PACT: Pathways for Carbon Transition

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Content

1 Executive summary

The PACT project did shape what a sustainable post-carbon society would look like and how we could reach it within the next 50 years.

It focused first on what shape the energy demand, and how this should evolve towards post-carbon concept, from two viewpoints: that of the infrastructures in relation to urbanisation and land-use schemes, and that of the life-styles and behaviours in relation to the technologies that should be available. The project deepened the question of urbanisation and land-use from the renewable energy perspective, including that of the systems (centralised/dependence versus decentralised/autonomous). Last, PACT did investigate the role of social forces, actors, stakeholders in the transition process toward this post-carbon concept. It was noticed in particular that Government and political movements don't play a role in building the opinion and behaviour of the adolescent, but educational and cultural context (school, in particular) do.

The ultimate objective of the project was to elaborate transition scenarios of post-carbon societies. Those scenarios are based on the 3 following observations:

- Because of limits in oil and gas resources, and because of climate change, the World will not have the possibility to continue for long developing on fossil fuels as it did in the past.
- Something else (energy efficiency/thriftiness, renewables, nuclear, carbon capture and sequestration), either forced or anticipated, will take the lead well before the end of the century.
- Because of time delays for nuclear and CCS to prove sustainability on large amounts, renewables and efficiency/thriftiness might well be the core of the "something else".

The post-carbon transition may take very different routes, with different consequences as to the greenhouse gases (GHG). 3 scenarios are therefore elaborated and quantified to capture three "extreme" routes towards post-carbon EU. Demography, economic growth, World tensions on resources and climate, policies, behaviours and life styles, technologies, are the main discriminating factors among scenarios.

- "Hard Way" is the scenario in which the oil prices will reach the highest levels (close to an average 250 US$2005/bbl in 2050, with the highest fluctuations), but the lowest carbon value (lowest constraint, around 100 US$2005/t), and the lowest GDP/capita.

- "Smartphone" is the scenario with the highest carbon value (constraint), around 800 US$2005/t in 2050, with also high oil prices (around 200$2005/bbl in 2050) and higher GDP/capita than in "Hard Way".

- "Spacecraft" is the scenario in which the increase of oil prices is the slower (around 140 US$2005/bbl in 2050), with a rather high carbon value (around 400 US$2005/bbl in 2050) and a much higher GDP/capita as compared to the other two scenarios.

These scenarios do not attempt to indicate to policy makers and stakeholders what route must be chosen, but to give them two clear messages:

- The EU may reduce in any case by large amounts its consumption of fossils in the next 40 years, and therefore reduce its CO2 emissions in the same proportion, but the social, economic and policy costs would be very high if this transition is not properly planned and implemented;

- There not one single way for planning and implementing properly the transition. Indeed, social forces are currently pushing in two very different directions: some tend to reproduce the recipes that have cooked the economic growth of the OECD countries during the last 50, while others consider this model obsolete and fight for inventing a new "beyond GDP" model. Depending on which social forces will become predominant, the transition pathways, even if duly planned and managed, will be very different.

2 Objectives and work programme

2.1 Objectives of PACT

Most «business-as-usual scenarios» built up till now have shown that hydrocarbon resources scarcity and the growing release of greenhouse gases will bring the world far away from sustainability over the next decades. Then, deep changes in behaviours away from «BAU» are unavoidable long before the turn of the century in a move towards a post-carbon society.

Urbanisation and mobility are probably the domains where these changes might be the most important and they will be necessarily driven and limited by socio-economic and cultural forces that will dominate the century. They will induce further deep changes in behaviours of consumers and producers and are likely to deeply impact the use and production of bulk materials, large energy consumers and GHG emitters.

To address these challenges, key milestones were defined by the EU :
- A 20% reduction (minimum) of CO2 emissions by 2020 (compared to 1990) in Europe
- A reduction of the GHG emissions by 2050 and after, so as to limit the increase of the temperature due to climatic change within 2°C.

In this framework, the PACT project objective is to provide strategic decision-support information to decision makers to achieve these milestones. It will focus on 3 themes :
- What shape the energy demand, and how this should evolve towards post-carbon concept, from the infrastructures viewpoint, in relation to

urbanisation and land-use schemes, and that of the life-styles and behaviours, in relation to the available technologies.
- The question of urbanisation and land-use from the renewable energy perspective, including that of the systems.
- The role of social forces, actors, stakeholders in the transition process.

PACT addressed these issues in two phases: first, by developing the necessary analytical and conceptual framework, second in quantifying scenarios of post-carbon societies at EU and world level by 2050 and beyond, using enhanced versions of the VLEEM and POLES models.

2.2 Work programme

Phase 1

The first phase was dedicated to analyse, in a rather qualitative way, what post carbon societies may look like and how to reach them. It is split in four work packages.

The first work package did focus on the spatial organisation in post-carbon societies, taking into account the climate related availability of biomass, solar, hydro and wind energy in the one side, people densities and land availability in the other side. A special attention has been brought to urbanisation and relation to land-use, taking into account urbanisation schemes and related urban infrastructures for energy and transport in post carbon cities, and land-use schemes according to geography and climate and related infrastructures for energy and transport services.

The second work package focussed on the social life in post-carbon societies, in relation to the technologies from the demand and supply sides that should develop to decrease drastically the GHG emissions. A special attention has been devoted to daily life in urban areas according to the various urbanisation schemes, to mobility pattern, and to the technologies that may be available for daily energy and transport services. Life-styles and behaviours are addressed through time-use structure among various socio-cultural functions, on the basis of the results already achieved in the previous VLEEM research: food-feeding, shelter, working for money, self-accomplishment.

The third work package deals with the question of the production of goods and services in post carbon societies. Two main aspects were supposed to be covered, in close relation to the expected project SOVAMAT[2]. The first one relates to the production of bulk materials, which is responsible for more than two third of the energy consumption and GHG emissions of industry and services today. The focus was more precisely on cement and steel, with two main questions: how the changes toward post-carbon societies might impact the demand for these products, what alternative production technologies might be developed consistently with a different spatial organisation that may better suit a post-carbon world ? The second aspect, much more complex deals with the nature of the goods and services that may be consumed in 50 years or more, in a post-carbon context. But because the SOVAMAT

[2] SOVAMAT: SOcial VAlue of MATerials

project did not get through, it was decided to focus only on the first aspect, and to extend the list of the bulk material covered to glass, petrochemicals, aluminium ...

The fourth work package deals with the socio-political aspects of the transition towards post-carbon societies. It covers several aspects. The first one deals with the citizens and the actors which at the same time will drive and be impacted by the social changes towards values, representations and desires that will shape the post carbon societies: question related to the social heritage, the social inertia, the acceptability, etc…The second aspect deals with the governance of the transition and the question of how the risks associated with drastic changes, in socio-economic structures as well as in technologies will be accounted for in government policies and main actors strategies. The last aspect is more related to the process through which mentalities, values, representations, etc… actually change through education and how this may impose the maximum speed of the transition; this has been based on surveys at school.

Phase 2

The second phase of the project aims at giving a more precise and quantified view of the post-carbon world and the transition to it. It involves two main work-packages, dedicated first to the up-grading of the two models to be used, VLEEM and POLES and their adaptation to the project, then to the design of consistent scenarios of the post-carbon world and their quantification with the models.

The fifth work package is devoted to the upgrade of both VLEEM and POLES models, their adaptation to account for the new analytical inputs of the project and their combined use. VLEEM is mostly focussed on the demand of energy services in the various regions of the world, in relation to demography, access to education; changes in the structure of time-use, etc…Energy services do not mean electricity or gas demand. This is why POLES is necessary, to convert in a consistent way these energy services first in demand for energy products, then in balances demand/supply of energy at regional and world levels. Up-grading and adaptation will involve data updating and development of new functions to better grasp the specific dimensions of the project, in particular as regard urbanisation and land-use. Combined use of the two models means to work out an interface between energy services according to the VLEEM definition, and the demand functions of POLES.

The sixth work package leads to the quantification of the post-carbon world, according to consistent scenarios: consistent as to the description of the post-carbon world and societies at the target year, 2050 (and beyond) and consistent as to the description of the transition towards this world. The first aspect of this work-package defines the scenarios and writes their story-line: this is done through a process involving all the fields of expertise available in the project. The second aspect converts these scenarios in exogenous inputs for the models and starts an iterative process between the analysis of the results of the models and the revision of the exogenous inputs up to a point where an overall consistency between the qualitative description and the quantification is achieved.

