We promote the concept of green energy by building an international network of power plants that use renewable sources.

Such a complex system requires a strong control, provided by our well organized, flexible and efficient database, meeting all our company's needs.

We make the world of tomorrow a safer place to live.

Project Manager,
Livia Toca

From,
National College
of Computer Science
TUDOR VIANU,
Bucharest

Statement of Business Concept

NERGON is an international electrical energy producer using only renewable energy sources. Our company is built on a chain of power plants spread around the world in areas where climate conditions are favorable for our business. The types of power plant we own are **wind turbines**, **small scale hydro electrical power stations**, **solar panels** and **wave energy devices**.

The electricity generation is under **free competition** conditions: our company acts on a **global market**. Our clients are energy suppliers and eligible consumers. Energy is distributed to clients through contracts.

Electrical energy producers, beside contracts, trade energy on a day ahead basis: we estimate the quantity of energy that we produce and release offers for the day ahead market.

The amount of energy produced by our power plants depends on meteorological factors like **wind**, **precipitations**, **clouds**, **temperature** and others. Thus the accuracy of these factors is essential to correctly estimate the energy production.

We need a database to enhance the estimation process: relevant meteorological data will be stored and efficiently linked to all other influence parameters.

Project Manager: Livia Toca

From: National College of Computer Science “Tudor Vianu”, Bucharest, Romania

Statement of Business Concept

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The required meteorological data is undertaken from meteorological institutes.

If no meteorological stations are available for the required area, our meteorologists enter data gathered from other sources such as private companies or from our own small meteorological weather stations.

Our challenge

The authors of this project are members of the company's IT Department: we need to develop an international database that will ensure access to worldwide energy production and estimation reports, improving the company's services offered to clients.

The designed system must keep track of meteorological conditions and further link them to our power plants characteristics.

It must be able to inform about meteorological events such as wind gusts, thunderstorms or others that may cause damages to our power plants.

References

Preliminary internet research

Meteorological related resources

- **www.wmo.ch**, World Meteorological Organization
- **www.meted.ucar.edu**, University Corporation for Atmospheric Research, a vast collection of online research papers.

About the energy market and technical issues regarding renewable energy production

- **www.opcom.ro**, Romanian Power Market Operator Website
- newspaper articles from the Official Gazette of Romania in which are established the commercial and technical aspects of renewable energy production and distribution
- Practical Proposal for Very Large Scale Photovoltaic Systems, Earthscan, UK and USA, 2006

Based on the demand on world energy and global environmental issues we came up with the idea of building . We discussed about possible scenarios and, after more internet research, we found out that such a company perfectly meets the requirements.

Interviews

First interview

Mr. George-Aurel Lavrov

Power Systems Department Coordinator

Institute for Studies and Power Engineering, Bucharest

We discussed about the energy market and how an electrical energy producer interacts with it. Also Mr. Lavrov cleared issues regarding:

- bilateral contracts, between energy producers and their clients
- the impact on the environment and on the electricity consumers
- problems raised by this business
- energy markets: Day Ahead Market (DAM), Real Time Market (RTM) and others
- rights and obligations of each participant, consumer, supplier, producer in the energy market

After the first interview, along with strong online preliminary research, we defined the **company structure**. Our idea came to life.

Interviews

Second interview

Mr. Andrei Stefanescu

General Counselor of the Technical & Financial Board,
Institute for Studies and Power Engineering, Bucharest

At second interview we already had the **business concept** well defined and we received a positive feedback about the way we organized ENERGON and also more precious insight about the meteorological dependency our company.

Also, we had the possibility to discuss about the characteristics of each type of power plant defined in our company and their connections to meteorological factors. Other topics covered were:

- recent researched technologies in the field of renewable energy production
- feasibility projects are made before a power plant is installed. We had the possibility to study a feasibility project for a wind turbine

After this interview we started a more detailed internet research using the guidelines received from Mr. Andrei Stefanescu.

Interviews

We found out about the following projects that revealed us precious information **combining** the **technical** aspects of power plants with **meteorological factors**:

- **www.retscreen.net**, Clean Energy Project Analysis Tool which helped us in detailing our previous power plant concept, including detailed technical factors that are influenced by meteorological factors
- **www.eohydro.com**, aims to improve hydro power plant management at a global scale, providing satellite data regarding amount of snow melt on the higher cliffs of mountains where hydro power plants are located
- **www.magenn.com**, a nonconventional wind turbine

Third interview

Dr. Dan Florea

Chief of Meteorological Service of the Romanian Air Force,

Main Air Operational Command, Bucharest

The last interview detailed all the meteorological aspects of our project. Dr. Dan Florea confirmed most of our projects aspects and helped us understanding the **international meteorological codes** provided by meteorological stations from all over the world.

Business Needs

Company Structure

In **countries** where we own power plants there is at least one **subsidiary**. Subsidiaries located in the same country may have the same name but their location may differ.

NERGON Germany may have one subsidiary located in Munich and another one in Berlin.

To enter the market as a green energy producer a subsidiary must use a **license**. Subsidiaries located in a country use the license emitted for our company by the national regulation authority.

