NORTH SEA – SUSTAINABLE ENERGY PLANNING

WORK PACKAGE 4/ACTIVITY 4.4
FINAL REPORT – GIS-TOOLS

NORTH SEA
Sustainable Energy Planning

Final Activity Report turned in 2012, October 12th

Work Package 4
Activity 4.4

GIS-Tools

Final Report

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1 Introduction

The use of Geographical Information Systems (GIS) is now commonplace for all forms of planning work. It is universally used to graphically depict planned future land-use at a local and regional level and to assess environmental impact. Furthermore, GIS is used in helping to identify suitable locations for wind turbines, biogas plants and other technical facilities which either use or generate energy from sustainable sources. To this end, standard GIS tools for spatial analysis are generally used, such as the intersection and buffer functions. The aim of such an investigation is, on the whole, to find a location where there is no direct competition in terms of land-use.

This approach in using GIS is limited, in the sense that it is based on one single perspective provided by specific technology and the rules, directives and laws associated with it. Planning processes using GIS must, therefore, be understood as being from the 'viewpoint' of the technology in question. The environmental impact can be clarified in each specific case using a variety of procedures: 3D visualization, shadow-analysis, noise assessment etc. With this approach, however, a holistic view of the impact of extended energy planning is not possible.

Alongside the location analysis mentioned above, the analysis of the potential for renewable energies and energy saving has become more common in the past few years. Specifically, this means a comprehensive survey of the energy-generating potential and energy requirements within one planning area (community, district, region etc.).

As well as planning criteria, others factors have to be taken into account, such as:

- potential for bio-mass production
- optimization of location selection based on local energy needs
- consideration of spatial restrictions and commercial limitations in relation to transport distance

- distribution of energy requirements allowing for demographic development over time (e.g. using reliable heat requirement analyses)
- allowance for regional and inter-regional planning proposals (trade, industry, bigger events)
- existing and planned infrastructure must be taken into account to ensure optimum energy transfer (i.e. optimized routing of distance heating pipes)

When these data have been analyzed, the mix of energy types, the spatial distribution of energy sources and the supply routes can all be taken into account as part of a comprehensive decision-making process for a sustainable future.

During the project a number of sub-projects with focus on renewable energies have been executed and evaluated to demonstrate the variety of possibilities that are resulting from the implementation of GIS processes into regional planning processes.

2 Evaluation of sub-projects

2.1 3D-Visualisation of planned wind site in Oldenburg

The city of Oldenburg has used GIS to conduct location assessments for wind turbines. With the help of basic data (land registry data, real estate maps), planning and other specialist data (land-use maps, protected areas) buffer zones can be determined and drawn up, thus defining areas which are free of restrictions.

Of central importance is the well-being of local residents and those who work in the area as well as the protection of facilities that should not be affected or negatively impacted by the erection of wind turbines. To this end, protection zones are normally defined (in Oldenburg city for example, a distance of 750m to residential areas must be kept) to keep shadow and noise disturbance to a minimum. For the protection of infrastructure features, the tip-over radius for wind turbines must be taken into account.

Moreover, particular attention must be paid to nature conservation issues. Thus, prescribed distances to conservation areas and other specially sensitive or environmentally-valuable areas must be adhered to.

In December 2009 a proposal for the location of wind turbines was made. The aim was to assess the feasibility of erecting wind turbines within the city limits of Oldenburg while complying with current planning regulations. Possible reasons for rejecting any proposal are the rights of land and property users to protection from disturbance, regional planning regulations and land-use regulations and, of course nature conservation law.

For the visualization project digitized data was provided, partly, by the Oldenburg authorities in conventional GIS formats (real estate maps, conservation areas) and partly from the open-access server for nature conservation information (GEOSUM-Server) run by the federal state of Lower Saxony, Germany. This server is a free source of GIS data about conservation areas and areas of particular natural value.

On closer inspection it became clear that, in specific cases, the land-use information given by the land registry (forest, arable or pasture etc.) was not correct, even though the current issue was used. Thus, some forests to which a protection zone of 200m had been allotted were not depicted. The greatest impediment was the land-use map which had not, at the time, been digitized. The digitization of these data had to be carried out as part of the process.
The result of the investigation was that, within the scope of current planning criteria, no land within Oldenburg's municipal boundaries can be made available for wind turbines.

2.1.1 Participants and involved parties

The study was carried out by Jade University of Applied Sciences in cooperation with the city of Oldenburg in Lower Saxony, Germany.

Fig. 1: Location of Oldenburg in Germany. Source: GoogleMaps.

2.1.2 Activities

The political will to erect wind turbines is, however, strong. In a further step in the process, a detailed review of the criteria and of the distribution of authorities and responsibilities was carried out. It thus emerged that the Oldenburg city authorities have the power to carry out an assessment which may conclude that public interest be ranked behind the benefits of promoting wind energy developments within the city boundaries. It remains to be seen, in a referral process, if the erection of wind turbines is actually contrary to the aims of nature conservation.

The use of GIS in its current form has reached its useful limits. Any further assessment requires the use of methods with which it is possible to evaluate the impact of wind turbines on people's objective experience of the country-side. 3D visualizations are a good option.

2.1.3 Key findings

Through the use of CAD programs, with the so-called 3D visualizations can be created, the construction of wind power plants are illustrated in advance realistically visually. Thus it provides an ideal complement to a geographic information system and viewers of visualization, that has the quality of a video can a nearly realistic impression of how a future installation could look like and which are the impacts.

As an example, a wind farm on the "kleiner Bornhorster See" in Oldenburg was implemented digitally. In this territory five wind energy turbines with a hub height of 108 meters are planned. The results are images and videos. This shows very plainly illustrated the wind turbines integrated in the land-scape. With this opportunity it is possible to demonstrate all concerned parties the effects of the turbines.

Fig. 2: Screenshot - 3D Visualization of wind turbines on the location "kleiner Bornhorster See", Oldenburg Germany.

Fig. 3: Video sequences of the landscape "kleiner Bornhorster See", Oldenburg Germany with the wind turbines. (Screenshots).

2.1.4 Benefits and impacts for stakeholders

GIS and CAD Software are most helpful for the planning of wind energy plants. With these tools all parties can recognize positive and negative effects of the wind turbines on a certain location.

2.2 Visibility analysis as a tool for regional planning in the context of re-powering

2.2.1 Context (regarding the general project)

The spatial impact of wind turbines depends, of course, on factors such as noise emissions and shadow disturbance but also, to a large extent, on its visual impact at distances far beyond the site itself. The current trend in wind energy technology is towards higher output units with taller towers and longer rotor blades. Taking a rural district in Lower Saxony, Germany, as a test case, this project describe a new technique for using visibility analysis as a tool to support decision-making in regional planning.

There are (spring 2010) 314 wind turbines located in the district of Diepholz. The largest units have a nominal output of 3 MW and a hub-height of 140 m. The smallest ones, however, have an overall height of only 11.5 m. In the future, units of 200m will not be exceptional. Compared to the first generation, today's wind turbines have a disproportionally greater impact upon the landscape because of the larger dimensions.

Against this background, the responsible regional planning department decided to run a study to determine if the "visual impact of wind turbines on the landscape" is an acceptable criterion for evaluating the suitability of sites for erecting such units, alongside the more concrete prohibitory factors such as proximity to housing areas. For planning purposes, it is therefore important to establish what visual impact wind turbines have on a landscape before any evaluation of the landscape can take place. This is particularly important in the context of the imminent, so-called “repowering” scheme to upgrade and renew existing wind turbines. The “repowering” scheme will allow the results of former approval practices to be rectified by dismantling as many isolated units as possible and then replacing the lost generating capacity by more high-performance units in wind farms.

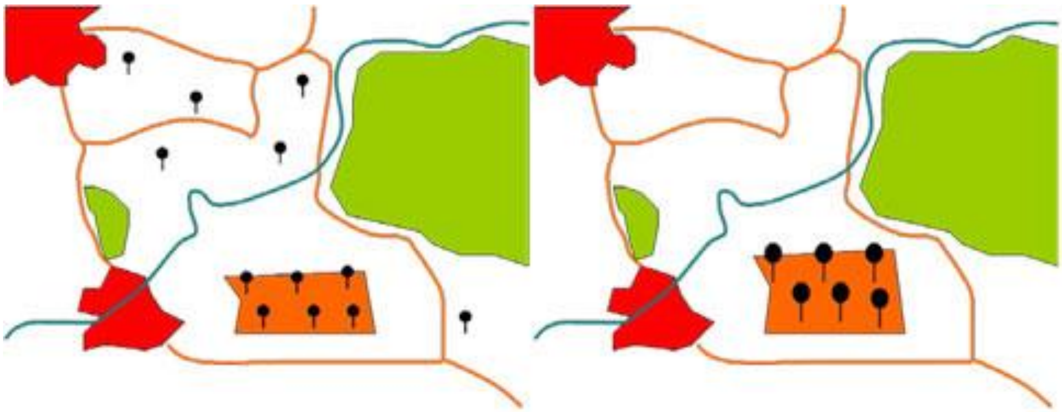

Fig. 4: The principle of repowering – Numerous isolated units are dismantled; larger and more efficient wind turbines are erected on a more advantageous site, increasing the total output (based on DStGB 2009).

The impact of wind turbines depends on several factors, not least the unit itself. The taller the tower, the further the visual impact carries. The topography of the adjacent landscape as well, is a significant factor for the long-range impact of wind turbines. Exposed sites on the ridge of hills have a longer range impact than those located in a valley. The impact of such units depends very much on the location of the viewer. The presence of these industrial units is much more tangibly felt from close up than if they are at a distance. However, if the viewer is, for example, in a forest or a built-up area then the view of the units is masked.

It must, however, be pointed out that the visual impact does not respect administrative boundaries. It is therefore important to take a holistic, cross-boundary approach to repowering.

A so-called impact analysis, a tool which has, to date, been little used in regional planning, takes account of all of these factors.

2.2.2 Participants and involved parties

The analysis was commissioned by the district of Diepholz and carried out by GIS-Plan-Service (Jürgen Knies, Oldenburg).