<u>Cross-cutting activities</u>

In order to make sure that the outcome of the research is considered in the decision-making processes likely to lead to post-carbon society, it was necessary to involve major stake-holders concerned by the transition process at some point of the research. Among the targeted stake-holders, three groups are critical: the public policy makers (EU, national, local); industries directly impacted by the technology evolutions in transport, building and energy; representatives of the public.

From a scientific viewpoint, we tried to create opportunities for the analytical and modelling developments considered in the research to be discussed and challenged by the scientific community. This is important to give robustness to the findings and messages of the study, and to make participating stake-holders confident and comfortable with the results. Therefore, the seventh work-package, dedicated to cross-cutting activities, is devoted to communication.

3 Main findings of WP 1: Post carbon cities and land -use

3.1 Objectives and overview of achievements of WP1

Two main objectives were assigned to this work package:

- description of future land use patterns in Europe considering the mega-trends of ageing society, climate change, agglomeration effects and rural depopulation, with a special emphasis on urbanization;

- Development of linkage between future land-use patterns and required changes of the transport and energy infrastructures.

Max Planck - IPP was in charge of this work package, with assistance of ISIS, FraunHofer-ISI and Enerdata.

3.2 Urbanisation and Land use Patterns

3.2.1 Observing and measuring land-use pattern

Within the discussion of land use and urban form, one of the key problems researchers face is the task of measuring land use patterns and change processes. Thus accessible indicators are needed to determine both land use type as well as the land use intensity (or compactness), which can be described as *continuous* or *discontinuous* urban fabric.

In order to measure the land use pattern and urban form and their changes on different scales, different approaches can be found in the literature. Generally studies use either <u>statistical</u> data for certain administrative units (municipalities, regions, or countries) or <u>geographic-spatial</u> data (going down to the level of site development. Furthermore a combination of both can be often found.

Within the PACT Project we have mostly used data from CLC (CORINE Land cover) which allows us to include the aspect of 'continuity' of urban fabric, when categorising the countries into land use types. This spatially specific information is a good indicator for the urban density of built environment, rather than falling back on statistical data collected for a larger area, hiding the different patterns of land use as well as densities.

3.2.2 Focus on urban sprawl in Europe

A special emphasis has been put in the PACT project on the urban sprawl phenomena in Europe, with attempts to address three main questions: how to measure it, what are its main societal and economic drivers and what are the European and local policies implemented to promote instead polycentric city's development.

Urban sprawl is a complex phenomenon, leading to different definitions of what urban sprawl is, and to difficulties to measure it. Different research disciplines like landscape and urban research or even mathematical branches like fractal geometry research developed different indicators to measure urban sprawl phenomena.

From a social viewpoint, urban sprawl reflects the European citizens' preference for a new house or second house in suburban/rural areas outside the city. The lower land prices and the expected rise on land value have made the detached or semi-detached houses the preferred choice for many European citizens. Living in the suburbs areas is indeed often the choice of the families with small children who consider the suburbs safer and healthy than the core areas.

Globalisation and European economic integration has also contributed to shape the spatial distribution of population and the urbanisation patterns. The development of information and communication technologies, the shift toward a service oriented economy linked with the transfer of production activities had and still have a major impact on urbanisation. The high price of land zoned for housing or services in the inner city has brought investors to look at the agricultural land surrounding the city, especially when new transport infrastructures are being developed that make the peripheral locations more accessible.

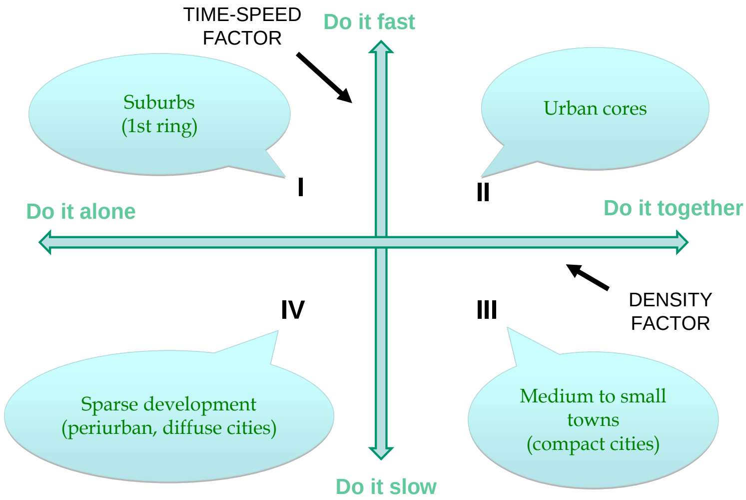
A wide range of urban planning systems and solutions to urban sprawl have emerged throughout Europe, however, their effective application requires political commitment, administrative and technical coordination and stakeholders involvement.

3.2.3 Envisioning different urban scenarios in the post-carbon society

The link between urban form and energy requirement in the one side, carbon footprint in the other side, has been clearly demonstrated. But the research carried out in PACT eventually concluded in the absence of a single model for post-carbon cities, even the absence of a preferred model of such cities. Instead, PACT has investigated how existing urban forms in Europe would evolve towards a post-carbon economy.

Two key factors have been identified to describe different dominant lifestyles and urban forms – the **time-speed factor** and the **density factor** – building a 2x2 grid as follows:

Fig. 1 Urban forms in relation to the time-speed and density factors



The time-speed factor makes a distinction between “doing things fast” or “slow”. “Fast” production or consumption activities require that the number of products made or consumption opportunities exploited in a unit of time are large. This is the paradigm of modern globalised economies and lifestyle, which requires high amounts of extra-somatic energy per capita, high productivity per worker, high capital intensity and global markets to be sustained.

“Slow” production and consumption activities do not require the concentration in large production, distribution or service units, as for them it is usually sufficient and more effective to have smaller organizational units, using lesser amounts of extra-somatic energy per capita, lower capital intensity and productivity per worker – i.e. more labour intensive processes – and greater reliance upon local resources and markets.

The density factor makes the distinction between “doing things alone” or “together”. We are all doing things “alone” when we drive in our own car and we live in low density suburbs or detached houses in peri-urban or rural areas, whereas we are all doing things together when we live in compact villages, towns or in the inner cores of large cities, when we share collective transport services (public transport or other forms, such as car sharing and/or pooling) or whenever we walk or cycle around in a compact urban environment. “Togetherness” is seen here as a condition where people live in more physical proximity to each other, when they travel, work, enjoy their life etc. in compact city environments.

The same 2X2 grid representation can be focused on the nexus between the distributions over space of:

- Population (where people live: houses)
- Consumption opportunities (where people consume private and public goods)
- Production opportunities (where people produce)

The urban forms are therefore understood as combinations of people and activities spread in the four quadrants. They were the foundations in PACT to analyze the transition to a post-carbon society, and how the dominant lifestyle, technologies and infrastructure for urban life, housing and mobility could/should change to drastically reduce the use of fossil fuels and CO_2 emissions. These changes may concern different ways of organizing production and consumption activities, and different mixes of “fast” and “slow” activities which will characterize future urban daily activity profiles of human beings.

3.3 Land Use Patterns, transport and energy in the European Countries

3.3.1 Land use pattern and transport infrastructures in Europe

From a historical land use and demographic development based on CLC, a typology of land use patterns has been proposed by PACT. The following data are taken:

- total share of built-up area, agricultural area and natural land in 2000,
- growth rate of built-up area, agricultural area and natural land from 1990 to 2000,
- growth rate of discontinuous urban fabric from 1990 to 2000, and
- forecasted annual population growth rate 2000-2030

Using this typology, EU countries have been allocated to specific clusters of future land use pattern. The transport infrastructures have then been analyzed according to the typology of land-use pattern. The CORINE land cover database also provides information of the area occupied by transport infrastructure and facilities. In order to evaluate the requirements of adaptation it was necessary to appraise the infrastructure against the land use pattern. It is not helpful to compare the transport infrastructure with the total area of one country, because the total amount or share of transport infrastructure does not determine requirements of adaptations, rather its relationship to the accessible land (=built-up area), its pattern (continuous or discontinuous) and the demographic perspectives of the countries.

