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Use of Environmental Data for GIS-based Risk Assessment of Biogas Plants in Baden-Württemberg

Abstract - This paper illustrates how environmental risks potentially emerging in conjunction with an observed growing number of biogas plants can properly be estimated, integrated and visualized in an overarching risk management application.

On the one hand, due to safety flaws observed in the past, biogas plants have direct environmental risks as they can cause environmental pollution (e.g. groundwater contamination or emissions of methane). On the other hand, environmental hazards such as floodwater or storms are a threat especially to unsafe biogas plants and an enhancement factor of these risks. Moreover, the growing number of plants causes indirect risks for economy – e.g. dependency on dependable operation of or impact on smart grids - and society, e.g. transition to monocultures, over-fertilization or threatened species.

This contribution describes how and which environmental data can support the assessment and visualization of these risks up to the calculation of corresponding risk indicators. The idea is to provide thematic layers for the iNTeg-Risk atlas offered by means of the Web Map Service (WMS) as defined by the Open Geospatial Consortium (OGC). Such a biogas plant layer may comprise information about the geographic position, power and/or gas output, used substrates, security concepts, approvals and observation. It may be combined with further environmental layers describing environmental objects (e.g. nature protection areas), objects at risk (e.g. schools, plants) or traffic flows. Finally, by means of geospatial data analysis, such an integrated geospatial view allows risk managers to evaluate emerging risks caused by biogas plants.

As a prototype implementation based on a few scenarios we provide an interface to the Environmental Information System of the German federal state of Baden-Württemberg, from which the base data used for these evaluations will be drawn. As a next step, this application may be enhanced towards a planning instrument for environmental administrations as well as a communication and information means for the citizenship concerned.

Keywords – biogas plants, environmental information systems, risk atlas, GIS, Web Map Service

1. Introduction and Overview

In this paper, we describe how environmental risks potentially emerging in conjunction with an observed growing number of biogas plants can properly be estimated. We start with an introduction to the operational processes of biogas plants and give a brief classification of the associated risks we want to tackle (chapter 2). We then describe the information that is required to analyze risks which can have effect to the environment, to technological and cultural assets or to humans and human society (chapter 3). In the next step, we look at available sources where we can get this information from; we report on a case study about information on biogas plants in Baden-Württemberg which we have carried out (chapter 4). We then describe how we process the available information in order to support the assessment and visualization of risks in a Web-GIS application (chapter 5). We conclude with a description of the progress we have achieved so far and position the work carried out into the context of our vision of an open architecture for generic and flexible risk management applications (chapter 6).

2. Environmental Risks of Biogas Plants

In a biogas plant (figure 1), biogas is produced by means of anaerobic digestion or fermentation of biodegradable materials such as manure, sewage, municipal waste, green waste, plant material, and crops. Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S), moisture and siloxanes.

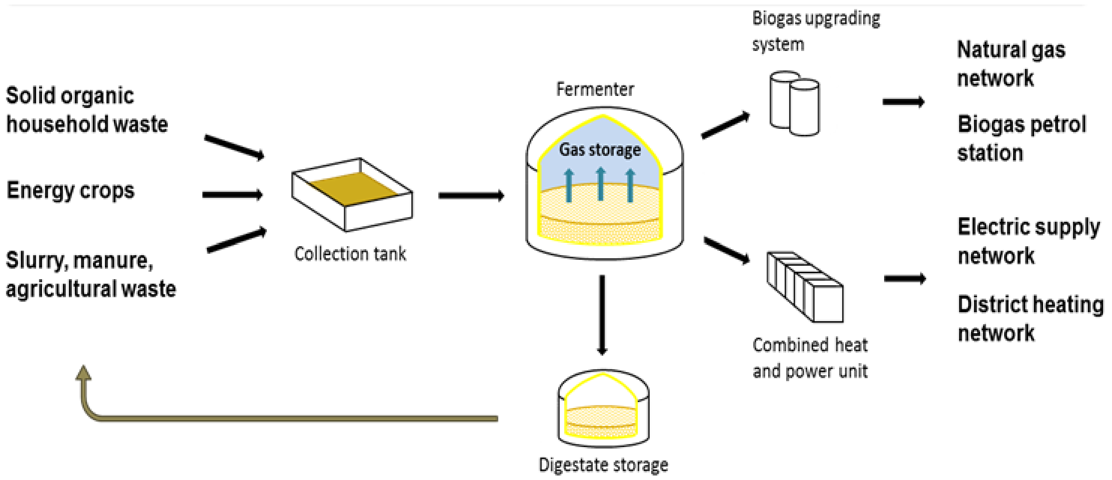

Figure 1: Schema of a Biogas Plant

For farmers biogas plants are rentable investments. The biogas can directly be used for heating the farm, but can also be converted into electricity by means of power units and fed into electric supply networks. Moreover, it may be cleaned and fed into gas networks. In Germany, the law of renewable energies[1] guarantees fixed compensations for producers of electricity from renewable resources.

