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Ensuring Security of Energy Supply in Europe

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REACCESS Risk of Energy Availability: Common Corridors for Europe Supply Security

Content of the presentation

Introduction

The REACCESS research project aims at making available a new tool (the REACCESS Global Model) for evaluating the impact of future European energy security policies.

The most innovative aspects of the tools developed by the project are linked not only to the number and the detail of the description of the energy systems taken into consideration, but (and mainly) to the exploration of some risk dimensions related to the energy supply routes to Europe and Member States inside long term scenarios (2010-2050)

the REACCESS Global Model

The REACCESS Global Model is constituted by the aggregation of the adapted versions of two existing TIMES models:

- **the Pan-EU27++ (PET), originally implemented by the NEEDS IP and RES2020 and REALISEGRID Projects and**
- **TIAM (The TIMES Integrated Assessment Model), developed in the framework of the IEA–ETSAP Implementing Agreement,**

  with

- **a new module describing the Energy Resources & Corridors World System (RECOR).**

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The integrated panEU27++ (PET) Model

PET represents the energy systems of the European Union (+ Iceland, Norway and Switzerland and + 6 Balkan Countries) and their possible long term developments.

PET is linking together **36 Country Models** (and the rest of the world), by means of trade variables. The integrated model is more than the sum of the national models as it allows reflect the links between countries and impose constraints at the European level, reflecting the possible coordination of policies across borders.
It can be useful for both EU policy evaluation and the analysis of national policies, allowing evaluating the benefits of cooperation among countries in the fulfilment of international agreements (such as the Kyoto Protocol).
Adjacent regions can **trade** bi-laterally high voltage electricity via international transport infrastructures.

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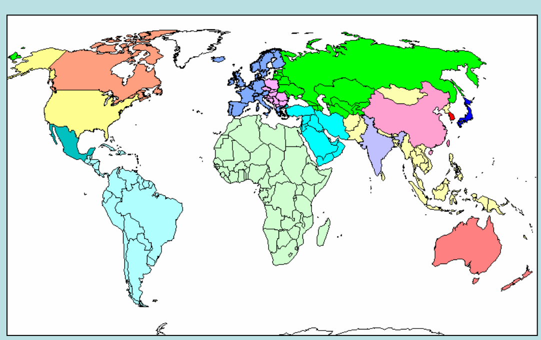
The adapted TIAM Model

TIAM represents the energy systems of 16 World regions/Countries (the 16th region is EUR that means the aggregation of the 30 Country systems described in PET).

TIAM -16R
Africa
Australia-New Zealand
Canada
Central Asia & Caucasus
Central & South America
China
India
Japan
Mexico
Middle-East*
Other Developing Asia
Other Eastern Countries
Russia
EUR
(EU27+Switzerland + Norway + Iceland)



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The RECOR Module

RECOR describes:

- the "captive" (pipelines, cables, rails, etc.) and
- the "open sea" energy corridors

The energy flows are supplied by feeders connecting the commodities' extraction, primary and secondary production processes, located in exporting countries (generally located inside the regions of the TIAM model), and other processes (like refineries, regasification units) that are in common with the EU27++ Countries (PET model).

A full traceability (origin – destination) of the energy flows is assured.

The corridors are geo-referenced in order to allow the requested environmental evaluations.

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The energy corridors

The complete set of energy corridors includes:

- Crude oil pipelines: 2 main corridors from Russia (with 6 feeders and up to 16 segments)
- Crude oil shipping routes: 152 open sea corridors from 18 exporting countries/regions to 9 EU importing countries
- Oil products shipping routes: 26 open sea corridors, from 3 exporting countries/regions to 5 EU importing countries
- Natural Gas pipelines: 20 corridors (with 1 - 20 segments)
- LNG shipping routes: 54 open sea corridors from 10 exporting countries/regions to 7 EU importing countries
- Coal shipping routes: 91 open sea corridors from 8 producing countries/regions to 9 EU importing countries
- Uranium shipping routes: 6 open sea corridors
- Biomass routes: 28 open sea corridors, from 9 producing countries/regions
- HVDC lines: 100 corridors from 7 MENA producing countries/regions to 12 EU Countries
- Hydrogen routes: 12 corridors (5 pipelines and 7 open sea corridors)