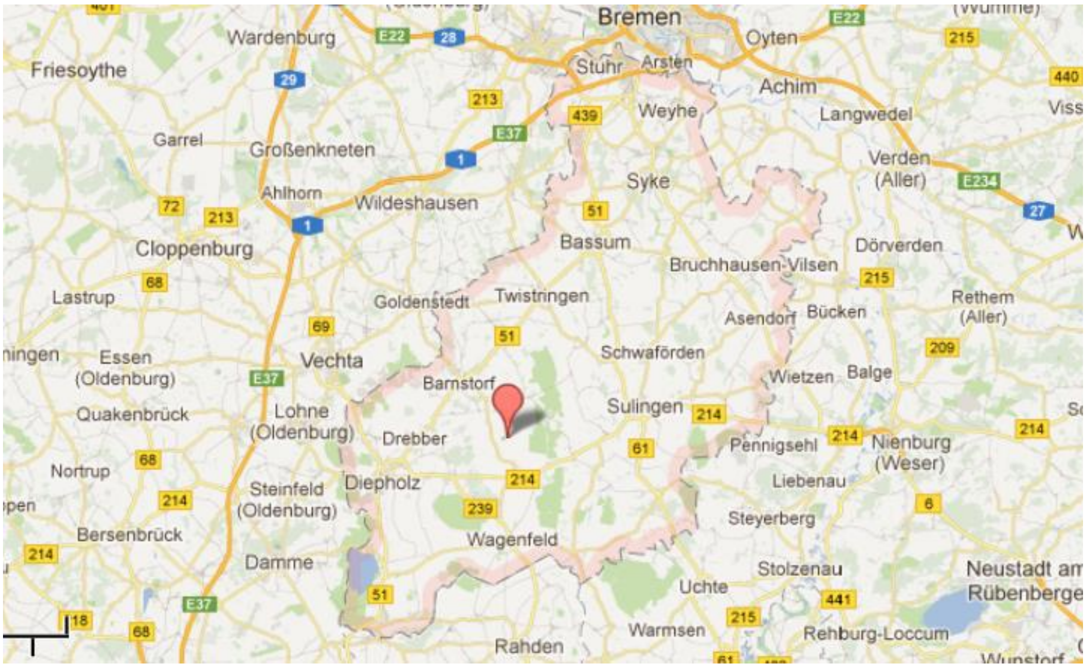

Fig. 5: Location of the district Diepholz in Germany. Source: GoogleMaps

2.2.3 Activities

The impact analysis is based on a weighted visibility analysis of wind turbines which takes into account the distance from the tower to the viewer. Making allowance for the working-scale and the degree of abstraction, it is possible to make relatively accurate predictions of sight-lines/sight obstruction. The result of a visibility analysis does not provide any indication of the degree of any impairment of the landscape but it does, however, allow a first assess

The following parameters are the basis of a visibility analysis:

- impact zone/working scale
- digital model of the terrain
- features of the terrain with visual effects
- height of the viewer

The data used were made available by the GIS department of the district. The parameters and the methodology are described in more detail below.

Impact zone / working scale:

The landscape in the analyzed district of Diepholz is a patchwork of land-use types and varies between flat and rolling terrain, so it can be said that wind turbines with an overall height of over 100m are structures with a long-range visual impact. However, the actual visual perceptibility of the units depends on factors such as the transparency of the landscape and prevailing meteorological conditions. If these are left out of the assessment then the degree of visibility of wind turbines depends, to a large extent, on the given sight-lines from the viewer's standpoint.

The human eye has a vertical angle of vision of about 37° (27° of the range is above the horizontal); the horizontal angle of vision is 54°.

Accordingly, a wind turbine fills a certain part of the field of vision and will thus be perceived as either conspicuous, visually dominant or subdominant, depending on its elevation and distance from the viewer's standpoint (see table 1).

Table 1: Visual impact zones for wind turbines (WT) with an overall height of 150 m, 100 m und 80 m (Source: Schleswig-Holstein 2003).

Impact zone	Distance for a 150m WT	Distance for a 100m WT	Distance for a 80m WT	Description of the typical impact of the WT for the given distance
1	2	3	4	5
Close proximity	< 300 m	< 190 m	< 150 m	The distance is too small to allow views of the complete object; it can only be fully viewed by scanning.
I Foreground	300 m - 570 m	190 m - 400 m	150 m - 300 m	Object is conspicuous and captures the attention. WT fills half to all of the field of vision.
II Middle distance	570 m - 1.100 m	400 m - 800 m	300 m - 600 m	Full view, dominant; the complete outline of the WT can be seen in one view; it fills a quarter to half of the field of vision.
III Distance view	1.100 m – 2.800 m	800 m – 2.000 m	600 m – 1.500 m	The view is sub-dominant; WT fills 1/10 to 1/4 of the field of vision.
Far distance view	2.800 m - 40 km	2.000 m - 35 km	1.500 m - 30 km	Max. visibility zone. Only visible at max. distance in very good visibility and light conditions and if the tower is white.

A comparative study for the whole district was commissioned but the main focus of attention was on zone III and the far distance view. The working scale was set at regional level (in this case 1: 75000).

Digital model of the terrain:

The digital terrain model (DTM) was taken from the official topographical cartographical information system digital. Due to the prescribed working scale DGM 25 (DGM 25 is a nationwide **D**igital **T**errain **M**odel with a screen width of 25 meters) was used. The data were converted onto a grid-based terrain model with a resolution or 5x5m (**L**evel **o**f **D**etail, **LoD**, 0). With the level of detail (LoD) virtual models in different levels of detail can be describe.

There are several of detail (ALTMAIER 2004):

- LOD 0 = regional model
- LOD 1 = blocks model without roof structures
- LOD 2 = textured models; differentiated roof structures; vegetation
- LOD 3 = finely differentiated geometric architectural models; vegetation; street furniture
- LOD 4 = Interior model - walk architecture model

Features of the terrain with visual effects:

In order to evaluate the visibility of wind turbines, features of the terrain which obstruct the view must be taken into account as well as the digital terrain model. These include woods, housing and man-made structures. To gain a relatively accurate picture of these surface features, the computerized land registry maps were used in all areas. Each feature category was given a height based on typical values for the region so, for example, typical average heights of 20m – 25m for woodland and of 8m – 12m for built-up areas were taken, depending on type and land-use. The standardized heights for these sight-obstructing landscape features are then integrated into the digital terrain model using a resolution of 5mx5m. In this way, a digital model of landscape features is built up and this serves as the basis for further analyses (LOD1). It must be stated that accurate conclusions about specific, localized sight-lines/sight obstruction cannot be drawn from the model.

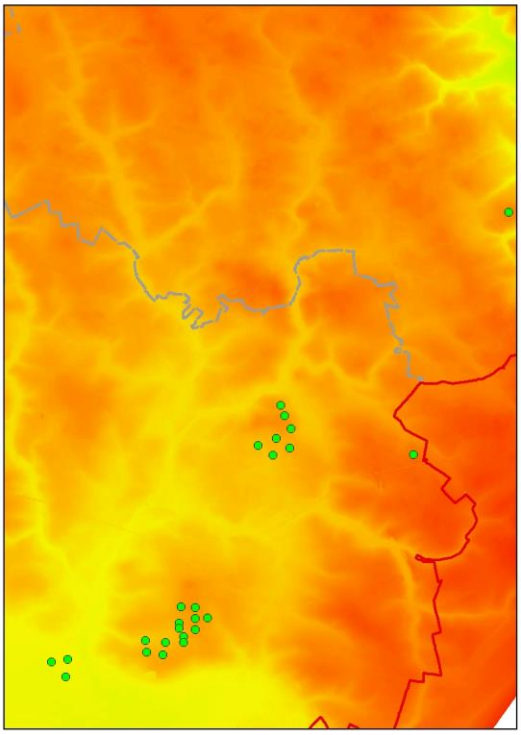

Fig. 6: Terrain model showing existing wind turbines

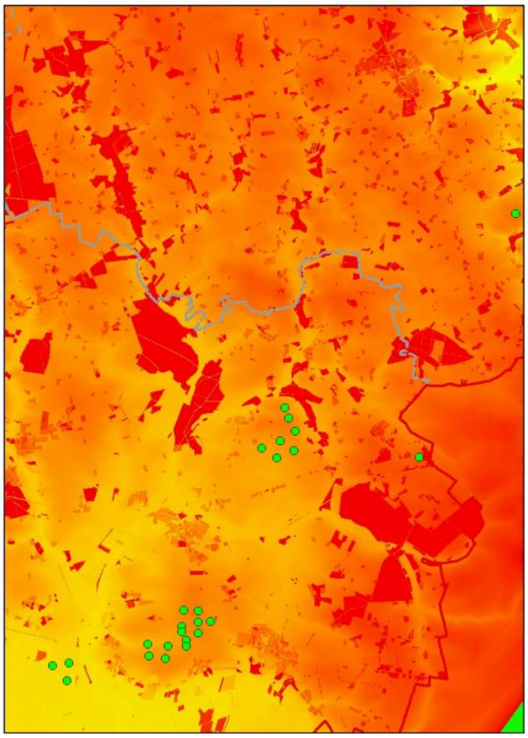

Fig. 7: Model of terrain features(terrain model including features with visual impact) showing existing wind turbines

Viewer's height:

A standardized viewer's height of 2 m was taken.

Method for impact analysis:

The impact analysis uses radii of impact which are determined by the height of the wind turbines. Now it is possible to carry out a visibility analysis, using geographical information systems (GIS) and, at the same time, incorporating the digital model of terrain features, and taking into account the viewer's height and the extent of impact zones. To this end, the methodology was refined in that the impact zone for larger units was defined and the impact zone "distant view" more critically defined. A theoretical visibility distance of 40 km is measurable but for planning purposes not practicable. Thus, distant view was defined as double the distance given for zone III after perceptibility was also factored in. This zone can thus be seen as a more accurately defined extension of zone III and the alteration can be seen as a response to the current debate on impact zones.

Table 2: Re-adjusted analysis zones and evaluation of impairment.

Impact zone	Weighting	Distance for WT height up to 180 m	Distance for WT height up to 150 m	Distance for WT height up to 100 m	Distance for WT height up to 80 m	Distance for WT height up to 50 m
Subdominant perception (Zone III)	2	3.600 m	2.800 m	2.000 m	1.500 m	900 m
Far distance view with factored-in perceptibility (double of Zone III)	1	7.200 m	5.600 m	4.000 m	3.000 m	1.800 m

2.2.4 Key findings

In conclusion, the regional planning authority received maps giving an overview of the impairment to the landscape from existing wind turbines. This enables them to predict the impact of planning proposals on the landscape and, moreover, various scenarios and their consequences can be clarified, thus benefitting the communication process.

The following illustrations show the impacts arising from various scenarios. In order not to jeopardize the on-going discussions the topographical map is not included as, otherwise, project developers could draw concrete conclusions from what are only proposals.