On the other hand, with the growing number of biogas plants the number of observed flaws and accidents increases [Höflinger, 2012]. Up to now, official statistics are not available, because the

[1] „Erneuerbare-Energien-Gesetz, EEG", see http://www.bmu.de/bmu/parlamentarische-vorgaenge/detailansicht/artikel/erneuerbare-energien-gesetz-vom-29032000/)

damages have not been reported and recorded in central registers. Although numerous directives and building regulations on different levels (state, national, European) exist, the main reasons for their occurrence seem to be ignorance, excessive demands and sloppiness. A problem is that there are just too many regulations which mostly can only be understood by professionals. Training courses are offered – e.g. by professional associations such as the German „Fachverband Biogas“ – but are not obligatory. Höflinger reports on examples of environmental and human disasters which have occurred in the recent past:

- Slurry and digestates flew out into trenches, ditches and lakes and caused contamination and fish kill.
- Gas leaked out of the fermenter and flew into the operating room and sparked the gas mixture.
- Due to incorrect statics calculation, a fermenter collapsed, explosions slurry and debris slipped hundreds of meters away.
- Chemical reactions due to wrong mixtures of digestates caused leakage of hydrogen sulfide and killed four plant workers.

In addition to these risks which originate from the flaws at the plants, environmental hazards such as floodwater or storms are a threat especially to unsafe biogas plants and an enhancement factor of these risks. Figure 2 gives an overview of risks which should be taken into account for risk management of biogas plants:

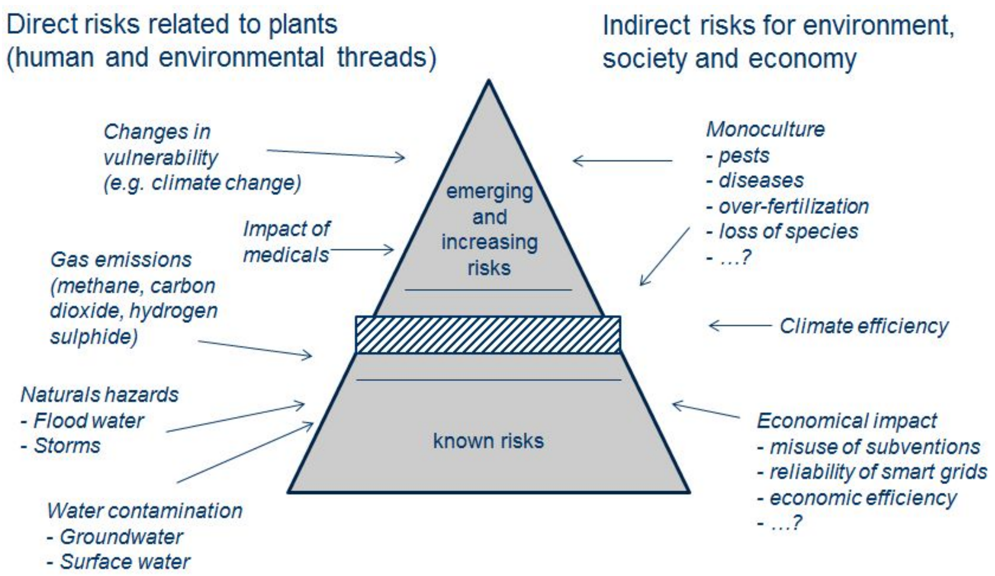

Figure 2: Known, increasing and emerging risks associated with biogas plants

The pyramid in figure 2 indicates that there are known risks, i.e. risks we are just aware of nowadays or where a disaster has already occurred. Certain known risks are expected to increase in the future; a simple reason for this is, for instance, the rapidly increasing number of biogas plants. A special challenge is to identify emerging risks, i.e. risks we are aware of but don’t have sufficient knowledge about, and risks we don’t know today but we want to identify as early as possible. An example is to consider impacts which result from expected changes in vulnerability, e.g. climate changes. The distinction between known and emerging risks is not sharp, i.e. there is an intermediate layer in the pyramid which is preserved for risks we cannot exactly classify for various reasons, e.g. different opinions of experts. A comprehensive definition of “emerging risks” is given in [iNTeg-Risk D2.1.1.1].

