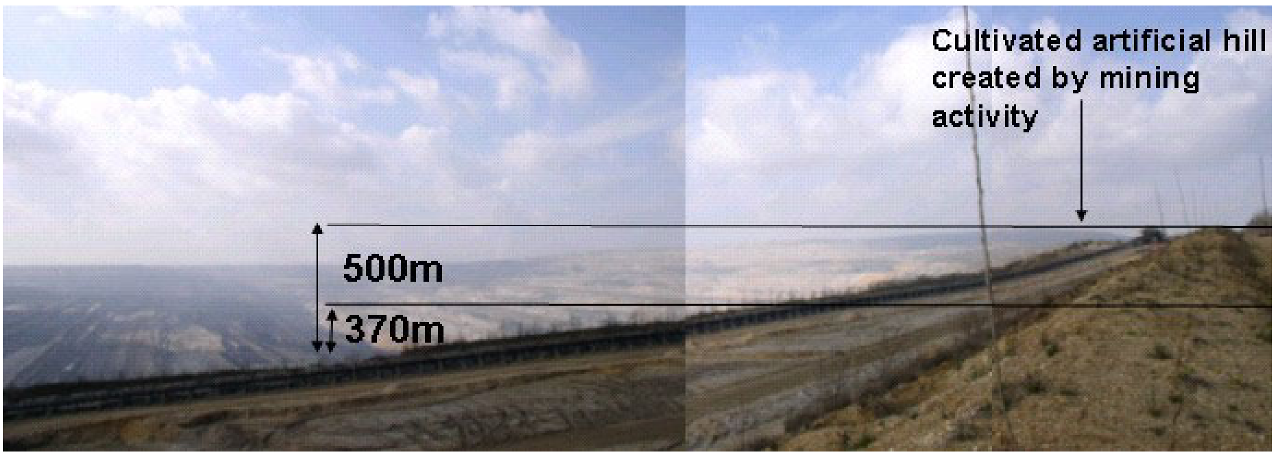

Figure 3. Looking from the northern rim into the mine. The artificial slope from the stacked Sophienhöhe to the deepest part of the mine is more than 500m high.

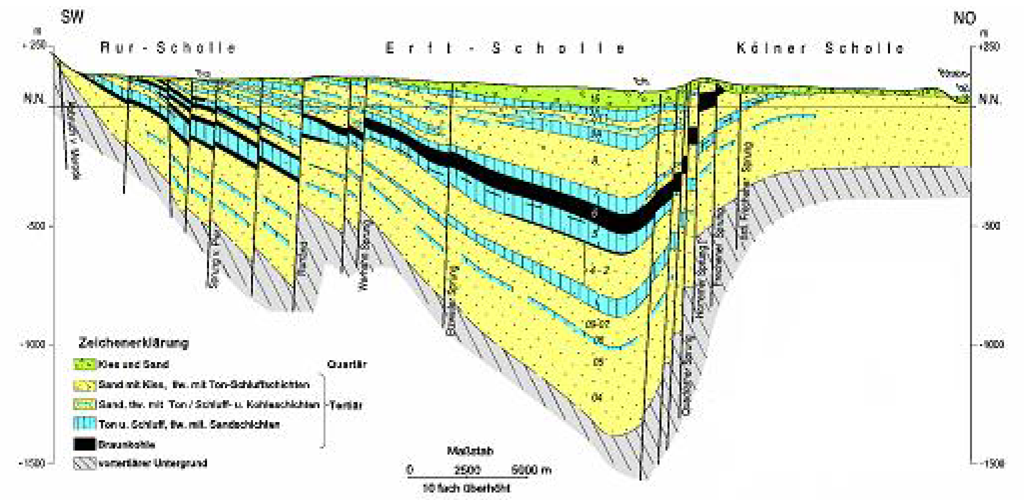

Figure 4. Geological section through the NRW lignite mining district. The deepest of the deposits shown is the pre-Tertiary base rock, followed by sand and clay layers. The thick black layer is lignite. On top of this lignite, sand (yellow), clay (blue) and gravel layers can be found. In the Hambach mine the thick lignite layer in the centre of the figure is excavated.