Fig. 8: Legend

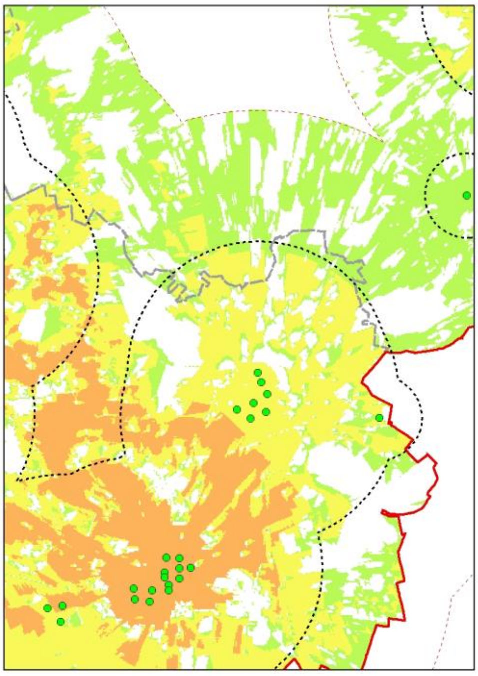

Fig. 9: Status Quo – existing WTs in wind farms and stand-alone units

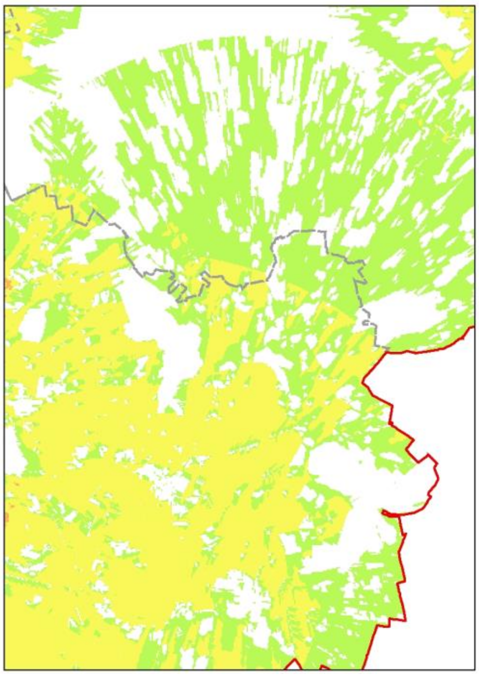

Fig. 10: Restricted development only in currently prioritized areas (tower height up to 180 m); dismantling of stand-alone units

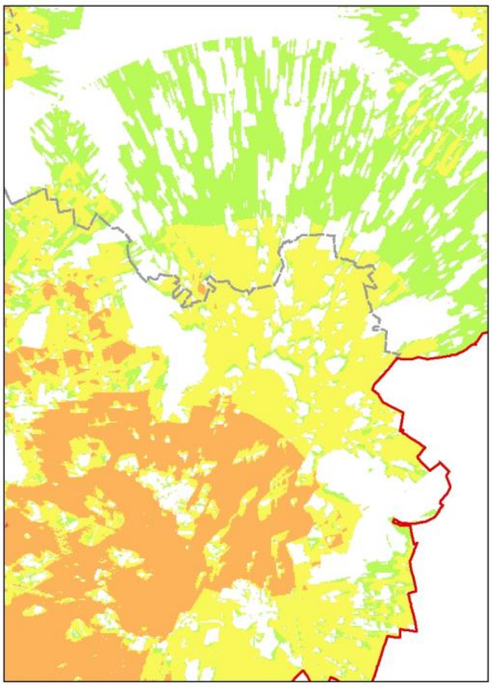

Fig. 11: Uncontrolled development (Worst Case)

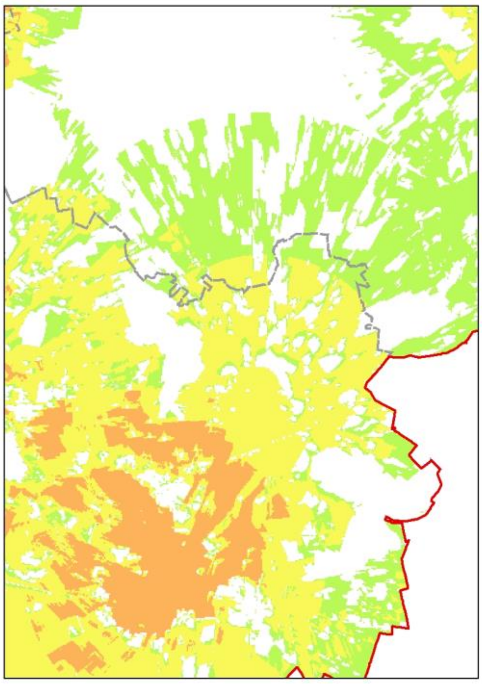

Fig. 12: Vision 2020 – coordinated development (expansion of prioritized areas; dismantling of stand-alone units)

2.2.5 Benefits and impacts for stakeholders

Impact analysis is a tool which enables regional planners to define terrains in which the impact is extensive and also to classify other areas in which the impact is minimal or, indeed, non-existent. Random tests in the field have confirmed the impacts predicted by the analyses, even in localized situations. With impact analysis at its disposal, the district of Diepholz now has a practical tool with which to model the impact of wind turbines on the landscape in a well-founded and easily-understandable manner.

Various scenarios can, with relatively little effort, be examined and their impact on the landscape be clearly shown. For example, the impact of planned wind farms or of alterations within existing prioritized areas can be depicted by simply changing the appropriate parameters i.e. location or height of the wind turbines.

The regional planning department of the district of Diepholz uses this tool not only for the spatial evaluation of new locations but also in political forums to present the impacts of planned developments. The political decision-making process has benefitted from the possibilities offered by the visualization of the impacts and, particularly, the ability to depict a variety of scenarios.

References

KNIES, J. (2011): Visibility analysis as a tool for regional planning in the context of repowering.

2.3 An energy database - laying the foundations for local community action plans

2.3.1 Context (regarding the general project)

Due to rising energy costs, scarce resources and climate change all possible technical and economically feasible solutions for energy saving must be exploited. In the field of building re-development and renovation lies also a huge potential for the reduction of green-house gas emissions. House-owners need access to qualified, reliable advice. If individuals take action in energy saving, it has a cumulative effect from which local communities themselves may benefit. Hence, the goal is to bundle information processes to give easy accessible information. At Jade University of Applied Sciences a concept for an energy data base has been developed which can be used for providing independent advice to house-owners in the case of a planned energy renovation. A data-base created by the community of Ritterhude, North Sea SEP sub-partner in Germany, has been taken as a basis and was customized to meet the project requirements. The concept responds to the requirements of the EU building guidelines (Guideline 2010/31EU) on overall energy efficiency of buildings. It provides pragmatic approaches for implementation: “The recommendations included in the energy performance certificate shall be technically feasible for the specific building and may provide an estimate for the range of payback periods or cost-benefits over its economic lifecycle”.

2.3.2 Participants and involved parties

The study was carried out by Jade University of Applied Sciences in cooperation with the community of Ritterhude, which is located close to the river Weser in Lower Saxony, Germany.

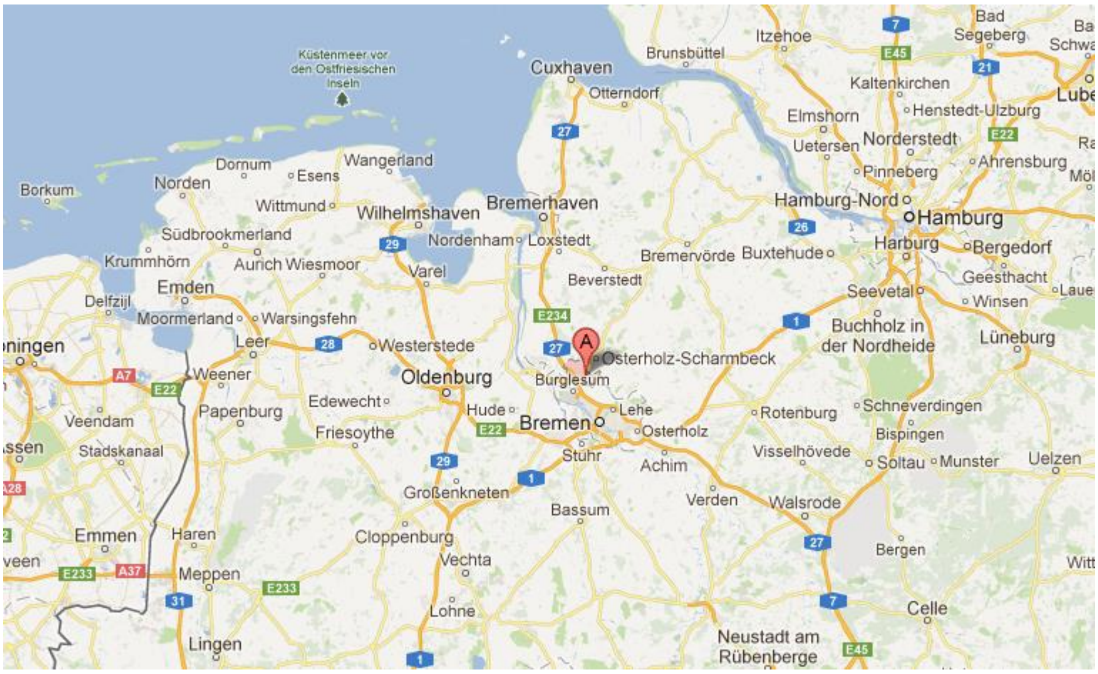

Fig. 13: Location of Ritterhude in Germany. Source: GoogleMaps

2.3.3 Activities

As part of the integrated climate protection concept drawn up by the community of Ritterhude in 2000, a data-base was created which lists the heat-energy requirements of private households in the community. This was calculated on the basis of house-plot areas taken from the land registry, population figures from the citizens' registry office as well as estimates for heat requirements. The results are therefore only extrapolated values for energy requirements and have not been checked against real consumption data.

In addition, information about roof construction and orientation were also recorded in order to gauge the approximate potential for solar energy exploitation. Since that time the database was not updated. The community of Ritterhude foresees significant demographic changes leading to new life-style patterns and wishes to meet the demands with new and attractive housing solutions. The community intends to make independent energy advice available to all private households and thus support and encourage reconstruction work that may be necessary. The data-base provides the advisors with the basic information they need to answer citizens' enquiries. At the same time the data-base should be improved to allow consumption figures, building renovation status and improvements (for example, new heating installations) to be recorded and processed.

The aim was:

- to provide high-quality energy advice over a long time-span (documentation of advice given and measures taken)
- to make a comprehensive estimate of energy requirements for all the area in question and
- develop a spatial evaluation of energy requirements in order to identify specific, local issues, pool resources and exploit new forms of energy generation and usage (combined heat and power units, distance heating and heat recovery from waste water etc.).

Of particular importance is that the scheme can be, made transferrable to the needs of other national and transnational municipalities.

2.3.4 Key findings

In the next step a model for a database will be developed. It will include a spatial analysis and support function and should fulfill the following criteria:

1. A central database with open access for personnel in the advice centers.
2. Spatial analysis and support tools using internet-based geographical information systems (Web GIS-Technology).

These two applications are to be linked so that, following every analysis, spatial information can be added to the database. It will also be possible to graphically represent (in the form of maps) database information according to selected criteria.

The data (geographical features and attributes as well as meta-data) will be stored and interlinked in a data-base. The data should be structured in such a way that redundant information is avoided so, for example, standardized orthography of place and street names is essential.

Moreover, the reference values for the specific heat energy consumption for various building types and hours of occupation will be included. The energy data-base of Ritterhude calculated specific heating energy requirements using the thermal insulation regulations valid at the time and adjusted for the age of the building. These values are given in three ranges (from …to) for each type of building. The model should take into account new developments such as the German energy saving regulations of 2009 (ENEV 2009). To assist in the classification of building types, the guide “Gebäudetypologie Deutschland – Stand 2003“ (German building types – 2003) (IWU 2003) will be used. It may, however, be necessary to make adjustments for regionally specific building types and for reference values to take regional particularities into account.