Moreover, we can classify risks according to the objects at risk, e.g. environmental risks or risks to human, society or economy. A further approach is to distinguish risks which are directly associated with the plants, e.g. gas emissions or water contamination, and indirect risks which can origin from changes in culture (e.g. transition to monocultures, but cultural change in society as well) and economy, e.g. dependency on dependable operation of or impact on smart grids. This paper focuses on known, increasing and emerging risks for the environment. Our approach is to enable risk assessment by means of geospatial data analysis based upon geospatial and environmental information that is available at various sources.

3. Required Information for Biogas Plant Risk Assessment

According to the risk model of the United Nations Office for Disaster Risk Reduction (UN ISDR, see www. unisdr.org) we consider a risk as the probability and the amount of harmful consequences or expected losses resulting from interactions between hazards and vulnerable conditions (figure 3, right side).

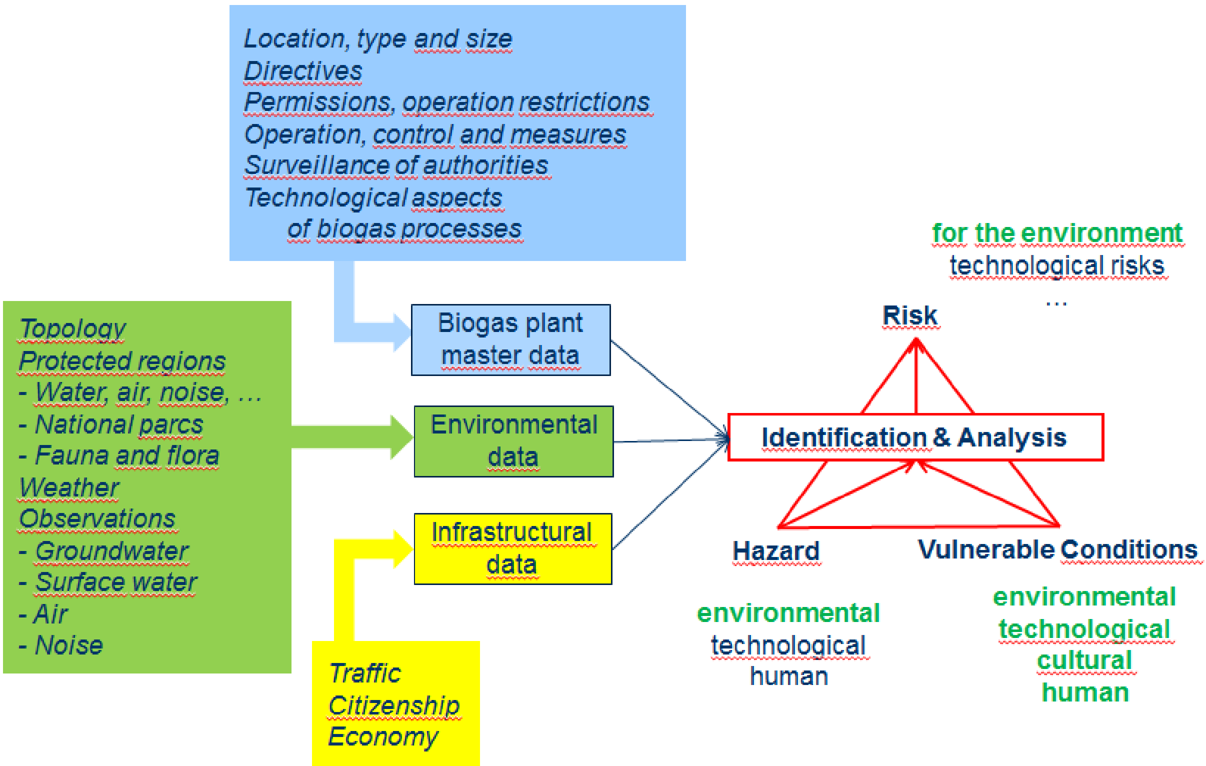

Figure 3: Information Required for Biogas Plants Risk Assessment

In this paper, we focus on the identification of environmental risks. Therefore, we attempt to analyze environmental hazards which can be vulnerable to the environment, to technological and cultural assets or to humans and human society.