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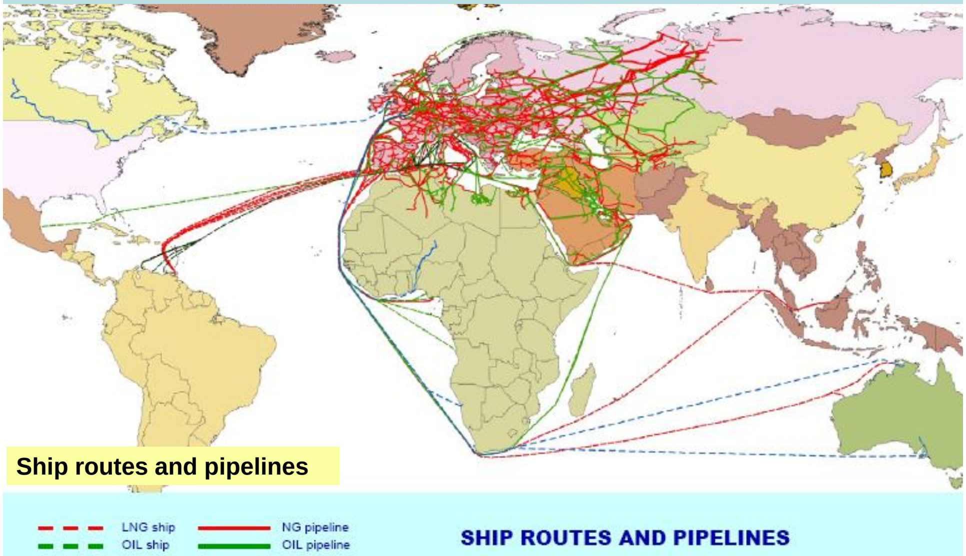
Ship routes and pipelines



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The time attributes

The <u>time horizon</u> of the analysis is 2050 and the trajectory of the system (composed by 36 European Countries, 15 World Countries/Regions and some hundredths of captive and open sea energy routes) is computed throughout a series of <u>milestone years</u>:

2005, 2010, 2015, 2020, 2025, 2030, 2040 and 2050.

Annual flows of electricity are split by seasons, day and night and peak times.
The seasonal dependence is extended to heat and natural gas.
Each technology can operate in the same twelve time-slices (fraction of the year).

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The demand for energy services

As for all bottom up approaches, the model is driven by exogenous demands: in order to supply enough commodities and satisfy final consumers several technologies are built and used, in chains from primary resources to end-uses through defined supply routes.

The demand for energy services (exogenous input) are projected taking into account to the most important socio-economic drivers.

The following drivers, generated by GEM-E3, are used in the model:
- GDP and GDP per capita growth rates,
- Private consumption, as a proxy for disposable income,
- Sectoral production growth
  with a distinction between energy intensive sectors
  (e.g., ferrous and non-ferrous metals, chemical sector, etc.),
  other industries, and services.

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Some details on the RECOR Module

The modelling of the energy corridor chain includes the full description of the following steps/processes:

Captive corridors

For captive corridors:

- Resources
- Primary and secondary production
- Connecting segments in each producing Country/Region as well as in the EU Countries until the commodity final delivery to national systems
- Connection to the Reference Energy Systems of the receiving EU Country

Some natural gas corridors have multiple connections and splitting nodes (Hubs).

Open sea corridors

For open sea corridors:

- Resources
- Primary and secondary (for LNG liquefaction) production
- Feeders and connecting segments between resource fields and the port/terminal/plant (for LNG) of the exporting Country/Region
- Open sea route from the exporting port/terminal/plant to the receiving EU port/terminal/plant (for LNG regasification)
- Connection to the Reference Energy Systems of the receiving EU Country

Several energy routes involve captive and open sea

The spatial analysis (1)

The corridors have been fully geo-referenced by using ARCInfo tools and methodologies.

Suitable Geographical Information Systems referred to the main spatial indicators (land use, population, activities, and so on) have been also taken into account and associated to the corridor paths for performing the analyses needed for the technological risk evaluations.

The corridors paths and the shape-files of the spatial indicators have been cross-correlated.

