



Climate & Energy

**Coppe Tackles
Climate Change
Challenges**

COPPE
UFRJ

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The Time has Come for Geoengineering



Reconciling energy needs and climate concerns is one of the century's most important challenges, if not *the* most important one. Over the last few decades, meteorology and climatology studies have accumulated evidence demonstrating that the production and use of energy for human activities is the major cause of the intensification of global warming, which threatens the planet's climate, with dire consequences for humanity.

Accumulated expertise in the field of engineering will be essential for facing the problem, both in terms of mitigating the emissions of global warming gases and adapting to the impacts and variations of climate change.

Since the early 1990's, before climate change became a part of the global political agenda, Coppe has been engaged in increasing understanding and influencing the formulation of public policies related to climate and energy challenges. Coppe has always maintained that both issues (climate and energy) are directly linked and cannot be solved separately.

Coppe helped to create the document presented by the Brazilian government at the UN Conference on Environment and Development which took place in Rio de Janeiro, in 1992. Coppe also developed a model for calculating the world's historical emissions together with the Brazilian proposal presented at the UN Framework Convention on Climate Change, in Kyoto, in 1997. It was during this time that Coppe launched a pioneering worldwide project for measuring gas emissions from hydroelectric power plants.

In recent years, Coppe's professionals and workgroups have actively contributed to national and global initiatives aimed at the formulation of diagnosis and mechanisms for climate governance, such as the Intergovernmental Panel on Climate Change (IPCC). Coppe also participated in the production of the first local and national inventories of greenhouse emissions, in the formulation of Brazil's National Plan for Climate Change, which sets out policies aimed at mitigating Brazil's gas emissions, as well as in the creation of voluntary targets agreed to by the Brazilian government at the UN Framework Convention on Climate Change, in Copenhagen.

Coppe established the Brazil-China Center for Climate Change and Innovative Energy Technologies, in partnership with Tsinghua University. The Brazil-China Center, headquartered in Beijing, is focused on formulating strategies and actions to support the decisions of the Brazilian and Chinese governments in the energy and environmental areas.

Coppe believes that it is now time to look into Brazilian vulnerabilities and the corresponding adaptation necessities. Engineering insights have an essential role to play in helping to focus on local realities. In this historical moment for Brazil, in which newfound economic prosperity is coming face to face with the permanence and aggravation of old environmental and social dilemmas, this is an essential undertaking. It is

necessary to find Brazilian solutions to the Brazilian problems related to the adaptation to climate change and its impacts.

Although it may seem paradoxical, Coppe's solid experience in the development of offshore oil production technologies is being used to meet new energy and climate challenges. It will contribute to the development of newer and cleaner marine-based energy sources, and help the world migrate from a fossil fuel-based economy, responsible for greenhouse gas emissions, to a low carbon economy. One example is South America's first wave energy power plant project, which will be installed at the Port of Pecém, in the state of Ceará.

Another challenge is the reconciliation of economic and environmental goals, without losing sight of its social impacts. In Brazil, as in other parts of the world, the poorest people and regions are the most vulnerable to the impacts of climate change. Coppe's pioneering studies have already shown, for example, that the rise of the mean sea level due to global warming will have a greater impact on people who live in the poorest regions, such as the Baixada Fluminense (a suburban region in the state of Rio de Janeiro), than on people who live along the sophisticated beachfront avenues. Studies have also pointed out that climate change will have a major impact on the country's poor Northeast region, due to desertification of semi-arid regions.

Given that the task of dealing with the economic, environmental and social challenges surrounding the reconciliation of climate and energy needs requires an interdisciplinary and interinstitutional approach, Coppe has recently launched, in partnership with the Ministry of Science and Technology, the Global Change Tech-

nology and Engineering Institute, also known as the Coppeclima Institute, whose governance is in the process of being defined.

The Coppeclima Institute is aimed at increasing the impact of the broad range of initiatives made possible over the last two decades by the creativity and leadership of Coppe's professionals, such as the electric, alcohol hybrid, hydrogen and fuel cell powered buses and the magnetic levitation train. Respecting the integrity and established nature of these initiatives, the Institute intends to be the interface among all of them, as well as between them and organizations outside of Coppe. The Institute's role is to identify the opportunities for interaction and suggest new partnerships and prospects aimed at improving Coppe's active and productive role in this area.

As you will see in the following pages, Coppe is ready to help Brazil face the global challenge of reconciling climate concerns and energy needs, by taking into consideration the country's perspectives and potentialities.

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The Future is Now

For many years, human-induced climate change was considered a problem – if there was any – for a distant future. The Intergovernmental Panel on Climate Change (IPCC) most recent report, published in 2007, has contributed to introduce the climate change issue in the global and national agendas. The report shows that there are more than strong evidences that global warming is attributable to human activities and consistent with an increase in concentration of greenhouse gases. In addition, the report also predicts an increase in the intensity and frequency of extreme climate events, such as droughts, tornados and torrential rains.

In many countries – Brazil included – some of the predicted impacts due to global climate change are already a reality, although the uncertainty of the models and the lack of historical measurements to compare with present data do not allow us to assert that climate change is responsible for these impacts or, on the contrary, if they are the consequence of the phenomena related to the natural variability of the climate, such as El Niño and La Niña.

One of the IPCC projections is that the mean sea level will rise between 20 and 60 centimeters in the 21st century. Cláudio Neves, from Coppe's Ocean Engineering Program, mentions that the transitional elevations of the sea level in Rio de Janeiro's coast due to meteorological events can reach up to 90 centimeters. This happens when cold fronts cause strong wind over the continental platforms. The sea level rises due to the wind, causing meteorological tides. These tides are associated to high waves and heavy rains over the coast.

Transitional elevations of the sea level are already sufficient to cause severe problems that affect the poor people living in the margins of rivers and streams of the Baixada Fluminense (a coastal lowland in the metropolitan area of Rio de Janeiro). It also causes flooding in the urban centers of big cities like Rio and Recife. According to Paulo Cesar Rosman, from Coppe's Ocean Engineering Program, "if the sea level continues to rise, as reported by the IPCC, things can get even worse."

"Climate extremes are one of the aspects associated with climate change. Therefore, in lowland regions, periods of heavy rain combined with the rise of the sea level causes flooding. On the other hand, long periods of dry weather increase saline intrusion into estuaries," Cláudio Neves explains. Freshwater rivers near the sea become more brackish, which affects the agriculture, the city supply and the industrial operations.



Recently, it was necessary to replace the cooling system of Furnas' Santa Cruz Thermal Power Plant, in the city of Rio de Janeiro, because it was being corroded by the saltwater of the river that supplies the system.

The state of Rio de Janeiro already suffers the consequences of extreme climate events (droughts, rains and winds), as well as the Northeast regions, the southern states, the Pantanal and the Amazon. According to Marcos Freitas, the coordinator of the International Virtual Institute for Global Change (Ivig), at Coppe, "climate models already show that these events will become more and more frequent, so we must study what is already happening in the country."



Evidences show that the climate issue is a reality, especially to the low-income population. That is why the Brazilian National Social Mobilization Network (Coep), a national initiative in which Coppe plays a part, has given a strategic priority to the climate issue. But instead of using the expression 'climate changes', the president of Coep, André Spitz, prefers the expression 'climate variations'. Coppe, Coep and the Brazilian Forum for Climate Change (FBMC) are carrying out several studies to investigate how vulnerable is the low-income population to Brazil's climate variation.

Another Coppe partner, the mathematician and meteorologist Pedro Leite da Silva Dias, who is also the director of the National Laboratory for Scientific Computation (LNCC), suggests that joint research (Coppe/LNCC) give priority to the investigation



of the natural climate variability, so as to reduce the uncertainties of today's climate models. But that is not the only reason. "We need more information about natural variability to learn how to deal with great natural phenomena – such as El Niño and La Niña – that cause the extreme events seen today," Pedro says. "By this, we'll be able to prepare ourselves to face the aggravation of these events, which are the result of human-induced climate change."

The other aspect of the climate issue – energy production and use – is also today's challenge. According to Coppe director for Technology and Innovation, Segen Estefen, "all sorts of energy will have to be used, unless people search for different types of comfort and radically change their life styles and the way they use the planet's resources, and this is not likely to happen."

Because of all the things mentioned above, the future is now. It is time to focus on the investigation of the energy and climate vulnerabilities and prepare ourselves to adapt to possible economic, environmental and social consequences. In a scenario of uncertainties, lack of knowledge is the major vulnerability.



1 The Different Scales of Climate Change

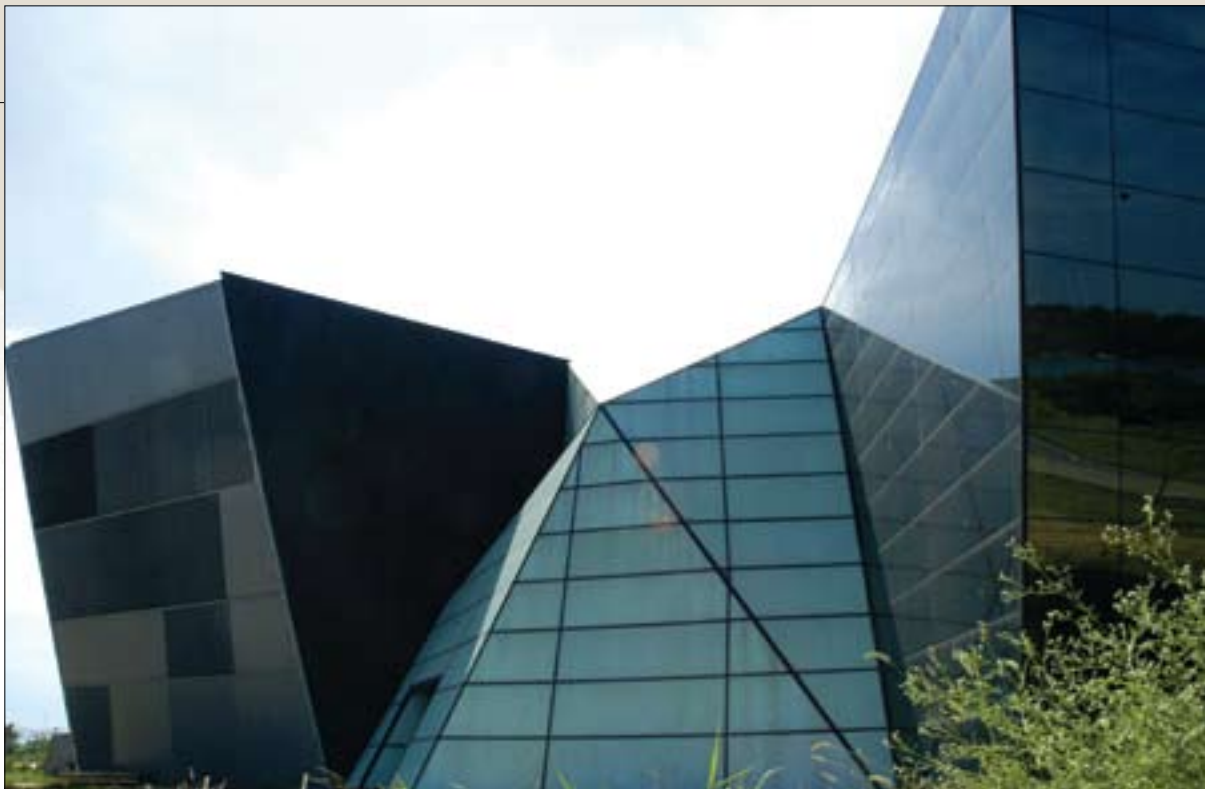
Projections regarding an increase in the planet's temperature and the possible climatic effects of this increase are produced by computer models that simulate the Earth's climate. The results of these studies are compiled in reports published periodically by the Intergovernmental Panel on Climate Change (IPCC), an entity established by the United Nations to collect climate change data produced by scientists around the world and apply it to the formulation of international policies.

In order to understand the characteristics of each region, country, city and activity, it is necessary to move from a global outlook to a regional or a local one. Due to the variety of factors involved in climate behavior and the complexity of relations among them, changes in scale, and dialogue among the different scales, are not trivial tasks. It is therefore necessary to develop new computer models, capable of dealing with different scales and their multiple interfaces. Above all, it is essential to rethink established concepts and develop new ways of facing old and new problems.

Coppe has many ongoing projects and initiatives, ranging from the recently installed supercomputer to research being carried out on the coasts of Brazil, which mainly focus on these types of issues.

Multiscale Modeling: the difficult journey from the global to the local

The meteorologist and physical oceanographer Audalio Rebelo Torres Júnior, a professor at the Geosciences Institute at the Federal University of Rio de Janeiro (UFRJ), works in liaison with a group headed by Professor Luiz Landau, from Coppe's Laboratory of Computational Methods in Engineering (Lamce). The group is interested in carrying out what they call the "down-scaling" of ocean and climate models. This means increasing the model's resolution in order to detect details that could go unnoticed in global models. "The resolution of one of the atmospheric models used by the IPCC is 1.5 degrees, which is equivalent to an area of 160 kilometers. This type of model, for example, would miss the coastal



Coppe's Supercomputer

In order to dialogue with the professionals and computer infrastructure at the National Laboratory for Scientific Computation (LNCC), the National Institute for Space Research (Inpe) and other institutions which will eventually collaborate on climate and energy research, Coppe is equipped with the 2nd largest computer in Latin America, which is also one of the most powerful computers in the world.

Built with the support of Petrobras, the supercomputer has a computing power of 65 teraflops, which are available for use in the studies and projects carried out at Coppe and on the Rede Galileu (Galileo Network). This network focuses on offshore research and development and has financial backing from Petrobras.

The supercomputer will be partially used in research directly related to climate. According to Alvaro Coutinho, from Coppe's High-Performance Computer Center (Nacad), the supercomputer will simulate in days what smaller machines would take years to simulate. Such an example is the climate simulation, which has a great number of variables and multiple interfaces and different scales of time and space.

The supercomputer started its operation in 2010, when Nacad began to train professionals and adapt simulation software used in smaller machines to the new machine. The work demands high-level professionals, as the supercomputer changes the software development paradigm. "Developing a parallel program for 16 processors is totally different from developing a program for eight thousand processors," Coutinho says.





details of an entire Brazilian state,” Audalio explains.

One application of this project is to utilize the IPCC model, which predicts an average rise in the sea level of 59 centimeters by the end of this century, and apply it on a smaller scale. When there is a forecast of a 59 centimeter rise in the sea level, this does not mean that all of the coastal areas around the world will be equally affected. There may be regions where the rise in sea levels will be greater, and other areas where the sea may not even rise at all. This happens because the sea is a fluid that is affected by currents tied to atmospheric processes and distortions, and also because of the asymmetric shape of the planet and the irregular distribution of land and water. “This is what we have to investigate: model our coastal areas and check how the scenarios modeled by IPCC scientists will impact different areas of the Brazilian coastline,” Audalio explains.

Another example is offered by Alvaro Coutinho, the coordinator of Coppe’s High-Performance Computer Center (Nacad): a cloud might cover an area of hundreds of square kilometers, but it may rain in a

much smaller area. If the simulation is not carried out on a smaller scale, the model will not be able to make forecasts regarding the rain.