Identification and analysis are based on information and data from three areas:

1. We collect information about biogas plants. We describe a biogas plant by its location, its type (e.g. the intended purpose of its use) and its size (e.g. volume of gas and electricity production, number of fermenters and power units, type and volume of raw material). Moreover, we look at aspects of safety, e.g. how the plant is secured against operational failure, which measures of emissions are taken by which authorities and which flaws have been observed in the past. Furthermore, we take into account technological aspects of the processes, e.g. how the raw material is stored and processed.

2. We look at environmental data. We use environment maps to illustrate topology and protected regions enclosed to biogas plants, we use observations and measurements that indicate water and air pollution in the plants' environment. Moreover, possible influences of the weather conditions around the plants are taken into account.

3. We consider infrastructural data, e.g. the traffic streams, the population structure and critical buildings such as schools, festival halls or industrial plants close to the biogas plants.

The idea is to analyze and pre-process these different kinds of information and display the results in aggregated maps such that specific risks become transparent directly or give input to further analysis. This methodology instantly depends on available data of high volume and quality. It is based not only on static data such as topology maps, but also requires incorporation of live data which are available and accessible at specific information systems. Acquisition of environmental and infrastructural data is technologically uncritical, as modern Environmental Information Systems (EIS) have proper interfaces for search and retrieval. The main challenge is to obtain proper information on biogas plants. We have examined the availability of and access to available data in the state of Baden-Württemberg and outline the situation in the next chapter.

4. Case Study: Information about Biogas Plants in Baden-Württemberg

The situation of biogas use in Germany is different from other European countries. According to [ene't 2010], most of the plants are agricultural and municipal solid waste methanation plants.

In Baden-Württemberg, the Institute of Energy Economics and Rational Use of Energy (IER) of the University of Stuttgart has carried out surveys on biogas plants in Baden-Württemberg on behalf of the Ministry of Agriculture (MLR) [Stenul, Eltrop 2010]. To our knowledge, it is the most comprehensive survey that is available today. It is structured according to the subjects of operational characteristics, used substrates, technology, thermal use, economical efficiency and climate efficiency. The surveys were addressed to a representative number of selected plants in Baden-Württemberg.

The survey carried out in 2009 states that about 90% of the biogas plants are associated to agricultural business which mostly operate in mixed mode. The size of the biogas plants does not proportionally correlate to the size of the agricultural business, but stronger. Large biogas plants mostly rely on additional purchase of substrates. The most used substrates are slurry, silage maize and grass silage. The technical status of the plants was estimated as good and they operate very efficiently w.r.t. to electricity generation, however, several weaknesses have been discovered, e.g. failures of the gas engines, mixers and pump systems. About 88% of the plants work at full load. The survey has yielded, that heat use for own business and heat sale as well play a minor role at the conceptual design of biogas plants. Heat sales are only relevant for larger biogas plants.

The surveys carried out by IER mainly focus on technological and economic efficiency rather than on risks generated by the biogas plants or even emerging risks. Aspects such as methane emissions caused by leaks could not be investigated, because this would require measurements, which nowadays are not executed in common operation of biogas plants. It is recommended, that biogas monitoring should be enhanced, not only due to safety reasons, but also in the context of economic efficiency. It is also reported, that only 25% of the digestate stores don't have gas emissions, as only 8% of the minor and 54% of the larger stores have a cover.

Currently, the MLR has the most exhaustive database with information on biogas plants in Baden-Württemberg. Most of the data is not public and subject to official grant for retrieval and further usage. The public data comprises information comprise information on location, performance, electricity feed/year, number and type of power units and date of startup and closedown. An advantage of the database is that it covers most of the plants in Baden-Württemberg (currently around 800).

Data about biogas plants are also available at the EIS Baden-Württemberg. However, currently there are no public data, and the number of plants covered is around 100. A further problem is that filtering the data on biogas plants out of the EIS requires expert knowledge. This data must be selected from all entries which are assigned to an object class that describes all instances related to the 4. BImSchV (Federal Emission Control Act). However, availability and access to data on biogas plants in the EIS will enhance in the near future: the Ministry of Environment is currently carrying out a major survey on security and risks of biogas plants in Baden-Württemberg. The survey is expected to be finished in 2013, and the data retrieved will be entered into the EIS.