3.3.2 Harmonization of Energy Infrastructure with Land Use and Urban Form

There is a clear difference of the potential of the production of energy regarding to the urban density. Urban cores and medium and small towns are characterized by a high density of both population and built up area, on the other hand sparse developments and suburbs have a low density (cf. Fig. 1). The lowest density can be stated for rural areas, which are the usual location of centralised conventional energy technologies and offer many opportunities to supply renewable energy. On the other hand the demand is rather medium due to the sparse population, so that the current situation requires huge energy transfer between the two land-types, with a total energy consumption globally too high to be “post-carbon compatible”.

In a Post-Carbon society, the energy system should be more balanced between high density, low density and rural areas. All areas should increase their post-carbon compatible renewable energy collection, while old fashion energy supply from rural areas (i.e. centralized CO_2 emitting technologies) will dramatically decrease. Simultaneously, total energy demand would decrease thanks to high energy conservation and energy efficiency. At the end, energy would mostly be produced in-situ, with networks ensuring the remaining necessary energy transfer between different urban forms and rural areas.

Urban areas are and will probably remain with an adverse energy balance, both in high and low densely populated areas. Reducing energy deficit of urban areas would require increasing on-site energy production and cutting energy consumption in urban areas. Ways to achieve these results could be however much different between high and low density urban areas, because of the differences in urban characteristic. For instance, large quantities of renewable energy are difficult to produce on compact urban areas, while large energy efficiency programs focused on buildings and public transport development are much feasible. On the contrary, energy consumption would remain higher on least dense urban areas because of incompressible energy needs for individual transport. However, larger spaces would enable to collect more renewable energy on these areas.

In order to address these key issues, PACT has investigated in details the question of renewables potentials and harvesting possibilities in the four urban forms, and the more specific question of the competition for land-use in the rural/low density urban areas.

4 Main findings of WP 2: Post-carbon social life and technologies

4.1 Objectives and overview of achievements of WP2

Four major objectives were assigned to WP2 in the Grant Agreement:

- Technology assessment for housing, energy and transport services of households in post-carbon society
- Technology assessment for supply of housing, energy and transport services in post-carbon society.
- Quantification of material inputs for housing, energy and transport services in post-carbon land use patterns.
- Description of life-styles and behavioural changes to achieve a post-carbon society.

Fraunhofer-ISI was in charge of this work package, with the assistance of Enerdata.

4.2 Material requirements of new technologies to reach post-carbon society

Pathways and material requirements are investigated in three fields: housing, energy services and transport services used by households. For each field three steps are discerned:

- In a first step the potential technologies for decarbonisation are identified.
- In a second step the pathways, which are either a trajectory of penetration of a new technology into the market or a sequence of new technologies that enter the market and replace each other one after the other, is developed.
- In a third step the materials inputs of the different technologies are estimated. In addition also the possibility of new materials being used is considered. It is also taken

into account that the material inputs may change along the pathway of the technology penetration in the market. Examples for technologies in the housing sector would be new insulation materials, zero-energy houses concepts, highly-energy efficient electric appliances but increases in demand could prevail e.g. the growing number of new energy services, particularly related to ICT.

Building concepts for new buildings could move from current standards to low energy and then passive house standards by 2020. After that, zero emissions housing and then plus energy house concepts should take over. By 2050 at the latest, new buildings should be built to plus energy house concepts. Retrofits of existing buildings will follow a similar path, but with a later timescale and with some exceptions in terms of completeness and in terms of extensiveness due to technical and architectonic reasons. By 2040, typical retrofits of existing building would be similar to the zero energy standards and elements of the plus energy concept would be included.

For aviation by 2050, it is possible that the use of biofuels will be widespread, possibly the main application for biofuels in the long run. Open rotor engines could become the standard technology for short and medium haul airliners. The trend to adoption of composite materials will continue, replacing current aluminium construction with carbon fibre reinforced polymer.

Ships would sail slower, especially container ships and ferries. Widespread adoption of combined sail and power, with changes in ship design and navigation to optimally combine winds for sailing and power plants could reduce energy demand in freight shipping by up to 40%. For some smaller auxiliary power requirements, fuel cells using e.g. methane could become common. Diesels for propulsion could use biofuels.

Rail vehicles could also change significantly. Following the aviation and automobile industries, aluminium construction and then carbon fibre reinforced polymer could make a major contribution to weight saving. Major energy savings will also come through comprehensive power management, air conditioning and heat recovery systems by 2050. Improvements in aerodynamics including pantographs can also make a significant contribution to energy saving.

Road vehicles will also follow the path of lightweight construction using carbon fibre reinforced polymer as a main structural material. For cars and light duty commercial vehicles (LDVs), plug-in electric hybrids and electric vehicles seem the most promising current technology to minimise emissions. The very large energy demand of the road vehicle fleet will then require extensive adoption of renewables power generation, also for the main current alternative, hydrogen based fuels cells. For HDVs, diesels are currently seen as the power system for the foreseeable future, probably with biofuels. Lightweight structural materials will also make a major contribution to reductions in energy demand, while improved aerodynamics also has the potential for significant energy savings. For all road vehicles, driver assistance systems will become much more extensive. This may enable the adoption of platooning, where vehicles under semi-automatic control drive close behind each other, thus considerably reducing air resistance.

For local public transport, buses will experience similar technological improvements to LDVs and HDVs, while trams can be expected to adopt the improvements in rail vehicles, especially light weight construction and power system management. A significant further change may come through the use of ICT to improve the performance and convenience of public transport, with real time multi-modal information for users and flexible routing such as with the Taxibus concept, real time car sharing systems and home delivery.

For building concepts and the building envelope, most of the technologies for the passive house, zero energy houses and the plus energy house are applicable to different housing densities. The main impact of urban density is in energy and heating provision. Medium and high density urban forms provide the most favourable conditions for centralised systems. In particular, larger scale central district heating systems using waste incineration and heat pumps to tap local renewable sources, with connections to large scale wind farms, thermal or photoelectric solar power or other centralised renewable power generation, would be the most effective energy system for urban cores or compact cities. An important contribution of the technological pathway identified is that housing can be expected to have much lower energy demands by 2050, both average and peak, such that the energy required to be provided by centralised systems will be much less than with the current building stock and urban fabric. Medium density settlements in suburbs might also be most efficiently supplied with heat through a local district or individual heating systems, depending on the case. If zero and plus energy houses are common, power requirements in medium density settlements will be small. For low density settlements, decentralised systems will be optimal. The zero and plus energy house concepts show that it will be possible to have low density urban settlements, using low carbon energy systems without requiring supply from centralised systems.

In transport systems, the core cities and compact cities can support high capacity/high speed rail public transport systems. These have to be complemented by LRT and bus systems to cover areas between the most densly populated corridors and also medium density urban forms. The attractiveness of public transport systems compared to private vehicles is dependent on waiting time as well as price and the quality of vehicles. Therefore, the new ICT concepts for flexible routing and timing using minibuses or car sharing without booking ahead offer the possibility of making public/shared transport modes more attractive in both high and low density urbanisation patterns.

4.3 Living in post-carbon societies: a series of stories

Six stories have been elaborated, describing life in cities, in a low carbon society in the future. These stories paint a picture of life in post-carbon societies in different European countries (Germany, France, United Kingdom, Spain, Italy, Sweden), and in the different urban settings adopted by the PACT project to grasp cities in post-carbon societies (core-city, suburb, sparse settlement, small town).

The purpose of these stories is not to capture the diversity of the society in 2050 in post-carbon societies. Instead, their aim at illustrating with practical examples how these new technologies for post-carbon daily life of citizens may cluster, and accompany changes in life styles. In order to make these stories comparable and to highlight the role of the climatic and natural environment, we decided to consider the same typical family - 2 adults and two children, with more or less similar income - in different countries and urban environment.

In all the situations, each family has a direct carbon footprint equal to zero. Energy efficiency has significantly improved, including the thermal insulation of the buildings. None of the energy used or produced at the building level emits CO2. Electricity obviously plays a major role in this new energy paradigm. Biomass and solar energy are also extensively used either to generate decentralized electricity or to warm water and space or through biofuels; electricity storage systems have been implemented on large scale (batteries, hydrogen,...).