2.3.5 Benefits and impacts for stakeholders

The actual situation in local communities varies immensely. Currently, some integrated energy and climate protection concepts are providing some initial data for the heating requirements of houses. In exceptional cases, spatially-specific heat requirement data is available. The content of the energy data-base of the community in the investigated community constitutes a good basis which can be expanded in the course of client consultations. Other local authorities can, in a similar way, make use the data-base- framework for recording client consultations and can, in this way, build up a rudimentary data-base. In conjunction with the GIS analysis of the building stock quickly provides a community with an overview of the spatial distribution of the local heat requirement.

Depending on the local situation, the energy data-base can be usefully employed by local authorities in a variety of ways, but the success of the scheme can only be ensured if all stakeholders work closely together:

- local authorities,
- energy suppliers (e.g. public utility providers),
- energy advisors and
- other local companies

Data protection regulations must, of course be observed but depending on the specific structure of each scheme, it would be possible to grant read-and-write data-access to the staff involved. In rural areas it makes sense for groups of local authorities to work together to spread the work-load.

References:

KNIES, J. (2010): An energy database – laying the foundations for local community action plans.

2.4 A GIS model to estimate the sustainable potential of forest fuel in Växjö

2.4.1 Context (regarding the general project)

The Swedish NREAP (National Renewable Energy Action Plan) aims to extend renewable energy sources to make out 50% of the total nationally provided energy by 2020. Växjö, a municipality located in the province of Kronoberg in Southern Sweden, even wants to surpass those goals and create a fossil fuel free city until 2030. The city once has been awarded the title "The Greenest City in Europe" by the British BBC back in 2007, because of the city's efforts focusing on building a renewable energy future since the 1970's, including the establishment of a district heating system for the city in the 1980's. The heating system is run by a combined heat-and-power plant (CHP), which produces heat and electricity and almost is powered by wood alone.

2.4.2 Participants and involved parties

The study was conducted by Jade University of Applied Sciences and the municipality Växjö located in the province of Kronoberg in Southern Sweden.

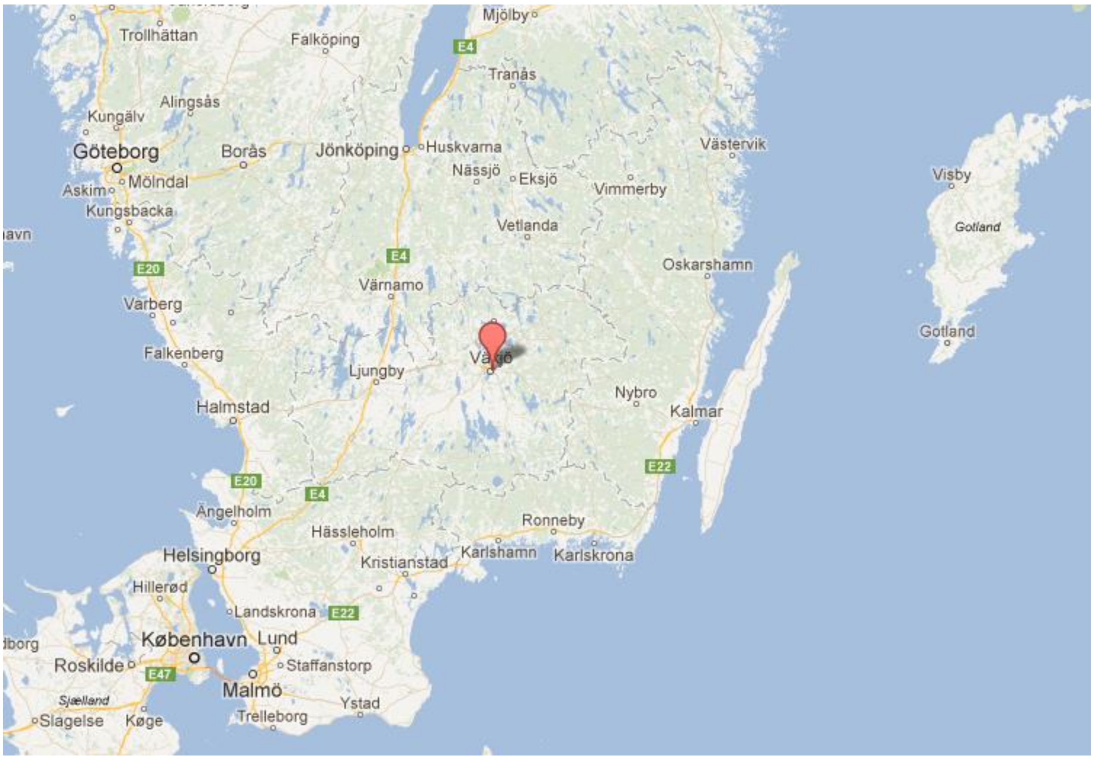

Fig. 14: Location of Växjö in Schweden. Source: GoogleMaps

2.4.3 Activities

The aim of the project was to find out if the municipality of Växjö was able to be self-sustainable by only relying on the wood from within its own municipal borders until the year 2050. A geographic information system (GIS) would be used to set up a model using spatial and temporal factors for an analysis.

In this study the term forest fuel, which was the goal of this biomass potential analysis, described primarily forest fuel, which describes forest wood that is directly obtained from the forest for its usage as biofuel.

The RESEARCH STUDIOS AUSTRIA (RSA) in Salzburg developed an approach, which was used in this project, about how to generally model the biomass potential in a top-down strategy: the theoretical potential (sustainable biomass potential without any disturbing factors), the technical potential (introducing technical limitation) and a reduced technical potential (modeling losses during the energy conversion process).

About how much biomass single tree components contained an extensive study has been carried out, including taking hundreds of tree samples, dividing and weighing the trees' components and setting up biomass functions for each tree component. In 2006 some of those functions have been revised.

Other background researches included the definition of a sustainable forestry management style, as well as analyzing the energy balance for the municipality of Växjö to be able to compare the modeling results to actual energy figures to draw significant conclusions about the self-sustainability of forest fuel within the municipality.

The most fundamental dataset for this project was a digital, geographical forest coverage dataset called kNN-Sweden from 2005. It included "continuous estimates of specified forest parameters, such as total wood volume, wood volume by tree species, stand age, and above-ground tree biomass". Field plot data obtained by the SWEDISH *NATIONAL FOREST INVENTORY* (NFI), by the help of satellite images and topographic maps, were therefore interpolated by using the k-Nearest Neighbor. Also digital topographical maps (provided by the Swedish mapping, cadastral and land registration authority Lantmäteriet) were used in the project. The energy balance for the municipality of Växjö (delivered by the North Sea SEP project partner ENERGIKONTOR SYDOST) delivered extensive numerical energy data for the years of 1993 until 2009.

The modeling process was divided into five steps:

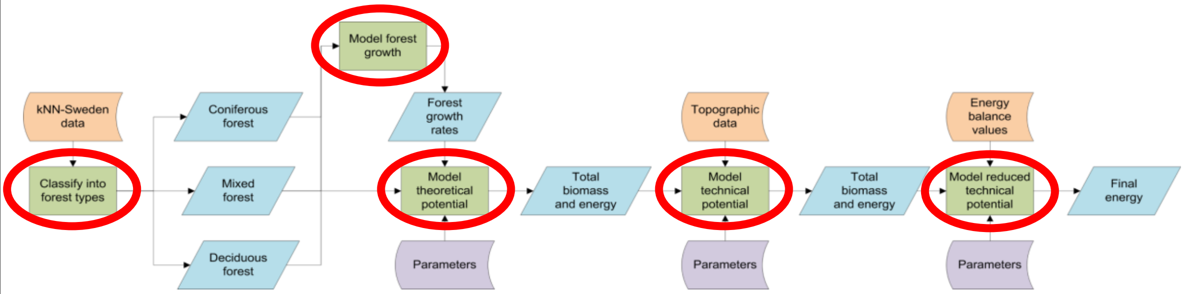

Fig. 15: GIS model design.

First the forest was classified into three different forest types, namely coniferous, mixed and deciduous forest according to a threshold value.

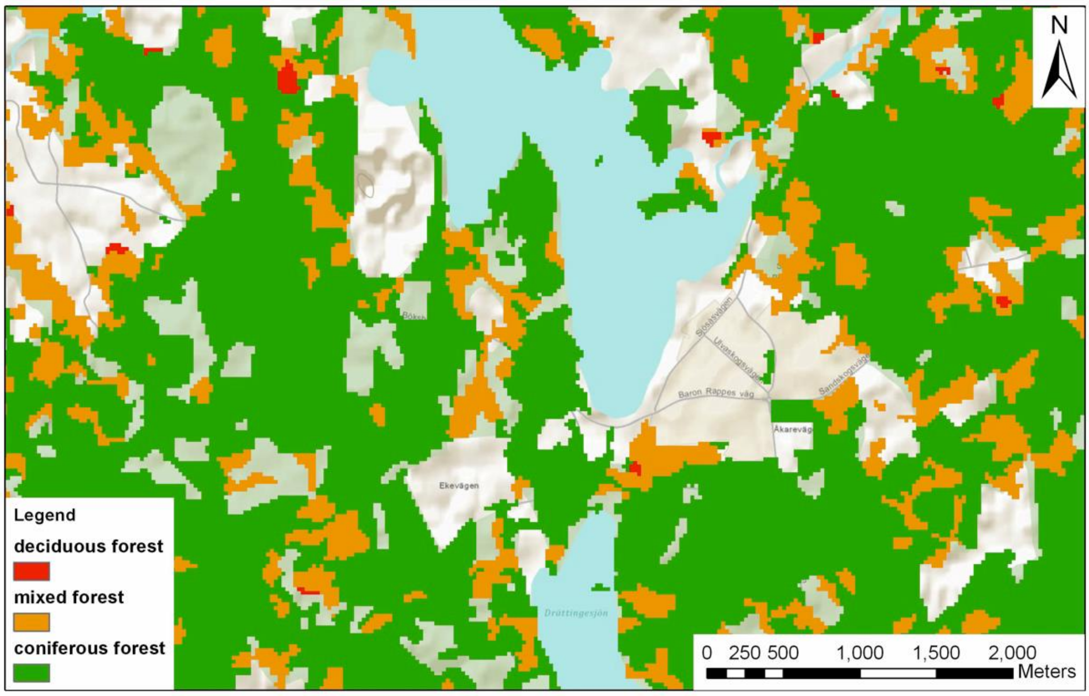

Fig. 16: Step 1: Forest classification.

The **second** step was to model the forest growth until the desired date that should be modeled. The growth function for each forest type was hereby determined by a regression function which was created based on assumptions mainly using the age and biomass variable from the kNN-Sweden forest dataset to perform a regression analysis.