Another source of information on biogas plants in Baden-Württemberg is the portal on renewable energies operated by the Ministry of Environment (see http://www.lubw.baden-wuerttemberg.de/servlet/is/223581/). However, the construction of this page is at an early stage and currently only very few biogas plants are covered.

5. Risk Management Application

According to ISO 31000, a risk management application can be described by a set of interworking processes, which can be arranged in three functional groups (figure 4): Monitoring and review, risk assessment and communication and consultation.

Each functional group can be supported by means of specific IT (the green boxes in figure 4): Monitoring and review comprises functions such as data acquisition, assignment of metadata, information gathering and storage and information fusion. Risk assessment is mainly concerned with information processing and can be supported by IT-modules for risk identification, risk analysis, risk evaluation and risk treatment. The communication and consultation part requires intelligent information management and user interfaces.

The iNTeg-Risk project has developed a tool called "Risk Atlas" which isa Web-GIS tool for mapping of emerging and other risks with over 200 layers of data related to hazards and vulnerabilities – e.g.

earthquakes, hazardous materials, industrial plants (refineries, power plants, nuclear power plants), nature protection areas, carbon caption and sequestration plants, etc. The emerging risks can be "recognized" by calculating the risk indicators for hazard-vulnerability pair from the points in the layers, respectively. The IT structure of the Risk Atlas is compliant to the ISO approach described above.

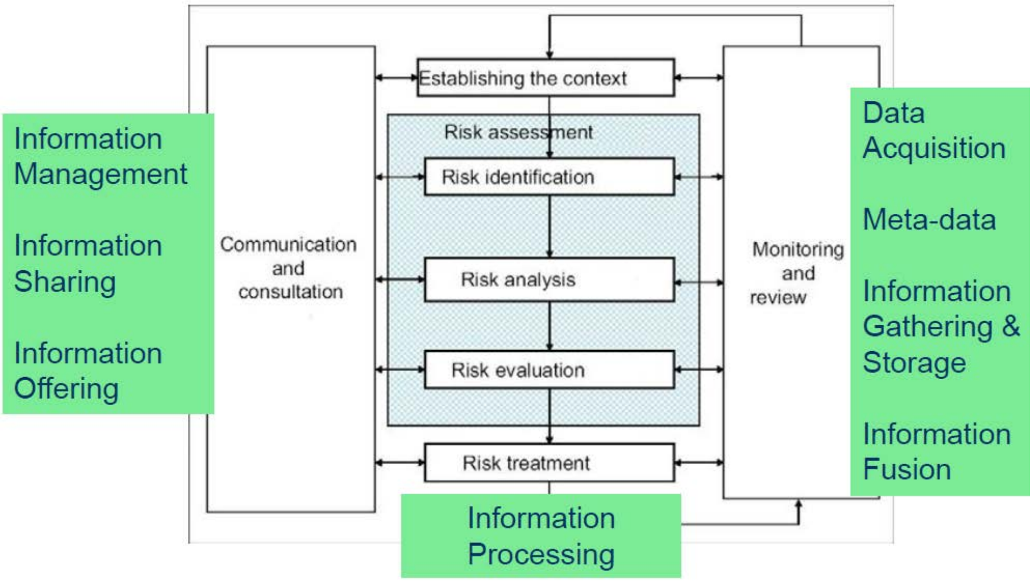

Figure 4: Risk Management Processes in ISO 31000 and corresponding IT-Perspective (green boxes)

For the risk assessment of biogas plants, the Risk Atlas shall be extended with additional functionality in each of the ISO functional blocks (figure 5). Figure 5 shows four layers describing the flow and processing of information:

- The lower three layers comprise the “monitoring and review” functionality according to ISO specific for the aspect of biogas risk assessment. These developments are actually carried out by the iNTeg-Risk partner Fraunhofer IOSB in order to extend the Risk Atlas with information on biogas plants in Baden-Württemberg (as a case study, see above).
- The upper layer contains the functionality for the ISO blocks “risk assessment” and “communication and consultation”. This functionality is available for a number of risk management applications. Some of these applications are application independent and can be re-used for risk assessment of biogas plants. The idea is to provide geographic layers for the OGC Web Map Service (WMS) of the Risk Atlas, which present layered data of biogas plants (e.g. geographic position, power and/or gas output, used substrates, security concepts, approvals and observation etc.) and layers describing environmental objects (e.g. nature protection areas), objects at risk (e.g. schools, plants) or traffic flows. The “risk assessment” part of the Risk-Atlas may then be extended with specific functions for biogas risk assessment. By means of geospatial data analysis tools, this integrated geospatial view will then allow risk managers to further evaluate emerging risks caused by biogas plants.