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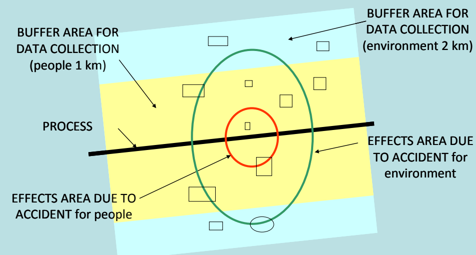
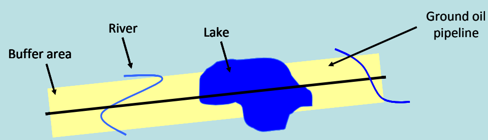
The spatial analysis (2)

A buffer area along each corridor has been defined in order to give the maximum order of magnitude of the extension of accident damage around plants and transportation routes.

Inside this area, safety and environmental risks for all the commodity routes have been evaluated





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The new tools and methodological content

To the existing scenario building TIMES tools, the new REACCESS Global Model adds:

- **the option "energy supply corridors", with all their technical-economical-geographical details, which compete with any other energy technology option at the same level playing field**
- **the risk parameters and aggregate system indicators of "supply risk", which <u>becomes a scenario objective</u>, at the same level of any other policy objective – economic sustainability, climate change mitigation, etc.**

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Some of the more widespread definitions of the concept of "energy security"

"**Energy security, broadly defined, means adequate, affordable and reliable supplies of energy" (International Energy Agency, 2007).**

"[Energy security is] the continuous availability of energy in varied forms, in sufficient quantities and at affordable prices" (United Nations Development Programme, UNDP, 2001).

"The European Union's long-term strategy for energy supply security must be geared to ensuring, for the well-being of its citizens and the proper functioning of the economy, the uninterrupted physical availability of energy products on the market, at a price which is affordable for all consumers (private and industrial), while respecting environmental concern and looking towards sustainable development (…)" (European Commission, 2001)

A classification of energy risks

European Commission (2001)	Checci, Behrens, Egenhofer (2009)	Doukas, Flamos, Psarras (2009)
• Physical risks • Economic risks • Social risks • Environmental risks	• Geological risk • Technical risk • Economic risk • Geopolitical risk • Environmental risk	• Accidents • Conflicts • Political instability • Terrorist attacks • Restrictions on export • Weather conditions • Monopolistic practices (cartels)

Clingendael International Energy Programme CIEP (2004)
• Changes in producer countries' policies • Insufficient investment in the energy sector • Macroeconomic instability in producer countries and regions • Socio-political instability in producer countries and regions • Regulatory instability in energy consumer countries • Market failures • Public sector failures

Source: European Commission (2001): 64-65; CIEP (2004): 37; Checci, Behrens and Egenhofer (2009): 3; Doukas, Flamos, Psarras (2009): Table 1.

The energy supply security

With reference to developed economies the concepts of "energy security" and "energy supply security" are normally interchangeable.

However, the concept of energy security is relevant not only to countries that consume or demand energy, but also to producer countries, whose economies often depend almost exclusively on energy export revenues.

In symmetry with "energy supply security", therefore, we could speak of "energy export/production security".

REACCESS lies within a research framework that focuses on the energy supply security of the European Union, and we concentrated accordingly on energy risk for consumer countries.

"Energy security" and "energy supply/procurement security" are thus used as synonyms.

Primary and secondary energy risks

Risks that cause supply disruption (or primary energy risks) are sometimes mixed with risks that are properly viewed as effects (or secondary energy risks).

Physical or technical risks, for instance, are causes of supply disruption, but economic, social and environmental risks, as described by the Commission in the Green Paper, are effects of a disruption in supply.

Both kinds of risk form part of energy risk, but it is an important consideration for the purposes of assigning priorities and framing policy.

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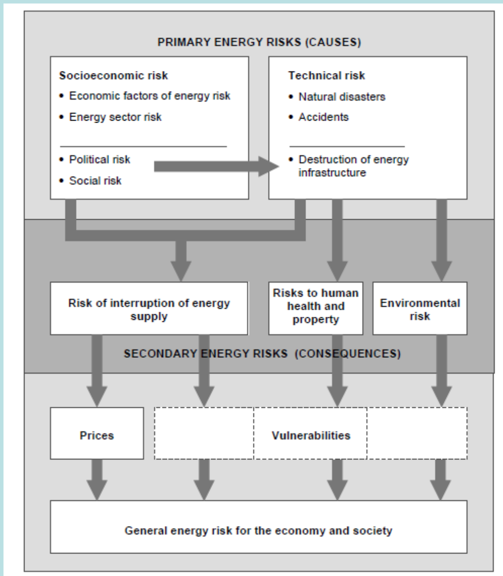
Types of energy risks (1)