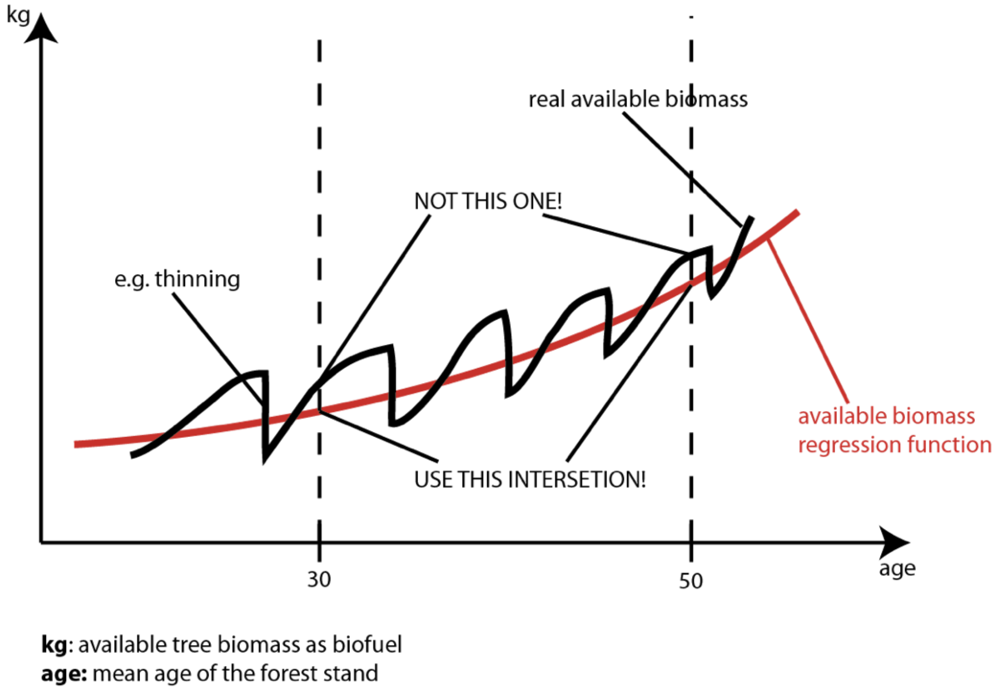

Fig. 17: Step 2: Forest Growth.

The **third** step marked the first of the biomass potential models called the “theoretical potential”. A default forestry style was defined here, so that it could be determined how much forest fuel could be theoretically obtained in a particular year. This forestry style already has to be sustainable.

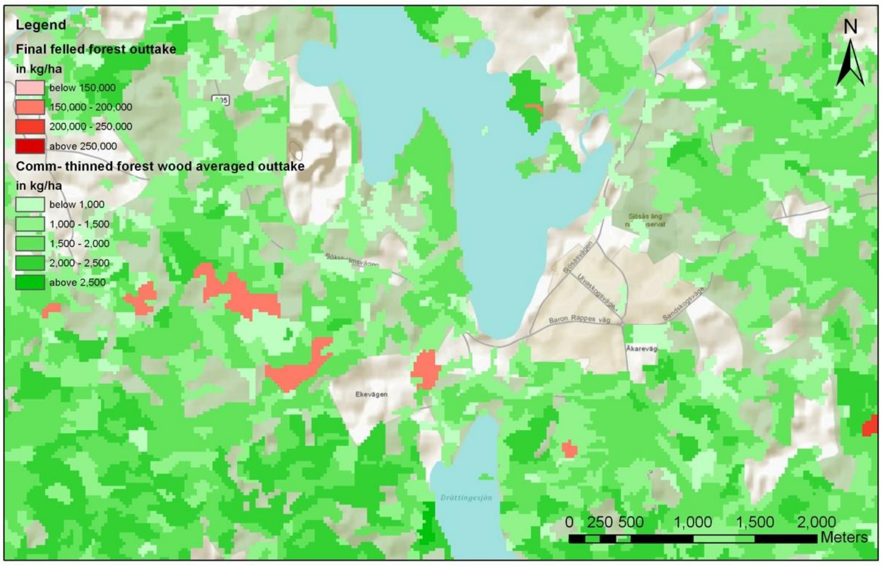

Fig. 18: Step 3: Theoretical potential.

The **fourth** step marked the “technical potential”. In this step all technical parameters which would affect the forest fuel outcome are applied. Those included topographic features (slopes, distances to forest access roads and the exclusion of natural habitats), competition factors (timber and paper industry), as well as the optional harvest of stumps and roots.

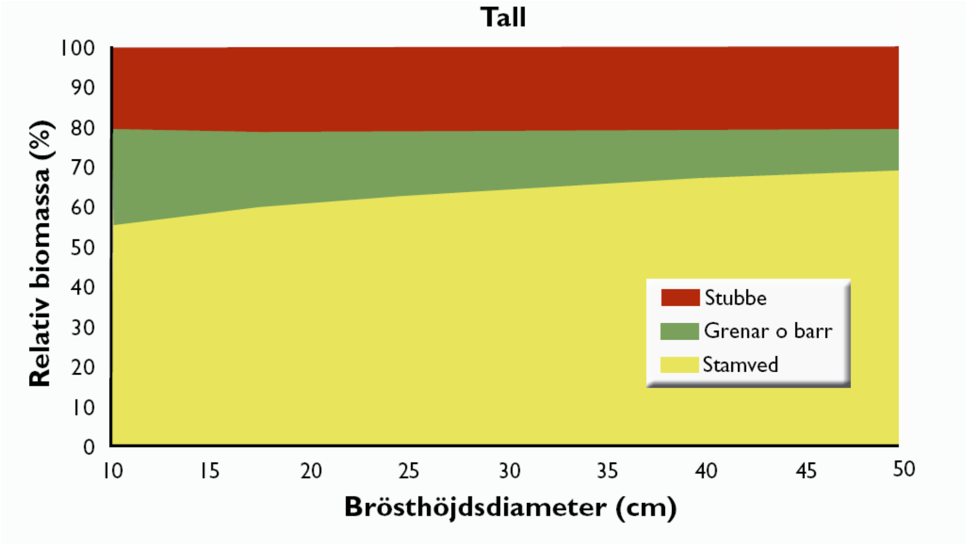

Fig. 19: Step 4: Technical potential (1); Source: G. Egnell. Skogsbränsle (Forest fuel). Skogsstyrelsen, 2009.

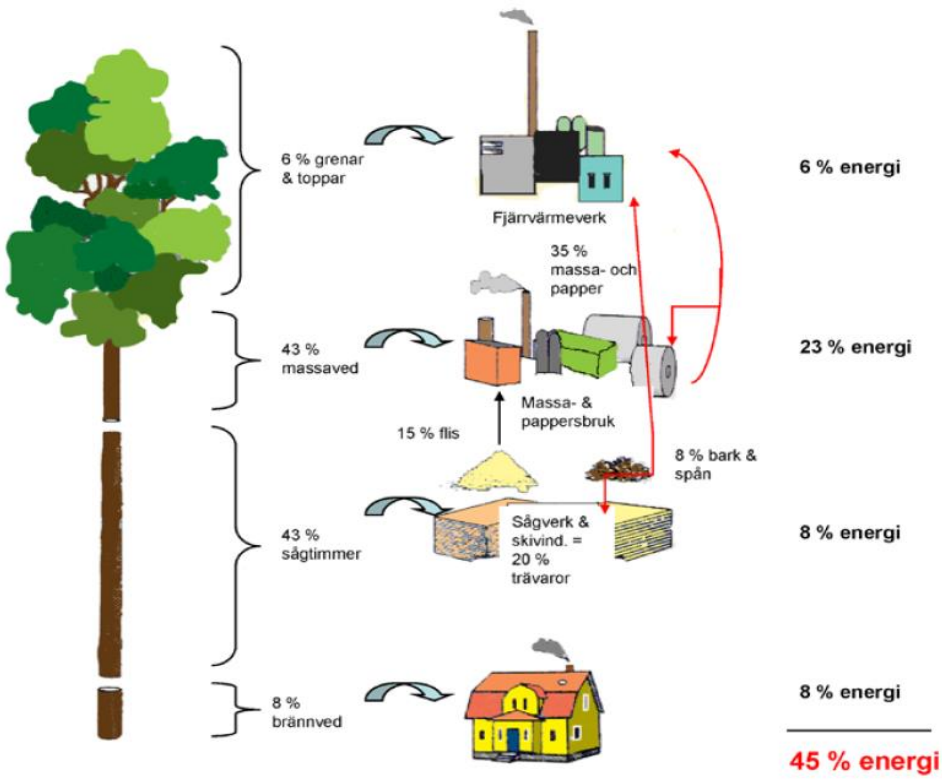

Fig. 20: Step 4: Technical potential (2); Source: Biobränsle från kogen Tillgång och efterfrågan (Biofuel from Wood - Supply and damand). Skogsindustrierna.

In the **fifth** step, the “reduced technical potential”, the primary *energy* (the theoretical energy before the energy conversion process) was transformed into final energy (the usable energy that arrives the customer). This included modeling the losses that occur during energy conversion and transportation.

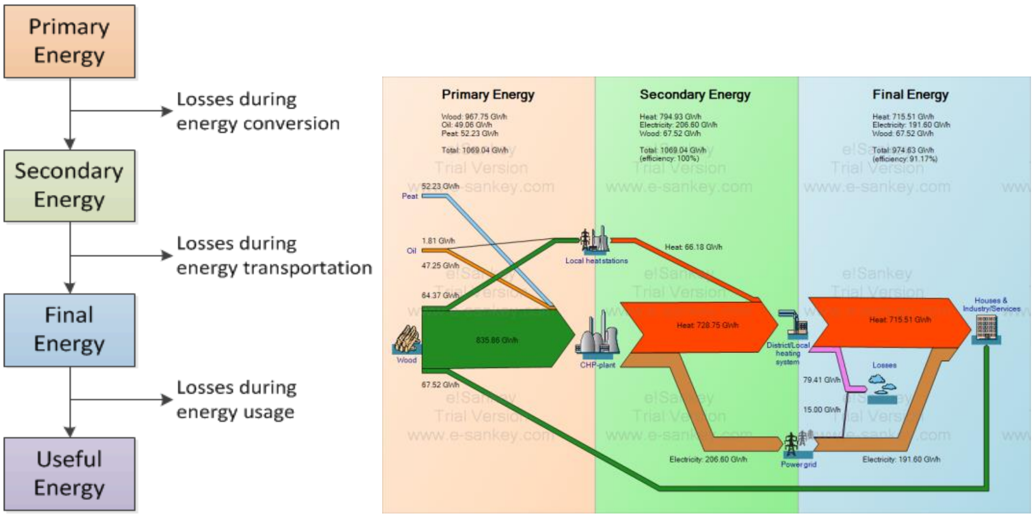

Fig. 21: Step 5: Reduced Technical Potential (1).

2.4.4 Key findings

The result shows that the municipality of Växjö should be able to satisfy its demand for energy wood from harvested forest wood alone until around the year 2035, but might have shortages afterwards until the year 2050. This thesis concludes that for the next 40 years the Växjö municipality should not only rely on its annually available forest fuel capacity, instead, different wood resources have to be utilized or forest wood from surplus years have to be stored for future tighter years. The study also concludes that the estimation of the forest fuel potentials highly depends on the accuracy of the input data. It is advised to treat the numerical modeling results for a large region with caution.