The work carried out actually concentrates on the lower levels. At the lowest level (level 4 in figure 5), we have the raw data available at various sources as described in chapter 4. In the first step, the database of the MLR will be attached. The data of the EIS-BW Intranet may then be integrated at a later stage, i.e. when the Ministry of Environment will have completed its survey and the EIS-BW will contain a more comprehensive set of data. However, the EIS-BW may provide valuable input in terms of environmental objects (e.g. nature protection areas) and a number of observations and measurements (e.g. water tides, wind, air quality etc.). Moreover, further sources for biogas data will be examined, e.g. at municipalities and administrative regions.

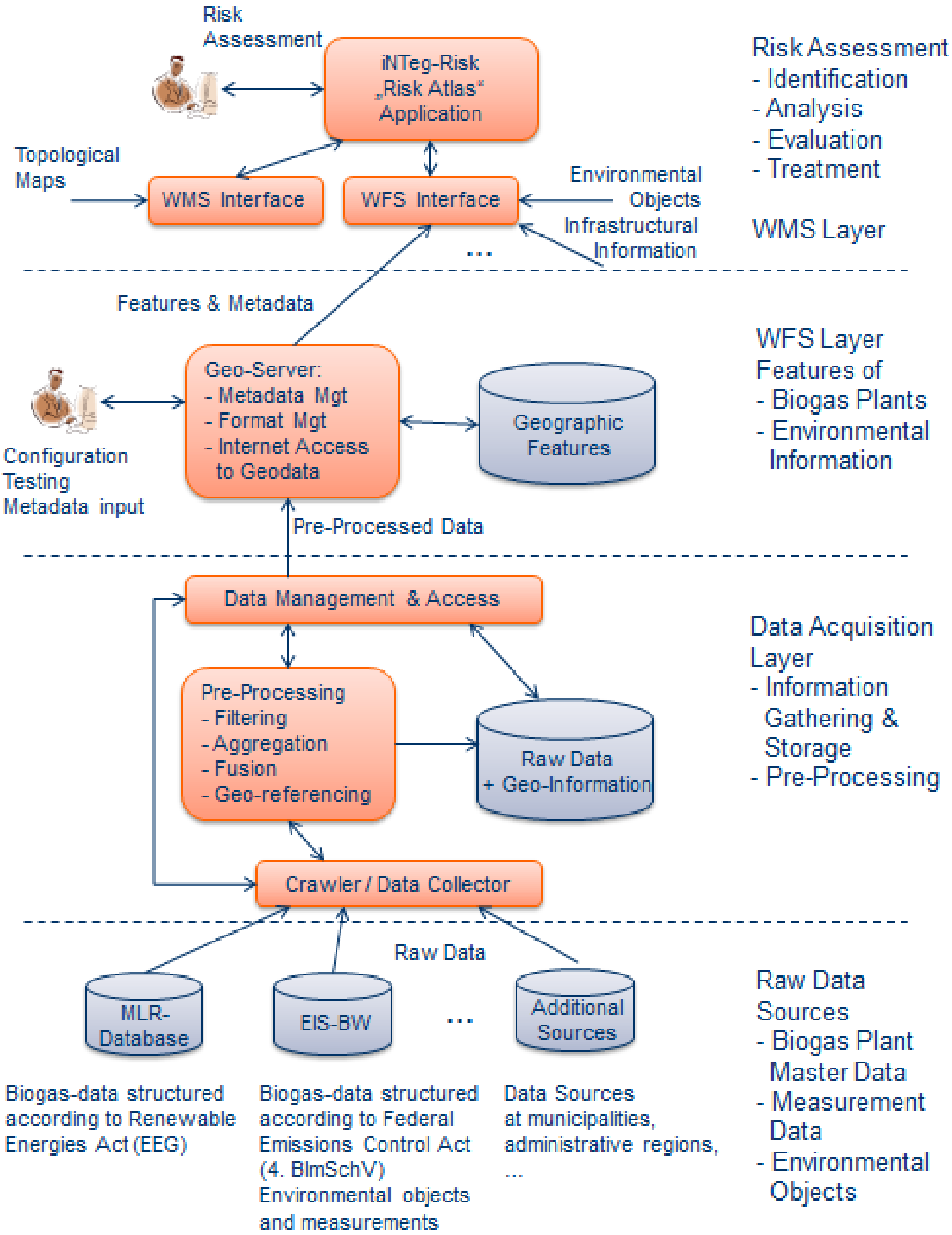

Figure 5: Implementation Architecture for Data Collection and Risk Management Application