These stories specifically describe what families use for transportation and heating appliances, and how they run electrical equipment and produce energy for personal consumption... The solutions developed are necessarily dependent on the unique climatic conditions in each country. For example, Spain, with its abundance of solar radiation, is not in the same situation as Germany or the United Kingdom. With its vast forests, Sweden could achieve this transition to a post-carbon society more rapidly.

This post-carbon life not only results from technological progress. New ways of organizing our societies are also suggested, such as new transportation methods within a town, or urban planning actions at the city level.

For each of the six families, a complete energy balance detailing supply and demand is shown and can be compared with one another. Also, stories are based on common assumptions: it is a family of 4 persons, incomes are similar, all families go on vacation at least once a year, and their annual mileage by car varies from 9,000 km to 13,000 km.

These stories reflect lifestyles and levels of final energy consumption. They do not describe the centralized generation systems for electricity and hydrogen, which also must have a low carbon footprint (nuclear, wind farm, hydro dam); nevertheless, integration of those systems with the grid and with more decentralized generation plants are taken into account. In addition, these stories offer an assessment of the cost of current energy systems, and knowing that intermittent renewable energy might bring some more volatility to the market.

4.4 Conclusions

The research work of WP2 intended to provide a qualitative overview of the technologies and lifestyles that would make up a low carbon society in Europe in 2050. It also assesses the main material requirements for buildings and transport, together with the changes in material use that may occur due to the adoption of new low carbon technologies.

The pattern of urbanisation has a fundamental influence on both energy service and transportation provision. The typology of urban forms developed in WP1 of the PACT project is used as the basis for assessing the relevance of different technologies given different forms of urbanisation.

This qualitative assessment is intended to provide a basis for scenario development with the POLES and VLEEM models in the PACT project.

Both building and transport technologies will undergo a transition from the current technologies by 2050. Buildings would not only be much more energy efficient, but would mainly be zero or plus energy buildings. Hence the energy demand from buildings would be very much smaller than the building stock of today. Heating in high density urban areas with very high efficiency district heating, using heat pumps and renewables would be the main centralised technology for heating. Given the near zero net energy demand, power requirements could be met from renewables. Even in low density areas, a high proportion of zero and plus energy houses would mean that power requirements from a centralised system would be minimal.

Transport technologies would also undergo a transition. A shift to more public transport, powered by electricity for road and rail systems, will be made more attractive by new ICT systems with real time control and information. A change to electric cars, buses and light commercial vehicles will transform the fuel system for transport away from fossil fuels. In HGVs and aviation, where no large scale change from diesel motors and kerosene is foreseen, biofuels would be prevalent. In shipping, lower speeds and use of wind power will reduce the energy demand, especially of freight transport, while the remaining diesel engines would also be powered by biofuels.

Developments on the potential of renewables carried out in WP1 of PACT show that by 2050, the building integrated photovoltaic potential in new construction would reach around 20% of the total potential of today's' existing stock. Centralised solar power has considerable potential in Spain (1278 TWh/year), with Portugal also having a large resource (142 TWh/year). Cyprus, Italy and Malta could generate up to around 29 TWh/year. The contribution of wind could increase to cover 28% of the electricity demand by 2030, in particular through the development of new off-shore wind farms. In some part of the country wind energy has already occasionally supplied 100% of instantaneous electricity demand. Wind power potential development in Europe is closely connected to the power-grid issue and the possible development of interconnections between European areas (EWEA, 2005). Biomass also has potential for a significant contribution. Scenarios for up to 400 EJ/year have been developed (Van Vuuren et al., 2010).

The stories of low carbon energy lifestyles illustrate different solutions for energy provision. As shown by the German case study, even a low density urban scheme can use a hydrogen based energy system, thanks to low value surpluses of wind power. Suburban living in London is based on public transport for daily transport needs, together with a high energy efficiency house using a heat pump and renewable energy from the grid. Electricity is generated form renewables or imported. Urban living in a historical city centre (Rome) is based on low use of cars, solar/PV heating and district heating/cooling, together with electricity from the grid generated by renewables. Living in the centre of Stockholm also uses district heating, fuelled with biomass and electricity from the grid.

Overall, the adoption of the low carbon technologies in buildings and transport would enable the maintenance of a very high standard of living in Europe. This could be achieved with electricity generated from renewables and with biofuels where electric power or fuel cells cannot provide sufficient power density. Buildings with very high energy efficiency and transport vehicles using lightweight construction and comprehensive power management systems have the technological potential to make such an energy system feasible. A transition in technologies in both buildings and transport would however be necessary to achieve this vision.

5 Main findings of WP 3 : Producing goods and services in post-carbon societies

5.1 Objectives and achievements of WP3

WP3 aims :

- at providing a list of probable technologies that can become available by 2050 in order to fulfil the basic environmental and social conditions of that time and,
- to come up with a confrontation between social services and post-carbon technologies presented in a matrix form. WP3 is an intermediate work package that feeds on scenarios from WP1 and WP2 to deliver quantitative data to WP5, the latter being aimed at describing the pathways from the present to the post-carbon society.

The technology issue is strongly related to the materials issue, as there is no such thing as a dematerialized technology. Therefore, materials are the core of the problem of social services and WP3 ought to focus on the materials that will usher in post-carbon technologies. Besides bulk and structural materials as steel and concrete are, non ferrous metals, glass, plastics, fibres reinforced materials, wood, have an important role in WP3. The issue of new innovative materials is also tackled.

For now, WP3 has completed a qualitative step corresponding to phase 1 of the project, which consists on a qualitative approach before transition scenarios to the post-carbon society can be quantified in terms of energy and material needs. The WP3 deliverables D 3 "producing goods and services in post carbon societies" is structured in three parts:

- the first part considers materials from an historical point of view as well as through long-term foresight projections, explored through various scenarios. These all confirm that material demand will be driven by population growth and by the improvement in the worldwide standard of living, with only a very weak connection to the carbon constraint.
- the second part tries to detect what the likely technological drivers might be at the 2050 horizon. It focuses on mobility and building/shelter;
- finally, materials are reviewed relative to their CO_2 and energy intensity, with a look at present technologies and expected ones in the future.

ArcelorMittal and MEFOS were in charge of this work package.

5.2 Trends for materials

The 20th century past data show:

- A substantial increase in the production of all materials;
- A time kinetics that reflects history and economic history, as the wars, the great depression and the lesser ones are easily visible in the blimps of the curves;
- Steel, cement and wood are running at the same level in terms of weight from the end of the 2nd world war until the 1st oil shock; plastics run parallel to them, with a historical start point in significant volumes at the beginning of the second half of the century;
- Then cement starts diverging: the other core materials slow down with the crisis of the 20 "piteous years" triggered by the so-called 1st oil crisis, while cement does not. It actually doubles its production compared to steel and wood during this period. This clearly means that while the former materials were connected to GDP evolution, the latter continued to increase in terms of intensity per unit of GDP. A clear analysis of why this was the case is lacking;
- Finally, with the economic boom launched by China at the beginning of the 21st century and carried on by the other BRICS countries, an acceleration of growth takes place, which the 2008 crisis has slowed but not necessarily for a very long time, if present data are to be seen as a sustainable trend.

The foresight data also exhibit some interesting features:

- The 2050 production of all materials shows a significant increase with respect to 2000, roughly a tripling in volumes (a 2.2% average growth rate along the period); this projects a strong increase in material intensity per capita, as the world population is to increase by roughly 30% "only" during the period. The intensity per unit of GNP exhibits an elasticity of roughly one with the increase in GDP.
- Production level forecasts for 2050 are rather insensitive to the carbon constraint, like in the case of steel where slightly lower and slightly higher values are projected by 2 variants of a 50% reduction scenario: aluminum and glass projections are slightly lower and cement is slightly higher. Nothing like the uncoupling of cement from the other materials, shown in the historical data record, is exhibited here, which probably goes to say that the underlying behavior of the markets has not been modeled into the studies as the effect had probably not been identified by the researchers and is certainly not well understood.

Based on the previous analysis, the trends for materials in PACT will be the following:

- The major materials described as structural will remain the same as today, i.e. steel, metals, cement (or rather concrete), wood, glass and plastics: because of this time stability, they are often called traditional or conventional materials. New materials will not be invented that can drastically reshape the market in this area, which is determined by a century-long investment in knowledge and in capital for production facilities. Of course, some small market share can be grasped by new materials in some applications, such as the switch of commercial airliners from aluminum alloys to carbon fiber composites, but this will not turn into a revolutionary, all encompassing new paradigm in materials within the PACT time horizon.