Figure 5. The circle marks a Landrover Defender for scale. The bucket wheel excavator (here operating on a bench 14 m above the conveyor belt) is 90 m high.

Geo-scientific and geo-engineering tasks

Because of the long mining tradition in the region and the accompanying long history of exploration programmes the coal seam, its thickness and extent were known long before the Hambach surface mine commenced in 1978. Before 1978, the large excavators, which can excavate 240 000 m³ of sand a day were not available. For that reason it was not considered to be economic to excavate all of the overburden to reach down to the coal. Therefore, the first mining activity in the neighbourhood of the present day Hambach mine was subsurface mining. As one can deduce from the geological information given above, the overburden consists of loose sediments with a large hydraulic conductivity. The subsurface mine was developed, but before production started the geomechanical properties of the overburden (which called for massive support measures) and the hydrogeology (which called for massive pumping operations in the mine) caused the ceasing of underground mining activity.

Today's open pit with slope heights exceeding 500 m, calls again for knowledge in the field of geoscience and geoengineering. In the Hambach surface mine, slope stability of the intact massif and that of the inner and outer dumps is of primary importance. Next to inclinometer monitoring, online monitoring of slopes using automated theodolites, large scale in situ test are performed to optimize the set up of the inner dump from a dispositional and geomechanical point of view. Another important aspect is the water management of the region around the mine and inside the mine. These geoscientific and geoengineering aspects are controlled and engineered by the geotechnical and water management departments of RWE Power. However, all these aspects require a detailed knowledge of the geological set-up of the subsurface based, on site investigation and exploration.

SITE INVESTIGATION AND EXPLORATION

Geo-scientific and geo-engineering tasks

Exploration for lignite mining in the region is based on borehole drilling, coring (Figure 6) and geophysical well logging. In the coal layers, samples are taken for chemical analysis of the coal composition. The overburden is cored on special request by the geotechnical department and the mineral deposit and surveying department, which uses this information to render a three dimensional subsurface model. The boundaries between the different clay and sand layers are determined accurately by geophysical logging: gamma ray logging, gamma-gamma logging and electric well logging.

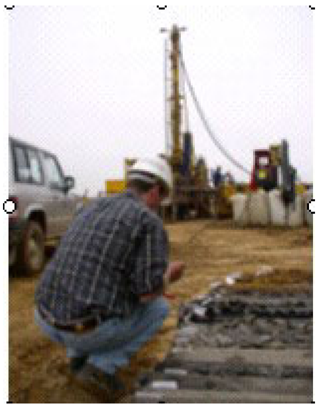

Figure 6. Some parts of the overburden and all of the coal horizons are cored and analysed. A first petrographic description is performed on site.

SUBSURFACE MODEL

Geo-scientific and geo-engineering tasks

The information obtained by site investigation and exploration is used to generate a three dimensional subsurface model. This model is overlain by the up-to-date geometry of the surface mine. The actual mine geometry is subtracted from the subsurface model. In this way the actual 'outcrops' of the different lithologies in the surface mine can be displayed in three dimensions as shown in Figure 7. In addition, the position of the bucket wheel excavators is given by continuous accurate GPS measurements. In this way the actual position of the excavators and the position of the bucket wheel can be displayed in the three dimensional subsurface model which is continuously updated depending on the excavation rate of the excavator.