When signing **contracts** with our clients (**suppliers** or **eligible consumers**) it is necessary to specify monthly quantities of energy produced by our power plants; thus the accuracy of **meteorological data** is essential. Each subsidiary uniquely indexes its contracts. Contract numbers may be the same for different subsidiaries. Remaining quantities are traded on **DAM.**

The **Day Ahead Market** (**DAM**) is the energy market where active electricity is traded for each hour gap, named **trading interval**, of the following day. It is characterized by the following principles:

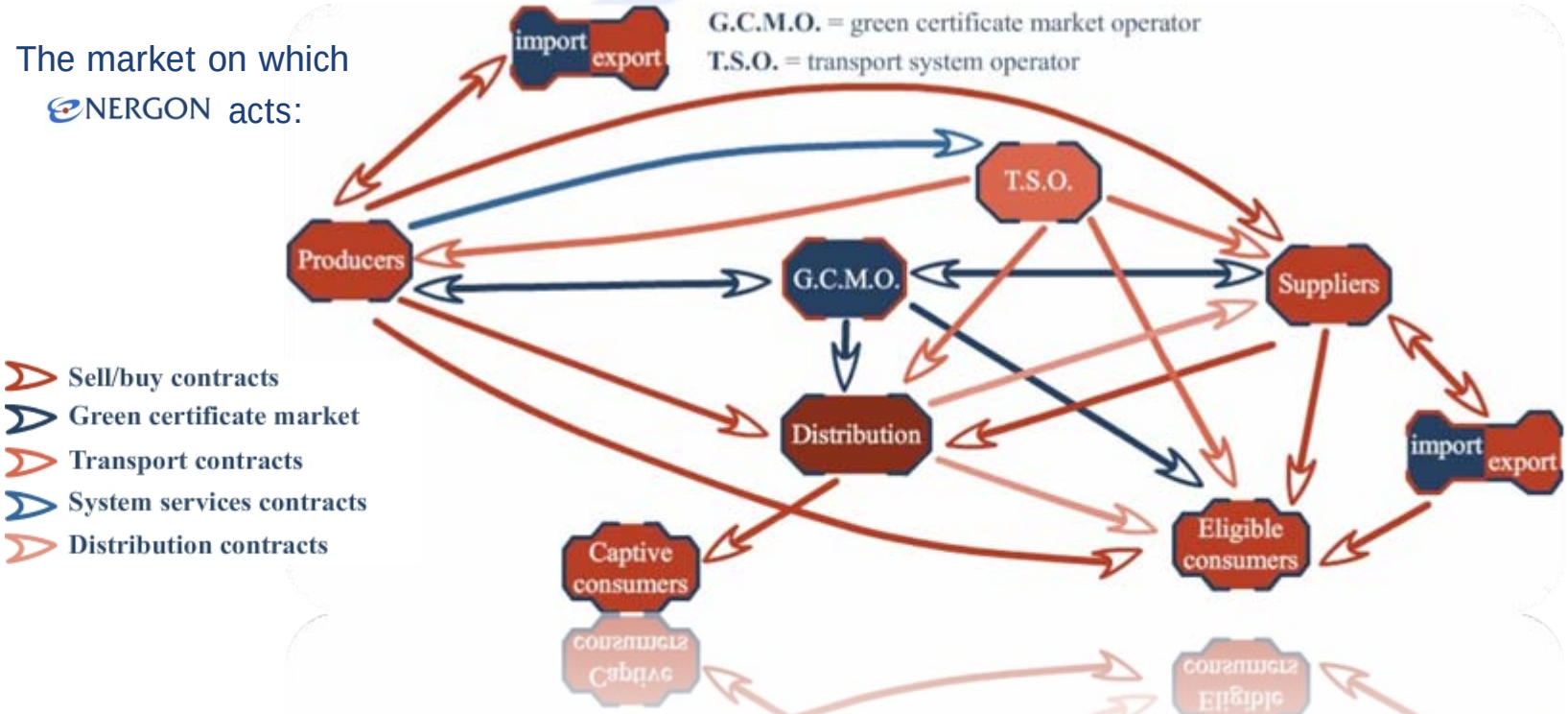
- Electricity selling/buying offers are simple and comprise a fixed number of quantity-price pairs for each trading interval (one hour).
- A participant can submit only one buy offer and one sell offer for each trading interval

On the **Real Time Market** (**RTM**) energy is sold with a real-time change price. In our conceptual model it has no importance of who updates the status of DAM offers and RTM.

Business Needs

Each subsidiary may sign **contracts** with **clients**, trading monthly quantities of energy produced by the administered **energy farms**. Beside clients, subsidiaries have **partners**. These are institutes which provide meteorological or astronomical data.

The market on which ENERGON acts:



The regulation authority certifies each year the producers that are eligible to receive green certificates**.** For each megawatt-hour produced from renewable energy sources, the producer receives such a certificate, which represents a supplementary source of profit, beside the income issued by selling energy.

Business Needs

On the green certificate market, the prices are established in a bilateral **contract** between the **supplier** and the **producer** or simply on centralized market organized and administered by a legal entity, the operator of green certificates' market**.** The price of a green certificate may vary between certain limits specified by a governmental decision.

On the **energy market** there is a **mandatory quota system**, which is a way of promoting green energy production. The **suppliers** must buy a minimum quota of energy from renewable sources, assigned by the regulation authority, and a number of green certificates equal to this quota in order to sell energy to consumers. The sell price to **captive consumers** is also established by this authority.

The way **DAM** and **RTM** interact is shown in the following example:

- NERGON Finland sells 200 MWh of energy in **DAM** for the trading interval determined by hour 14, December 27th. The price is $60 per MWh. NERGON Finland supplies 170 MWh (for a change from the commitment of -30 MWh). The price in the **RTM** is $70 per MWh.