Much like with a camera, it is necessary to enlarge the image in order to observe the details. By doing this, the simulation results will be similar to the scale used in engineering projects and will be accurate enough to enable public and private managers to make their decisions.

The issues mentioned above were discussed at a seminar which took place at Coppe, in 2010. The event was the result of a partnership between Coppe, the Brazilian Panel on Climate Change, the Brazilian Forum on Climate Change, the National Institute for Space Research (Inpe) and various Brazilian universities.

The downscaling of climate models involves Coppe, the UFRJ Geosciences Institute and the National Laboratory for Scientific Computation (LNCC). The director of the LNCC, Pedro Leite da Silva Dias, has collaborated with Coppe on climate studies since the early 1990’s. At that time, he was the director of the Center for Weather Forecasting and Climate Studies (CPTEC/Inpe) and collaborated with

professors from various programs within Coppe – Luiz Pinguelli Rosa (Energy Planning); Luiz Landau (Civil Engineering) and Cláudio Neves (Oceanic Engineering) – on the creation of a graduate course in Atmospheric Sciences that would bring together professors from Coppe and the Meteorology Program at UFRJ. Luiz Bevilacqua, a professor in the Civil Engineering Program, was the course’s first coordinator. The Atmospheric Sciences course was the seed from which the graduate program in Meteorology grew. The program’s activities are carried out at the UFRJ Geosciences Institute, but it continues to interact with Coppe.

Now the director of the LNCC, Pedro Dias is formulating, together with Coppe, a collaborative effort that includes the development of climate modeling techniques. It is not only necessary to downscale computer models so as to improve the spatial resolution, but also to carry out a more complex task: to develop an integrated and multiscale modeling technique. Climate, Professor Dias explains, involves the atmosphere, the oceans, ice, surface water hydrology, plants, animals, solar radiation, human activities and the multiple interactions among all of these elements in different scales of time and space. The computer models used to simulate the climate must have the capacity to exchange information between the different scales.

Much like the Inpe, the LNCC has detailed knowledge of numerical techniques for dealing with multiscale problems in different areas and it will now use this experience for meteorological and climatic modeling. The first project will be the downscaling of the model used by Audalio in his research at Coppe.

New Perspectives, New Concepts and Some Surprises

The creativity that results from focusing the lens of engineering on the local scale is generating new perspectives and new techniques for dealing with old problems. This does not necessarily imply the use of computer models. Projects developed by Coppe's researchers – or in liaison with them – have made important contributions in this respect.

In a study carried out for the state government of Rio de Janeiro, aimed at mapping the areas and populations that are most vulnerable to the effects of heavy rain in the metropolitan area, the question of scale was approached

in an unprecedented manner. The researchers were in need of the population's economic and social data to compare with geographical information and other data provided by the Civil Defense Agency, so as to identify the most and least vulnerable locations.

The customary unit used for this type of census information is the municipality. This level of information is normally sufficient when dealing with a national scale, but on the scale of the state of Rio de Janeiro the results would be meaningless, because the final map would only feature 80 polygons – the number of municipalities in the state of Rio de Janeiro – and it would not be possible

to visualize what would happen in each neighborhood, for example. As a result, the researchers came up with the idea of using as their base unit the area assigned to each census taker from the Brazilian Institute of Geography and Statistics (IBGE). Each census taker was assigned a location with 500 inhabitants. The result was a map with 110 polygons.

According to Marcos Freitas, the coordinator of the International Virtual Institute for Global Change (Ivig) — which is a Coppe institute that has conducted and promoted research and theses on the topics of climate and energy through a variety of the institution's programs over the last ten years — “it was as if we





had placed a magnifying glass over the state of Rio de Janeiro. We got detailed information and increased the complexity through a small investment, due to the fact that it was not necessary to conduct field research ourselves.”

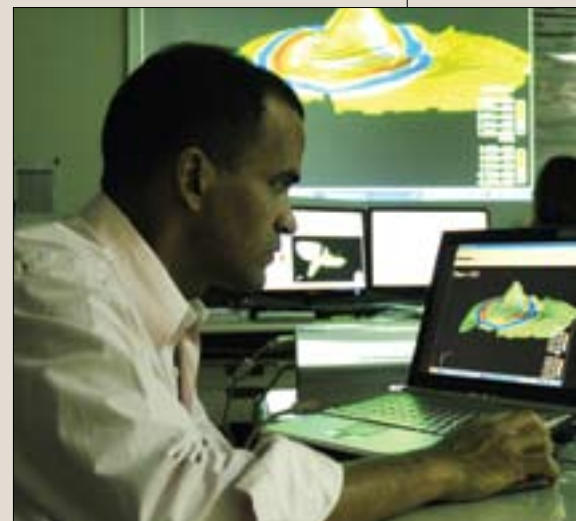
The same creativity has been applied to studies on the vulnerabilities of Brazilian coastal areas. These studies are carried out in partnership with various research institutions and with the participation of professors from the Naval and Ocean Engineering Program. Since the early 1990’s, Professor Cláudio Neves, from the coastal engineering area, has been developing new parameters to identify these vulnerabilities. One of the parameters is called population per kilometer of coastline (PCL). It was developed during Brazil’s first major research project on the topic. The study was cited in the first report issued by the IPCC, in 1990, and was based on a common practice in engineering: using as a parameter of comparison the cost of construction in

relation to its extension. For example, the cost of the construction of a highway is calculated by dividing the total value by the extension of the highway in kilometers. The new parameter applied to studies of the coastal zone was created in partnership with the geographer Dieter Muehe, from the UFRJ Geosciences Institute, in conjunction with researchers from other universities.

The study included five large coastal regions: Belém, Fortaleza, Recife, Rio de Janeiro and Lagoa dos Patos. The geographical unit used by the researchers was IBGE’s microregion. In each microregion they identified the coastal municipalities, i.e., the municipalities bordering the sea or an estuary. Then they calculated the population and the extension of the coastline for each municipality, thus reaching the PCL value. This figure demonstrates that half of the Brazilian coastline has a population index inferior to one thousand inhabitants per coastal kilometer. Only a few areas have

high population density and it is usually around the big coastal capitals, such as Rio de Janeiro, with 70 thousand inhabitants per coastline kilometer; Recife, with 40 thousand, and Fortaleza, with 10 thousand. The populous states of São Paulo and Paraná have low population density in their coastal municipalities.

The same study had previously shown that the total population of the coastal municipalities is equal to only 20% of





From the Paleoclimate in Cabo Frio to the Hurricanes in Santa Catarina

Although Professor Audalio Rebelo Torres Júnior is a meteorologist and a physical oceanographer, his doctoral dissertation at Coppe was on Ocean Engineering. Working out of the UFRJ Geosciences Institute, he studies temperature anomalies of the Pacific and Atlantic Oceans, associated with climate variability processes such as El Niño and La Niña phenomena. He is especially interested in investigating how these phenomena impact Brazil. He recently supervised a doctoral research project that assessed the impact of these phenomena on rainfall in Brazil and electrical power generation. This kind of information is relevant for the country's future energy planning.

Not only is Audalio developing a project in liaison with Coppe aimed at adapting computer models to local scales and attempting to understand what will happen to the climate in Brazil in the future, but he is also involved in a joint project with the Fluminense Federal University (UFF) and with Coppe's Laboratory of Computational Methods in Engineering (Lamce), to study the history of Brazil's climate. The project involves computer-aided paleoclimate modeling, in order to reproduce the paleoclimatic history of the coastal resurgence area of Cabo Frio, in the state of Rio de Janeiro. His hypothesis is that the paleoclimate modeling in this type of region may reveal the existence of oil deposits.

Resurgence is a phenomenon in which the cold water from the depths of the sea comes to the surface, bringing with it a great quantity of nutrients. Therefore, the resurgence areas are the regions with a high concentration of organic matter deposits. It has been established that as the geological eras advance, sedimented organic matter becomes oil. Audalio's objective is to use the technique of climate modeling to determine if, in the past, when the climate was different from what we see today, resurgence occurred in certain locations. A positive answer would indicate the possibility of the existence of oil deposits.

Another joint project is being carried out by the LNCC and Coppe's Naval and Ocean Engineering Program. It has financial backing from the Brazilian Innovation Agency (Finep) and it is aimed at studying the impacts of cyclones on the Brazilian coastline. The project was developed in response to Hurricane Catarina, a tropical cyclone that, in 2004, devastated the southern region of the state of Santa Catarina and the northeastern region of the state of Rio Grande do Sul. It was the first hurricane ever recorded in the Southern Atlantic Ocean.

The objective is to understand the process of cyclone formation on the Southern and Southeastern coastlines, and its natural variability, which refers to the large scale controls that determine the frequency and intensity of this type of system, and the impact of these cyclones on the ocean. Coppe is focusing on this specific aspect, due to the wealth of information regarding the behavior of waves in the Brazilian Sea that has been compiled by its Naval and Ocean Engineering Program.





the population of Brazil. The study concludes that the number of people living in coastal cities is lower than what had initially been thought and that the coastal population is poorly distributed. "This fact even has implications for national security, because it shows that there are huge areas of Brazil's coastline that are empty and uncharted," Neves says.

Another implication is economic in nature. Even though, from the perspective of the vulnerability to climate change effects (such as the elevation of the sea level or the collapse of hillsides and floods), the municipalities with greater PCL values are the most critical ones, they are also the ones in which the cost of preventive measures against climate-related incidents can be shared by a larger population. The state would be responsible for the costs of monitoring and preventing undue or inappropriate settlement in the low population density regions.

In more recent studies, researchers have been developing ever more sophisticated parameters and working with the idea of gross domestic product (GDP) versus kilometer of coastline, that is, GDP per kilometer. This parameter will be an instrument to help evaluate possible impacts on the economies of states and municipalities from climate-related incidents in coastal zones. With this information, mayors and governors can make more

informed decisions about coastal protection measures.

In another study carried out in 2009, Neves and another Coppe professor, Paulo Cesar Rosman, joined forces with Dieter Muehe and professors from universities in Pernambuco and Santa Catarina. The effort to increase the potential of the "magnifying glass" placed over Brazil's coast provided another surprising figure: the Brazilian coast, which is usually considered to have roughly eight thousand kilometers of extension, had grown by 50%. The "trick," which required a tremendous amount of patience, was to include the contours of the beaches and islands in the calculations. "By doing this, the extension of our coastline increased to 12,500 kilometers. And if we add more details, the coastline will be even greater, since we only considered the islands which are also municipalities," Neves explains. Large islands, such as Ilha Grande and Ilha do Governador in the state of Rio de Janeiro, were not factored into the equation. This is a common problem in fractal geometry.

Neves is especially interested in scales. He wants to reexamine, for example, the concept of the biome. There are various definitions for the concept, but most of them include its great geographical extension. Therefore, a biome would be a set of complex ecosystems that are inter-

related in various forms and occupy large areas, such as the Amazon, the *cerrado* (a savanna ecoregion) or the Atlantic forest. However, Neves says that both a mangrove and a coral reef should be considered biomes due to their high levels of complexity. "Biomes are thought to be big spatial areas because we use global models that only allow us to see big areas. But if we use a small scale, we will see that mangroves and coral reefs are extremely complex and fantastically diverse systems, in which all the elements interact to maintain the system's complexity. Therefore, they are biomes," he says.

In practical terms, in the future, the new way to approach the problem will result in radical changes in the conception and carrying out of engineering projects. Presently, engineering projects are conceived as definitive projects and are designed to resist a probable maximum impact, which is calculated based on the recurrence statistics of past events – specific conditions related to waves, or wind, or rain. But the statistics of probable maximums only make sense if the environmental conditions remain stable, that is, if the conditions in 50 years' time are the same as conditions today. Given that the tendency is for change – specifically, climate change – the engineering projects will have to be increasingly flexible. "It's what we call structure resilience," Neves explains. "It's the capacity of the structure to face unknown climatic situations."

This means that new engineering projects will have to consider, from the outset, forecasts regarding preventive and corrective maintenance during the service life of a project. Definitive projects will be replaced by adaptable ones.

2 Inventories and Scenarios: pioneering actions and studies

Coppe participated in Brazil's first studies on greenhouse gas emissions and was part of the pioneering efforts to bring together the scientific community and the government in order to understand the country's problem.

One example worth citing was Coppe's participation in the creation of emissions scenarios for the energy sector, projected until 2025, which was carried out as part of a project with the Lawrence Berkeley National Laboratory, in the United States. In order to participate in this project, Coppe created a research group headed by Professor Luiz Fernando Legey, with the assistance of the economist José Miguez. Just after that, when the Ministry of Science and Technology (MCT) decided to create a Climate Change Commission, Miguez was invited to take the helm. Leading the commission, he organized a network of scientific institutions that would create the first Brazilian emissions inventory. Under the supervision of Professor Luiz Pinguelli Rosa, Coppe compiled data on the emissions produced by the energy sector.

The first national greenhouse gas emissions inventory, which covers the period between 1990 and 1994, was presented to the United Nations (UN) by the Brazilian government in 2004. Coppe was responsible for compiling the emissions data for the energy sector. Since then, Coppe has been developing methods, inventories and scenarios for states, municipalities and companies. In addition, Coppe is contributing to the second version of the national inventory, which covers the period until 2005, and is being finalized by the Ministry of Science and Technology for delivery to the UN in March, 2011.

Today, the Coppe Energy Planning Program's Center for Integrated Studies on the Environment and Climate Change (the Climate Center), headed by Emilio La Rovere, plays an important role in the development of emissions inventories in



cities and states and in the development of mitigation scenarios. The Center was created in 2000, thanks to the initiative of the Brazilian Ministry of the Environment, to develop and disseminate knowledge about climate change in the country. Since then, the Center has been responding to requests from public and private institutions for the development of inventories and scenarios, due to the growing interest in the topic of climate change.

In 1999, Coppe's Climate Center team developed the first emissions inventory for a Brazilian city – Rio de Janeiro – which covers the period between 1990 and 1998. It was necessary to develop a unique method because, as Emilio explains, it is more difficult to compile emissions inventories for a city than for a country. Rio is a good example: there is little industrial activity and no farming or ranching in the city. The city's main source of emissions is the public transportation system. It is worth mention-

ing that it is a mobile source. "The cariocas (residents of Rio de Janeiro) go to São João de Meriti (neighboring municipality) by car, fill their cars up there and go back to Rio. On this journey, there were gas emissions in two different municipalities. How can we calculate that?," Emilio asks. The second major source of emissions is

the urban waste, yet most of Rio de Janeiro's garbage is disposed of at a landfill in Gramacho, located in Duque de Caxias (another municipality in the greater metropolitan area).

Setting borders is one of the main challenges to emission inventories. The United Nations Framework Convention on Cli-



mate Change issues some guidelines on how to calculate this type of emission in national inventories – emissions from international aviation and maritime transportation are calculated separately and are excluded from national totals. However, there are not international guidelines for cities and states.

Providing these guidelines has been one of the Climate Center's contributions. The method developed for Rio's inventory was then applied to the inventory requested by the mayor's office of São Paulo. Researchers then developed a method that could be used statewide. The method was used in the inventories carried out for the states of Rio de Janeiro and Minas Gerais. Presently this method is being used in the state of Espírito Santo, besides the update of the inventory of the city of Rio de Janeiro.