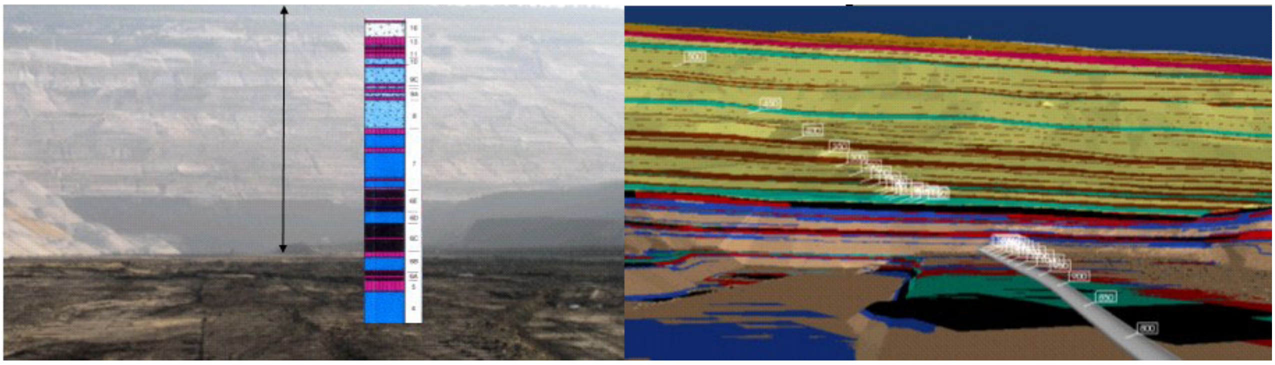

Figure 7. On the left: In this figure a large slope of the Hambach mine is shown from the lowest level of the mine. The lowest level (base of the coal deposit) is located at -280 m below sea level; the original surface is located at 90 m above sea level. In the figure the generalised stratigraphic column for the region is shown. On the right: the subsurface model is shown pointing in the same direction. The different colours correspond to different lithologies (see Figures 10 & 11).

RESOURCE FOR THE CITY: LIGNITE

In the Hambach mine ~$40 \cdot 10^6$ ton of Lignite are mined each year. The Lignite is excavated at two levels by two large excavators. From the excavators the lignite is transported via conveyor belts to the storage bunker (Figure 8). From here the lignite is transported by the haulage department via RWE-Power's railroad system (more than 200 km tracks) to the different power plants and factories. Depending on the chemical composition of the coal, different coal types are identified and mined separately: Factories which produce briquettes have other requirements, with respect to the consistency of the coal, than electrical power plants. The composition of the coal has been measured on samples obtained during the exploration drilling campaigns and is displayed in the three dimensional subsurface model to aid the disposition of the bucket wheel excavators on a day-to-day basis. In addition, the chemical composition of the coal is measured in at two minutes interval by taking samples directly from the conveyor belt. This analysis is automated and the information is sent on-line to the offices of the mine-production and disposition staff.

Geo-scientific and geo-engineering tasks

As discussed above, site investigation and exploration are needed to determine the size and quality of the raw materials and the mining method, which is optimal considering the mechanical/chemical and hydrological properties of the overburden and the mineral resources.

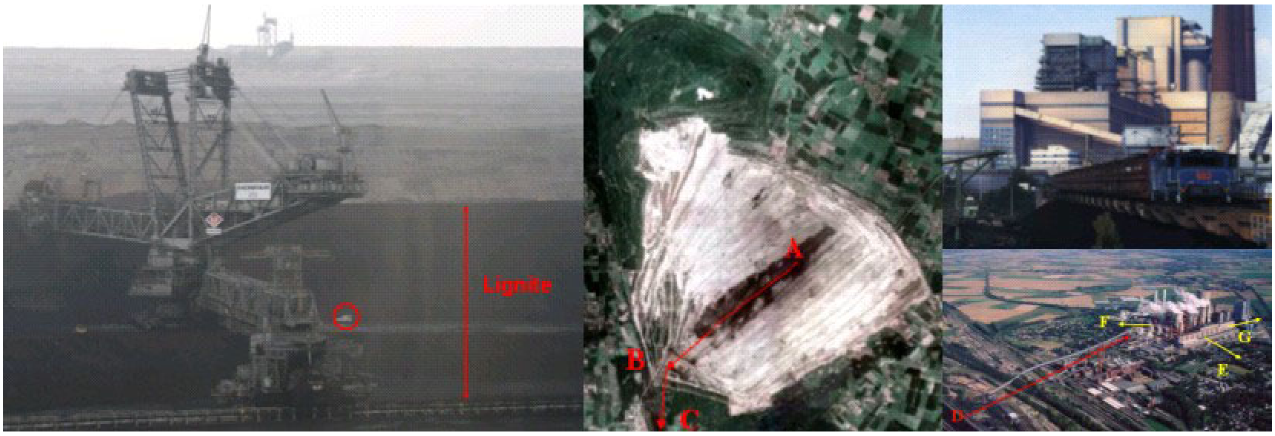

Figure 8. On the left: the thick lignite seam is excavated by huge excavators. Middle: from A where the coal is excavated it is transported to the bunker located at B. Top right: From the bunker the coal is transported by the haulage department by rail. Bottom right: in the factory or the power plant the coal is combusted and the energy is transformed into electric energy and heat, in the factories lignite is transformed into industrial coal dust, briquettes and many other products.