- Materials production will continue to increase, roughly at the pace of increase of GDP. This would seem to do justice to the *dematerialization concept*, be it expressed in absolute terms or per unit of GDP. These projections are based on the assumption that growth is necessary to increase the standard of living in the world, while new technological epistemes are ready to take over the economy and decarbonize it to a sufficient level for Climate Change to be brought under control. This means in particular that material intensities per capita will increase, thus expressing once more the fact that standard of living and material intensities are strongly correlated.
- These structural materials, in addition to being necessary to create the infrastructure of a modern society that can accommodate up to 9 billion people in this century, are plastic enough in the set of properties that they exhibit that they can make carbon-lean technologies happen. Most structural materials, in that sense, will demonstrate how sustainable they are indeed, mainly through the continuing introduction of higher-level properties and thus through *a decrease of their intensity per functional unit – which will probably end up being the only proper definition of dematerialization.*

5.3 Qualitative description of materials use in society

The connection has been explored between a post-carbon society and the artefacts that are used to fulfil its social services in terms of materials needs. The approach is necessarily qualitative, as the scenario construction which will be one of the key parts of PACT has not been carried out yet. The post-carbon society is seen in a loose way as a desirable transformation of our present world, a kind of intellectual thought experiment.

We have tried to project a post-carbon scenario, which is radically unrelated to the present situation and not simply a business as usual (BAU) projection. Assumptions have been stated below in order to provide food for thought. Of course, this intuitive projection shortcut a lot of complex debates based on the intrinsic uncertainty of future studies and a plain lack of vision in many areas, for example concerning agrofuels and land usage. Production technologies are used to make the artefacts which will be needed by society and people.

Artefacts are of course made of materials, and, as stated in the introduction to this section, the focus is on the following materials, consistently to what has been stated in the introduction:

- Concrete, and cement or mineral materials for construction
- Glass, conventional and technical
- Metals, ferrous (mainly steel) and non-ferrous
- Plastics and carbon fibers-reinforced matrixes
- Wood.

Social services considered here are the followings (from VLEEM's classification):

- **Mobility**
  - Passengers
  - Freight

- **Building and shelter**
  - Construction
  - Maintenance
  - Thermal and sanitary comfort
  - Lighting

Key drivers have been indentified that will cause the change over from today's society to the post-carbon one.

As macro-results, we found that material use for housing services will be mainly driven by “Ecodesign” of building and shelters, as well as of entire city parts. Eco-areas experiments already achieved in Europe have been considered as sound prototypes for estimating technologies and materials in post-carbon cities.

Service	Specific Technologies	Main materials
Construction / Maintenance	Dry building works Assembling-based technologies Green roofs	Steel Concrete – bricks – stones Wood
Thermal comfort	Thermal bridges avoidance Thermal inertia control Solar radiation control	Insulation materials Glass Metals Wood
Lighting	LEDs	Plastics/polymers Metals
Sanitary comfort	Damp control Air exchange	Metals Plastics
Energy supply	Heating/cooling pumps Stationary fuel cells Solar panels Wind mills Biomass	Metals Plastics Wood

And about mobility, we found that a large technology panel is desirable to fulfill the wide range of personal and collective mobility needs.

Service	Specific Technologies	Main materials
Individual mobility	100% Electric car Hybrids ICE	Metals Glass Plastics Reinforced matrixes
Public mobility	Buses, streetcars, trains Aircrafts	
Freight	Road : hybrids and efficient diesel engines Rail Water (inland waterways and sea) Air transport	
Road safety	Signals Barriers	Metals Concrete
Infrastructures	Roads and railroads, waterways, airports Energy supply –electricity, hydrogen	Concrete, Bitumen, Metals

6 Main findings of WP 4: Transition towards post-carbon societies

6.1 Objectives and achievement of WP4

This work package focuses on transition towards post-carbon societies. It covers three main aspects all of them of a sociological nature.

- The first aspect deals with the citizens and the actors which at the same time will drive and be impacted by the social changes towards values, representations and desires that will shape the post carbon societies: question related to the social heritage, the social inertia, the acceptability, etc…
- The second aspect deals with the governance of the transition and the question of how the risks associated with drastic changes, in socio-economic structures as well as in technologies will be accounted for in government policies and main actors strategies.
- The third aspect deals with the social and human capital of the youngsters as regard the transition towards post-carbon societies.

6.2 Driving socio-economic forces and actors, acceptability, heritage, policies

The research work of task 4.1 of work package 4 was carried out by Laboratorio di Scienze della Cittadinanza.

The research was based on the identification and interpretation of a series of "anticipatory experiences" of energy transition, i.e. those bearing (thus anticipating) the basic features of a more complex transition to environmentally sustainable society. In this sense, the anticipations should be regarded as yet existing "parts" or "pieces" of a future post-carbon society. The objective was to highlight constants, and regularities among these experiences in order to identify connections between changes in energy technologies and social dynamics.

"Anticipatory experiences" of energy transition were analysed according to 4 main theoretical and methodological criteria:

1. Factualness: they introduce a new technological system (at least in the local contexts)
2. Social impact: they produce changes in attitudes, rules or standards, way of using resources, local production systems, living and working environments, etc.
3. Systematicity: they act simultaneously in several areas (technological, economic, social and cultural) affected by energy transition
4. Transparency: they are oriented towards "self-communication”, providing information on the results achieved, critical elements, and interaction with other initiatives

The work was dedicated to the study of 270 experiences and functional to the selection, first, of 60 anticipatory experiences, and then a smaller group of 20 experiences for in-depth study. Each of the 270 initiatives was therefore analysed on the basis of information collected and filed applying descriptive parameters (type of project, scope of action, size, number of people involved, etc.). Then, using the four theoretical and methodological above criteria, the first group of 60 "anticipatory experiences" was identified and then the smaller group of 20 experiences was selected. The experiences are heterogeneous in size and target area and concern 10 different European countries.

The anticipatory experiences were studied in depth to identify phenomena related to the theoretical structure of the project. For each of the experiences, a dossier was drafted containing reports, papers and essays, case studies and web-based material. The dossiers were analysed indepth by means of a reading computerised grid, which led to the drafting of an analytical fact sheet for each experience. To integrate the fact sheets, in-depth interviews were carried out by handing out a semi-structured questionnaire to the key informants of individual experiences (mainly the promoters). All this led to the identification of 700 "de facto situations", which after a condensation process were reduced to 249 phenomena, collected in a database.

All the information collected in the fieldwork was elaborated by the research team, for the production of a Sociological Predictive Operational Model on Energy Transition (SPROMET). SPROMET defines Energy Transition as made up of two variables:

- Technological Societal Process: enablers and obstacles
- Political Societal Process: enablers and obstacles

The main conclusions as regard the complexity of energy transition are:

a) Pervasiveness
- Energy transition materially affects the lives of all individuals
- Energy transition concerns individuals at several levels simultaneously
- Energy transition affects the entire spectrum of organisations in an area

b) Close interaction with social dynamics
- Short-range societal dynamics, mainly of local significance (widespread behaviour at local level; recurrent orientations of certain actors; local real estate market trends, etc.).
- Long-range societal trends, mainly transnational in origin and perspective, previously operationalised in the five vectors of social and cultural change (Political institutional vector; Anthropological vector; Social vector; Science and technology vector;Globalisation of knowledge vector)

c) Energy transition as technology transfer
- Not merely the implementation of new technological equipment, but a process of technology transfer of which no single step is purely technical but always involves social, political, economic, cultural, communicational or organisational dynamics.
- For this reason, energy transition requires considerable social and cultural investments, equal to and probably more than technological ones.

d) The centrality of energy transition in governance processes
- Energy transition reaches deep into the political dynamics that characterise a given social context.

- Energy transition has **broad** effects on political dynamics. It affects almost all public policy areas: energy and environment, economic development policies, agricultural, planning, transport, science and technology, and health policies, etc.

6.3 Risks and governance in the transition process towards post carbon societies

Finland Futures Research Centre, University of Turku (UTU) and the Regional Energy Centre for Policy Research of the Corvinus University of Budapest (REKK) contribute to the production of the Deliverable 4.2. "Risk and Governance in the transition process towards a post carbon society".