The Center also develops methodologies for specific sectors. The Rio de Janeiro Secretariat of Environment requested the development of an initial methodology for calculating potential carbon dioxide emissions at buildings sites and also the formulation of parameters and acceptable ranges to compensate for those emissions.

The national inventory is not the sum of municipal and state inventories. These are aimed at informing municipal and state governments so that they can establish emissions mitigation policies. That is why, after the completion of the inventory, the Climate Center team formulates scenarios, which are projections of future emissions, so as to identify the main sectors responsible for emissions and point out the recommended actions to mitigate these emissions.



The discovery that the urban public transportation is the largest source of emissions in the city of Rio de Janeiro led another research group at Coppe, headed by Paulo Cezar Martins Ribeiro, a professor in the Transportation Engineering Program, to propose the Rio Bus project to the mayor's office, in March, 2001. The Rio Bus project was aimed at streamlining the city's bus routes. The recommended actions would potentially reduce the CO₂ emissions by 25%. The project has not been implemented.

Coppe also helped the mayor's office set voluntary emissions reduction targets with the Projeto Rio Sustentável (Project for Sustainable Rio). Due to its knowledge about the city of Rio de Janeiro, the Climate Center participated in the studies that were used to create the chapter about the environment that was a part of Rio's winning bid to host the 2016 Olympic Games. The Climate Center's group has already completed the 2005 inventory and has provided a new set of emissions scenarios up to 2020, in accordance with the contract signed with the Rio de Janeiro mayor's office in November, 2009.

In addition to the routine maintenance of systems that control local atmospheric pollution, which is now law, companies

will have to develop similar systems to control the emissions of the gases that cause global warming. Many companies are aimed at meeting future requirements and are starting to develop their own inventories and scenarios. Some of them are candidates to receive carbon credits through the UN's Clean Development Mechanism.

The projects must be approved beforehand by the Brazilian government. The Climate Center helped formulate the criteria for assessing how these projects can contribute to sustainable development and not only to the reduction of greenhouse gases. There are five criteria: the reduction of the local environmental impact, job creation, regional development, income distribution and technological innovation.

Ambev, one of the world's largest beverage manufacturers, was one of the companies to request the help of Coppe in the creation of carbon credit projects. The project was aimed at replacing fossil by with biomass boilers. The Climate Center also collaborated with the Brazilian Mercantile & Future Exchange in São Paulo to help bring information about the Clean Development Mechanism to other Brazilian companies.

3 The Brazilian Vulnerabilities

A variety of Coppe programs is investigating Brazil's vulnerabilities to climate changes. Studying the country's vulnerabilities is essential for formulating adaptation policies. As in the majority of the countries, the most vulnerable people and areas are also the poorest ones. Studies show that the Northeast region is more susceptible to damages than other regions. The possible aggravation of dry weather in semi-arid areas, the shortening of electric power production in the plants of the San Francisco River and the impacts of the sea level rise on the coastal zone are some of the possible damages.

But some other regions are also vulnerable. Some studies show that the coast of the metropolitan area of Rio de Janeiro is fragile, especially in the periphery of the largest cities. They also mention the possible impacts on water supply in the states of Rio and São Paulo.

However, one of the major vulnerabilities is the lack of environmental monitoring. Coppe professors point out that the lack of continuous and trustable records that help the analysis of the environment is one of Brazil's greatest vulnerabilities

When there is Too Much Water

Based on the climate models from the Intergovernmental Panel on Climate Change (IPCC) and on information about climate and meteorological changes that affect the wind, rain and sea, it is already known that these changes will impact the shape and position of the beaches. The increase in

rainfall activities will cause more flooding in lowland areas and landslides in hillsides.

Even though there is a lack of environmental data on Brazil's coastal zone, studies carried out at the Ocean Engineering Program have identified that the country's coastline is potentially vulnerable and they recommend that Brazil should start monitoring its coast. The metropolitan area of Rio de Janeiro and the northeastern capitals are the most vulnerable areas in the coast, due to their population density and economic activities. Seventy per cent of the population of the state of Rio de Janeiro lives on the coast of the metropolitan area of Rio. From 30% to 60% live on the coastal zone of the Northeast region. The figures are less significant in the remaining states, except for Amapá, where 100% of its inhabitants live on the coast; however, the state has low population density.



The variation of the sea level and of the behavior of winds, rains and waves cause various problems. They may affect port structures or may threaten oil, gas and offshore sewage pipelines. They can also damage road and tourism infrastructures, such as the beachfront avenues and resorts. Finally, they may destroy houses, buildings and coastal protection constructions, such as breakwaters and piers.

Coppe team has thoroughly studied some climate events that happened in the city of Rio de Janeiro and in its neighboring areas. These phenomena give us an idea of what might happen to the Brazilian coast, in case extreme climate events become more frequent.

One of these phenomena is the shoreline disturbance caused by waves and tides, producing the so-called dynamic

beach zone. Shorelines may get narrower or larger, depending on the amount of sediments transported by the sea. "The shorelines are continuously changing and whether they narrow or enlarge depends on meteorological variables and sediment budget" explains Paulo Cesar Rosman, from the Ocean Engineering Program.

In the city of Rio de Janeiro, this phenomenon is especially observable in Arpoador and Leblon beaches (two of the most important beaches in Rio). The Arpoador shoreline is usually narrower at the end of the summer, because during the spring and summer the waves transport sand to Leblon. On the other hand, at the end of the winter, the fall and winter cold fronts cause heavy surf, transporting sand to Arpoador. But this climate pattern changes when there is the

El Niño phenomenon – an extreme event caused by the change of temperature of the Pacific Ocean surface. The variation of the atmospheric circulation produces different winds, changing the direction of the waves. Winter's typical heavy surf transports sand to Leblon. When the effects of El Niño are especially strong, the Arpoador shoreline disappears. In 1999, the offshore sewage pipelines at the Ipanema beach were found uncovered on the sand and the erosion destroyed a life-guard post. Climate change projections show that the extreme events caused by El Niño or La Niña will be more frequent and intense.

Not only is the coastline affected by the waves, but also by the meteorological tides. Unlike the astronomical tide, which is the result of the Earth-Moon-



Sun interaction and is predictable, the meteorological tide is a transitory change of the sea level caused by meteorological conditions. Storms with strong winds 'raise' the level of the ocean, bays and lagoons. The additional water invades

the lands and joins the river and stream waters, whose levels are also high due to the rain, which causes floods. This is what happens, for example, at the Lagoa Rodrigo de Freitas (a lagoon in a sophisticated neighborhood in the city of Rio de Janeiro) and in the Baía de Guanabara (a bay in the metropolitan area of Rio), which especially affects the cities of the Baixada Fluminense.

A study coordinated by Paulo Cesar Rosman, from the Ocean Engineering Program, for the Rio de Janeiro State Environment Secretariat, has shown the vulnerability of the city of Rio de Janeiro and its neighboring areas (the Baixada Fluminense, Baixada de Sepetiba and

Baixada de Jacarepaguá), as well as of other cities in the state of Rio de Janeiro located in the margins of bays and coastal lagoons (Niterói, Maricá, Araruama, Rio das Ostras, Cabo Frio and Macaé). The sea level rise will affect the level of the bays and lagoons connected to the sea. When there are strong cold fronts, with strong winds and heavy rain, there will be high meteorological tides that will last for five, ten days and that will add to mean sea level rise. "Today there are meteorological tides of 30 to 60 centimeters. In the city of Rio de Janeiro, there were already tides of 90 centimeters. Imagine that in the next 40 or 50 years the mean sea level rise will have



increased 30 centimeters and that the meteorological tides will have increased from 50 centimeters to 1 meter. Therefore, during extreme climate events, the sea level would possibly increase up to 1.30 meters," Neves says.

As a result, water would flow back in the sewers during heavy rains in those cities. Many of them have streets located too close to rivers and lagoons. It is therefore necessary to adapt to this situation and construct embankments and dams, as well as use drainage systems. When this is not technically possible or economically feasible, it is necessary to remove the population from entire neighborhoods.

Not only are the cities mentioned by Neves vulnerable due to their morphological conditions, but also because of the high population density and the extension of urbanization. According to Rosman, the metropolitan area of the city of Rio de Janeiro covers a zone of almost 300 kilometers, from Itacuruçá, a city in the southern state, to Macaé, located up north state. It is a problematic coast, i.e., the cities are almost attached to one another. The uninhabited zones are very small; they do not exceed ten kilometers.

Soil Risks

One of the expected effects of the climate change is the intensification of landslides, due to the rainfall increase or to the erosion of the bottom of the hillsides caused by the sea level rise. On the coastal plains, which are vulnerable to flooding, the soft clay soil is especially subject to subsidence.

The Geotechnics professors from Coppe's Civil Engineering Program conduct several projects to collect information about soils



and develop tools capable of helping these studies.

The group headed by Professor Fernando Danziger is developing, in partnership with the Petrobras Research Center (Cenpes), the 'piezocone-torpedo' – the equipment that measures the soil prop-

erties. Not only may it be applied in the offshore oil industry, but also in researches, so as to describe the characteristics of soft clay soil in lowlands. Climate change adaptations involve the construction of more embankments to raise the level of the streets that might be destroyed by

rivers and seas. That is why it is important to have solid information about the soil properties. "Gathering information will be faster if we use the new piezocone. The equipment is capable of measuring parameters in a short period of time and in large areas," explains Professor Willy

Adaptation in the Baixada Fluminense

An ambitious project developed by the state government of Rio de Janeiro in partnership with Coppe is being implemented in the Baixada Fluminense in order to prevent flooding that routinely strikes this suburban region located in the outskirts of the city of Rio de Janeiro consisting of six municipalities: Duque de Caxias, Nova Iguaçu, São João de Meriti, Nilópolis, Mesquita and Belford Roxo.

Three major rivers are responsible for Baixada's macro drainage system: Pavuna/Meriti, Sarapuí and Iguaçu. The Sarapuí and Iguaçu rivers flow in extremely flat areas and are particularly affected by the tides. The influence of the tides can be observed up to 20 kilometers upstream. This phenomenon is even more severe when there is a storm tide due to heavy rains and a temporary change in sea levels. As a consequence, there are floods that affect entire neighborhoods and subdivisions, usually in very poor regions.

The project, which was launched in 2007 and which will continue until at least 2012, includes a variety of measures, such as drainage systems, a dam, polders like those used in the Netherlands, and the creative urbanization of the margins of the rivers: the areas susceptible to flooding will be transformed into wetland parks. On pleasant days, the parks will be leisure areas for the population. On days with heavy rains, they will be flooded, as they would be in nature. Professor Paulo Canedo, from the Civil Engineering Program, explains that "the wetland parks require special attention. After storms, the city government will have to clean up the parks, just like what is done in the streets." There are also parks that are not designed to be flooded that help to mitigate the effects of heavy rains.

THE BAIXADA FLUMINENSE – RJ



2008



2009



Lacerda, one of the best Brazilian experts in soil mechanics.

In the Geotechnics field within the Civil Engineering Program, Professor Mauricio Ehrlich has been monitoring ongoing constructions and testing technical specifications of soil reinforcement,

while Professor Anna Laura Nunes has been working, in liaison with researchers from the Pontifical Catholic University of Rio de Janeiro (PUC-Rio), to develop a new type of bar to be used in the soil nailing technique for reinforcing slopes. The new bar is made of resin and syn-

thetic microfibers and it will probably be cheaper than steel bars. The bar is being tested in a slope in Laranjeiras, a neighborhood in the city of Rio, to see if it is as resistant as the one made of steel.

But, according to Willy Lacerda, using technology is not enough to deal with

In the project's first stage, 3,500 families living in areas subject to flooding will be resettled in residential complexes. People who live in other areas will stay where they are. However, in all of the riparian zones, the riverbanks are being forested and urbanized, so as to discourage people from living there. In the areas without parks, there will be a bicycle lane.

Although the project has been designed to handle current flood levels, some projects have been designed to be resistant to extreme events, such as those related to climate change. Some of them were designed to handle a possible rise in sea levels during the next 25 years. "But this does not mean that all of Baixada Fluminense will be safe for 25 years, because only some projects were designed this way, mainly the ones that have a longer projected service life," Canedo explains.

One factor that contributes to the floods in the Baixada region – the garbage thrown into the rivers and streams – has not been completely assimilated into the project's plans. The project was designed by the state government, while the city governments are responsible for the waste pickup and disposal. But since the climate does not respect geographical or political limits, Coppe suggested the creation of an intermunicipal agency in the Baixada region to solve problems that can neither be solved by the state government nor by a single municipality. Among the problems that can be addressed in this way are the waste and the macro drainage, for the same river runs through several municipalities. Another issue requiring attention is the public transportation.

Canedo is optimistic above the positive impact that the project will have on the daily lives of the poor people who live in the region. "We've worked in the Baixada region for many years and we've seen that the population living in the flood-prone areas is getting poorer and poorer. A person who used to have a three-seat sofa would lose it because of the rain. That person couldn't afford to buy another three-seat sofa, so he would buy a two-seat one. The rain would destroy it again. Things would get worse, year after year," the professor explains. He guarantees that if the population is protected from these losses and if the neighborhood where they live is improved by installing measures to protect against the floods, people will start to save money again and invest in their houses and small businesses, even if these are informal enterprises, such as bars and markets.

"The most important thing is that they don't lose their hope, their capacity to dream and make plans for the future. Everybody is full of hope, except for those who experience chronic impoverishment," he explains.



Rio de Janeiro vs. São Paulo – a battle for the Paraíba River

The conflict has not exactly started, but the problem is already known by the Brazilian government. The two Brazilian biggest cities are heading towards a 'water conflict' because of a river they share – the Paraíba do Sul River. This river is important for the metropolitan area of Rio de Janeiro and it can also become important for the city of São Paulo.

The city of São Paulo has serious water supply problems. It depends on the water resources from other cities in the state of São Paulo, such as Campinas and Americana, where there is also a great demand for water. The metropolitan area of Rio de Janeiro city, on the other hand, essentially relies on the Guandu River, where discharge is largely due to a diversion of waters from the Paraíba do Sul River.

The Brazilian Ministry of the Environment detected the possibility of an interstate conflict if the state of São Paulo needed more water and got it from the part of the river located within their borders. In the state of Rio de Janeiro, the recent wave of industrial growth in the municipalities located in the greater metropolitan area, such as Itaguaí and Itaboraí (where large-scale industries are being established), there is a growing demand for water, which gives rise to an interstate dispute over the different uses of water resources.

As a result, Coppe was hired by a consortium of businesses and the Brazilian government in order to help finding solutions to the problem. The first project was the Guandu Master Plan. A detailed study showed that several engineering projects – some of them quite simple – combined with water rationing would increase the supply capacity of the Guandu River, which would then meet the demand of the state of Rio de Janeiro in the next ten years. According to Professor Paulo Canedo, from the Civil Engineering Program, "researchers found out that it was a matter of incorporating intelligence into the system."

The first step is to manage the supply by using a complex calculation that allows for the rationing of water use according to time. "Imagine that two farmers share the same stream, a discharge of $5\text{m}^3/\text{s}$, but each farmer needs $4\text{m}^3/\text{s}$. They can make a deal: one farmer irrigates from 1:00pm to 2:00pm and saturates the soil. The other



irrigates from 2:00pm to 3:00pm. The first farmer will only need water again from 6:00am to 7:00am and in this way they can take turns. The actual system is obviously much more complex than the example, but there is a solution much more readily available than what was originally thought," Canedo explains.