Tr. ID	Start Date	End Date	Qty.	Price	Unit	Total
T1	12/27/07 14:00:00	12/27/07 15:00:00	200	$60	$/MWh	$12000
T2	12/27/07 14:00:00	12/27/07 15:00:00	-30	$70	$/MWh	-$2100

The markets mentioned above are particular for each country in which NERGON has subsidiaries. Data about these is entered as required by the **employees**.

Business Needs

The **regulation authority** specifies the units with **priority production**, dividing them into the following categories: **incontrollable** and **controllable** units. These units may enter the **DAM** market at fixed prices established by the same authority.

All our company's energy sources are considered to be **renewable,** with **priority production** and **incontrollable**:

- **wind energy**
- **solar energy**
- **hydro electrical energy** provided by small hydro with a capacity lower than 10 MWh.
- **wave energy**

Employees

There are three types of employees which have access to the database. They may be organized in teams by their activity field:

- **Administrator**: manages energy farms and updates power plant damages and effective production.
- **Meteorologist**: updates meteorological information from meteorological stations or, if not available, introduces forecasts for a specific farm containing minimum required information in order to create an energy production report
- **Other:** such as financial analysts, mechanics etc.

Business Needs

Meteorological data

In order to satisfy our company's needs, our meteorologists have access **through our partners** to the **Surface Synoptic Observations**, SYNOP and SHIP codes (**FM-12** and **FM-13**), which are the World Meteorological Organization (WMO) standard method for transmitting surface weather information.

The **coded report** is given in six groups of data, but only the first three of them are relevant for us:

- **Identification and Location**:
  - WMO number of station, ship or buoy identifier and the latitude, longitute and elevation of the weather station
  - day of the month and hour of the observation in UTC time
- **Land Observations**:
  - cloud base of lowest cloud seen, total cloud cover and other cloud information
  - wind speed
  - temperature; minimum, maximum and currently observed temperature
  - air pressure
  - precipitation type and amount and other meteorological events like duststorms, sandstorms, thunderstorms, showers etc.
- **Sea Surface Observations,** not reported by land stations:
  - period and height of waves

Business Needs

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If wind speed is available at only one altitude our system will estimate it at the required altitude through the **wind shear exponent** of the region in which the **farm** is located, which is a dimensionless number expressing the rate at which the wind speed varies with the height above the ground.

If there is only one mean wind speed value available the designed system will use a **Weibull wind speed distribution** for which the **shape factor** will be considered 2 if not specified.

The structure of the SYNOP codes may suffer modifications through time, therefore our database model **stores explicit information** extracted from this code and not the code itself.

If there are farms where it is impossible for any of our partners to supply the required meteorological data, our company invests in special equipment that provides the needed information.

If the equipment does not provide the information through a WMO international code then a **meteorologist** may manually enter a **forecast** based on the information gathered through this device.

The next paragraphs describe how the meteorological factors influence the energy production, for each type of power plant we own, and hence our income.

Business Needs

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Wind turbines

Wind turbines produce electricity using the kinetic energy from the wind. A power plant is installed only in areas where **wind speed** is at least 4 meters per second during the whole year.

For a **wind farm** the administrator will enter the following information:

- **number of turbines**
- **shape factor** for the area in which the wind farm is located
- **array losses** caused by the interaction of multiple wind turbines with each other through their wakes. Turbines in the "shadow" of others do not "see" as much wind as the front ones.

Also, our designed model takes in account that a **wind farm** may be affected by:

- airfoil soiling and/or icing losses of the turbines. Airfoil soiling losses are caused by soiling of the blades from such things as bugs and/or ice build-up. Accumulation of bugs or ice affects the aerodynamic performance of the blades. Icing losses occur when accumulation of ice forces a wind machine to shut down or prevents it from starting. Icing losses depend on the **ambient temperature**, the **altitude** at which the machine is installed, the **level of humidity** and the machine design.
- **miscellaneous losses** for all wind turbines in a wind farm represents percent losses of energy production due to starts and stops, off-yaw operation, high wind and cut-outs from wind gusts

Business Needs

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For each **wind turbine** component of a wind farm the following **technical specifications** need to be known:

- **hub height** is the height at which the centre of the rotor of an horizontal axis wind turbine is mounted
- **swept area** per turbine is the area perpendicular to the wind direction that a rotor will cover during one complete rotation. The power and energy output of a wind turbine is strongly related to the swept area of its rotor.
- **power curve** data, a table containing amount of energy produced at certain wind speeds

Our company implements **Magenns Air Rotor System**, which is a floating wind turbine, having the shape of a balloon, filled with helium gas, that may be lifted up at any **altitude**, where **wind speed** values are favourable.

For each **wind farm** characteristics of the region need to be known in order to accurately estimate the way **meteorological factors** influence the energy production:

- **altitude**
- **wind shear exponent**

Air density directly influences the energy production, hence **air pressure** information is needed.

Business Needs

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Solar panels

Our company owns **photovoltaic** solar panels which collect and convert solar energy into electricity. The **meteorological factors** that influence the solar energy collected are the **solar radiation** and the **clouds** on the sky.

In order to determine the total **solar radiation** in a certain day our database retrieves from an **astronomical institute** the celestial coordinates of the Sun, **declination** and **right ascension** at day noon. In conjunction with a calculation procedure the Sun's position may be determined at any required hour. They are similar with the well known longitude and latitude, respectively, but refer to the celestial sphere.

These uniquely determine the position of the sun on earth's sky and, correlated with the **latitude** and **longitude** where the solar panel is positioned, the total **solar radiation** may be obtained.