The Deliverable is composed by a theoretical part based on the concept of governance for complex critical infrastructure, and in the specific case, for identifying pathways for a free carbon energy society in 2050. Theoretical findings about security and risk in respect to complex energy issues are also treated.

In depth analysis of regulatory risk governance is also performed, through theory and interviews to relevant stakeholders.

In the final part, as a result of the theoretical thinking, a risk governance model for stakeholders' participation in decision making is realised. The Delphi survey (workshop + online survey), translated in 4 transition scenarios, is able to realise an alternative cost-effectiveness analysis, which is based on stakeholders' perspectives, perceptions, expectations and expertise. This methodology, in contexts of high uncertainty and soft scientific facts, tries to find out the desirability (effectiveness) and probability (economic feasibility) of a given policy or technological choice. The methodology results to be particularly useful when continuously performed, in order to grasp the dynamic changes in society, technological achievements and in order to involve stakeholders in a permanent exercise in support to decision-making. The methodology, again, is built to be further developed, added with possible statistical tools or modified. Issues, if required, can be broken in more parts for realizing further analysis on the matter.

This research exercise is actually a first try to implement risk governance practices for managing European energy policies and infrastructures by participatory approaches, which have been first theorised at European Commission level, by the Security of Critical Networked Infrastructures Group of DG Joint Research Centre. The activity of Energy Governance should be further developed, also in the consideration of the positive feedbacks received from the concerned stakeholders.

For the WP 4.2 of the PACT report a section focused on the governance and regulatory risks present in energy systems moving towards a post carbon society. This specific section is broken into two parts. The first part establishes the theoretical framework to assess risks associated with market, regulatory and institutional efforts to transition to a post carbon society. This theoretical framework addresses short term, medium term and long term risks. These are further broken down and analyzed within specific risk categories with definitions which help to develop risk mitigation methods. Within this framework key EU initiatives for energy security and climate change is reviewed which highlights the security of supply risks and technological and institutional lock-in present. The second part of this section is shaped around the input from stakeholders. This input was gathered from workshop participation, questionnaires and in the majority of cases, interviews.

6.4 Young people's human capital and social capital in a post carbon social life

The activities of work-package 4.3 were carried out by the University of Padova, and reported in the Deliverable DI4.3. They were designed with two main objectives:

- to identify, in view of the various agencies of socialization (family, peer groups in their various forms, school, and other) of young Europeans, the socio-cultural factors affecting the training of different outlines of credibility. It is intended to understand which agencies make up the main formative reference for the young interviewees on the basis of socio-demographic characteristics of the latter. This will provide for the prefiguring of suitable and effective formative paths and policies.

- to identify scenarios of future life (desired and expected) that European teenagers imagine in their own transition to adulthood and to the post carbon society, and to understand what kind of influence is exercised by interaction (interplay) between SC (Social Capital) and HU (Human Capital) in the representation of these scenarios, as well as the socio-cultural variables that influence the creation of differences. In the definition of future life scenarios, we will focus both on the ability of young Europeans to envisage the period when oil sources will be exhausted and alternatives that will replace it, and on various aspects of daily life (transport, labour, entertainment, interpersonal relationships, etc.).

Consistent with the bask-casting perspective of the project, the assumption that drives these objectives is that, the comparison between expected and desired scenarios can provide various useful indications to policy-makers to identify appropriate formative channels and promote effective policies compared to the reference values of the new European generations.

The initial objective of the research proposed to collect the impressions, desires and the hopes of the young world hypothesizing in particular the scenarios in a post carbon society in 4 European states: France, Great Britain, Germany and Italy. Consequently in its construction phase, the project called for the distribution of a paper questionnaire to be sent to two high schools in different cities of each of the 4 individual countries. As it dealt with the world of European youth and considering that all of them have a particularly friendly rapport with computer and multimedia technologies, it was then hypothesized, as a later thought, to directly offer the young people a questionnaire online.

The main conclusions are :

1. The centrality of school in the life of young Europeans

The gathered information confirms the centrality of school within the network of educational references for young Europeans. The same young people consider school as *medium* in the journey between their daily lives and their future adult lives. The scholastic institution, the most repeated, is not the only socialization arena that the young people consider legitimate in influencing their own educational journey. From the information gathered it emerges that education it is still considered as a springboard from which to build a future and for the transition towards adulthood, representing a vehicle through which to proceed with sensitisation campaigns regarding the opportunities and risks linked to a *post-carbon society*.

To this end we consider the importance attributed to school by the young students, above all the males, as they look for help in the search of the “deep meaning of life”. That does not mean that family and a network of friends do not have a strong impact on their construction of the imaginary society of the future. On the contrary, further confirmation as to the centrality of the education system and its social acknowledgement is provided by the survey of the social capital of the young Europeans and the importance and value of friendship, which is typical in this age-group and which underlines the particularity of the peer group in confirming one’s identity.
Therefore we are not talking about young people lacking in social relationships outside of school, considering school as the only socialization arena, but that the educational institution continues to play a central role in the daily life of young Europeans because it slots into the net relationships in their daily lives. If school represents the bridge across which we find adulthood in terms of the spendability of educational knowledge, no longer and not only in terms of work but also in the construction of their future social network, it constitutes therefore the junction from which the complexity of the changing cultural scene is disentangled (Douglas, 1966). This causes us to consider school as the epicentre of the distribution of educational projects aimed at the adolescents of today’s *carbon society* against the adult of the *post-carbon society*.

2. Misinformed and fearful in the future post-carbon society

The hypothetical end of oil does not seem to worry young Europeans who link the issue to a sufficiently remote time and do not imagine that it will coincide with their daily lives or interfere with their habits and experiences. The youngest, born and raised in a time of uncertainty and risk showed the most detachment and the least fear: we imagined them “surfing to the future” with an attitude that on the one hand foresees them as already aware of a context characterized by continuous change and therefore already educated and adapt to instability, which they perceive as normal and therefore do not worry about it, to on the other hand immersed in their present and incapable of imagining possible different future scenarios. The “older” individuals (over 16) tend to view the end of oil as a more short-term possibility (within 50 years) and demonstrate an ability to foresee different scenarios which are almost entirely negative. Even when they showed to be capable of identifying possible alternatives they seemed to be more the result of slogans than of realistic life styles.

Some regional exceptions can be pointed out however, in particular France, which we can imagine as well connected to social and educational policy and whose young people demonstrated awareness and sensitivity. Even when identifying the states “guilty of pollution”, the young people tend to turn their attention towards countries outside Europe, identifying the two great peaks of world capitalism as the countries responsible. The same is repeated when they chose possible “saviours” where, within a highly varied context, the USA emerged again.

In this context there can be a distancing from environmental issues due to a lack of sensitivity and knowledge. The young people do however place great trust in science and knowledge: in the future the young Europeans feel that they can trust scientists and doctors and that knowledge and education represent important supplies for their future. The *appeal* of knowledge in the daily lives of young Europeans is therefore strong: knowledge is interesting and useful in their eyes to those who possess it but also something to which they can aspire. Another institution among those who are worthy of the trust of the young people is a young and *super partes* institution, that is, the EU.

To conclude, this report seems to be able to underline a diffuse lack of sensitivity and knowledge among young people regarding environmental issues: a lack of knowledge that causes imprudence, serenity and security or a strong fear splits our sample in half regarding their vital statistics (young vs. old). This context does not exclude, but rather seems to be particularly favourable towards and receptive to educational projects aimed at increasing their knowledge of the future and the tools necessary to live in it, as promoted or carried out by the figures that gain their trust (scientists, doctors and members of the EU).

7 Main findings of WP 5 : modelling

7.1 Objectives and achievements of WP5

The fifth work package is devoted to the upgrade of both VLEEM and POLES models, their adaptation to account for the new analytical inputs of the project and their combined use. VLEEM is mostly focussed on the demand of energy services in the various regions of the world, in relation to demography, access to education, changes in the structure of time-use, etc…Energy services do not mean electricity or gas demand. This is why POLES is necessary, to convert in a consistent way these energy services first in demand for energy products, then in balances demand/supply of energy at regional and world levels. Up-grading and adaptation will involve data updating and development of new functions to better grasp the specific dimensions of the project, in particular as regard urbanisation and land-use. Combined use of the two models means to work out an interface between energy services according to the VLEEM definition, and the demand functions of POLES.