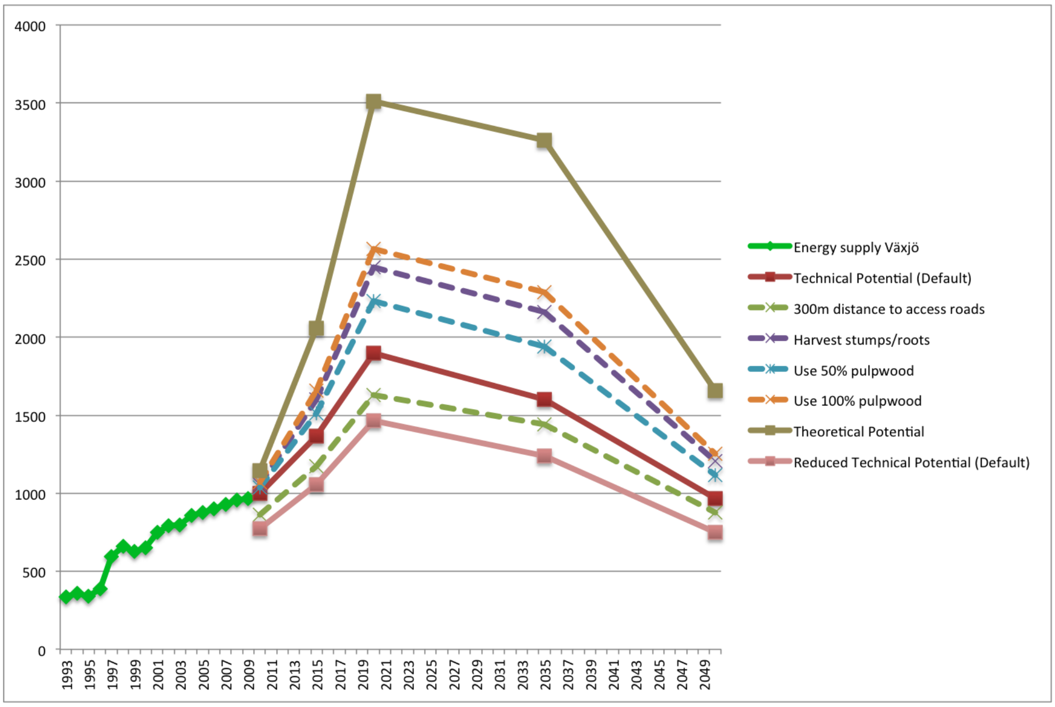

Fig. 22: Final results of forest fuel potential modeling from 2010 to 2050.

2.4.5 Benefits and impacts for stakeholders

Stakeholders benefit from the results of the sub-project in the way that secure information on one extremely relevant element of the future energy mix in Växjö are made available. Supply and demand can be sketched and calibrated according to regional biomass potential. Moreover, different strategies and scenarios for future forest energetic potential may be discussed. Hence, GIS based analyses play a vital role for decision makers regarding the turn towards renewable energy which cannot be imagined without considering spatial aspects.

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WOHLETZ, G., KNIES, J. (O.D.): A GIS model to estimate a sustainable for forest fuel for energy generation in the municipality of Växjö, Schweden.

2.5 *GIS concept for heat exchanger in the sewage*

2.5.1 Context (regarding the general project)

Both old and new buildings, whether isolated or not, have one issue in common: Energy losses caused by waste water. Hot water runs in the sewage which was formerly used in dishwashers, washing machines, showers and so forth. The question is how to technically exploit the inherent heat energy. Since a couple of years, increasing efforts concentrate on heat exchangers in the sewage. Research and development have produced promising new options for tackling the hot waste water issue. The combination of heat exchangers and heat pumps can be a solution to generate energy. GIS are used to identify suitable locations to place heat exchangers.

2.5.2 Participants and involved parties

The study was conducted by Jade University of Applied Sciences, IRO GmbH and the municipality of Osterholz-Scharmbeck in Lower Saxony, Germany.

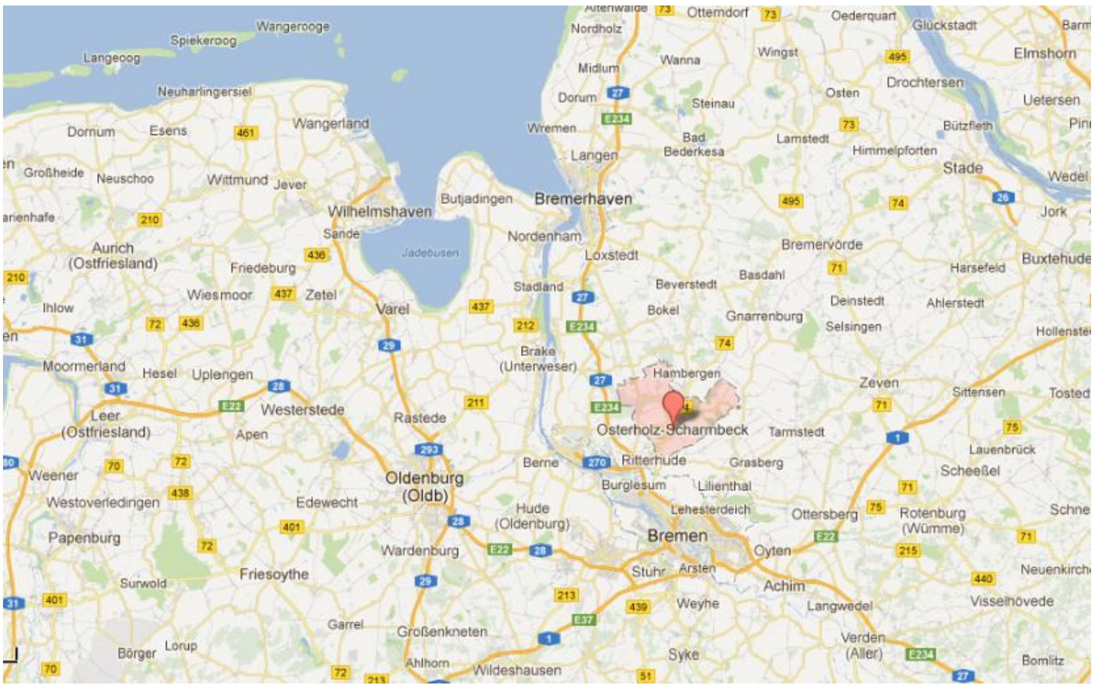

Fig. 23: Location of municipality Osterholz-Scharmbeck in Germany. Source: GoogleMaps

2.5.3 Activities

Heat exchangers were formerly constructed for larger sewage diameters of more than DN 300 (diameter = 300mm). A new generation of heat exchangers makes it possible to equip canals with smaller diameters. Moreover, it is today now possible to equip not only new canals with heat exchangers, but also existing ones during rehabilitation works.

At IRO GmbH in Oldenburg, two test facilities were installed in order to examine the new options (Fig. 24). Based on measurements in the community of Osterholz-Scharmbeck it was tested how the heat exchanger could work in relation to different locations. A feasibility study shows how an installation in Osterholz-Scharmbeck could be facilitated.

Hence, sewage parameters of the community were implemented in a GIS and evaluated regarding the requirements of heat exchanger solutions. With the help of GIS analyses, the individual local potential for heat exchangers was visualized.

Fig. 24: Test facilities at IRO GmbH.

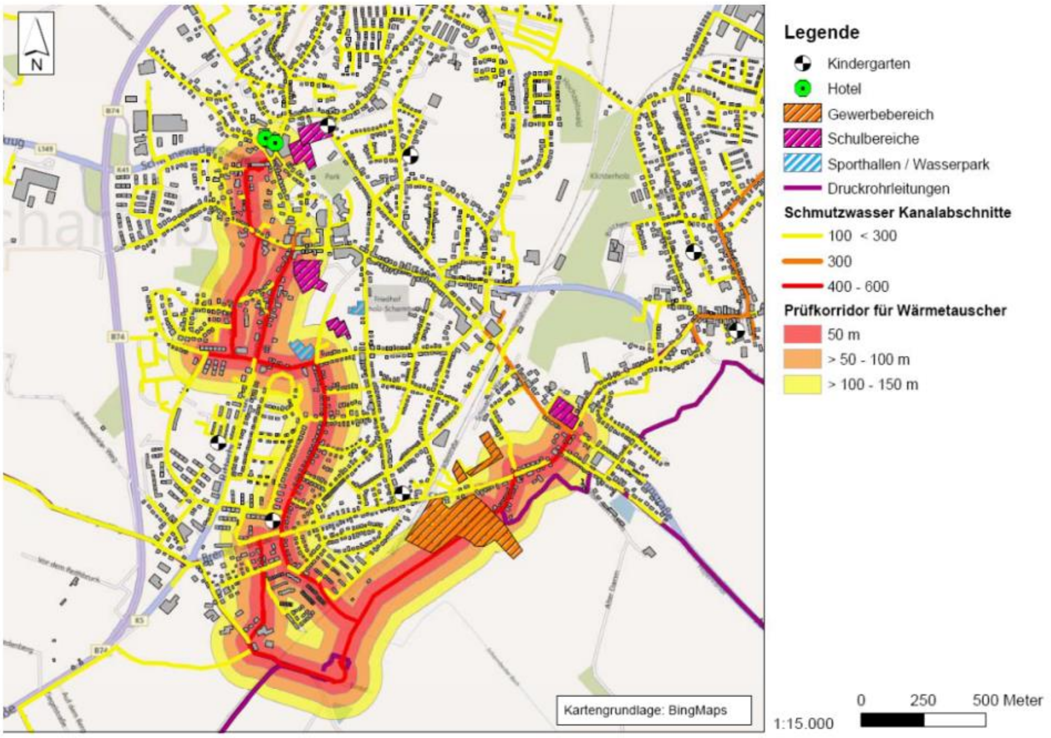

Fig. 25: Visualization of the energetic usage of waste water potential for heat exchangers in Osterholz-Scharmbeck, Germany.

A decision support model was developed which acts as basis for the implementation and installation of different heat pump technologies.

2.5.4 Key findings

Apart from new technical options in relation to heat pumps and sewage technology, the project proved the vital importance of GIS applications. Geographical Information Systems help to spot ideal locations for technology deployment and hence is an indispensable tool for all planning and completion stages.

2.5.5 Benefits and impacts for stakeholders

Based on GIS decision support, involved actors like investors, communities, residents and engineering companies have better access to visualized information. It is obvious and well known that decision making may be easier using good maps and charts. During discourses between actors GIS help to spot ideal locations for heat exchangers and to detect heat potentials in the sewage system.

References:

BÖGE, M., KNIES, J. (o.D). Abwasserwärme für Kommunen – Konzept und Umsetzung im Interreg-Projekt "Sustainability Energy Planning".