It is necessary to know the **total cloud coverage** for the region in which the solar panel is located and the **cloud types** that appear on the sky. The amount of solar radiation that passes through a cloud is related to its **thickness.** The clouds, when reported by a meteorological station, are classified in three large categories, and further in smaller subcategories of these:

- **high-level**, with cirrus, contrail etc.
- **medium-level**, with altostratus, altocumulus, nimbostratus etc.
- **low-level**, with stratocumulus, stratus , cumulus etc.

Business Needs

Technical specifications

In order to maximize the solar energy collected, the incidence angle of the solar beam must be minimal, hence the panel may be equipped with a **solar tracking device**:

- **one-axis trackers** track the sun by rotating around an axis located in the plane of the collector
- **azimuth trackers** have a fixed slope and rotate about a vertical axis
- **two-axis trackers** always position their surface normal to the beams of the sun by rotating about two axes

The **slope** represents the angle between the solar collector or the tracking axis and the horizontal, and the **azimuth** is the angle between the projection, on a horizontal plane, of the normal to the surface and the local meridian, with zero due south.

The **efficiency** and **temperature coefficient** of the solar collector is given by its **cell type**.

The temperature of a photovoltaic module affects its electrical output characteristics and efficiency. The temperature of solar cells has been characterized using the nominal operating cell temperature (**NOCT**).

The total amount of energy collected is also influenced by the panels **surface**.

Business Needs

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Small scale hydro electrical turbine

There are two types of hydro power plants:

- **run-of-river**, a mode of operation in which the hydro plant uses only the water that is available in the natural flow of the river. No water storage is implied and power fluctuates with the stream flow
- **reservoir**, requires the construction of one or more **dams** and the creation of new lakes.

In order to estimate the discharge of the river and hence the energy production from a hydro turbine we must take in account the following **meteorological factors**:

- **measured precipitations**
- **sun radiation hours**
- **temperature**

These factors must be correlated with the characteristics of the site where a farm of hydro turbines is located:

- **area of each tributary watershed**
- **infiltration** factor, the ratio between the discharged volume versus precipitated volume
- **evaporation** percent
- **residual flow** that must be left in the river throughout the year for environmental reasons
- **mean flow** of the site

Business Needs

Since rivers are influenced by the amount of precipitations along their whole length, meteorological information from different locations may be required rather than the ones at the site.

Our company has contracts with partners that have developed systems in order to monitor the **snow amount** in the watershed and offer periodical reports on snow melting that increase the rivers discharge.

The energy production is also dependent on the **technical specifications** of the equipment used:

- **turbine design coefficient**: this coefficient adjusts the turbine efficiency to take into account varying manufacturing techniques.
- **hydraulic losses**: some of the energy is lost as water flows through the water passages
- **generator efficiency**
- **miscellaneous losses**, consisting in transformer losses, etc.

Wave devices

The amount of energy produced depends on the **height** and **amplitude** of the waves at the site. This information is available from the buoy stations found in the proximity of the wave devices.

Wave devices are also characterized by the **technology** used (oscillating water column, stingray etc).

All our devices have a **power capacity** an attribute defining the rated power of the power plant.

Preliminary ERD

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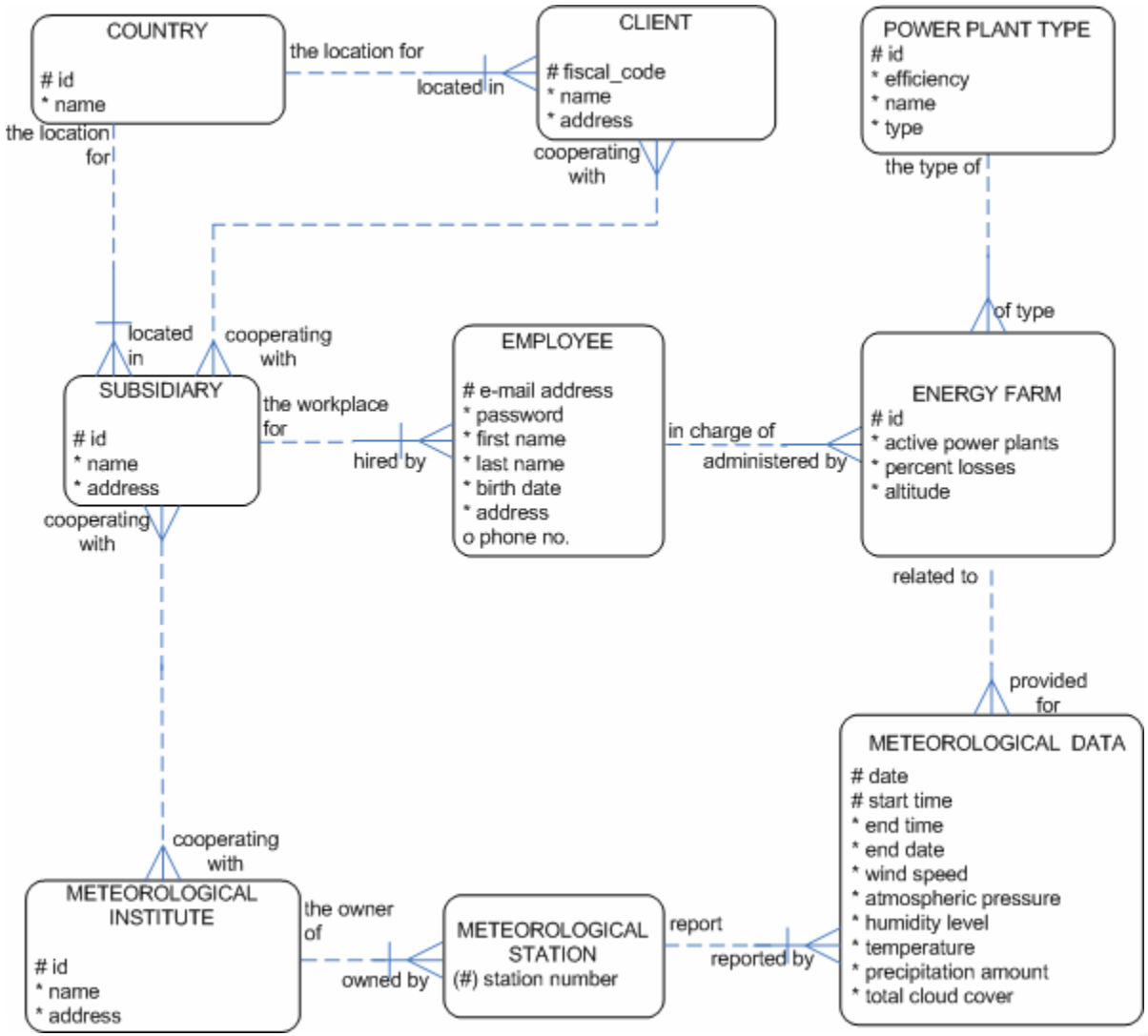