7.2 Enhancement of VLEEM

The VLEEM (Very Long term Energy Environment Model) model has been developed and applied to all world regions, including Europe, in previous EU research programmes. VLEEM attempts to capture the evolution of the needs of energy services over the very long term, up to 100 years.

TILT (Transport Issues on Long Term) has been developed and applied in previous French research programmes on sustainable mobility. It is formally linked to VLEEM and develops the relation between the mobility needs (VLEEM) and the resulting energy demand and CO2 emissions, taking into account the vehicles and the competing technologies. In the course of this PACT research, VLEEM / TILT modelling package has been enhanced on three aspects:

- introduction of a spatialization of the population, mobility and dwellings in order to simulate the consequences of differences in future urbanization pattern as investigated in Phase 1 of PACT ;

- reformulation of the demographic model in order to fit with the above spatialization, and of the time-use, production, activity modules to capture possible changes in the transport time-budget;

- Development of a dwelling stock model including energy efficiency and decentralized electricity production features.

In addition, the modelling package has been entirely calibrated (TILT) and recalibrated (VLEEM) on the EU-27. At this occasion, the ergonomy for data input has been also entirely reformulated.

For the other parts of the model which have not been changed, the reader will find the description of the modelling package components in two documents: - www.vleem.org, VLEEM2, final report, annex 4, May 2005 - PREDIT 3 "Scénarios de mobilité durable: comment satisfaire les objectifs internationaux de la France en terme d'émissions de gaz à effet de serre et de pollution transfrontières ?" Rapport final, April 2008.

7.3 Enhancement of POLES

POLES is a simulation model for the world energy system in 57 regions, with endogenous energy demand, supply and prices (up to 2100). The demographic and economic evolutions, for every country or region of the world, constitute the main exogenous variables. The evolutions of all the variables characterizing the consumption, the transformation, the production and the energy prices are endogenous in the model.

Our objective in this task was thus to improve the model in order to make it able to simulate the PACT scenarios with specific concerns on spatial dimension of population, economic growth, intensity of climate policy, technological innovation, etc. To that end we have decided to introduce new variables in the model that could reflect contrasted evolutions of the urban form: namely the share of the population living in the core city, periphery and sparse settlements, as well as the corresponding urban density.

In the PACT project, different modifications have been introduced in the POLES final consumption modules. First of all, and most important, the urban density has become a key variable. In accordance with the introduction of urban density, the urban population has been split in two areas, the city centre and the periphery, with the aim to better reflect contrasted behaviours of those populations particularly as regard demand for mobility, car ownership and use of public transport.

The transport module of the model has been deeply changed and adapted so as to be able to take advantage of the differentiation introduced in urban population.

In the building sector, as a result of the differentiation of urban population, new relationships have been introduced for taking into account the higher proportion of collective buildings in more densely populated urban areas.

The introduction of differentiated urban density between the centre and the periphery has also offered the opportunity to develop a new module in POLES, the distribution of heat. District heating was totally absent of the standard version of the model. The development made introduces a new energy vector for heating needs, the development of which is correlated among other things, with the density of heat demand (ie. the urban density).

At last, the differentiation of population in 3 categories offers the possibility of a better appreciation of the potential of dispersed energy resources. In particular, the potential for building integrated PV systems can now be estimated taking into account the type of building (collective buildings versus individual houses) in which people leave.

8 Main findings of WP 6 : scenarios of post-carbon transitions

8.1 Objectives and achievements of WP6

The purpose of the scenarios is twofold:

- to recognize that there is not a unique "post-carbon" EU and a unique path to it, and to draw the consequences of the uncertainties on these matters as to the future possible energy systems;

- to account for the interactions between the various dimensions of the post-carbon transition as investigated in phase 1 of the PACT project, within consistent visions of the transition.

8.2 Presentation of the scenarios and the main findings

Post-carbon transition scenarios for the European Union (EU) are based on the 3 following observations:

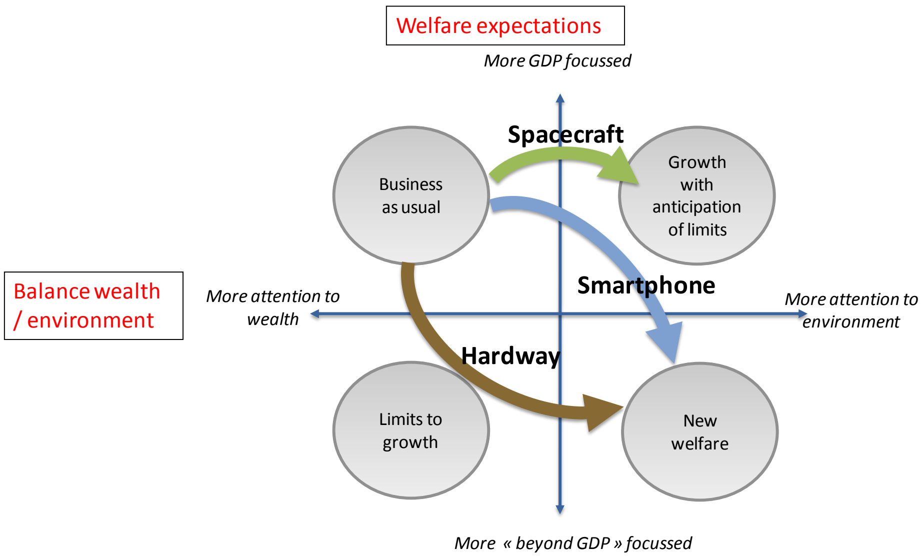
- because of limits in oil and gas resources, and because of climate change, the World will not have the possibility to continue for long developing on fossil fuels as it did in the past;

- something else (energy efficiency/thriftiness, renewables, nuclear, carbon capture and sequestration (CCS), either forced or anticipated, will take the lead well before the end of the century;

- because of time delays for nuclear and CCS to prove sustainability on large amounts, renewables and efficiency/thriftiness might well be the core of the "something else".

What is called "post-carbon transition" is precisely the process through which "something else" will substitute progressively and massively for fossil fuels, and start shaping new technological clusters, new economic and social organisations, new behaviours and preferences, i.e. new energy-technology paradigm.

Depending on its social and political dimensions, at local, national and international levels, the post-carbon transition may take very different routes, with different consequences as to the greenhouse gases (GHG) emissions trajectories up to 2050. 3 scenarios are therefore elaborated and quantified to capture three "extreme" routes towards post-carbon EU.



These scenarios do not necessarily include quantitative targets for GHGs mitigation or fossil fuels market shares by 2050: PACT focuses more on post-carbon transitions and less on the description of future post-carbon worlds, which may be achieved in a more or less distant future. But for easing the comparison among transition routes, and clarifying their consequences for policy making, we have assumed similar GHGs concentration in 2050 for all scenarios, around 500 ppmv for energy CO2.

Scenario 1 "Spacecraft": a highly centralized while cooperative project, the wedding of speed and technology, working well with absolute physical limitation in resources. "Spacecraft" describes a centralized transition process duly planned and managed by governments and big industrial and financial stakeholders, in a rather consensual movement among main GHGs emitting countries worldwide. In particular, they agree to commit themselves to mandatory reduction objectives of the carbon intensity of the GDP, accounting for carbon content of imported and exported goods. "Spacecraft" is highly technology oriented. Centralized technologies and innovation driven by big industries, in particular the "green" ones, are the pillars of a fast World economic development, respectful of the limits in natural resources and climate in this transition process.

Scenario 2 "Smartphone ": a bottom-up carbon transition process in which social networking and ICTs plays a critical role. "Smartphone" starts more or less as "Spacecraft", but diverge rapidly when it became obvious that Governments and big stakeholders will fail to implement a real and effective governance of the problems related to oil/gas resources and climate change. Instead, EU and member states governments, which are fully aware of the nature and urgency of the climate and resources problems, rely as much as possible on local / regional authorities, NGOs and citizens to address these issues. Although there are no global commitments on GHG mitigation, most cities in Europe, US, China and other main emerging countries adopt and implement drastic energy and climate plans.

Scenario 3 "Hard Way": a Business-as-usual scenario, that account for development / adjustment through violent/brutal crises. "Hard Way" describes a carbon transition process which is imposed by the growing problems and crises resulting from the un-ability of countries and societies to address in due time the question of the limits in natural resources and environment. Globalization and international relations are driven mostly by national interest considerations, paving the way for increasingly conflicting relations among nations. No global governance mechanisms neither for climate change, nor for oil and gas resources.