RESOURCES FOR THE CITY: ELECTRICAL POWER

In former days lignite was transformed into briquettes and was as used as source of heat for domestic and industrial purposes. Today 90% of the lignite is transformed into electrical energy. The amount of energy produced from the lignite mined in the Hambach, Inden and Garzweiler mines supplies 50% of the energy consumed in NRW. Besides lignite, the power plants require water. This water, too, is delivered by the mines.

RESOURCES FOR THE CITY: GYPSUM

As discussed above a large part of the mined lignite is transported from the mines to the power plants. The element sulphur is present in almost all coals (Thomas 2002). During burning this sulphur is transformed into SO_2. This SO_2 is removed from the flue gas by guiding the gas trough a $CaCO_3$-CaO suspension. Hereby $CaSO_4$, gypsum, is produced. Gypsum is used by the construction industry (SRB 2005).

Geo-scientific and geo-engineering tasks

A large-scale mining operation depends on thorough exploration of the subsurface. At this stage, the important parameters, method of mining as a function of the geomechanical properties of the overburden, amount of resources, possible production per year *etc*. must be determined. Then the power plants and other industries must be constructed or adapted to process the raw materials. A detailed analysis of overburden and the raw materials must lead to a correct determination of all elements involved. Only in this way, mining methods and treatment plants can be designed correctly.

RESOURCES FOR THE CITY: WATER

Eco-water

Surface mining operations in the geological setting described above (large hydraulic conductivity, high groundwater table) require that the groundwater table is lowered. Due to the geological history in which many successions of sand and clay layers were deposited on a flat terrain many, horizontal extensive, aquicludes and aquitards are present. North of the northern mine in the district, the Garzweiler mine, marshes and wetlands depend on the uppermost aquifer. To avoid a lowering of this groundwater level, water pumped from the different aquifers in the vicinity of the mine is re-injected close to the wetlands. Therefore two eco-water treatment plants have been constructed (Figure 9) in recent years and 125 km of pipeline has been installed to lead the water from the wells near the surface mine to the treatment plants and from there to the wetlands. The water is not injected directly on the surface, but use is made of more than 70 infiltration trenches (40m long, 6m deep) and more than 160 infiltration wells (1 m diameter and up to 150 m deep). $55 \cdot 10^6$ m³ water will be injected annually. Experience gained since the eighties and ongoing monitoring have shown that the systems performs well (ÖIN 2005).

Figure 9. Water pumped in the vicinity of the Garzweiler mine is pumped to the eco-water treatment plants on the left. After treatment the water is pumped to infiltration trenches and infiltration wells. In the middle an infiltration trench is shown. These infiltration trenches guarantee a high water table for the wetlands shown on the right.

Geoscientific and geoengineering tasks

Groundwater lowering and re-injection without disturbing the biosphere is only possible if the hydrogeological system of the subsurface is exactly known. Therefore, RWE Power has an indoor water management department for the planning and engineering of the water balance. Only by using state of the art geoscientific and geoengineering tools such delicate operations are possible.

Drinking-water

Next to the eco-water, water is delivered to the cities as drinking-water. Therefore, water treatment plants have been constructed.

Water as working medium

Not only lignite is provided by the opencast mines to the electric power plants, water as working medium of a thermal power plant is supplied as well.

RESOURCES FOR THE CITY: BRIQUETTES

$1.7 \cdot 10^6$ ton of briquettes were produced last year by the factories of RWE-Power. These briquettes are used for domestic and industrial heating. Industries working with briquettes are *e.g.* the sugar factories operating in the region (on the fertile, loessic lands many sugar-beets are grown). Other industrial users of briquettes include brick factories.