BÖGE, M. (2012): Analyse eines Wärmetauscherprototyps zur Rückgewinnung von Wärme aus Abwasser.

2.6 Potential study for wind energy use in the Aberdeen City council

2.6.1 Context (regarding the general project)

Wind turbines have an ambivalent impact on public discussions: On the one hand, wind turbines significantly contribute to a renewable energy mix. Onshore and offshore facilities help to replace fossil power plants and avoid CO2 emissions. On the other hand, due to their height wind turbines are visible in large areas and influence or in the worst case destroy historical sceneries. Hence, visibility analyses play an important part in energy planning. Geographical Information Systems (GIS) can be appropriate tools to conduct so called view-shed analyses.

The Scottish Natural Heritage organization (SNH) defined prerequisites for the analysis, collection and evaluation of wind turbines on local sceneries. In this sub-project, the planning process of nine wind turbines near Penbreck, seven turbines in South Lanarkshire and two turbines in East Ayrshire started. The project site is situated about 6 km south of Muirkirk, East Ayrshire, adjacent to the coniferous Penbreck/Carmacoup Forest. Open Plateau Moorland extends Westwards of the proposed site. One of the turbines is situated within the adjacent Muirkirk & North Lowther Uplands SPA and the Muirkirk

Uplands SSSI. The area is sparsely populated. Site selection followed technical conditions, environmental sensitivities, planning policy and wind farm local guidance. It is situated predominantly within a Potential Area of Search for wind farm development, according to the Glasgow and the Clyde Valley Joint Structure Plan 2006. The 9 turbines will be of 3.0 MW generating capacity each and a maximum height to blade tip of 125 m. Further development comprises new and upgraded access tracks, a temporary site compound and borrow pits. For the connection to the electricity grid system a substation and an accommodation unit would be necessary. The grid connection and substation does not form part of this application but will be the responsibility of Scottish Power. The proposed wind farm is designed with an operational life of 25 years.

Access to the wind park is possible from the North via the A70, and according to contractual agreement with the neighbors via the heavy-duty road to be built by Scottish Coal plc (connecting the A70 to Carmacoup forest) on the property of the client.

2.6.2 Participants and involved parties

Apart from local authorities the study was conducted by Jade University for Applied Sciences [and ARSU GmbH in Oldenburg].

2.6.3 Activities

With the help of ArcGIS - "a complete system for designing and managing solutions through the application of geographic knowledge" (ESRI: 2012) - and the 3D visualization model was constructed wind turbines were placed on top of the surface. The viewer gets a first impression of the local situation (Fig. 26). Various limitations resulting from limited financial and personal resources need further investigation to generate a full visualization of the planned investment:

- Land cover has to be visualized,

- the dimension of turbines may have to be flexible,
- the turbines have to be made visible in 3D and
- the blades have to be mobile (-rotating).

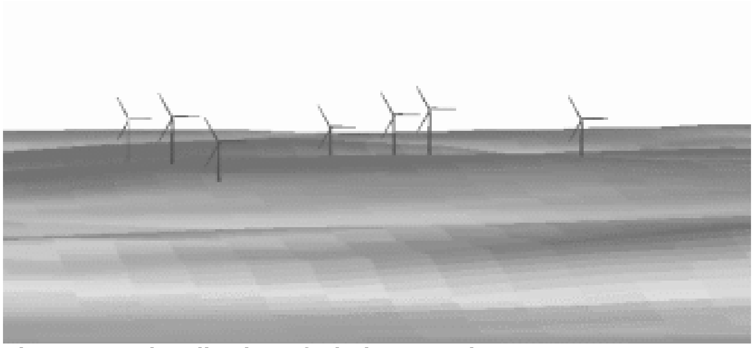

Fig. 26: 3D-Visualization of wind power plants

2.6.4 Key findings

GIS may help to foster the participation of citizens in every stage of the planning, building and operation process. Maps or 3D visualizations act as perfect media for public discussion and decision making on all levels.

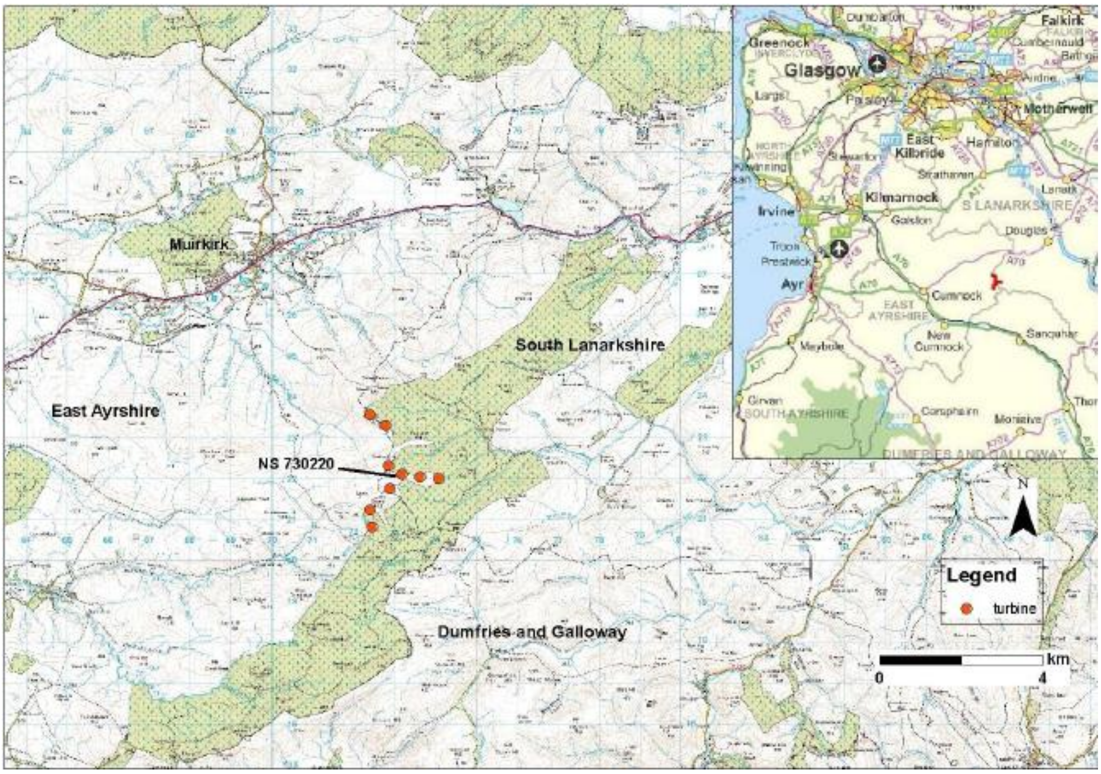

Fig. 27: Indicative turbine positions of Penbreck Wind Farm. Source: ARSU GmbH.

2.6.5 Benefits and impacts for stakeholders

Maps and business charts on the impacts of wind turbines cannot be seen as "results" of GIS, but GIS enables users to quickly generate desired maps and visualizations, often within minutes, if all relevant data are collected and managed properly. Hence, participation processes can be supported, no matter if maps are prepared for the introduction of wind energy planning or if caveat reactions have to be put on a rational basis. It is easy to discuss about maps, but as Mark Monmonier put it, it is also easy to lie with maps.

References:

KNIES, J. (o.D.): Windkraftplanungen in Schottland – Möglichkeiten von Sichtbarkeitsanalysen.

2.7 A GIS-model for the solar potential analysis of buildings

2.7.1 Context (regarding the general project)

Rising prices for energy lead responsible thinking people to look for possibilities to save energy rsp. for alternative technologies to produce energy. Especially solar power plants (PV) to produce electrical energy are such an alternative. The electrical power produced by these plants is one of the technical available alternatives to generate a save energy supply for the future. The solar energy can be used in many different ways:

- roof integrated photovoltaic,
- roof integrated,
- solar water heating or
- open landscape photovoltaic.

This work focuses on the roof integrated modules. Aim of the work is to define a workflow for identifying those buildings inside of a certain region, which are most applicable for installing photovoltaic panels.

2.7.2 Participants and involved parties

The study was conducted by Jade University for Applied Sciences Oldenburg, Germany. The areas of interest in this analysis were:

- Grasberg (Germany)
- Tynaarlo (Netherlands)
- Växjö (Schweden)
- Leiedal (Belgium)
- Dundee (Great Britain)

The areas were selected by the partners themselves based on information from Jade University concerning dimension on structure of the areas. As premise for the areas of interest these should cover the following city characters:

- inner city
- new housing areas
- older housing areas
- business park
- rural area

2.7.3 Activities

The different city characters have been analysed to demonstrate, that these typical areas of a city or municipality can have different results regarding the implementation of solar power plants because of their architecture, shadowing effects and the possible potential for implementing solar power plants.

For the project the technique of photogrammetric, used in several industrial and research sectors, was used, which offers a number of solutions to problems and questions generated during design processes.

In the following image were create a Digital Surface Model (DSM).

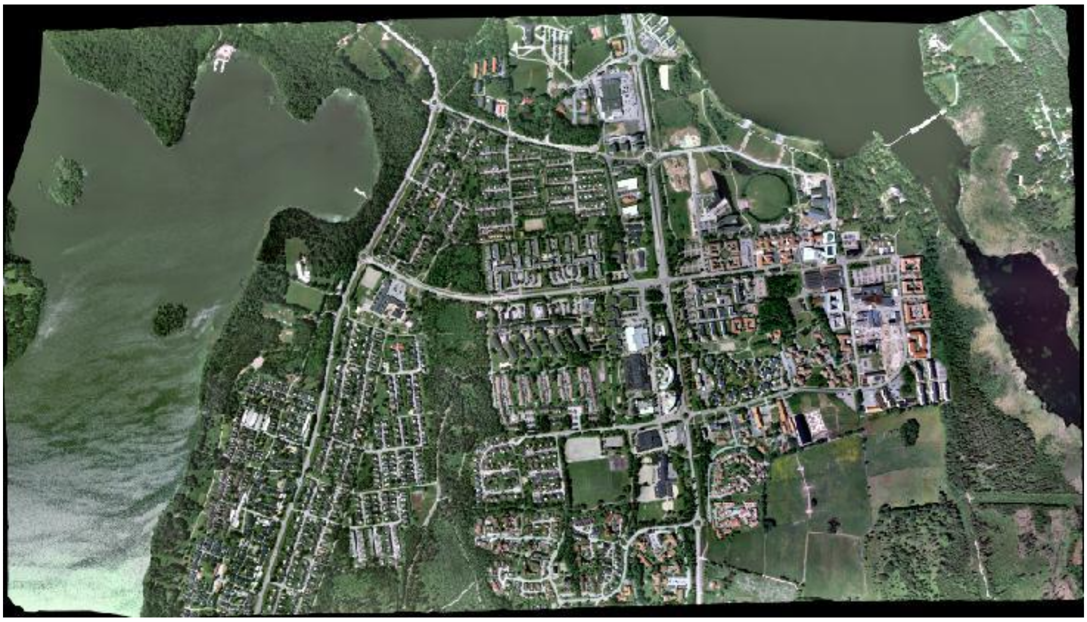

Fig. 28: Digital Surface Model and ortho mosiac (region: Växjö (Schweden). Source: Final Report 4.5 - Photogrammetric Plotting.