Primary and secondary energy risks

Effects on prices and vulnerabilities

Source: F-UNED

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Types of energy risks (2)

Risk Category	***Description***
R1. Conflicts	War and civil
R2: Political Instability	Political instability, regime change, revolutions, strikes, sabotages, protests
R3: Terrorist Attacks	Successful, or attempted, terrorist attacks on fuel facilities
R4: Export Restriction	Embargoes, trade route closure, export suspension
R5: Accidents	Explosions, tanker sinking, fire, leaks, and generally any form of unwilling interruption
R6: Weather Conditions	Interruption of supply due to hurricanes, earthquakes, temperature and other physical phenomena
R7: Monopolistic Practices - Cartel	A country's effort to create monopolies, making other countries totally or partially depended

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Types of energy risks (3)

Primary energy risks can be grouped into socioeconomic factors and technical factors.

Socioeconomic risks are all those arising from the organization of human activity in its main forms: economic, political and social activity.

Since energy is our concern, a fourth distinct socioeconomic category of risk caused by the variables intrinsic to the energy sector have been added.

Technical risks, for their part, embrace all factors that might affect the normal functioning of energy infrastructure. On a second echelon, secondary energy risks include interruption of supply, risks to human health and property, and environmental risk.

These three risks might in turn cause, as an ultimate effect, a general energy risk for the economy and society.

The evaluation of the risk parameters in REACCESS

Two dimensions have been explored:

- technical

and

- non technical (political-economic)

The technical risk

For the technical risk, two approaches have been taken into account:

- the risk for people safety and for the environment and
- the unavailability of the infrastructure

These kinds of risk are considered as additional costs related to the use of the process or corridor, due to the potential accidents or failures occurring in the life cycle.

The unavailability evaluation involves a probabilistic estimate of the average annual loss of production of the system due to accidents and failures or external natural events and due to restoration of technical failure/accident (Risk vs. Production).

The political-economic risk (1)

For the political-economic risk evaluation, four dimensions have been taken into consideration:

Economy-driven risk: a country's energy risk derived from its economic characteristics, including its energy trade patterns (i.e. energy intensity, trade with the EU, etc.).

Intrinsic energy risk: energy risk emerging from a given energy resource base and energy imports concentration (i.e. reserves-to-production ratios, HHI, etc.).

Political-institutional risk: energy risk derived from institutional and political factors that usually imply external political frictions (i.e. use of energy as a political weapon, good governance index, etc.).

Socio-political risk: risk emerging from socio-political factors that usually imply internal political turmoil (i.e. HDI, democracy index, etc.).

The political-economic risk (2)

The evaluation of the energy risk of the 158 Countries has been performed through a Factor Analysis, with the following assumptions:

- **the variables can share (correlate) more than the risk vector (need to differentiate energy risks)**
- **all the systematic differences in the variables among countries or periods arise from differences in factor values:**
  - **every variable can be used in the same way in every country for measuring the common underlying risk (a single "structure" for each vector)**
  - **relationships between variables and risks vectors are steady enough over time (results for today could be used tomorrow).**

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The political-economic risk (3)

Risk has been measured with the information contained in a large set of variables considered for each of the four dimensions.

Initially, a total of 101 variables were initially chosen:

38 for the Economic Vector
12 for the Energetic Vector
33 for the Political Vector
18 for the Social Vector

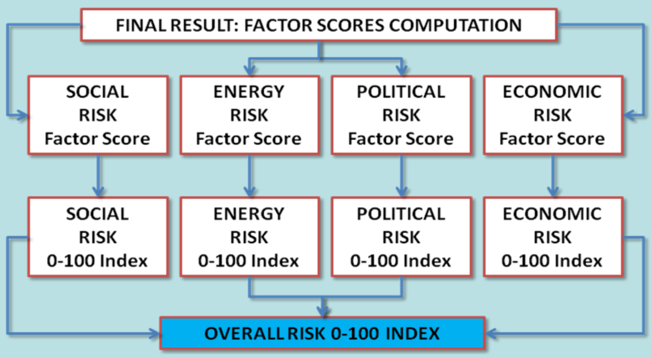
(the selection of these critical variables for each vector was driven by two major principles: theoretical relevance and quality of data available).