In addition to the time-based water rationing system, Coppe's studies identified a variety of projects for increasing the water supply from the Guandu River. Some are quite simple, and just need to be pointed out. Marcos Freitas, who is the coordinator of the International Virtual Institute for Global Change (Ivig), offers the example of pollution prevention on the Poços River. The Poços River is a tiny tributary of the Guandu River, which is extremely polluted with sewage. Due to this pollution, the state water utility (Cedae) is obliged to draw more water from the Guandu River – to dissolve pollution particles – than what would be necessary if the apparently insignificant Poços River was clean. Or at least if the state water utility would relocate its point of collection.

This type of study made it possible to continue to invest heavily in the Itaguaí industrial zone, with the expansion of the port and the installation of large-scale metallurgy projects in the city of Itaguaí.

In fact, it is currently the second largest investment in the state of Rio de Janeiro. The largest is the construction



of the Rio de Janeiro Petrochemical Complex (Comperj), in Itaboraí. This undertaking, which costs over US\$8 billion, is being carried out by Petrobras and the Ultra Group and will begin to operate in 2012. It promises to change the socio-economic profile of 11 municipalities. But there still remains a problem: how to meet the water supply needs of the industries and the people who have moved to these areas due to the construction of the Petrochemical Complex and the migration of new chemical industries to the new complex?

Coppe was hired by Petrobras to carry out studies proposing a variety of solutions. These are currently being evaluated by the company. Coppe has suggested the desalination of sea water from the Guanabara Bay and also the construction of a reservoir to capture the water that goes down the slopes of the Serra do Mar mountain range.

climate impacts. He supports the idea of having a prevention policy, in order to map the geotechnical risks and urban zoning. This would save lives and would avoid wasting financial resources. "We constantly have to remove people from precarious houses that are about to tumble down. We have to find a safe place for them," he says. Willy's research at Coppe may contribute to formulate such a policy by improving and developing technologies that can help determine and reduce risks. In order to achieve that, Willy works in partnership with researchers from the Geoheco Laboratory, which is headed by Professor Ana Luiza Coelho Netto, within UFRJ Geosciences Institute.

When there is not Enough Water

There is a great deal of uncertainty about the future behavior of the climate, especially concerning what will happen to the water cycle in the Southern Hemisphere. There are only a few studies about the topic and the available data from the Northern Hemisphere are not much helpful for the Southern Hemisphere, where there are more submerged lands than emerged lands.

In order to deal with future uncertainties, Coppe is searching for solutions for present issues. "Australia and Ethiopia have the same hydroclimatic variability. But while Australia has five thousand cubic meters of stored water per inhabitant, Ethiopia has 20 cubic meters. Which country is more prepared to face climate changes?," asks Marcos Freitas, the coordinator of the International Virtual Institute for Global Change (Ivig) – an institute that brings together researchers from different areas within Coppe to develop specific projects for companies and governmental bodies.

For several years, many of Coppe researchers have been studying the water vulnerability in Brazil's Northeast region, as well as in the city of Rio de Janeiro. The Northeast region was chosen because it is a semi-arid region. It is one of the world's most densely populated semi-arid regions and it is susceptible to chronic droughts that have been devastating local agriculture and livestock and expelling families for centuries. Rio's vulnerability is due to the fact that it is the country's second largest metropolis and there is already a possibility of a battle between the city and São Paulo, the larg-





est city in the country, for the waters from the Paraíba do Sul River, which is Rio's primary source of water supply.

The Ivig carried out a study on the effects of the public policies concerning water in the northeastern semi-arid region. There are two million families of

small agriculturists living in this area facing permanent problems with water supply for food production and sanitation.

The conventional water supply system is a reservoir with capacity of several hundred liters where people store the rain-water that only possibly falls during four

months in the region. Some water trucks also supply those regions, but not on a regular basis.

In the beginning of this decade, a partnership between NGOs and the federal government launched a program to build cisterns capable of storing 16 thousand liters. Since then, 230 thousand families – or about 10% of the total – received a cistern.

Coppe was invited to evaluate the results of this program and concluded that the semi-arid region is actually a zone consisting of semi-arid, arid and semi-humid areas. Cisterns are a very good solution for the semi-humid areas. They are also a good option for the semi-arid regions. However, in the arid areas – which cover some parts of the countryside of the states of Paraíba, Pernam-



buco, Rio Grande do Norte and Ceará – the cisterns are not a good option, as they do not store enough water. A study has concluded that in these places it is necessary to enlarge the area meant for capturing water, by increasing the area of the roof of the house, which is usually of 40 square meters. In addition, it is necessary to test other surfaces, made of more efficient materials. One of the ideas being tested is the use of a kind of a PVC tent to capture rainwater and throw it into the cistern.

Agriculture in the semi-arid depends on the volume of rain that falls from December to March. In the years of long-lasting droughts, the agriculturists may lose up to 90% of their harvest. This same study carried out by Coppe investigated the water use for agriculture and evaluated different irrigation technologies. Emilio La Rovere, from the Climate Center, has been carrying out a project in liaison with some NGOs to demonstrate a drip micro irrigation technique that was considered appropriate to local conditions. The project is conducted by the Adapta Sertão network and is aimed at the adaptation of communities of small farmers to climate change. It started its activities in the city of Pintadas, in the countryside of the state of Bahia and is spreading to other cities of the state: Quixabeira, Baixa Grande and Brumado.

The Price the Economy Will Have to Pay

The most complete document to date about the economic impacts of the climate changes in the country is the so-called 'The Economics of Climate Change in Brazil: costs and opportunities', pub-



lished in 2010. The study carried out by researchers from various research institutions estimated a GDP loss between 0.5% and 2.3% in 2050, if the IPCC's global warming projections become a reality. Seven Coppe professors participated as coordinators and advisors in the study and their research was included in the report's section on energy and coastal zones.

The section about energy was produced by the group from Coppe's Energy Planning Program. The study developed by the group forecasted great reduction of the river flow in the Northeast region, with losses in the generation of firm energy from the hydroelectric power plants and in the reliability of the water supply system. The cost of adaptation, that is, the installation of additional capacity for producing energy based on other energy sources, can reach up to US\$ 51 billion. In addition, according to the document's section about the coastal zone impacts, the estimated value of infrastructure and properties at risk along the Brazilian coast ranges be-

tween R\$ 136 billion and R\$ 207.5 billion. Therefore, the study suggested some management actions and public policies for adaptation that would cost approximately R\$ 93 billion per year, until 2050.

This pioneering study is only a rough estimate, as it is subject to many uncertainties due to methodological and data limitations. That is why research developed at Coppe is aimed at finding results that would help make the safest political and economic decisions. It is not an easy task to decide whether to invest US\$ 50 billion to increase the reliability of the electrical power system, because of possible climate changes. "The new power plants would be kept on standby. They wouldn't necessarily operate, and if so, they would only be used in critical events. It is an investment difficult to amortize," explains Alexandre Szklo, from the Energy Planning Program within Coppe), mentioning the type of economic and financial decision one has to make.

That is the why the Brazilian Ministry of Science and Technology asked Coppe



to continue the study using new models and climate scenarios. Among other issues, it is necessary to check if the energy vulnerability in the Northeast region is the same as the one pointed out in a previous study.

One of Coppe's contributions to the development of methodologies has already started to improve the calculation of the cost of infrastructure and properties at risk along the coastal areas. A research funded by the World Bank Group evaluated the economic impact of climate change on 136 port cities (including 10 Brazilian cities) and used Brazil's GDP to estimate the costs of investments and urban improvements. Cláudio Neves, a coastal engineering researcher at

Coppe, developed an alternative concept that was used in the study published in 2010. Neves used the regional GDP to evaluate each city and create more complex indices. He formulated the concept of the equivalent coastline extension, which means that the estimated cost of each type of property (urbanization, public services etc.) would be converted to a coastline extension, whose protection would cost the same. By calculating the other index suggested by Neves, the population per coastline index (PCL), and having the figure of the GDP per capita, it is possible to establish the GDP per coastline kilometer (GDP/PCL).

The result of this methodological contribution was the change in the ranking

of the Brazilian cities whose coastal properties were threatened by a possible sea level rise. While Maceió was the highest-ranking city due to a mistake caused by the use of the national GDP by the World Bank Group, Rio de Janeiro is on the top list according to Coppe's studies. Rio has 40% of the total of properties at risk in the Brazilian coast. In the list established by Coppe, Maceió was not even one of the seven first cities (Rio de Janeiro, Salvador, Porto Alegre, Vitória, Santos, Recife and Fortaleza) in the ranking.

This kind of information has to be carefully considered when having to decide about port infrastructure projects, for example. Brazil's National Growth Acceleration Program (PAC), a federal government initiative, estimates investments for the expansion of the main Brazilian ports, which would increase the country's exportation.

In the Energy Planning Program, Roberto Schaeffer and Alexandre Szklo coordinate various research projects to support public policies and the decisions made by different economic sectors.

One of the most ambitious projects was the study about the so-called carbon risk to oil industries. The project was requested by Petrobras, because the company wanted to know its vulnerabilities, as well as the vulnerabilities of other companies, to the future implementation of climate change policies by governments (tax policies and carbon emission quotas). Coppe has thoroughly evaluated the vulnerability of 30 oil companies located in Brazil and worldwide. Among many other criteria, Coppe analyzed the market conditions, the available technologies, the type of oil produced and

how each company was prepared to deal with the new problem. Pleased with the results, Petrobras requested some other studies to outline the evolution of carbon prices and simulate scenarios for the Brazilian energy matrix.

The group from the Energy Planning Program also helped to formulate a guide, so that the World Bank Group could evaluate the vulnerability of energy projects funded by the institution in developing countries with respect to climate change. There is a possibility that renewable energy systems be vulnerable to climate change. For example, the change in wind patterns may impact wind energy power plants. Change of rainfall rates may impact the production of agrofuels, as well as the operation of hydroelectric power plants.

Presently, the Energy Planning Program is developing a new line of research. The project coordinated by Professor Luiz Pinguelli Rosa aims at evaluating technologies for carbon capture and storage (CCS). The project investigates the economic feasibility of the various technologies being developed worldwide for dealing with carbon emissions from the production and combustion of oil and coal. One of Eike Baptista's companies, the MPX, requested a study on carbon emissions from coal-fired thermal plants.

Carbon capture is still expensive nowadays. Typically, a coal-fired thermal plant has a thermal efficiency of 30% to 40%. There are technologies that capture carbon emissions, but with an energy penalty. In addition, with these technologies the coal-fired thermal plants require more water and produce more residues, which significantly increases the costs.

The cost of capturing and storing 1 ton of CO₂ by integrating a CCS system into a conventional coal-fired thermal plant ranges from US\$60 to US\$100, depending on the evaluated system. "Presently, the carbon market does not pay for that amount," Alexandre Szklo explains. The Energy Planning Program wants to find out solutions to the existing and future coal-fired power plants. The future plants may be adapted to include advanced fuel combustion technologies integrated with carbon capture technologies.

Climate vs. Poverty: From a Social Perspective

Climate change has also been studied from a social perspective at Coppe. One of the first studies showing that the poor regions are the most vulnerable to cli-

mate change was carried out by Paulo Cesar Rosman, in the Naval and Ocean Engineering Program. When Rosman evaluated the possible effects of the sea level rise in the coasts of the metropolitan area of Rio de Janeiro, he drew attention to the fact that the people who live in fancy housing in Barra da Tijuca (a rich neighborhood) or in the beachfront apartments in Ipanema and Leblon are exposed to different risks from those who live in poor communities in the Baixada Fluminense.

"In the most developed areas, where the population has a stable financial situation, the constructions are built over embankments, according to safety standards," he says. "The lower areas, which are always flooded, are left to the poor people." The lack of housing policies and





master plans for the cities facilitates the occupation of these risky areas.

Various Coppe programs carry out projects that include climate and poverty issues. The projects are conducted by Rosman and his colleague, Cláudio Neves, in the Ocean Engineering Program, by Paulo Canedo in the Civil Engineering Program and by Emilio La Rovere in the Energy Planning Program. There is also a new initiative that will create new research projects and help promote the interaction between the existing projects within and outside of Coppe.

The new initiative is the Hebert de Souza Technology and Citizenship Laboratory, which is closely linked to Coppe's Board of Director and is being built in a 200 square meter area. The laboratory will concentrate its activities on the environmental, climate change and poverty issues.

The new laboratory is the result of a partnership between the Brazilian National Social Mobilization Network (Coep), created in the 1990's by the past sociologist Herbert de Souza (Betinho), together with Coppe director, Luiz Pinguelli Rosa, the Bishop Dom Mauro Morelli and the engineer André Spitz.

Presently, the Coep is a national mobilization network against poverty which brings together companies, public organizations, NGOs and people. More than 1,100 organizations, 110 communities and 12,500 people throughout the country are involved in this project. Even though the Coep had been initially created to combat starvation (which was Betinho's battle in the 1990's), in 2000 the mobilization network aimed at accomplishing the Millennium Development Goals established by the United Nations (UN).

Climate issue was included in the Coep strategies in 2008. André Spitz, the institution's president, explains why: "Working with low-income communities made us realize that climate variations are the main causes of the problems they face. Problems concerning sanitation, water supply, food safety and emergency are related to the environmental issue."

Headed by Brazil's president and installed at Coppe, the Brazilian Forum on Climate Change created the Group for Environmental, Climate Change and Poverty Issues, in 2009. The group is coordinated by Coep in order to add the new social perspective to the documents that help create Brazil's climate change policies. The

new working group began to encourage companies, universities and organizations that deal with food safety, agroecology, human rights and with the development of low-income communities to explicitly include the climate issue in their strategies. The working group even took a document on the issue to the UNFCCC 15th Conference of the Parties, which took place in Copenhagen, in 2009. In 2010, the working group contributed to Brazil's position in the 16th Conference of the Parties. Presently, the Group for Environmental, Climate Change and Poverty Issues is developing a document with principles, guidelines and targets to be sent to the Brazilian government as a contribution to the formulation of Brazil's National Adaptation Plan. This plan will be presented by the government when it launches Brazil's National Policy on Climate Change. The creation of the Hebert de Souza Laboratory is one of the results of this initiative.

"Much is said about the vulnerabilities of the poor people, but it's necessary to understand what does this mean, so that public policies can be more efficient. And this doesn't happen only in Brazil," Spitz says. The focus has been on mitigation actions, that is, on the reduction of greenhouse gas emissions, and little has been thought about adaptation actions. "From the perspective of the low-income population, adaptation actions are important. Meanwhile, mitigation actions have to be linked to social inclusion," he suggests. It is important to reduce deforestation, but this must be done on a socially fair basis. It is necessary to find a solution that generates money to the poor people.

Coppe and Coep will establish a two-fold partnership, which will be even stron-

ger with the creation of the new laboratory. On one hand, it will provide Coppe's scientific and technological knowledge to the organizations interested in the climate issues and social perspectives. On the other hand, it will help Coppe include the climate change issue and the social perspectives in the research and studies developed at the institution, as well as maintain close partnership with other academic institutions. "We'll work together to help the vulnerable population," Spitz says.