RESOURCES FOR THE CITY: COKE

Coke used in the steel production industries can be produced as well from lignite. Last year $0.6 \cdot 10^6$ ton of coking coal were produced from the lignite mined by RWE-Power.

RESOURCES FOR THE CITY: INDUSTRIAL COAL DUST

Industrial coal dust is used in cement production and the production of bituminous road construction material. Last year $5 \cdot 10^6$ ton of industrial coal dust were produced by the RWE Power factories by the lignite transported to them.

RESOURCES FOR THE CITY: CLAY

Clay has been mined in the region on a large scale since Roman times. The clay outside the environs of the present day Hambach mine was used to make bricks for housing and ceramics for daily use and as art object. Today clay is used for technical porcelain manufacturing and fire resistant objects (Grabert 1998). Five large deposits exist in the region. These are clay from the formations of Cologne (Oligoncene/Miocene), Reuver (Pliocene) and Tegelen (Pleistocene) (Grabert 1998). In Hambach, clay from several of these formations and others are mined (Figure 10). In the last 10 years $400 \cdot 10^3$ ton of clay were mined for use outside the Hambach opencast mine with a peak production of $140 \cdot 10^3$ ton per year. Hambach clay is predominantly used as landfill seal.

Geoscientific & geoengineering tasks

The analysis of clay deposits for industrial use is very difficult, because the link between the properties of the raw material and the required properties of the final product is very complex. In order to give a reliable estimate of the available clay reserves in a deposit, particular precise geological-mineralogical analysis is necessary. The required methods are so time/cost intensive that not any number of samples can be tested. In this light the esteemed sheer unlimited resources of such "common" materials as brick clay must be questioned (Pohl 1992). Hambach mine has the capability to determine the nature and reserves of its resources accurately. Therefore, Hambach mine can help to provide the necessary clay minerals to society.