- sketched after the first interview and preliminary online research
- minimal business representation
- clear and intuitive
- received positive feedback
- main guidelines for the final ERD

We decided to continue our research and expand this preliminary conceptual model to a **strong ERD** that **meets all the business needs**.

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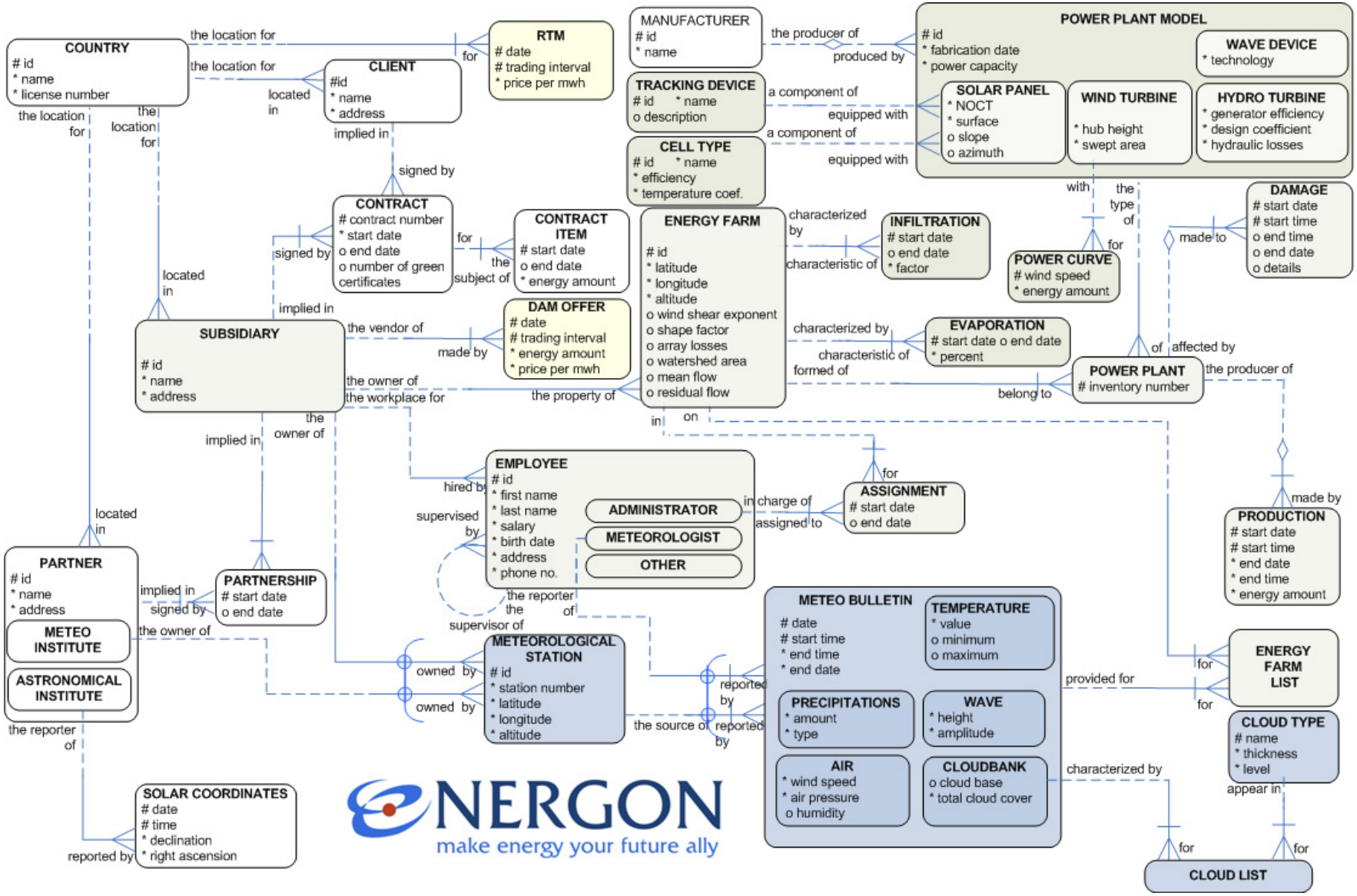
From: National College of Computer Science "Tudor Vianu", Bucharest, Romania