Coep is involved in two ongoing researches. The first one is coordinated by Professor Renato Maluf, from the Rural Federal University of Rio de Janeiro. The study analyzes five communities within Coep network, in different biomes, so as to assess how these communities understand the climate issue. In addition, it is aimed at creating an agenda to discuss the climate issue. The communities include the Amazon riparian community, an agriculturist community in the north-

eastern semi-arid region, a *quilombola* community in the *cerrado* (a savanna ecoregion) and two urban communities, one in the neighborhood of Jacarepaguá, in the city of Rio de Janeiro, and the other in Florianópolis, the capital of the state of Santa Catarina.

The second research is coordinated by the sociologist Anna Peliano, from the Institute of Applied Economic Research. The study is aimed at identifying public and private companies committed to social responsibility, in order to analyze how they are dealing with climate and poverty issues. By doing this, it is possible to recognize models to be followed and create guidelines for other organizations.

However, a more ambitious project is being developed in Coppe's new laboratory: to map social vulnerabilities to climate change in Brazil. The creation of this map is inspired by Betinho's starvation map, created in 1993. The starvation map called the attention to the starvation issue in the country. "The starvation map

was easier to be drawn. The climate issue is more complex and it involves many variables," Spitz says. One of the first goals of the Hebert de Souza Laboratory will be the selection of the appropriate methods to be used for the starvation map.

Emergencies: When Everything Has Gone Wrong

If the Hurricane Catarina, the first extra tropical cyclone registered in the Southern Hemisphere to hit the state of Santa Catarina, in 2004, had moved a little further to the north and had reached the states of Paraná and São Paulo, the damage would be much worse. On the coast of the states of Paraná and São Paulo there are many port installations and oil infrastructure that could have been destroyed, possibly causing a disaster.

Moacyr Duarte works in the Technological and Environmental Risk Analysis Group (Garta), which has been operating at Coppe since 1992. His job is to predict what might happen "after ev-



everything has gone wrong,” that is, he must analyze the risks in order to predict emergency situations and anticipate the response to them.

An emergency can be a panic situation in a crowded stadium, a shooting in the slums or even the collapse of an oil refining tower due to an extreme climate event.

In Brazil, the slopes of the Atlantic Forest are vulnerable to climate change, because they are an extremely rainy transitional zone in the country’s most industrialized region. There are many transmission lines and towers, distillation columns, oil refining towers and oil and gas pipelines in the hillsides of the Atlantic Forest. Mudslides have already damaged some oil pipelines

in the mountain ranges of Serra do Mar, in the state of Rio de Janeiro, and Serra do Espinhaço, in the state of Minas Gerais. The oil pipelines broke and spilt oil into the environment.

With this in mind, the Garta has just finished a high definition mapping of the suburbs of Petrobras’ 14 industrial facilities (12 refineries and two fertilizer industries) spread all over the country. The system shows what surrounds each industrial facility (population, housing, rivers, nursery schools, schools, bus lines etc.) and predicts the damages caused by a potential accident, without considering the influence of climate changes. With this information, it will be possible to for-

mulate scenarios that represent extreme climate events, as well as the reaction of the population and the response of the industrial facility emergency systems. For example, it is possible to simulate if heavy rains have caused, at the same time, leakage in a refinery and mudslides on hillsides, which would block roads and prevent from rescuing the population.

With this scenario, the company will be able to formulate and change its emergency plan. More than one million people have benefited from this study. They had their houses mapped and were included in Petrobras’ emergency plan.

Moacyr and his group use powerful computer resources to develop scenarios

The Vulnerability of Ignorance

Professor Cláudio Neves, from Coppe’s Ocean Engineering Program, carried out a study on the mean sea level in Rio de Janeiro between the years 1965 and 1999. He noticed that the sea level first rose, and then fell. “It’s not possible to know what does this mean, because there is not enough set of measurements available,” he says. In 1990, Neves was the co-author of the first international study about the vulnerability of the coastal zones. The Brazilian city that received the detailed study was Recife, because it was the only city with a cartographic survey of its metropolitan area available in a 1:2000 scale and with measurements of the waves and tides, as required by the IPCC.

Unfortunately, things have not changed much. In a country with an extensive coastline, where 14 of the 50 municipalities with the highest GDP per capita are on the coast and have port installations or oil infrastructure in place, there is no systematic measurement of the mean sea level, beach profile and wave behavior.

When the data does exist, it cannot be accessed (which is the case of the wave measurements carried out by Petrobras) or it cannot be compared with other data (the information about the sea level, for example). “We don’t have a defined

level of reference for the sea level. There are several: the zero level on the maps from the Brazilian Institute of Geography and Statistics (IBGE) is not the same zero level defined by the Navy’s navigation charts, which is not the same zero level defined on the Portobrás maps,” Neves complains.

In the case of the sea level, an absolute measurement is not enough. It is also necessary to measure the relative level, because the ground is not static – especially in the lowland areas where the soil is geologically new and, as a result, has not yet been consolidated. The weight of urban occupation – with landfill projects and extensive building – makes the land sink, which means that in these areas the relative sea level rise is subsequently higher than in places where there are rocky shores. “It’s not possible to map vulnerable areas and design a master plan for organizing the urban occupation without a detailed analysis of the coastal altimetry,” explains the Naval and Ocean Engineering Program’s Paulo Cesar Rosman.

In the countryside of Brazil there is the tradition of measuring environmental data. There is regular measurement of temperature, rainfall, and river flow in various places. Some measurements have been taken regularly for more than a century. But there are only sporadic measurements of beach

and carry out simulations. The group is planning to use Coppe's recently installed supercomputer to develop models for evacuating the stadiums that will host the 2014 Fifa World Cup and the 2016 Olympic Games, in Brazil. They intend to use a model that allows us to predict, in case of collective panic, the bottleneck spots, the areas where people are susceptible to being trampled underfoot in the crowd, and the zones where people can be squeezed against the wall. Similar studies, though less complex, were already carried out by the Garta group in huge outdoor events in Rio de Janeiro, such as rock shows and the New Year's celebration at Copacabana beach.



profiles carried out by researchers such as Neves. At some uninhabited beaches, researchers have found variations of up to 100 meters on certain strips of sand after sea storms.

The lack of information about the environment is even more severe due to the disorganized occupation of these areas. Some buildings are located directly on evolving sand strips, some coastal protection projects are being undertaken without applying technical engineering standards and there is an indiscriminate utilization of sand beds in the estuaries and inlets. These factors cause rapid erosion, which has been registered in Fortaleza (in the state of Ceará), Olin-da (in the state of Pernambuco), Conceição da Barra (in the state of Espírito Santo) and Matinhos (in the state of Paraná). But the lack of historical data does not allow researchers to determine if these erosion processes are the result of human intervention or a natural long-term tendency.

For these coastal structures, the lack of environmental data is also an economic risk. If there is any structural damage after heavy surf, for example, the insurance company will investigate if the damage was caused by unusual sea conditions or if the structure itself was deteriorated. "Due to climate changes, monitoring the sea environment will become common practice. It is worth noting that not

monitoring the marine environment can be more expensive than the monitoring program itself," Neves warns.

The lack of information is evident at various levels. Mocyry Duarte, a researcher at the Technological and Environmental Risk Analysis Group (Garta), explains that the traffic jam that occurs in downtown Rio every time rains flood the area around Praça da Bandeira would be alleviated simply by installing indicators that measure the depth of the water. The researcher has observed that in this neighborhood, the water does not often exceed the height of 30 centimeters, which can easily be traversed by car. But the drivers do not have this information, so they simply stop their cars and, as a result, paralyze traffic in downtown Rio.

It is necessary to have more information in order to provide a precise evaluation of what is happening these days – and even more so to make forecasts about the future. "The data available now does not allow us to scientifically predict what will happen in the next 100 years. We would have to use magic," Rosman says. That is why Rosman and Neves recommend, in all of their studies on vulnerability carried out for governments, companies and other institutions, that monitoring measures be included. Monitoring coastal and oceanographic variables must become a permanent process in Brazil.

4 Anticipating the Future

Meeting the energy demands necessary to maintain its economic growth and also to limit global warming is only part of the challenge facing Brazil as the century unfolds. The difficult climate-energy equation is also a chance for the country to play a role in the green economy that is beginning to develop.

Everything indicates that there will not be a single solution. All forms of energy will be used in different scales, including the ones based on the use of fossil fuels. There will be a different solution for each problem, each location and each case. But all different solutions will have one thing in common: the necessity to operate in a low carbon, sustainable manner, without losing sight of the economic, environmental and social aspects.

In anticipating of the low carbon future that is appearing on the horizon, Coppe is developing technologies for the Brazil of the 21st century. These studies and projects include hydrogen-powered vehicles, the magnetic levitation train and technologies to extract biofuel from sewage and trash. The projects also include plans to generate electricity from ocean waves, the building of energy efficient houses,

and the development of techniques for managing public transportation, which would encourage people to use bicycles. The projects also mention techniques to reduce the production of radioactive waste by nuclear power plants.

Wave Motion

Deep water oil production research carried out by the Subsea Technology Laboratory has resulted in an unprecedented wave energy power plant. With a capacity of 100 kW, the pilot plant, installed in the Port of Pecém, in the state of Ceará, will begin to operate in 2011.

Entirely produced in Brazil and using Brazilian technology, it is the first wave energy power plant in South America. There are already some experimental installations in Europe, mainly in Portugal and Scotland. They are small installations, each based on different concepts.

Coppe's power plant has its own concept, which was developed according to the characteristics of the Brazilian sea: with medium height waves, constant throughout the entire year (in the North Sea, for example, there are high waves, but in the summer the sea is usually calm).

In the tests carried out at Coppe's Ocean Lab (LabOceano), the model has shown efficiency higher than 30%, i.e., a conversion capacity higher than 30% of the energy potential of the waves. This figure is equivalent to the top performances achieved by the foreign technologies with which Coppe intends to compete.

The wave power plant is located on the coast and it has a buoy 22 meters off the coast. The changes in the sea surface, due to the waves, move the buoy. The buoy pumps fresh water through a high-pres-

sure closed circuit, producing a stream of water that moves a turbine connected to an electric generator, which converts mechanical energy into electrical energy.

"In order to obtain the stream of water, we use a pressure equivalent to water falling from a height of 400 meters, which is similar to the fall in large hydroelectric power plants. The difference is that the pressure is kept in a hyperbaric chamber," explains Segen Estefen, a professor at Coppe's Ocean Engineering Program who oversees the project. The main feature of the Brazilian concept is the high-pressure system. Coppe has learned to use this type of technology by developing solutions for Petrobras, so that the company could operate in the deep waters of the Campos Basin, at depths of up to 3 thousand meters.



Segen estimates that wave motion on the Brazilian sea has the potential to add an additional 15% to 20% of capacity to the country's current 100 GW of installed generation capacity. This corresponds to 1.5 times the generation capacity of the Itaipu hydroelectric power plant, which is a considerable amount of clean energy produced with Brazilian technology.



Carbon Capture in the Pre-salt Layers

The discovery of big oil reserves in the pre-salt layer came together with some bad news: the oil found in deep layers is associated to great quantities of CO₂. This means that during the production stage there are already emissions of the most harmful greenhouse gas, without mentioning the fuel combustion emissions.

Researchers from all over the world are trying to find solutions to capture and store carbon from fossil fuel use. Pedro Leite da Siva Dias, the director of the National Laboratory for Scientific Computation (LNCC) and also Coppe's collaborator, sees a great opportunity for the development of Brazil's science and technology.

The LNCC coordinates a project that involves researchers from Coppe, from the Institute for Pure and Applied Mathematics (Impa) and from other research institutions. The project is entitled 'Modelagem Hidrogeomecânica do Sequestro Geológico do Dióxido de Carbono no Pré-Sal' (Hydrogeomechanical Modelling of the Geological Storage of Dioxide Carbon in the Pre-salt Layers) and is aimed at modeling the behavior of CO₂ that has been stored in geological layers for a long time (hundred and thousand years), so as to evaluate the feasibility of storing the gas in oil wells.

"The idea is to keep the carbon from oil extraction and combustion down in the wells. If we show evidence that it is safe and economically feasible, it will be a fantastic opportunity for Brazil," Pedro says. "The country's decision to explore the pre-salt layers points toward a carbon economy. But if the pre-salt layers help reduce the carbon amount, Brazil will be in a much more comfortable position in the international business," he adds.

Subsea carbon storage is a very complex issue. There are porous rocks under the sea, and the porous media change constantly. Due to special temperature and pressure conditions under the sea, the CO₂ is involved in chemical reactions that are not well known.

To carry out this project, the LNCC has the help of a group headed by Marco Murad. This research group is internationally recognized in the modeling of porous media. Impa's mathematician, Dan Marchesini, and experts in geochemical from universities in the states of Pernambuco and Minas Gerais also participate in the project.

Coppe's role in this field is still being discussed, but it is already known that the institution will help with the modeling of engineering aspects. After all, Coppe has been carrying out research on the pre-salt layers, in partnership with Petrobras, since the first oil discoveries in the region.

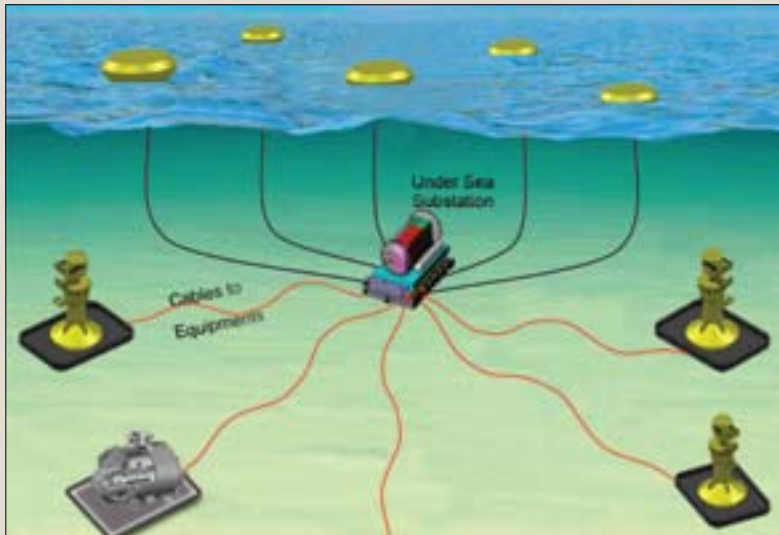
However, Coppe's researchers want to harvest more renewable energy from the sea. Wave energy can be captured from the Brazilian South all the way up to parts of the Northeast. Further to the north, in the state of Maranhão, the potential for energy generation can be found in the tides.

The technology is not new. The world's largest tidal power plant has been in operation for more than 40 years in La Rance, France, with a production capacity of 240 MW. Another large tidal power plant will be soon operating in South Korea. In the 1960's, there was an unsuccessful effort to build a tidal power plant in Maranhão. In 2004, the Eletronorte Company invited Coppe to study the subject. The partnership resulted in a Master's thesis and now Coppe and the Federal University of Maranhão (UFMA) are considering the possibility of building a power plant/laboratory.