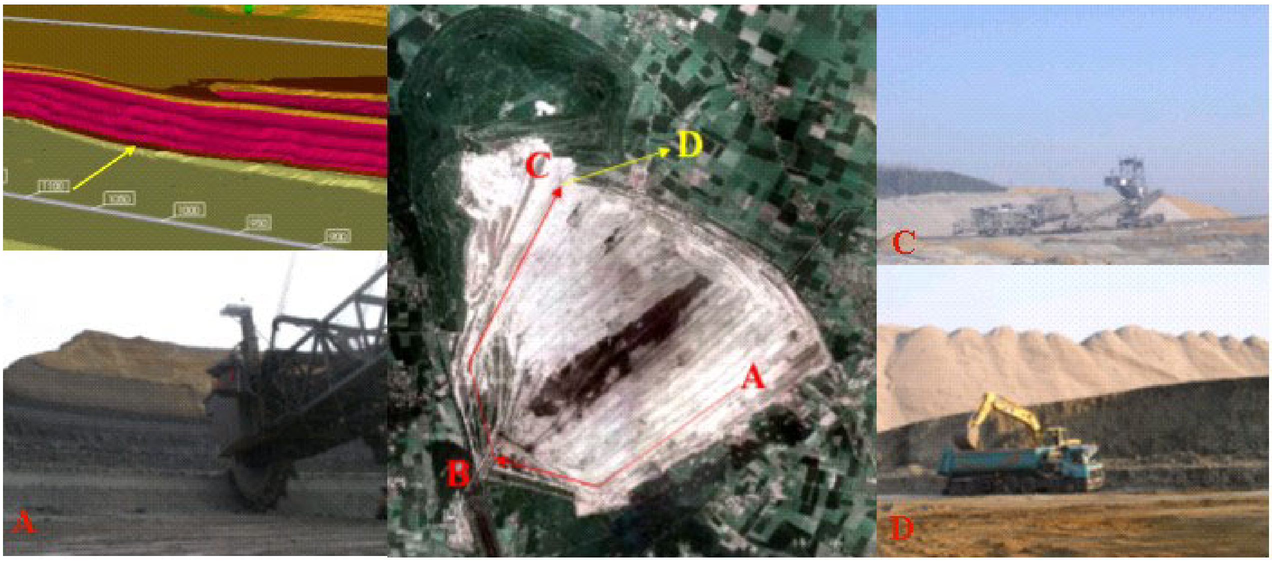

Figure 10. Top left: clay material, potentially suitable as seal in landfills, is recognised in the subsurface model. Bottom left: the clay is inspected in situ by the geotechnical department and excavated by the bucket wheel excavator. Middle: the clay mined at A by the bucket wheel excavator, is transported via the conveyor belt system to the conveyor belt junction at B. From here the material can be guided to the correct stacker *e.g.* at C close to an entry to the mine. Here the customer can collect and load the material into haulers which transport the material to the construction site. Top right: a stacker moving into position to deposit clay barrier material. Bottom right: loading of clay into haulers, which transport the clay to the customer.

RESOURCES FOR THE CITY: GRAVEL

Of all raw materials, the consumption of sand and gravel is the most important in Germany (expressed in tons per capita). In a 70 year life, each person needs 335 tons of sand and gravel. Gravel and sand play an important role in society. Gravel is used as additive (80%) in concrete used, for example, for the construction of buildings (domestic and public) and structures (dams and bridges) (Braus & Pahl 2004). $2.1 \cdot 10^6$ ton of gravel have been produced for costumers during the last 10 years. In this period annual peaks of $700 \cdot 10^3$ ton were delivered. The gravel mined in Hambach can be found on the highest level (Figure 11). The gravel was deposited on terraces during the Pleistocene. For large urban infrastructural projects, which need large amount of concrete and therefore gravel, civilisation can rely on the deposits available in the Hambach mine.

RESOURCES FOR THE CITY: DISTRICT HEATING

Sixty percent of the total energy consumption in Germany is used for heating of domestic and public buildings and for heating purposes in diverse industrial applications (Hering & Schroeder 2004). Some of this heat, extracted from large-scale power plants fed by lignite, is provided directly by the RWE-Power as heat source to several cities and to different industries in the region. District heat from cogeneration makes sense wherever there is sufficient demand in the vicinity of a power plant (FNP 2005).

RESOURCE FOR THE CITY: RECREATION

As a result of very early mining and agricultural activity and continuous industrialisation, the region is densely populated. Recreation in terms of hiking, mountain biking in hilly, forested terrains and enjoying wildlife *i.e.* to escape urban life, is provided by the nearby Eifel and Ardennes, which can be reached in 1.5 hour drive from many of the cities. Closer and very attractive with more than 100 km of hiking trails, small valleys, ponds and wildlife is the Sophienhöhe (Figure 12). The Sophienhöhe, rising 200m above the original surface was created in the course of the mining activity to serve as a forested hill for recreational activity and as a nature refuge.