Final ERD



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ERD Explanations

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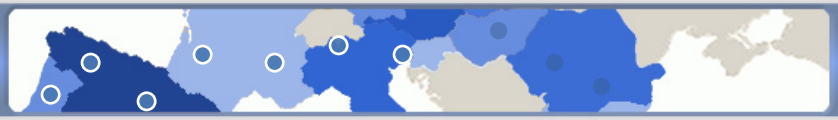
Company Structure

COUNTRY	Keeps track of the countries in which our company has subsidiaries, clients or partners.
SUBSIDIARY	The company is organized in each country in one or more subsidiaries.
PARTNER	Partners may be from other countries.
CONTRACT ITEM	Instances of this entity represent information regarding the monthly energy traded by one of our subsidiaries on a contract.
EMPLOYEE	When an employee from a subsidiary gets an online job assignment, either a **meteorologist**, **financial analyst** or an energy farm **administrator**, an account is created by the database administrator.
LICENSE	The license number is unique in the country where it was issued.

Energy Market

DAM OFFER	Each subsidiary after estimating tomorrow's energy production may create simple offers on the Day Ahead Market.
RTM	Each financial analyst may introduce information for the Real Time Market. These are used in his reports on the effective income of the subsidiary.



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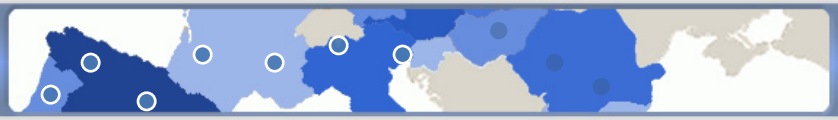
ERD Explanations

Meteorological Data

METEOROLOGICAL STATION	Represents meteorological stations from which data is acquired. The station number attribute represents a unique code assigned by the World Meteorological Organization for each station, and present in the SYNOP code. Station number is a mandatory attribute since we may own our own small stations, not registered with the WMO, and thus no station number is assigned.
METEO BULLETIN	An entity that stores the moment when meteorological information was entered into the database.
TEMPERATURE	Used to record extreme measured temperatures and current temperature
AIR	This entity is used to store information regarding air pressure, wind speed and humidity.
PRECIPITATIONS	The type of precipitations may be, as reported by the wmo codes: drizzle, snow, rain, rain and snow, freezing rain, rain showers, snow showers, fog, thunderstorms.
CLOUDBANK	This entity stores information for all the clouds present at a certain moment on the sky. Total cloud coverage (of all type of clouds). Cloud base attribute represents the smallest altitude from the ground where the first clouds are located.

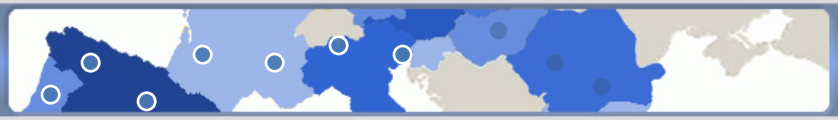


ERD Explanations

CLOUD TYPE	Cloud types may be nimbus, cumulonimbus, etc. The cloud thickness represents a dimensionless number characteristic for each of these types regarding clouds permittivity.
CLOUD LIST	An intersection entity between CLOUDBANK and CLOUD TYPE present at the moment observation on the sky.

Energy Farms

ENERGY FARM	A mode of organizing power plants. Miscelanneous losses are procents of the total energy that are caused by different external factors.
DAMAGE	This entity keeps track of damages done to an energy farm. These could be caused by the environment or a system malfunction.
PRODUCTION	Effective production is monitored. The financial analyst may use this information in order to estimate the income made on the RTM market. Relevancy of meteorological factors provided may also be checked by simply comparing estimated energy with the effective energy produced.
POWER PLANT	Each power plant is stored individually in the database, uniquely identified by its inventory number.



ERD Explanations

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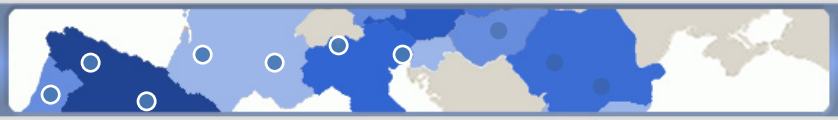
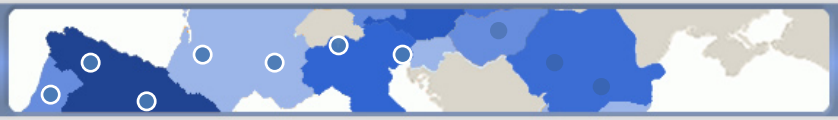
EVAPORATION	This entity refers to the percent of water that vaporizeze and
CELL TYPE	This entity represents cell types and their efficiency for a solar panel. They characterize the material from which the solar panel is made. Examples: mono-Si, a-Si, etc.
PP. MODEL	Stores characteristics for each power plant which may be found in an energy farm. The produced energy amount is directly dependent upon the values of these parameters. The type attribute specifies whether the model is a **wind turbine**, **small scale hydro electrical power station**, **solar panel** or **wave energy devices**.
TRACKING DEVICE	This entity refers to the solar tracking devices that may be attached to a solar panel in order to maximize the sun radiation collected



ERD Explanations

Relationships

COUNTRY – RTM	The Real Time Market is specific for each country. When a financial analyst enters information about the energy price of a trading interval then all the subsidiaries in that country may take in account the introduced data
METEOROLOGIST – METEO BULLETIN	If no other data source is available then a meteorologist may consult external sources and update meteorological data with minimal requirements for an energy farm.
METEO BULLETIN – ENERGY FARM	Some energy farms are influenced by particular meteorological factors and thus not all of them are required in order to accurately estimate the energy production. Also, information may be gathered from different meteorological stations. For example a wind bulletin for an energy farm is taken from one meteorological station and sun bulletin from another.