Tidal power plants can only be built in places where there is high variation of tide levels, such as in the state of Maranhão or in the Brazilian North region. A dam is built close to the sea. When the tide is high, the reservoir begins to fill and the sea water goes through a turbine connected to a generator, which produces electrical energy. When the sea level starts increasing again, the reverse movement also moves the turbine and produces energy.

"But tidal power plants can have a serious impact on the coast. That is why all projects either have to take steps to protect the environment or be positioned a little far from the coast. A possible solution is to use the energy produced by tidal currents," Segen says.





Although the Subsea Technology Laboratory is working on both wave and tide, in these two projects to harvest energy directly from the sea, there is the possibility of indirectly using the ocean, i.e., of using offshore wind power. In the sea, where there are no obstacles, wind speed is higher than it is on land. Likewise, the capturing of solar power requires large sur-

face areas, and the sea surface can be a solution.

Segeen envisions large energy parks on the Brazilian sea. They could even power the oil platforms that will operate in the pre-salt layers. "The future economy will definitely use energy from the sea. In five or ten years, it will become part of the system and will be an important step to-

ward the oil substitution in the low carbon economy." These technologies are still expensive, when compared to conventional energy sources, but there is a tendency for them to become cheaper. The well-prepared countries will be in a position to reap the benefits.

A Hydrogen Hybrid Bus Hits the Roads

In the 19th century, the French author Jules Verne forecast that water – or, rather, the hydrogen it contains – would be the fuel of the future. The prophecy is now becoming a reality. In some countries, research projects on buses powered by hydrogen, which is a clean and virtually limitless power source, are being put into practice. Brazil is one of these countries, thanks to the work developed by the group headed by Paulo Emilio Valadão de Miranda from the Metallurgical and Materials Engineering Program.

As a result of the research conducted at the Hydrogen Laboratory, coordinated by Paulo Emilio, there is a hydrogen hybrid electric bus – a pioneering initiative in the Southern Hemisphere. The bus was completely designed at Coppe and it was built by Brazilian companies. It looks like a normal bus, but it is powered by electricity supplied by a plug connected to the power grid. It is also supplied with electricity produced onboard by a hydrogen fuel cell.

In addition to their quiet operation, the pollution-free hydrogen hybrid buses are more energy efficient than the buses powered by diesel. Clean, drinkable water, for human consumption, is the only thing released from the tailpipe.





The technological innovations developed by Coppe put the new bus in the forefront of other similar buses tested in developed countries. The hydrogen hybrid bus is more efficient thanks to the use of fuel cells and to the devices that store and control the energy available onboard.

The hydrogen hybrid bus is one of the electric vehicles designed at Coppe's Hydrogen Laboratory. There is also a completely electric bus and an ethanol-electric hybrid bus. All the three of them are powered by electricity supplied by the power grid and stored in batteries. They also share the capacity to regenerate kinetic energy, which is captured when the bus is moving. On conventional vehicles this energy dissipates when the bus decelerates or stops.

Abundant in nature, hydrogen can be obtained from various sources. The most obvious source is water, but electrolysis,

which is the process used to get hydrogen from water, demands great amount of energy. There are alternative and renewable energy sources, such as solar, wind and tidal power. Current technology shows that the most viable process is the natural gas steam reformer. It is also possible to use hydrogen from the methane present in biogases produced by municipal waste, sewage, plant waste and liquid fuels like alcohol. These raw materials are abundant in Brazil.

Coppe's Nuclear Engineering Program will make an alternative contribution to hydrogen production. The Program's researchers, in partnership with researchers from other institutions, are studying new production routes for hydrogen by using nuclear reactors. It is a chemical process called thermolysis and it requires temperatures of 800°C to produce water vapor. It is possible to use a nuclear reactor to generate such high temperatures and produce water vapor for hydrogen production while generating energy.

Paulo Emilio explains that Brazil is in a privileged position. It is the only country in the world that offers a viable alternative fuel for automobiles, by introducing ethanol as a gasoline substitute. Now, with Coppe's project, Brazil is at the forefront of the design and building of hydrogen vehicles.

A Train that Levitates

The magnetic levitation train is futuristic, but it is not science fiction. On the contrary, it is an available technology that is ready for use today. It is the Maglev Cobra, a smooth, quiet and fast train that uses magnets and superconductors instead of wheels.

The maglev train causes less sound and visual pollution, has less physical impact on the places it passes by and, above all, it is more energy efficient than other means of transportation, such as airplanes, cars, subways and conventional trains using wheels and tracks.

The Maglev Cobra was developed at the Coppe Electrical Engineering Program's Applied Superconductivity Laboratory. The coordinator of the project, Richard Stephan, is proud of having a life-size model levitating in the lab as it awaits the financial backing to build the system that will enable the train travel a small distance – no more than 200 meters – at the Ilha do Fundão campus.

The professor is convinced that some investors will be interested in operating the maglev train commercially after the tests are completed. He guarantees that if investors make a decision by the middle of 2011, it would be possible to have the Maglev Cobra operating commercially in the city of Rio de Janeiro in 2014, serving the tourists visiting Rio during the 2014 Fifa World Cup and improving traffic flow. Stephen says that the train would initially run from the Santos Dumont Airport, in Downtown Rio, to the Tom Jobim International Airport and would also have stations at Cinelândia (downtown) and Ilha do Fundão (at UFRJ's campus).

Coppe's magnetic train uses superconductors. Although scientists had discovered these materials in the 20th century, it was not until two decades ago that researchers began to use them, and their use has yet to become widespread. Superconductors have two main features: zero resistance, which enables handle high currents, and diamagnetism, which

is a phenomenon that repels magnetic fields and enables levitation. Unlike the conventional wheel/track systems, since maglev trains float, there is no friction. Therefore, there are no wheels to wear out, which makes the maglev trains more energy efficient.

There are two magnetic train systems in operation in the world today. The first system uses a technique of attractive force called electromagnetic levitation, which lifts the train. This system is called Transrapid and was developed 20 years ago, in Germany, where there is a test facility. In 2003, China bought this technology and implemented the first commercial maglev train in Shanghai. The second system is Japanese and is being tested on a 18.4 kilometer test line. This system uses another type of repulsive force called electrodynamics. It also

uses superconductors, but it only uses the property of zero resistance to obtain high currents. The German and Japanese trains achieve speeds greater than 500 kilometers per hour and therefore are an appropriate transportation system for connecting distant cities (the Japanese intend to have a line from Tokyo to Osaka, its two main metropolises).

The system developed by Coppe is unique: it uses superconductors, but only makes use of their diamagnetic property to obtain the levitation effect. Stephan chose this property for the project because, unlike the two systems mentioned above, the project was designed for a low-speed train (70 kilometers per hour). It was designed for urban use only. The idea is to use the maglev train instead of cars, buses and subways in established areas of traffic congestion, where traffic

management solutions are neither sufficient nor applicable. For example, the maglev train is a good solution for places where there is no space to build an exclusive bus corridor.

The magnetic train is powered by electricity and, unlike cars and buses, does not emit greenhouse gases. As the train is light, it can float over a narrow guideway, no larger than a pedestrian bridge, doing away with the complex





and expensive public works required by the subway.

According to Stephan, the material used to build levitation trains is more expensive than that used for conventional trains, but it is still worthwhile. The construction and maintenance of the levitation train requires less money, as there is no friction and consequently no wear on the material. While the subway costs R\$ 100 million per kilometers built, the Maglev Cobra would cost R\$ 33 million.

With respect to energy consumption and efficiency, the magnetic train also comes out ahead. For each passenger transported a single kilometer, a conventional bus uses the equivalent of 0.44 kWh and the subway uses 0.16 kWh, the Maglev would use just 0.04 kWh.

Energy Accumulators

The Maglev is the most visible project developed at Coppe's Applied Superconductivity Laboratory, but it is not the only one. A line of research on magnetic bearings, which also use superconductive materials, is attempting to find solutions to one of the most important problems of electrical power production and consumption from

these new clean sources: how to store energy.

For example, how do we store wind or solar power, given the fact that it is not always windy or sunny? A conventional solution is the use of batteries, which brings with it all of the environmental pollution issues that arise when they are discarded.

The answer to this problem is the flywheel, a rotating mechanical system that rotates to very high speeds. While the flywheels rotate, they maintain the energy stored until it is used. When the flywheel is working, it converts mechanical energy into electrical energy.

The problem is that high speeds are always associated with friction, wear and breakdowns. That is why Coppe's research on magnetic bearings is important. By using the levitation properties of the superconductors, it will be possible to achieve the necessary high speeds with no mechanical friction and without the pollution of chemical systems.

Just as semiconductors were important materials for the technological revolution of the 20th century, due to their role in computer sciences and telecommunications, Stephan believes that superconductors will revolutionize the technology

of the 21st century. "They will be essential for the transmission and conversion of energy," he says.

Brazil lost the chance to produce the semiconductors of the 20th century and now has to import all the semiconductors it needs. Stephan sees no reason for that to happen with superconductors. Brazil has the necessary raw materials – yttrium, barium and copper. Stephan presented a project to the Brazilian Innovation Agency (Finep) suggesting that the country should produce magnets and superconductors. The goal is to make the future a reality.

Nuclear Energy Finds its Place

The alchemists dreamed of transmuting cheap metals, such as lead, into precious metals, such as gold and silver. Presently, nuclear physicists want to transmute materials that can remain radioactive for a period of up to 10 thousand years into materials whose radioactivity lasts no more than 300 years.

The goal is to solve one of the major problems related to the acceptance of the use of nuclear energy, which is the storage of radioactive nuclear waste. There are still no satisfactory technological solutions that guarantee the safety of the deposits for long periods of time.

The studies on transmutation carried out by Coppe's Nuclear Engineering Program are coordinated by the Brazilian National Institute of Science and Innovative Nuclear Reactor Technology. It is one of the national institutes created by the Ministry of Science and Technology in 2008 in order to bring together researchers from various institutions to discuss specific topics. Nine institutions from the states of Rio de Janeiro, São Paulo, Mi-

Contributions to Transportation Demand Management

The transportation sector is one of the sectors that can play a key role in the reduction of the growth rate of greenhouse gas emissions. It is responsible for 23% of the global emissions associated to energy consumption and it is the fastest growing sector, especially in developing countries, where there is an increasing demand for vehicles due to better income. In Brazil, transportation is the third main source of emissions of global warming gases. It comes right after deforestation and wildfire.

However, the transportation sector poses a great challenge to taking mitigation measures, as it involves mobile sources and economic and social actors. According to Suzana Kahn Ribeiro, from Coppe's Transportation Engineering Program, "unlike the industrial sector, where there are local sources and impacts of mitigation measures, in the transportation sector everything is spread." Changing the type of fuel demands a huge logistic effort to make the new fuel available in the whole country. Introducing a taxation policy has different impacts on different groups. "For public transportation passengers, fare rises have impact on their income. For the cargo transportation, cost increase has impact on the price of the products and on the exportation competition. Perhaps a taxation policy would not have a great impact on car passengers. Anyway, it's very difficult to find a policy that suits different users," she explains.

Suzana shows how limited is the technology used to face this issue. "Technology is improving a lot, the engines are becoming more efficient, the vehicle design is more aerodynamic and the materials are lighter. But the number of vehicles is growing and the transportation system is chaotic. Why have an efficient vehicle if it is stuck on a traffic jam?," the professor asks.

One of the answers can be found in the transportation demand management, a field that the Transportation Engineering Program has been studying for more than 10 years. Professor Paulo Cezar Martins Ribeiro, for example, helped formulate the Rio Bus Project to reorganize the bus lines in the city of Rio de Janeiro. Professors Ronaldo Balassiano and Licínio Portugal also dedicated themselves to study the problems concerning the traffic system and the transportation strategic planning. It is worth noting that the city of Rio de Janeiro has been the group's favorite 'laboratory'.

The professors suggest the creation of separate bus lanes, the so-called BRT system (bus rapid transit system) in many of Rio's roadways. According to Ronaldo Balassiano, although the BRT system was created by the group of the architect Jaime Lerner, in Curitiba, in the 1970's, Brazil is far behind when compared to other countries.

Today, there are 140 BRT systems operating worldwide. Some of them are highly sophisticated, in that they have operational and fare control devices that monitor the vehicles and fares in real time. One of the newest systems is the Transmilenio, which was implemented in Bogotá, the capital of Colombia. Statistics show that there has been a reduction of 90% in fatal traffic accidents since 2003. The BRT system has also reduced pollutant emissions by 40%.

A study carried out by Paulo Cezar in downtown Rio resulted in a great database about the traffic behavior in that area. Simulation has shown that implementing the BRT system would increase the average speed of buses and would make them more attractive than vans and cars that 'fight' for the same space in the streets of downtown.

Coppe's researchers are even carrying out studies on bicycles. A doctoral dissertation supervised by Professor Milena Bodmer mapped the profile of train, bus and subway passengers who live in two suburban neighborhoods of the city of Rio de Janeiro – Santa Cruz and Colégio – to evaluate the potential of using bicycles as an alternative to public transportation. The work concludes that, if it is not possible to substitute bikes for public transportation, it is possible to integrate them. More than 40% of the users said that they would use bicycles to get to the main transportation stop if there were bicycle parking lots, cycle lanes and more efficient public safety measures.



nas Gerais, Pernambuco and Rio Grande do Sul are part of the Institute, which is headquartered at Coppe.

The concept of a transmutation reactor was suggested by the physicist Carlo Rubbia, who won the Nobel Prize in Physics, in 1984. Theoretically, this reactor, while generating electrical energy, can drastically reduce the half-life and radiotoxicity

of about a hundred radioactive elements originating from the combustion of uranium in power plants like Angra 1.

Coppe's research is not aimed at investing in the development of such a reactor, because there would not be demand in Brazil in the near term. There are only two nuclear power plants operating in Brazil and there is one under construction. However, according to Aquilino Senra Martinez, a professor at the Nuclear Engineering Program, "it is important to keep abreast with what is being studied abroad."

In the United States, where there are 104 nuclear power plants in operation, estimates show that 17 transmutation reactors would be needed to treat the waste.

The nuclear industry has not grown considerably during the last 20 years, given that most countries decided to stop building nuclear power plants. This

has happened not only due to the issue of radioactive waste, but also because of the use of nuclear technology as weapon and the tragic accident in Chernobyl, in 1986. Now that climate change is a recurring topic in the global agenda, the nuclear industry has the chance to promote the increased use of nuclear energy in the global energy matrix.

A study carried out in Germany in the 1990's compared greenhouse gases emitted from different sources and concluded that nuclear power has some of the lowest emissions, losing out only to hydroelectricity. The study evaluated the entire emission production chain. Although there are no direct emissions of greenhouse gases while the nuclear power plant is operating, there are emissions during the uranium mining and fuel production, due to the use of large trucks and to the consumption of electricity to





refine the ore and produce fuel. Surprisingly, the analysis of the production chain demonstrated that solar power emits more global warming gases than nuclear power. The process of building solar panels is responsible for significant gas emission.

In the beginning of the 21st century, some countries that had stopped building nuclear power plants decided to expand again. The United States currently has six power plants planned for construction, but the most amazing figures come from China. Its nuclear power capacity will jump from 9 thousand MW to 72 thousand in 2014. China makes use of generation III reactors, which are more advanced than the ones spread all over the world, such as Brazil's Angra 1 and 2 generation II nuclear power plants. "After the Three Mile Island accident in the United States, in 1979, and the Chernobyl tragedy, the nuclear industry has undergone significant changes. The probability of having a serious accident using generation II reactors is ten times higher than that of the generation III reactors."