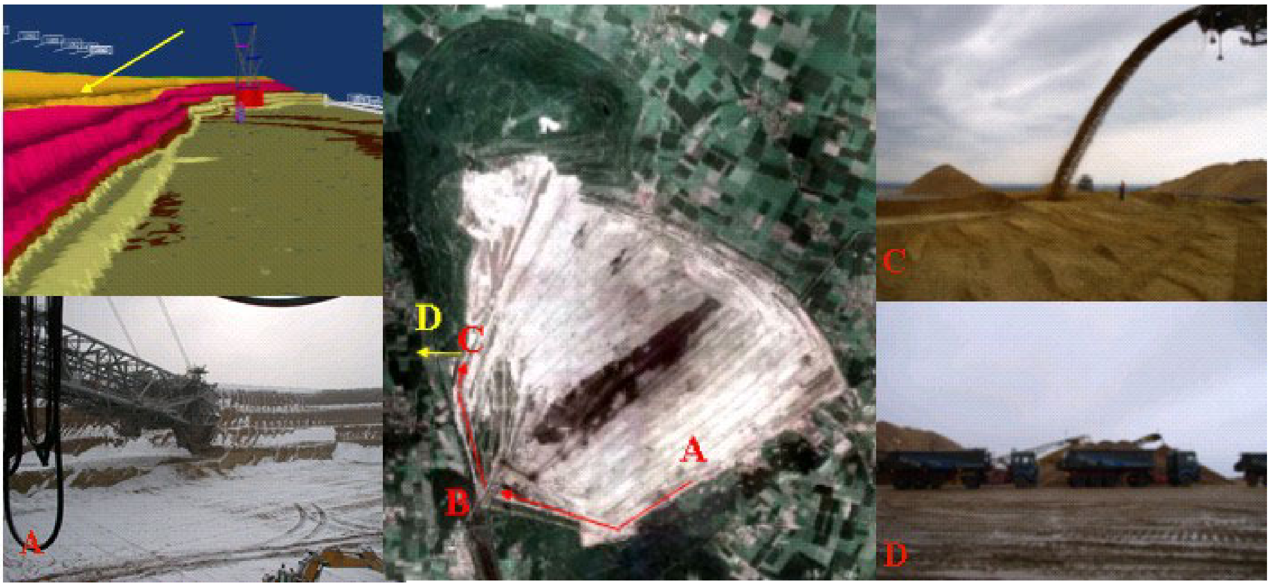

Figure 11. Top left: In the subsurface model the gravel layers (orange) can be identified. Bottom left: The bucket wheel excavator is moving towards this material. Middle: The gravel excavated by the bucket wheel excavator at *e.g.* A is transported via conveyor belts to the conveyor belt junction at B. From here the material is transported to stackers at C. Top right: a stacker depositing gravel. Bottom right (D): Stacking gravel is processed further by sieving. The haulers deliver the gravel to the customer.

Figure 12. On the left: Stacking of forest gravel. Top right: young trees planted in the topsoil. Bottom right: The older trees on the Sophienhöhe.

Geoscientific and geoengineering tasks

The creation of such a large hill calls for a detailed stacking of the different soils layers taking into account the different geomechanical properties of these layers. The hill has to be stable. Where ponds (Figure 13) or streams are planned, clay has to be top layer and the forested stretches need a special mixture of loess loam and gravel as topmost soil, this is called the forest gravel (Figure 12). While this material is so loose that tree roots can penetrate the soil deep enough, it is also so loamy that it can store sufficient water for the drier seasons of the year (PML 2005). This forest gravel is not levelled to avoid compaction and, hence, stagnant moisture and erosion, and to exploit the micro-climatic advantages of rough surfaces and small hollows (PML 2005).

Figure 13. A pond on the former site of the Bergheim mine.

RESOURCE FOR THE CITY: TIMBER

Every year, foresters and woodsmen of RWE Power plant several hundred thousand copses on the Sophienhöhe: mainly common oaks and red beech, but also small-leaf linden and wild fruit trees. They obtain the young plants from nurseries. In the young stock, enough gaps are left for naturally immigrating tree types like the birch. Today’s planting programme comprises numerous tree and shrub species. Deciduous trees have priority over coniferous woods. However, there is no complete lack of conifers. In places, they liven up the landscape and offer shelter in winter to the deer that soon immigrated here. One aims at founding forest communities that suit their location and are thus ecologically stable. Because less is often more when it comes to planning and caring for such new woods, the foresters follow the principle of close-to-nature forest management – as do their public colleagues (PML 2005).

CONCLUSION

Supported by our own geotechnical, geological, hydrological, surveying, hydrogeological, geophysical team, representing all branches of geological sciences and engineering together with our landscape architects our mining staff can proceed operations at these depths to guarantee a supply of all mentioned resources for the city, followed by a decent recultivation at those stretches where mining ceased.

The resources delivered by the Hambach mine in cooperation with the companies power plants and factories are:

- Electrical power (used for heating , lighting, computers, hospital operation *etc.*)
- Gravel (used directly or as major component in construction of domestic and public buildings and infrastructure)
- Coke (used in steel production, absorbent coal for filtering)
- Gypsum (used in the construction industry)
- Clay (landfill barriers, potentially for everyday ceramics or industrial ceramics and brick manufacturing)
- District heating (used for heating of public buildings)
- Briquettes (heating at home, heat for different industrial purposes: *e.g.* brick production or sugar industry based on sugar-beets)
- Industrial-coal-dust (used as ingredient in bituminous road construction material, and cement production)
- Timber (used in construction and decoration)
- Water (drinking-water, eco-water and for power plants)

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