The iterative Factor Analysis provided finally 63 variables:

25 for the Economic Vector
6 for the Energetic Vector
16 for the Political Vector
16 for the Social Vector

The political-economic risk (3)

In the absence of a priori criteria, every factor is equally weighted in a simple additive indicator.



The 158 World Countries have been ranked from lower to higher risk.

The political-economic risk (4)

Risk vector and overall index calculation for selected countries

COUNTRIES	Algeria	S. Arabia	Ukraine	Georgia	Turkey	China	India
SOCIAL RISK INDEX	69.0	87.1	43.8	58.0	48.2	83.6	47.2
ENERGETIC RISK INDEX	9.8	5.9	36.2	71.4	61.1	6.0	7.2
POLITICAL RISK INDEX	62.6	38.3	51.0	48.6	49.5	40.8	60.9
ECONOMIC RISK INDEX	57.4	80.5	32.6	33.3	28.2	66.2	58.3
OVERALL INDEX (0=LOWER RISK– 100=HIGHER RISK)	**49.7**	**52.9**	**40.9**	**52.8**	**46.8**	**49.1**	**43.3**
COUNTRY POSITION (0=LOWER RISK– 159=HIGHER RISK)	**70**	**77**	**40**	**76**	**54**	**65**	**47**

A comment on the variables of the Energetic Vector (1)

The variables of the Energetic Factor taken into account are:

- Herfindahl-Hirschman Index of Energy Imports
- Inverse total self-sufficiency
- Inverse Reserves/production ratio for coal
- Inverse Reserves/production ratio for gas
- Inverse Reserves/production ratio for oil

The initial variables that have not been taken into account are:

- Total Primary Energy Consumption per unit of Gross Domestic Product
- Oil discovery maturity
- Natural gas discovery maturity
- Relative index of geographical oil imports dependency: EU-27
- Relative index of geographical gas imports dependency: EU-27
- Relative index of geographical coal imports dependency: EU-27
- Relative index of geographical fuels imports dependency: EU-27

The variables of the Energetic Vector (2)

With the Lisbon Treaty, which entered into force on December 1st, 2009, more powers are possibly shared, to some extent also in the areas of energy policy, climate change, and territorial cohesion.

Solidarity in the area of energy is also emphasised.

The political commitment to tackle the twin challenges of climate change and energy policy is fully reflected in the Treaty.

For the first time, the Treaty contain a section on energy which assigns to Union policy in this sector the objectives of ensuring the proper functioning of the energy market, in particular energy supply and the promotion of energy efficiency and energy saving, and the development of new and renewable forms of energy.

For this reasons it is open to discussion to take or not into account the indexes related to the Energetic Vector.

The implementation of the risk (1)

Possible risk reduction patterns are analysed comparing the base scenario(s), where the risk is not taken into account and the total system cost is minimised:

EU case = MS case = min [CX] = COST

with a risk avert scenario where the total surplus is constraint to a max increase of α% over the base scenario value:

CX <= (1+ α) * COST

and the following indexes are alternatively minimised:

EU case: $\min [\mathrm{Max}_f \{ \Sigma_{MS}\, Q_{MS}(f)\}]$
MS case: $\min \Sigma_{MS} [\mathrm{Max}_f \{ Q_{MS}(f)\}]$

f designates a fuel category (coal, oil, natural gas, etc.),
Max is taken over all fuel categories in the relevant region(s),
Q designates the amount of energy f used (or imported from non EU countries)

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The implementation of the risk (2)

The modelling tool prefers the trajectory of future events that minimises the concentration (or general dependence on import) of Europe or the Member States.

The tool suggests the set of actions to be implemented at each level of general system risk value; the extra cost incurred in each risk reduction case can be considered the insurance fee.
Policy makers indicate what amount they are ready to spend as insurance to reduce in the future the general system risk of their energy system.

The modelling tool indicates what energy policies best achieve the goal.

The implementation of the risk (3)

The following indicator is used:

$$Max_s \{QER(s)\} = Max_s \{R(s)*Q(s)\}$$

Where s designates an energy import flow,
Max is taken over all energy import flows arriving in region(s)
Q is the energy import flow, and
R is the risk associated to the energy import Q(s)

(R=1 when the risk is maximum, R=0 when the risk does not exist).