During the analysis of the aerial pictures each building can be classified according to the criteria:

- applicable,
- limited applicable,
- not applicable.

For all buildings in the areas of investigation, the characters of the roofs must examined. Therefore a **four-step-workflow** has been developed at the Jade University of Applied Sciences Oldenburg, Germany.

- **First step** is to determine all objects/houses, which are applicable for solar power plants. The result will be a simple red/yellow/green marking of the objects inside a region.
- **Second step** is a more detailed analysis of sub-group of the houses of step one. This will result in information of direction, slope, available area and root-structures.
- **Third step** will be a full-year simulation of shadow an discrete houses.

- **Fourth step** is a detailed object-related measurement and design and a visualization of the planned solar power plant.

The main principle of the analysis is in fact very simple: each house, respectively each roof area is qualified by criteria listed above. As result a point is set inside the roof area and colored in:

- green (applicable),
- yellow (limited applicable),
- red (not applicable),
- blue (no evaluation).

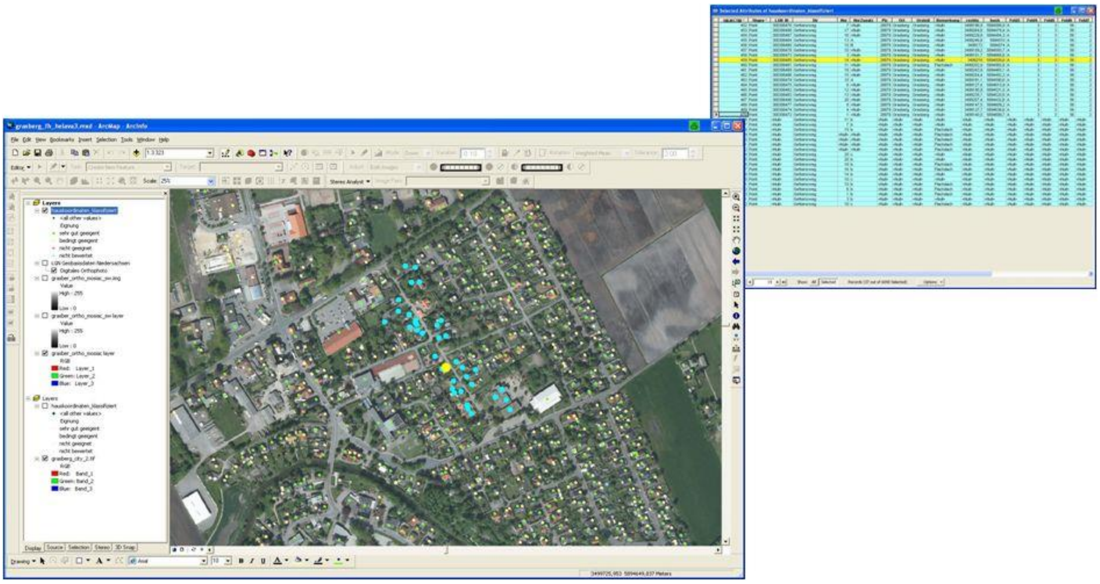

Fig. 29: SQL-selection in ArcGIS.

Spatial and SQL-based queries give support to the user during the analysis. Providing tht the data offers such information it is no problem to identify a special object via street name and house number or by entering the objects coordinates.

Fig. 30: Växjö - possible potential for implementing solar power plants.

2.7.4 Key findings

With this transnational study it could be demonstrated, that the technology to evaluate the regional/local potential for the implementation of solar power plants can be transferred from Germany, where this technology has been developed at the Jade University, to the participating countries. The essential basic information (aerial pictures incl. camera data, address information) are available in all countries.

2.7.5 Benefits and impacts for stakeholders

Based on the results from the evaluation of the local potential for solar power the participating municipalities have used these results to develop strategies for the implementation of solar power plants on their territory. It is possible to calculate the volume of electrical energy, that is processed by the solar power plants and in combination with national/regional legislation incomes for the municipality itself but also for investors can be estimated.

References:
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3 Management Summary and recomendations

Renewable energy facilities need space. No matter if it is biomass, wind turbines or photo-voltaic installations or other technical solutions, the spatial requirements as well as impacts are obvious. Even when dealing with energy reduction or energy efficiency, spatial disparities are important to consider. Geographical Information Systems (GIS) are perfect instruments to manage and analyze locational issues. The same is with energy distribution via existing and/or new establish grids.

The sub-projects in this work package clearly demonstrated the importance of GIS during different stages of the planning and realization of energy related projects and the positive effects on decision making. In order to consider spatial influences on planning and the operation of renewable energy plants, the following recommendations may optimize the process. In general, they match the recommendations published by the German Umbrella Organization for Geographic Information in a position paper on energy turn and geographical information.

a) Transparency for citizens

In all project stages of energy projects, participation and involvement of affected citizens can increase the acceptance of new facilities. Using GIS, scenarios of possible local impacts can be visualized and act as discussion basis to accelerate decision making processes.

b) Optimization of geodata access

Regarding the renewable energy turn, easy and free access for geodata can speed up planning processes and helps to find optimal locations for new facilities. A transnational coordinating and data distribution agency can be a solution to get access to state of the art data.

c) Monitoring

Renewable energy takes place in a rather decentralized form. Thus, impacts of new facilities may cause environmental, economic or social challenges. A continuous monitoring of impacts of renewable energy helps to identify severe interferences or damages.

In general, GIS allows the collection of any spatial and thematic data to implement it in integrated decision support systems. Once all available information is collected, analysis tools enable new perspectives for all involved parties. Hence, as general recommendation, the appropriate usage of GIS are a vital part of renewable energy planning. Due to the fact that GIS and spatial data are not easy to handle, the need for skilled GIS experts to make the information available is obvious. But the interpretation of the information as well as working with the conditioned data must be as simple as possible, so that also non GIS experts are in the position to make use of the systems.

A current problem of GIS is, that there are many different definitions of Geographical Information Systems (GIS). This reflects the prejudice that GIS is a complex topics and is based on the integration of a range of different approaches from a wide variety of academic and professional disciplines. In the further are two definitions of GIS, the first the standard definition from Bill and the second definition from Adams, this definition is understandable and simple knitted.

1. “A Geographical Information System (GIS) is a computerized information system. This consists of software, hardware, data and applications. The task of these system, it the digital capture, editing, saving, reorganization, modeling, analysis and the graphical and the alphanumeric presentation of the data” (BILL 1999).

2. “A GIS is a system containing a spatial database representing aspects of a cultural and physical environment of a particular geographic region together with procedures for analysing combinations of attributes and generating graphical or statical products. The key attribute of a GIS is the integration of geometric and thematic attributes of spatial

objects. Geometric data describes the precise location of an object within its surrounding environment, while thematic data describes the object´s other attributes" (ADAMS 2011).

Adams describes the significance of GIS in the paper "SmartCities - Using Geographic Information Systems to provide better e-services" (an output from the INTERREG IVB project SMART CITIES) especially comprehensible.

"One consequence of the transformation toward a digital society that is largely dependent on information has been the increasing political and economic significance of GIS - especially over the last decade. While GIS are (in principle) as old as human culture, the opportunities provided by recent developments in information and communication technologies provide a wealth of new possibilities and opportunities.
GIS are being used to provide solutions in numerous branches of government service as well as in businesses and industry. Geoinformation technology is being used in surveying, engineering, planning and logistics for the collection, processing, management and presentation of spatial information. The main reason organisations are investing in GIS is their potential to increase efficiency. These systems can be used to help develop and deliver new types of services such as better transportation and service information for citizens.

GIS integrate spatial and other information into a single system that can offer specialised processes for the analysis of spatial problems and questions. In short, GIS technology is for a geographer what a telescope, microscope or computer is to a scientist.

The digitalisation of maps and other forms of spatial information opens new possibilities for GIS to be used to visualize geographic knowledge and to transform geographic information. They provide users with a range of analytical tools that are only provided by GIS to explore spatial relationships in data, including data collection, data modeling, data manipulation, data analysis and data storage.

This combination of both basic and advanced spatial data analysis functions is not found in generic information systems. The functionally offered by GIS is often required to understand and to manage activities and resources for highly specific purposes" (ADAMS 2011).

According to Adams a GIS has the following requirements:

"A GIS strength lies in how it is able to analyze spatial data. This is the major difference between GIS and mapping and CAD-based systems. GIS allow users to access and even manage administrative data (e.g. resource data, taxation data and geographic location, etc.). The procedures and processes listed below are characteristic of GIS.

- Spatially guided data retrieval from a database so that users can search for data according to specific characteristics.
- Regionalization (classification of spatial phenomena, generalization).
- Survey of spatial objects (areas, distances in absolute and relative space etc.).
- Geographic superposition of different topics from congruent and non-congruent models (layer concept) i.e. combined data analysis.
- Neighbor-analysis (e.g. catchment areas, location finding problems).
- Connection and network analysis (including spatial statistics).

GIS can access and manage large amounts of spatial data. Effective data access should make it possible to perform a broad spectrum of interactive queries on the location and associated characteristics of spatial data. The system should to be designed in such a way as to exhibit a large degree of flexibility in order to suit the individual needs of a wide variety of users" (ADAMS 2011).

GIS can enable the efficient manipulation of large volumes of data. There are a number of common query types, for example:

- Where is object A?
- Where is object A with respect to object B?

- How often is object A present within a certain radius around object B?
- What is the value of a function Z at a position X?
- What is the result of a superposition of several spatial objects?
- What is the path of lowest cost, lowest resistance or shortest distance along a defined path P between points X and What is the path of lowest cost, lowest resistance or shortest distance along a defined path P between points X and Y?
- What is present near the points X1, X2, ...?
- Which objects lie near objects with defined characteristics?
- Assuming that the digital model represents a real world scenario, how will a simulated process P develop through time t for a given scenario S?

The latest developments in GIS demonstrate, that by using these developments, decisions with a spatial context can be precipitated much easier. New developments not only allow a 2-dimensional view on the situation but also 3-dimensional perspectives and full visualizations of existing and planned installations. And this allows interested public and affected citizens to have better access to the impact of the planned developments.

In this activity a number of sub projects have been realized together with national and transnational project partners to present new GIS applications especially in the field of renewable energies. During a transnational workshop, which was part of this activity, it could clearly be worked out, that in the participating municipalities and regions GIS seems to be a quite common instrument in the case of spatial planning in general but not for the strategic development of renewable energy applications.

Integrated GIS-tools into the decision making process of renewable energy projects is of benefit for all involved parties. Multidirectional communication between the involved parties possible based on the simple to figure information from easy to handle tools, so that decision making processes can be abridged.

4 Figures

The Interreg IVB North Sea Region Programme

European Community European Regional Development Fund

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