Assumptions and Constraints

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Assumptions

Only one set of coordinates, of latitude and longitude, are necessary in order to identify the location an ENERGY FARM.

Constraints

For the PARTNERSHIP, CONTRACT, DAMAGE, PRODUCTION, ASSIGNMENT, CONTRACT ITEM, INFILTARTION, EVAPORATION entities the **start date** must be before **end date**.

Start date in the CONTRACT ITEM entity must be after start date in CONTRACT entity. End date in the CONTRACT ITEM must be before end date in the CONTRACT entity.

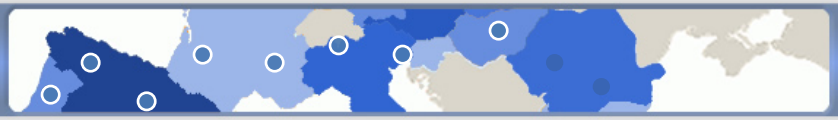
Start date in the CONTRACT ITEM entity must be after start date in CONTRACT entity. End date in the CONTRACT ITEM must be before end date in the CONTRACT entity.

There is at most one instance of METEO BULLETIN regarding a meteorological parameter like wind speed, air pressure or others at a given moment and for a certain ENERGY FARM.

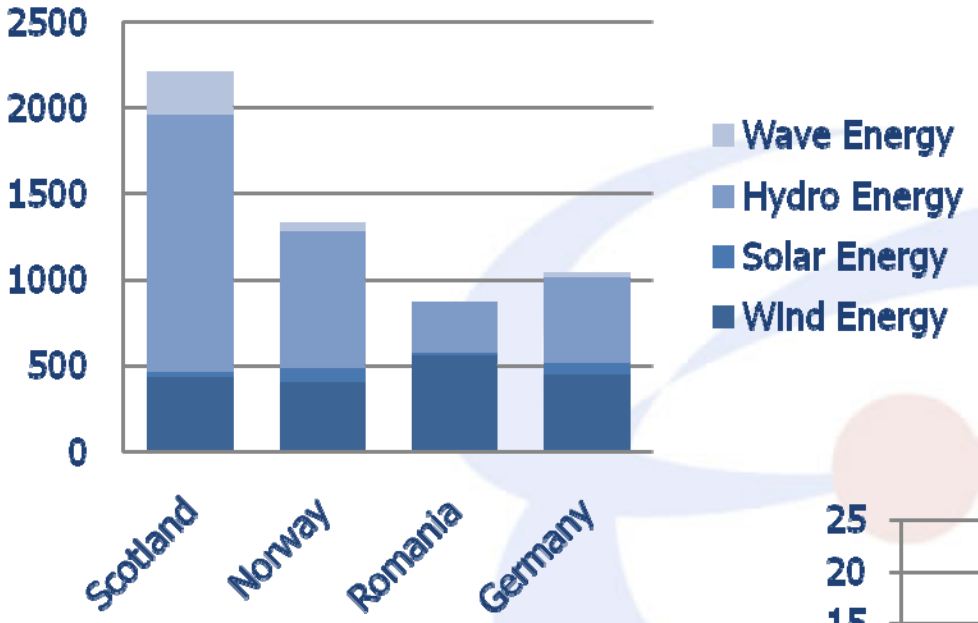
In a country there is one EMPLOYEE that updates RTM. In a subsidiary there is one EMPLOYEE that updates DAM OFFER.

The following measurement units are used

wind speed: meters per second (m/s)
precipitations: milimeters (mm)
temperature: celsius degrees (^{o} C)
air pressure: pascals (Pa)
energy amount: megawatt hour (MWh)
declination: degrees
right ascension: hours, minutes and seconds. 24 hours is equivalent to a full circle

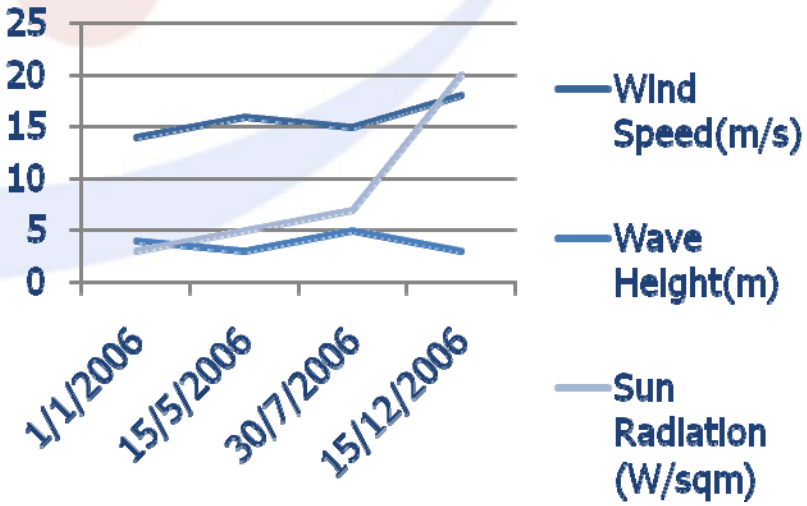


Sample Reports

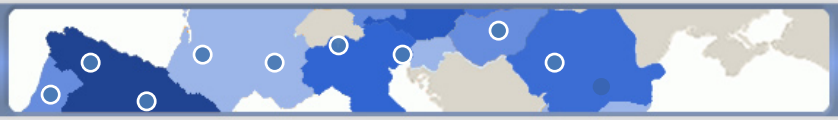


Detailed report of the energy produced by each type of power plant in four of our subsidiaries for the year 2007.