The implementation of the risk (4)

The risk R(s) of an energy import flow arriving from a region r to the EU directly is given by the risk of the country, R(r)

The risk R(s) of an energy import flow arriving from a region r to the EU indirectly, i.e. starting from region 1, crossing region 2, region 3 etc. before reaching Europe (*), is equal to the expression:

$$R(s) = \{1-[1-R(r1)]*[1-R(r2)]*[1-R(r3)]*\ldots\}$$

Choke points with their risks are treated as an extra crossing region.

(*) referring to the Socio-political instabilities of supply and transit countries, only the extra EU Countries contribute to the reliability index (as an application of the Lisbon Treaty).

The diversification of energy imports

This implementation procedure essentially penalizes excessive reliance on imports from a single risky source (or from a few large risky sources), while putting more emphasis on riskier corridors than on less risky ones.

It encourages diversification of importation corridors, weighted by their risk coefficients.

The tool suggests the set of actions to be implemented at each level of socio-political risk value; the extra cost incurred in each risk reduction case can be considered the insurance fee.

Policy makers indicate what amount they are ready to spend as insurance to reduce in the future the socio-political risk of their energy system.

The modelling tool indicates what energy policies best achieve the goal.

The proposed scenarios and storylines (1)

Ten scenario variables have been taken into consideration:

Exogenous:
- Demography,
- Economy,
- International Relations,
- Science of Climate Change

Risk:
- Internal System Concentration,
- Socio-Political Supply,
- Technological,
- Point Disruptions

Other policy instruments:
- Climate Change Mitigation,
- Investments in Energy Systems,
- Energy R&D,
- Innovation,
- Social Participation

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The proposed scenarios and storylines (2)

Considering the very huge dimensions of the REACCESS Global Model (>3 million variables), only a selected set of scenarios has been adopted and is under exploration:

Myopic (low CC mitigation, no risk prevention)
EU Secure (low CC mitigation, EU risk reduction policies)
Mitigated (high CC mitigation, no risk prevention policies)
EU Clairvoyant (high CC mitigation, EU risk reduction policies)

together with some variants that will explore MS prevention policies and the technological risk.

An additional scenario assuming the main driver evolutions used for the evaluation of the EU energy trends to 2030 in the Baseline or Reference scenario will be also analysed.

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The Web-GIS for the results presentation

Web-GIS tools for the presentation of the REACCESS results related to the full energy corridor system are under construction.

Some versions have been already done for the graphical representation of the energy routes characteristics during the phase of corridor identification and characterisation.

The new tool will be able to report, on standard maps and in connection with the more usual spatial attributes, all the relevant figures that describe the trajectories along the modelling time horizon of the energy routes considered in RECOR.

This tools will be also implemented on an easy-to-use commercial software, managed by a central server.

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The state-of-the-art of the Project activities

Presently, fine tuning and runs of the REACCESS Global Model are under way; the main activities of the near future will be the result analysis and presentation.

The three-year REACCESS Project activities close by end-December 2010 and the final International Conference, where the tools and the results will be presented and discussed, is planned by end-March 2011 in Brussels.

All the research phases have been object of dissemination activities among the partners and the EC Officers and described in the REACCESS Newsletters. Technical Notes and Deliverables are in the REACCESS Web site.

REACCESS Risk of Energy Availability: Common Corridors for Europe Supply Security

The Partners

POLITO: *Politecnico di Torino – **Italy***
ASATREM: *Applied System Analysis, Technology And REsearch, Energy Models – **Italy***
CCCC: *Climate Change Coordination Center – **Kazakhstan***
CIEMAT: *Centro de Investigaciones Energéticas, medioambientales y Tecnológicas – **Spain***
DLR: *Deutches Zentrum für Luft und Raumfahrt, German Aerospace Center – **Germany***
KANLO: *Kanlo Consultants – **France***
IET-IEP: *Institute for the Economy in Transition – **Russia***
IFE: *Institute of Energy Technology - **Norway***
NTUA-EPU: *National Technical University of Athens - **Greece***
ARC-RSA: *Austrian Research Centres – Research Studios Austria – **Austria***
F-UNED: *Fundación General de la Universidad nacional de Educación a Distancia – **Spain***
VTT: *Valtion Teknillinen Tutkimuskeskus, Technical Research Centre of Finland – **Finland***
USTUTT: *University of Stuttgart – **Germany***
CNR-IMAA: *Institute of Methodologies for Environmental Analysis - **Italy***

Thanks for the attention