The 3 scenarios describe very different pathways to post-carbon situations in Europe, resulting in much contrasted social, economic and technology panoramas in 2050. Demography, economic growth, World tensions on resources and climate, policies, behaviours and life styles, technologies, are the main discriminating factors among scenarios.

Nevertheless, these very different routes could lead to similar reduction in CO2 emissions of the EU, and similar levels of CO2 concentration in the atmosphere, by 2050. But with very different prices for oil and gas, and very different values (i.e. constraint) for CO2:

- "Hard Way" is the scenario in which the oil prices will reach the highest levels (close to an average 250 US$2005/bbl in 2050, with the highest fluctuations), but the lowest carbon value (lowest constraint, around 100 US$2005/t), and the lowest GDP/capita;

- "Smartphone " is the scenario with the highest carbon value (constraint), around 800 US$2005/t in 2050, with also high oil prices (around 200$2005/bbl in 2050) and higher GDP/capita than in "Hard Way";

- "Spacecraft" is the scenario in which the increase of oil prices is the slower (around 140 US$2005/bbl in 2050), with a rather high carbon value (around 400 US$2005/bbl in 2050) and a much higher GDP/capita as compared to the other two scenarios.

These scenarios do not attempt to indicate to policy makers and stakeholders what route must be chosen, but to give them two clear messages:

- The EU may reduce in any case by large amounts its consumption of fossils in the next 40 years, and therefore reduce its CO2 emissions in the same proportion, but the social, economic and policy costs would be very high if this transition is not properly planned and implemented;

- There not one single way for planning and implementing properly the transition. Indeed, social forces are currently pushing in two very different directions: some tend to reproduce the recipes that have cooked the economic growth of the OECD countries during the last 50 years (even if this economic model seems a bit tired these days), while others consider this model obsolete and fight for inventing a new "beyond GDP" model. Depending on which social forces will become predominant, the transition pathways, even if duly planned and managed, will be very different.

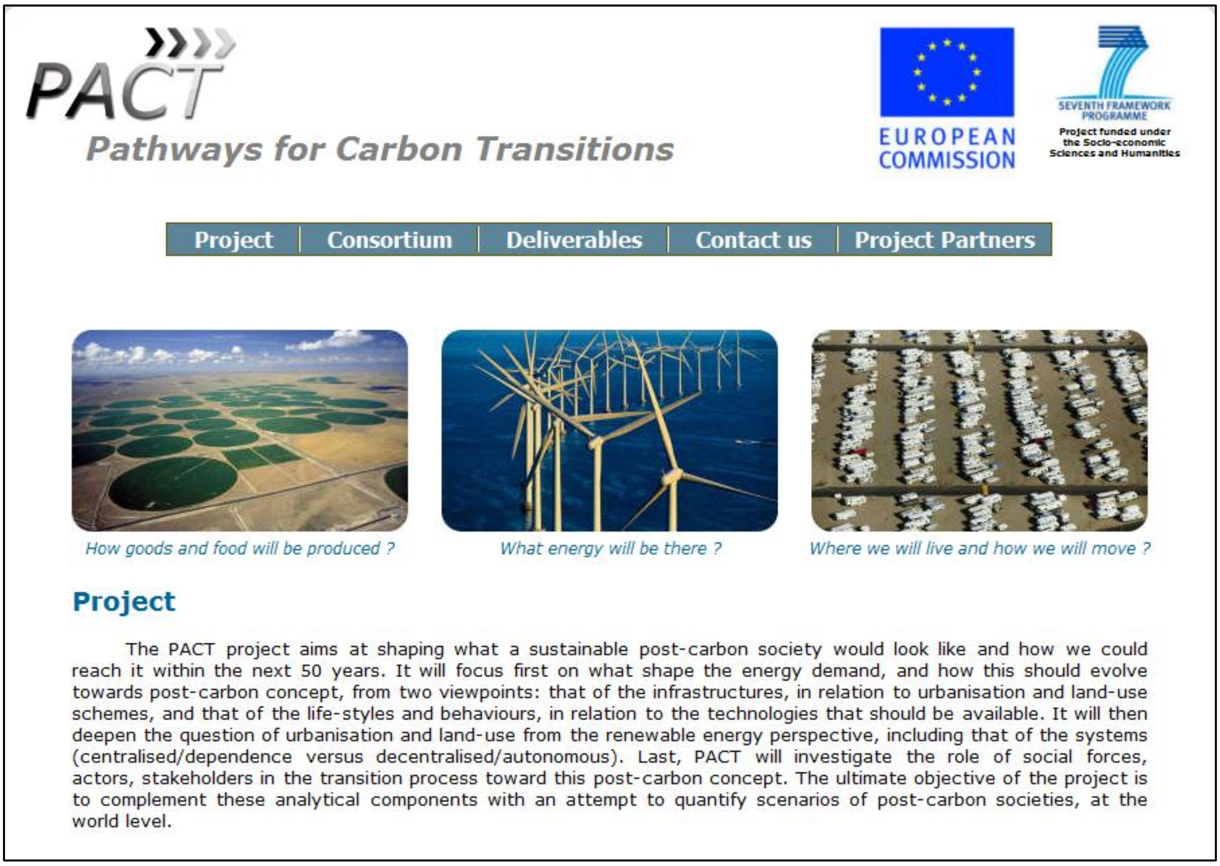
9 Main findings of WP 7 : Communication

The objective of this work package was to ensure communication within the project and with the sponsors, and to ensure that the results of the study will be duly communicated to major actors and stake-holders involved in the transition process, and that these results and methodology have been confronted to the scientific community.

After the project started, the Commission asked the coordinator to deliver a third issue of the WETO report for communication purposes, about post-carbon transitions. Hence a new objective assigned to this work package, the delivery of the WEETO - World Energy Environment Transition Outlook - report.

9.1 PACT Website

The Website of the PACT project : www.pact-carbon-transition.org



Most of the deliverables produced during the research can be download from the website.

9.2 Database of stake-holders

It is necessary to involve major stake-holders concerned by the transition process at some point of the research. Among the targeted stake-holders, three groups are critical: the public policy makers, at three major decision-levels: EU, national, local; industries directly impacted by the technology evolutions in transport, building and energy; representatives of the public.

In order to identify the individual receivers within the European settings (the EC, the EP, etc.), the following activities were carried out:

- consultation with contact points within the EC and snowballing (that is, asking to already known people to suggest other contacts)
- analysis of directories and European web-sites in order to single out the relevant policy makers and other representatives of European level associations (e.g. trade unions, NGOs, industrialists associations);
- institutions that carried out projects connected to the energy issue within 5FP and 6FP as well as on behalf of DG TREN;
- use of data made available by the consortium members.

The same was made for member states policy makers and mass media workers (journalists, producers, editors, etc.). As far as individuals and institutions within the relevant scientific communities are concerned, consortium members made their contacts available. A database containing the e-mail addresses was set up. This database contains more than 3600 individuals. LSC was in charge of this task, with help from other all partners.

9.3 The WETO-T report

The WEETO report could not be directly based on PACT outputs, since the project was in the middle of its course. Instead, this report was considered as a good opportunity to synthesize the outcome of several research initiatives launched or supported by the EC during the past years, and dealing with the general question of the transition towards low carbon economies. The report has three main parts:

- the first part aims at highlighting the main results of the VLEEM[3] (very long term energy environment modelling) research programme, dealing with the question of sustainable energy paradigms over the 21th century;
- the second part is focussed on the interrelated innovations in technology, social behaviours and socio-economic organizations that would accompany transitions towards post-carbon economies in the EU by 2050; this part is mostly based on the first results of PACT;
- the last part aims at summarizing the main conclusions of the studies carried out about policies and economic instruments necessary to mitigate green-house gases (GHG) emissions to a level so that the GHG concentration in the atmosphere would not exceed 450 ppmv, and the increase in the temperature at the surface of the earth would not exceed 2°C.

[3] www.VLEEM.org

Enerdata was in charge of the coordination of the report and of the writing of several pieces. Other PACT members (IPP, ISIS, FhG-ISI, Arcelor-Mittal, MEFOS, University of Padova, LEPII-EPE) were also involved, as well as external partners (SMASH, FEEM).