The MLR data can't be used directly but need some pre-processing. The database does not offer a direct selection of biogas plants. It is structured according to renewable energies act (EEG) and has further selections w.r.t. specific energies; with the selection "biomass" all biogas plants can be retrieved, but also other biomass plants other than biogas, i.e. at first the biogas plants have to be filtered. Moreover, the data are not geo-referenced, the references have to be computed from available location statements.

The pre-processing is illustrated in the 3rd level in figure 5. Here, the information gathered by various tools for information collection (e.g. Web-crawler, data collectors) is pre-processed and stored in an intermediate database (e.g. an SQL database) and can properly be managed and accessed. This database contains geo-referenced raw information.

On the 2nd level, the Web Feature Service (WFS) level, the geo-referenced raw information is retrieved on demand and transferred into a GIS-format which can be directly presented as layered information in a Web-GIS application. The Risk Atlas prefers the OGC Keyhole Markup Language (KML) to describe the information to be presented in GIS-layers, e.g. in Google Maps. Moreover, metadata and legend data describing what is presented in the layers must be attached. This layer is implemented by means of a GeoServer (see http://geoserver.org) instance operated at Fraunhofer IOSB. It contains a database with geographic features made available by means of the OGC Web Map Service (WMS) and Web Feature Service (WFS) interfaces. Hence, these features can be accessed from any Web-GIS application supporting OGC interfaces. Among others, it can directly provide layer information in KML format to the Risk Atlas.

On the 1st level, the Risk Atlas provides the functionality according to ISO 31000 for "risk management" and "communication and consultation". It presents user interfaces specific for biogas risk management with a proper legend. On a user demand, the Risk Atlas requests the layer data from the IOSB GeoServer via its WFS interface. Further on, the Risk Atlas combines the layers with the information on biogas plants with other layers it retrieves from external services via its Web Map Service (WMS) interface, e.g. infrastructural information, environmental information or topological maps.

6. Conclusions

The work carried out for the risk assessment of biogas plants is at an early stage and still in progress. As a first result, information about biogas plants in Baden-Württemberg can be presented in terms of features of an OGC Web Feature Service in a Web-GIS application (figure 6).

In the next step, integration with the Risk Atlas will be done in order to enable risk assessment by means of geospatial data analysis.

The work carried out so far has concentrated on the implementation of an open architecture for generic and flexible risk management applications compliant to well-established standards of ISO and OGC. Up to now, the ability to share all relevant data is often very limited because risk management tasks are mainly handled by public institutions on a variety of administrative levels, each with their own IT systems for the provision of data and services. Thus, the main problem today is that in any given activity in any given phase of the emergency management cycle, decision makers and stakeholders do not have easy access to the information that they need in order to fulfill their goals. As a consequence, we accomplished our approach to the vision of an open architecture for environmental risk management information systems as outlined in [Usländer, T., Denzer, R. (2009)]: the ideal support would be an IT infrastructure that provides seamless access to resources (information, services, and applications) across organizational, technical, cultural, and political borders, thus overcoming real-world heterogeneity and assuring a sustainable investment for the support of future, still unknown requirements.

Eigenschaft	Wert
Feature	
Feature-Eigenschaften	
Administrative region	Reg.-Bez. Tübingen
City	Pfronstetten
Closedown	
Combined heat and power	false
District	Reutlingen
Feed 2007 (kw)	0.0
Feed 2008 (kw)	0.0
Feed 2009 (kw)	0.0
Feed 2010 (kw)	19384.0
Feed 2011 (kw)	27284.0
Launched	2009
Network operator	EnBW Regional AG
Power(kw)	1327
Power units	5
Zipcode	72539
Geometrien	

Figure 6: Information about Biogas Plants in Baden-Württemberg as Features of an OGC Web Feature Service (WFS)

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