Today there are 436 nuclear power plants operating worldwide. Some estimates show that there will be 600 in

2030. "The increase of nuclear power plants is related to climate changes," Aquilino guarantees. But the low greenhouse gas emissions are not the only advantage. The nuclear power plant, just like the power supplied by hydroelectric power plants, is a fixed energy source, which means that it supplies the energy amount anticipated in the project. On the other hand, solar and wind power depend on weather conditions.

The generation III reactors are designed to produce more energy, use less uranium and produce less plutonium (which is the main material used in nuclear weapons). Therefore, these nuclear reactors are designed to be more energy efficient, produce less radioactive waste and generate less material that can be used for the construction of weapons. In the generation IV reactor designs that are currently under research, the increase in automated operation will be fundamental. This means that in the event of an emergency, it will be possible to eliminate human action. The ultimate goal is to avoid the meltdown of the reactor core, because it is the reactor fusion that produces radioactivity, which can reach the outside environment if the

containment building is not sufficiently reinforced. In Chernobyl, for example, there was no containment building.

Aquilino is convinced that, within 10 to 15 years, Brazil will launch a major program for the construction of nuclear power plants. The country will take these steps in order to meet its energy needs within the context of climate change. In addition, there are some favorable circumstances in Brazil: the country has uranium (one of the biggest reservoirs in the world), it has experience in the production of nuclear fuel and it already uses nuclear power to produce electricity. Only other two countries have the same circumstances: the United States and Russia.

Pioneer in the Study of Hydroelectric Emissions

In 1992, at UFRJ's Praia Vermelha campus, there was an international meeting where scientists discussed the hypothesis regarding hydroelectric power plant reservoirs behaving as natural water environments and emitting greenhouse gases. That same year, the UN Conference on Environment and Development took place in Rio de Janeiro.

At that time, there was little research on this topic. There were only a few lines published about an experimental area in Canada. Marco Aurélio dos Santos, supervised by Professor Luiz Pinguelli Rosa, from Coppe's Energy Planning Program, conducted his doctoral research on the topic. That is how Coppe became a world pioneer in the field.

Today, other research groups in Brazil and in the countries that have large hydroelectric reservoirs, such as France and Canada, carry out studies in this field.



They even use little tricks developed by Coppe's group during its first field researches, such as the use of funnels to facilitate the sample collection.

Coppe's studies demonstrated that the hydroelectric reservoirs – which were considered to be a totally clean power source – emit greenhouse gases in a process related to the biogenetic decomposition of organic material by bacteria. However, although there are some emissions, they are much lower than the emissions by thermal power plants, which use coal, natural gas and oil.

Coppe's research group formed by researchers from the Energy Planning Program and the International Virtual Institute for Global Change (Ivig) has studied the behavior of the hydroelectric reservoirs at many power plants, including the ones in Balbina, Samuel and Tucuruí, in the Northern region, and in Itaipu, in the Southern region. This work has given rise to various master's theses and doctoral dissertations carried out at Coppe.

After two decades, Coppe continues to study the topic. The challenge now is to develop a method for separating the gross emissions value from the net

emissions value. Studies carried out at hydropower plants located in different biomes – the *cerrado* (Brazil's savanna ecoregion), the *caatinga* (a semi-arid scrub forest in the Northeast of Brazil), the Atlantic Forest and the Amazon Rainforest – show that part of the emissions comes from the organic material brought into the reservoirs by the regions' rivers. "Much of the organic material that arrives at the dams comes from sewage and livestock waste that is discarded into the rivers. In Brazil, the inventories on greenhouse gas effects show the figures related to livestock waste in re-

lation to the number of heads of cattle in the country. You cannot count twice," Pinguelli warns. In addition, even if there was no reservoir, there would be some emissions due to life processes in the water of the river and in the soil, which also releases gases into the atmosphere.

In calculating the total amount of emissions from the hydroelectric lakes it is therefore necessary to leave out the part that is not related to the reservoirs. In other words, the net emission must be determined. However, the method used nowadays is still inadequate and Coppe is working on an improvement.



Green Buildings

Cement production is responsible for 7% of global emissions of CO₂. Each kilo of cement is equivalent to one kilo of dioxide carbon thrown into the atmosphere. According to Coppe's professor, Romildo Toledo Filho, "consumption rates will not stop increasing, especially in developing countries, such as China, India and Brazil, where the civil construction demands huge amounts of concrete." According to estimates, global cement consumption will increase from 2.5 billion tons/year to 10 billion tons in the next 50 years.

Having these numbers in mind, Coppe's researchers in the Civil Engineering Program are developing new types of concrete that can substitute for up to 40% of cement in the conventional mixture. The researchers use ultra-fine sugar cane bagasse ashes and rice husk ashes; civil construction residues, such as ceramic waste and tile powder. They even use sludge and trash ashes from sewage and waste treatment plants.

"The use of these materials, which are usually thrown away after the production process, would reduce waste deposits into the environment," the researcher Eduardo Fairbairn says.

The green concrete were successfully tested in constructions at Coppe. The material was used to build the houses where the International Virtual Institute for Global Change (Ivig) operates. The houses were built by using green construction techniques (green materials and architectonic concepts). The houses are actually three open laboratories.

According to Ivig's coordinator, Marcos Freitas, Rio de Janeiro is one of the hottest cities in the world, which means that it is necessary to use the air conditioner for longer periods. But researchers have already noticed that with a natural ventilation system it is possible to increase thermal comfort in the city's buildings, without increasing the energy consumption.

In the three Ivig houses, located at Ilha do Fundão, researchers are conducting an experiment on thermal comfort, aimed at increasing the energy efficiency of the Brazilian constructions. The architectonic project of the houses considers the aspects of natural ventilation, green roofs and different construction materials. Comfortmeters were installed in order to monitor temperature, humidity, wind speed etc. for 24 hours a day during the whole year. The idea is to identify the worst periods during the year and compare the different architectonic solutions and construction materials, in order to find the most thermally comfortable and energy efficient combination. Marcos Freitas believes that it will be possible to reduce indoor temperatures during the summer in two or three degrees.

According to Freitas, the thermal comfort techniques with little or zero electricity consumption are important to increase the energy efficiency of the buildings. The substitution of energy-efficient bulbs for incandescent light bulbs in 2001, when there was an energy crisis in Brazil that resulted in an electricity shortage – known as "apagão" (blackout) – does not work anymore.





In 2010, Coppe started a large project, funded by the Brazilian Ministry of Mines and Energy and by electrical energy companies, to improve the reservoir studies from all over the country and in natural areas, such as the Lagoa de Cima, a lagoon in Campos, in the state of Rio de Janeiro, and the Lago Dom Helvécio (a lake in the state of Minas Gerais). Emissions are also being calculated on the Xingu River, where the Belo Monte power plant is under construction. The idea is to compare the emissions before and after the construction of the reservoirs and the emissions released by hydroelectric lakes and natural lakes.

By estimating the net gas emissions, it will be possible to include the amount of emissions from the hydroelectric power plants in the national greenhouse gas emissions inventory. Based on Coppe's methods and on the Brazilian government's sugges-

tion, the hydroelectric power emissions are calculated separately. The importance of hydroelectric power to the Brazilian energy matrix makes the information on hydroelectric gas emissions extremely relevant to climate policy and to Brazil's position in climate change negotiations.

The New Energy Microuniverse

In the 20th century, the economy and techniques being used were aimed at increasing production and consumption scales, in order to obtain economic benefit. Because of the environmental crisis, the tendency is to find a new rationality, which makes use of technological instruments to design products and flexible processes, adaptable to small scales and local use.

According to the economic theory and the technological approval, the consumer usually has to adapt to the product. Therefore, the consumer buys unneces-

sary things because the manufacturing technology is not flexible, it is focused on the economy of scale, and does not offer the consumer what he needs. Maurício Arouca, from Coppe's Energy Planning Program, gives an example: "A consumer who needs to buy a ¼HP power pump is only able to find ½HP or 1HP power pumps, because it is more advantageous for the manufacturer to produce larger equipments. But these pumps demand more energy and material."

Coppe has two ongoing projects that use sophisticated technology to solve complex problems and design products for small customers, applying both economic and environmental rationality. The projects are aimed at creating a market for the new forms of clean and renewable energy, such as the solar and wind power.

The first project, headed by Arouca, a professor from the Energy Planning Pro-

gram, is on the microgeneration of electrical energy. The second project, headed by Djalma Falcão from the Electrical Engineering Program, is about microgrids used for power distribution. The first one is aimed at producing small-scale energy to be used by small customers. The second project is aimed at distributing this small-scale energy to the larger transmission grids.

Microgeneration

The heart of Arouca's project is an engine/alternator system that can operate at maximum efficiency in a variety of wind speeds. The objective is to use this system in vertical axis wind turbines. The market currently applies horizontal axis wind power generators. These generators are expensive because they need an additional mechanism to be pointed into the wind and heavy structures to lift them. They also produce high levels of noise. The horizontal axis wind turbines are not appropriate for what Coppe's professor has in mind: generating electrical energy for low-income housing.

The vertical axis wind turbine is less efficient in converting the wind's velocity into energy. On the other hand, it is a cheaper system and its maintenance is simpler. "Easy and cheap maintenance is extremely important to the market on which we are focusing," Arouca says. Experience with solar energy systems installed by social programs in isolated communities in the Amazon and in Paraty (in the state of Rio de Janeiro) has shown that after a while the users abandoned the expensive imported equipment. They were unable to solve some of the problems that arose.



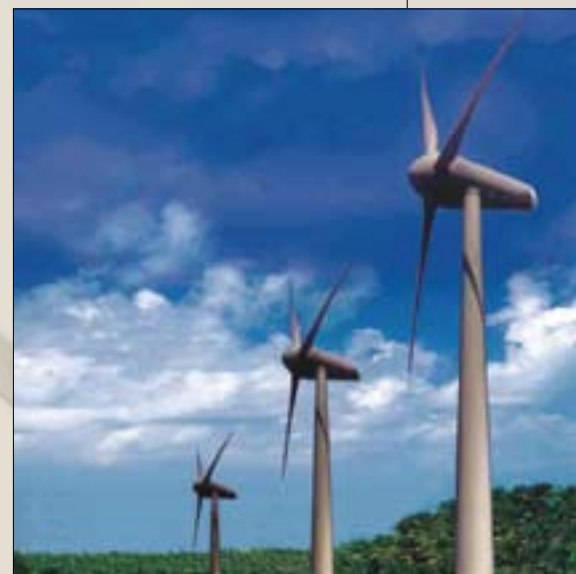
Coppe developed a vertical axis generator that is being tested in a wind tunnel. Coppe intends to commercialize the product in 2011 and there is already a manufacturer interested in producing it. The main market would be the Northeast region, but there is also favorable wind in the northern coast of the state of Rio de Janeiro, in the state of Rio Grande do Sul and in certain regions of the state of Minas Gerais.

A 1 kW generator, operating eight hours per day, with wind speeds of 10 meters per second, will generate 8 kW/hour per day. In 30 days, 240 kW/h will be produced. Just to have an idea of the product's potential for the target market, a low-income customer uses about 80 kW/h per month.

In the world market, the power of a generator is set for wind speeds of 12 meters per second. However, in Brazil, there are not many places with this average wind speed. In Rio de Janeiro, for example, the average is 4 to 6 meters per second. With these wind conditions, a 1 kW generator operates at a low efficiency of roughly 40%. Coppe is developing a maximum efficiency generator for

wind speeds of 4 to 6 meters per second. Therefore, a 400 W generator will be able to produce the same amount of energy as the 1000 W generator available in the market, at much lower costs.

The challenges of developing an alternator for wind generators are, except for some small adaptations, similar to those found in the design of engines capable of moving a boat or a car. The project's second product is a multiuse engine that can be regulated so as to reach the maximum efficiency with each application. In





order to achieve this, it is only necessary to change the program of the power control systems. Coppe will test this project on a boat powered by solar power and then in electric cars.

The concept behind this multiuse engine was successfully tested in wood stoves that produce steam to co-generate electrical energy for rural and/or isolated communities. By connecting a small caldron to a turbine attached to a generator, the stove can produce enough electricity to power a house with a few household appliances and low energy consumption. The original project tested an 860 W generator, which is available in the market. However, its power is too high for the purpose of the project. The

engine turned out to be inefficient. Then, in a more successful attempt, Arouca and his research group tested a 380 W generator that showed better results and whose installation was cheaper

Microgrids

Today's electrical energy systems in Brazil and around the world use a structure developed during the last hundred years: huge power plants produce energy (in Brazil's case, primarily from hydroelectric power plants or thermal power plants) and the energy "travels" a long way to consumers.

Technologies like the ones developed by Arouca enable communities or even individual consumers to produce the

energy they use and sell the surplus to electric-power distribution companies. But these technologies also pose a challenge: bringing together the electricity from different sources and operators in the transmission and distribution grid, without causing operational problems due to the differences between them.

Professor Djalma Falcão from the Electrical Engineering Program decided to face this challenge. He is designing a project aimed at installing a microgrid. Microgrids are smart microsystems that can manage the production and distribution of energy in a small community (a condominium village, for example) and at the same time be connected to a regular electricity company. Therefore, the community can produce its own energy and sell the excess production to electricity companies. If the consumer needs more energy than what was locally produced, he can buy it from an electricity company, through the same microgrid, which performs all of the operations automatically.

The electrical sector has been developing some computer, telecommunications and control technologies to produce increasingly automated responses to events that trigger faults and power outages. These technologies are called smart grids. Falcão's project is aimed at applying this type of technology to microgrids. The microgrids can be controlled by the electricity company as if they were one entity, which means that it does not have to deal with each individual energy source, because the microsystem takes control and behaves as a unique source to the electricity company system.

Everything is controlled by a centralized computer, with no human operators.

If there is a blackout, the microgrid will continue to operate independently and will automatically reconnect to the power grid after the system recovers.

In the future, due to high level of automation, customers will benefit from different electricity rates, calculated according to the time of the day. "When we reach this level of automation, we will be able to automatically manage our energy consumption. For instance, you can turn down the air conditioner when the electricity rate is more expensive and turn it up when it is cheaper," Professor Falcão explains. The computer will also be able to decide when it is more convenient for the consumer to use the locally produced power or the power produced by the electricity company.

Falcão is operating a project simulation and wants to install an experimental microgrid at UFRJ's Technological Center. The system will have a wind generator designed by Arouca at the Energy Planning Program, a fuel cell developed by Paulo Emílio Valadão at the Metallurgy



and Materials Engineering Program, and photovoltaic solar panels. For comparison purposes, the tests will also make use of a diesel generator. The idea is to work only with low carbon energy sources.