Weather evolution for a particular region where we have several power plants.



This report helps us increase the number of power plants depending on a specific meteorological factor, if that factor becomes favorable for our energy production



Project Manager: Livia Toca

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Sample Reports

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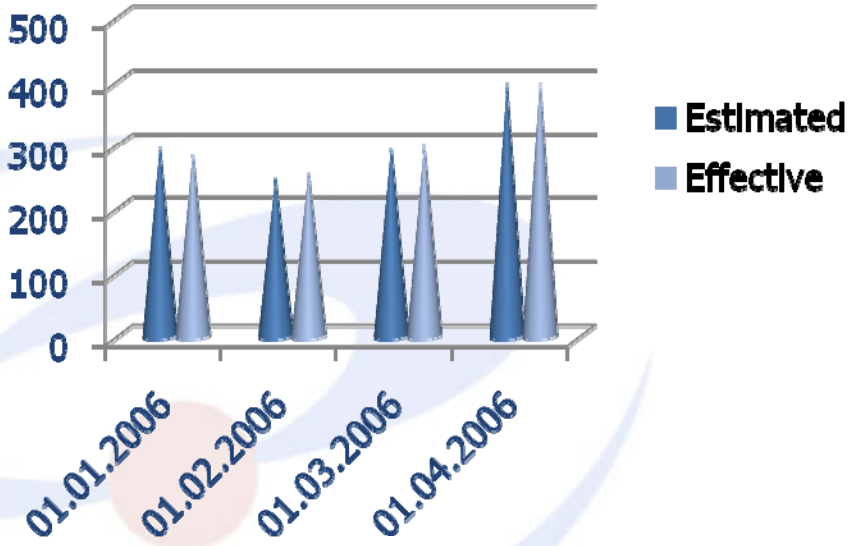
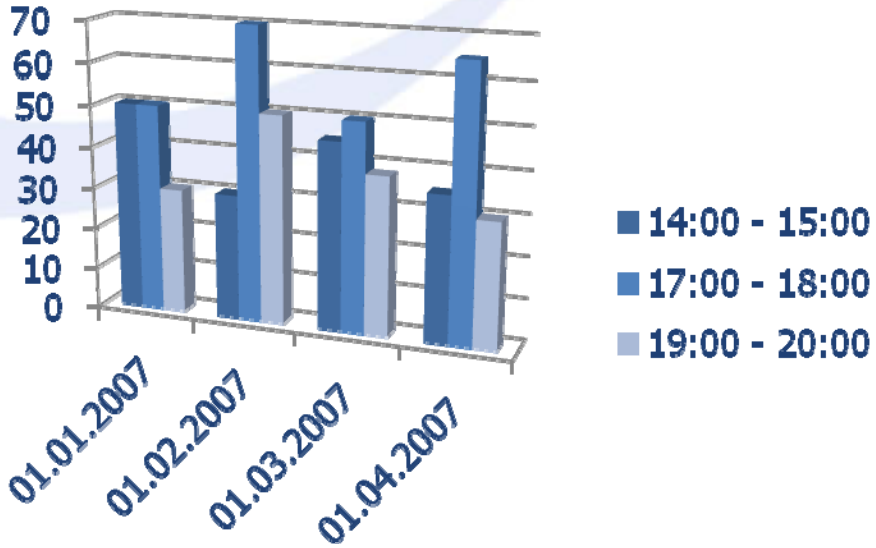
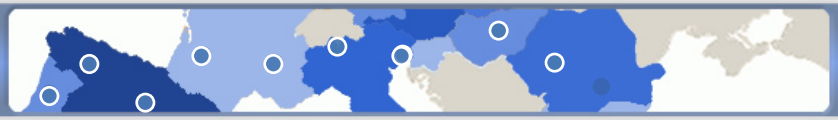
This is a sample report that shows the relevancy of the meteorological data provider for one of our subsidiaries.



Our system can provide full report for the evolution of price per megawatt hour for each country by the RTM information stored in the database.





Project Manager: Livia Toca

From: National College of Computer Science “Tudor Vianu”, Bucharest, Romania

Conclusions

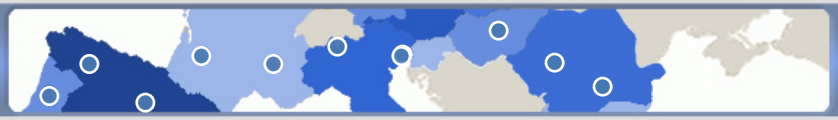
We provided an efficient solution improving our company's organization.

We created a reliable, flexible and secure database which keeps all of our subsidiaries up-to-date on the way the whole company evolves.

Our conceptual model may be used worldwide where such business is present.

Personal experience

- **creativity:** the first challenge of this contest was creating the scenario. After this challenge was solved we gained knowledge on what business requires to function and ultimately, achieve success.
- **responsibility:** being responsible for individual parts of the project was not an easy job for any of us. We understood the importance of always doing our job at maximum potential.
- **team work**: we discussed together every aspect of our idea. We always encountered problems and tried to offer the best solution there is.



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