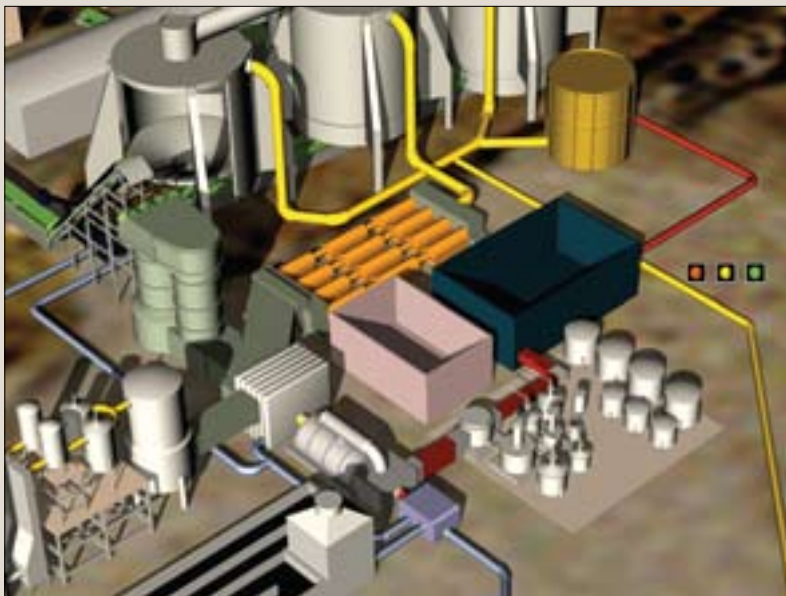
Energy Abundance Hidden in Garbage and Sewage

Presently, there are two thousand wastewater treatment plants for energy production. Together, they produce the equivalent to the total residential energy consumption in Brazil. In the future, today's sewage treatment and solid waste stations will produce more and more thermal and electrical energy. Coppe's International Virtual Institute

for Global Change (Ivig) is working hard to introduce Brazil in this trend.

The world's first facility using all types of effluents from a sewage treatment station for energy production has been operating in Rio de Janeiro since 2006. The effluents include biogas (the product of anaerobic digestion of organic material present in the sewage), the grease collected by skimmers and the dry sludge. These are processed and converted into natural gas, biodiesel, bio-oil and bio-coal. The pilot plant operates at the Alegria Sewage Treatment Plant (ETE), in the neighborhood of Caju, in the city of Rio, and is owned by the Rio de Janeiro State Water Utility (Cedae). The energy produced by this treatment plant is used for its own illumination and for equipment supply.

Coppe, in partnership with the Fluminense Federal University, developed the technologies that made it possible to use all the effluents mentioned above. The project was requested by Cedae and is funded by Termo-Rio, a company linked to Petrobras. However, Coppe wants to move forward, so as to integrate different technologies and improve its results. The research institution has a new proposal, supported by the Carlos Chagas Filho Foundation for Research Development in the State of Rio de Janeiro (FAPERJ).



Cooking Oil is at the Root of Everything

Every Wednesday, the electricity connection between the headquarters of the International Virtual Institute for Climate Change (Ivig) at UFRJ and the power grid is interrupted. The institute uses only the energy from a biodiesel generator. The fuel is produced at Ivig and is made with the waste cooking oil collected from one of the restaurants at the campus.

This is just one experiment among many others involving biodiesel. These experiments are the seed from which Ivig grew in 2000. The studies that were initially focused on producing biodiesel from cooking oil are now aimed at the production of the same biofuel from soybeans and oil palms. In addition, the studies are aimed at evaluating the use of biofuels in engines and their potential for atmospheric emissions. It is worth noting that cooking oil, when dumped in the kitchen sink, pollutes water.

Thanks to the experiments mentioned above, Coppe played an important role in the implementation of Brazil's National Biodiesel Program. Based on the results of the engine tests performed at Ivig, the Brazilian Federal Government authorized in 2005 a 2% biodiesel blend in the petroleum diesel, without having to adapt the vehicles to the new mixture. Later on, new tests made it possible to increase the mixture to 5%.

Since then, activities within Ivig range from developing technologies and carrying out studies on energy use from waste and sewage to evaluating the possibility of having a large-scale production of dendê palm oil in deforested areas of the Amazon and of integrating the hydrographic basins in South America.

According to Marcos Freitas, it would be technically possible to use a 30% biodiesel blend in conventional diesel engines. But the biodiesel derived from cooking oil, waste and sewage would not be enough. Although the positive environmental impact is relevant, economically and energetically speaking, a significant production capable of having an impact similar to what the ethanol had (which appeared as an alternative to gasoline) would require the use of other raw materials – new oily seeds.

However, there is a bottleneck in Brazil's agriculture production. Biodiesel blends at a high percentage would demand the entire soybean produced in the country. The Ivig studied other options and concluded that the oil palm – which produces the dendê palm oil – is the most productive raw material. In the global vegetable oil matrix, the soybean and palm correspond to 35% each. But while the soybean accounts for 40% of the planted ground worldwide, the oil palm accounts for only 5%, because its productivity per hectare is higher. Five hundred kilograms of soybean oil are equivalent to 4.5 tons of oil palm. However, oil palm production in Brazil is insignificant. Brazil's cultivated soybean area corresponds to 20 million hectares, while the cultivated oil palm area is equivalent to only 100 thousand hectares. The reason for this discrepancy can be explained by the lack of good quality seeds. "In order to solve these bottlenecks, it is necessary to introduce a government policy, something like the ProDendê Policy (Pro-Dendê Oil Palm Policy)."

According to Freitas, stimulating large-scale palm production in the Amazon is a solution for creating job positions in deforested areas and finding alternatives to herds of beef cattle in the region. Therefore, there would be three ways to fight global warming: using biodiesel, reducing the deforestation caused by agriculture, and limiting the increase of herds of cattle. Livestock enteric fermentation produces methane gas, which is one of the most powerful greenhouse gases.

According to Ivig's estimates, in order to supply electrical energy to isolated areas – most of them in the Amazon, where electricity is generated by diesel generators – it would be necessary to grow 700 thousand hectares of oil palms, that is, seven times more than the country's planted area today. "It seems a lot, but it's not. Seven hundred thousand hectares or seven thousand square kilometers represent only 1% of the deforested area in the Amazon since 1960, or 50% of the annual average of the country's deforested area in the 1990's."



In addition, also in the neighborhood of Caju and next to the Alegria Sewage Treatment Plant, there is a waste treatment station owned by the Rio de Janeiro's Municipal Urban Waste Removal Company (Comlurb). Luciano Basto, a mathematician who is expert in extracting energy from waste residuals, suggests the creation of a Bioenergy Ecocenter, so as to integrate the processing of urban waste and sewage in one place.

One of the technologies developed to use the urban waste as an energy source is being tested a few kilometers away from Caju, in UFRJ campus, in Ilha do Fundão. There is another pilot plant in the campus called UsinaVerde (Green Plant), which is the result of a joint project with Coppe's International Virtual Institute for Global Change (Ivig). It is a plant for incinerating the material that is left after the waste has been selected and sieved, so as to separate it from the recyclable material. The remaining material is hard to be separated and it has high calorific power.

A technology developed by Coppe may be helpful. The optimized combined cycle (COO) is a process that allows researchers to associate the heat produced by incineration to the exhaust gases from the biogas produced in the sewage, as well as to install a combined cycle for electric power generation.

Now working for Brazil's Energy Research Company (EPE), Luciano Basto estimates that building an ecocenter like the one suggested for Caju would cost US\$285 million. The energy conservation due to garbage recycling, together with the energy production from non-recyclable materials and sewage effluents, is equivalent to the production capacity



of a 67.5 MW power plant. This investment is too high when compared to the amount of energy produced and it is undoubtedly disadvantageous when compared to conventional ways of producing energy. "But it is necessary to change today's logic behind the way we calculate costs," Luciano says. "Waste and sewage treatment activities help reduce the potential damage of the inappropriate destination of waste and sewage. Therefore, they should be totally treated. We cannot continue to follow the cheapest practices. We have to find a balance between the best actions and the cheapest practices."

This means that it is necessary to include the environmental and social benefits in the calculation. According to Luciano's calculations, Rio de Janeiro's Bionergy Ecocenter would create 1,120 job positions for low-qualified workers (garbage scavengers) and would prevent the daily emissions of 15 thousand cubic meters of methane, which is the most powerful greenhouse gas and which significantly contributes to global warming. It would also prevent the emissions of 2,487 tons of CO₂ per day.



"Waste and sewage are environmental, energy, social and public health issues. If this investment reduces health risks, for example, part of the fund should be provided by the health sector," Luciano says. Otherwise the expenses will be extremely high. In Brazil, it would not be possible to collect a tax of about 100 euros per ton for waste collection and treatment. Many mayor's offices in Brazil already struggle to pay R\$ 20 or R\$ 30 per ton of waste disposed of at landfills.

"We are keeping a treasure and letting it decompose. We are wasting money. We produce waste, we pay its transportation, we pay so that it is disposed of at landfills and we pay to remove pollution. It's a perverse logic," Luciano concludes.

5 Climate Governance

Since the early 1990's, Coppe has made considerable contributions to create international and national governance instances that deal with climate change, as well as set their roles. The first contribution was to the Intergovernmental Panel on Climate Change (IPCC), established by the United Nations (UN) in 1988 to provide scientific support to global governance mechanisms. The most recent contribution was to the Brazilian Panel on Climate Change (PNMC), created by the Brazilian government in 2009 and headquartered at Coppe. It has the same role of the IPCC, but it acts nationwide.

The Brazilian Federal Government also created the Brazilian Forum for Climate Change (FBMC), which is aimed at achieving political consensus from different social groups, in order to help the Presidency formulate public policies related to climate. Coppe is also the home to the FBMC, which was implemented in 2004.

The IPCC publishes periodic reports – the so-called assessment reports. Scientists around the world contribute to these reports, which are used by the World Meteorological Organization and by the United Nations Environment Programme (UNEP) as a basis for international political decisions. The first report, published in 1990, resulted in the creation of the United Nations Framework Convention for Climate Change, signed in 1992. Since then, other three reports have been published (in 1995, 2001 and 2007). The fifth report started to be produced in 2010.

Coppe professors have been constantly participating in the IPCC reports since

1990, when they joined the group that produced the second report. In 2007, they were part of the group that released the forth report, which won the Nobel Peace Prize (together with the Former Vice-President of the United States, Al Gore).

In 2010, the IPCC has chosen 25 Brazilian scientists to participate as authors in the next assessment report, which will be released in 2014. Seven of them work at Coppe. It is the biggest Brazilian representation. The other scientists are from the University of São Paulo, the National Institute for Space Research, the Oswaldo Cruz Foundation (Fiocruz), the Pontifical Catholic University of Rio de Janeiro (PUC-Rio), the Institute for Applied Economic Research, the University of Brasília, the Ministry of Science and Technology, and the NGO Conservação Internacional (International Conservation).

Coppe also contributes to the so-called special reports, which are documents about specific topics, requested



THE FBMC MEETING, HEADED BY FORMER PRESIDENT LULA, TO DISCUSS THE BRAZILIAN PROPOSAL PRESENTED AT UNFCCC15TH CONFERENCE OF THE PARTIES, IN DECEMBER 2009, IN COPENHAGEN.

by the IPCC. Coppe participated in a special report on technology transfer from the developed countries to the other countries and is now participating in another report about renewable energy. In addition, Coppe professor, Suzana Kahn Ribeiro, from the Transportation Engineering Program, is one of the vice-chairs of the IPCC Bureau. The mandate of the vice-chairs normally corresponds to the duration of an Assessment cycle. In this position, Suzana represents the whole Latin America. Her mandate will end in 2015. Suzana is one of the two Brazilian women in the IPCC's governance bodies. The other one is Thelma Krug, from the National Institute for Space Research, who is a member of a task force.

The Voice of Science

It was Suzana who suggested the creation of the Brazilian Panel on Climate Change (PNMC) to the Brazilian Ministry of the Environment and the Ministry of Science and Technology. During the two years as a member of the Brazilian Secretariat of Climate Change and Environmental Quality, Suzana noticed that, in spite of the advances, the Brazilian governmental instances – either municipal or federal – have not yet really understood the issue of global warming impact. “There’s a huge gap between the knowledge produced in the academia and the initiatives of the body that formulate policies and make decisions,” Suzana says.

Due to the experience at the IPCC, Suzana suggested the creation of a similar

body in Brazil, aimed at listening to the local scientific community and formulating consensus. As climate change issues and the influence of human activities on global warming are delicate and controversial topics, it would be important to have a mechanism capable of listening to the scientific community involved. This would guarantee more reliable conclusions and would influence the decision-making process.

In 2009, the PNMC was implemented by the Brazilian Ministry of the Environment and the Ministry of Science and Technology. It consists of 300 scientists from universities and research centers around the country. There was a concern to choose members from all the country's regions. Suzana, who is the president

of the Panel's Scientific Committee, is responsible for the execution, management and organization of the activities.

The PNMC has not yet released a report, but has already made an important contribution in helping the Brazilian team at the Basic group meeting (a meeting between Brazil, South Africa, China and India), organized by the Brazilian Ministry of Foreign Affairs, in July, 2010. The Basic group consists of the first four developing countries in greenhouse gas emissions and was created for the formulation of common positions on the so-called 'carbon space'. The four countries suggest sharing the burden of the mitigation measures with the developed countries, which are the major responsible for global warming.

One of the main roles of the Panel is to serve as a bridge between the academia and the government bodies, that is, its role is to translate scientific knowledge to the decision makers. However, this is not its only role. The identification of possible gaps and creation of a solid and

helpful group is another task pointed out by Suzana. The third one is to stimulate the creation of lines of research that can be mentioned in the IPCC's reports.

The Voice of Society

The Brazilian Forum for Climate Change (FBMC), headed by the Brazilian President, and whose Executive Secretary is Coppe director, Luiz Pinguelli Rosa, has Coppe's scientific and management support to listen to the different representatives of economic sectors and social groups, as well as formulate suggestions for the government.

In 10 years of existence, the Forum has already helped formulate the Brazilian National Plan and Climate Change Policy – which were sent by the Brazilian Executive Branch and sanctioned by the Brazilian National Congress in 2008 – as well as set voluntary targets to reduce greenhouse gas emissions. These targets were announced by the Brazilian government in the 15th Conference of the Parties, which took place in Copenhagen, in 2009.

The FBMC also chose some members to formulate sector plans that will define how the goals announced will be achieved and to review the Brazilian National Plan and Climate Change Policy. This will also include the national adaptation plan, which was suggested by the FBMC and approved by the Inter-Ministry Committee, which is responsible for climate change affairs.

Neilton Fidelis, advisor of the FBMC Executive Secretariat, tells that the recent initiative to create a working group on poverty, social difference and climate change inside the FBMC was suggested by the Rede Nacional de Mobilização Nacional – Coep (the Brazilian National Social Mobilization Network). The group coordinated by André Spitz, who is also the president of Coep, is aimed at carrying out studies and evaluations to improve scientific knowledge and help include the issues of poverty, social difference and climate change in future public policies.

In addition to discussing those issues, the FBMC also offers courses about climate change to municipal, state and federal employees, as well as to companies and civil society organizations. The courses and seminars take place in various regions of the country and are taught by professors from different institutions. Coppe is one of the most active institutions.

Neilton points out that the Forum's mission is to promote debate and try to reach consensus. Then, the Forum shows the results to the Brazilian Presidency. By doing this, it helps guarantee the plurality of opinions and the ample participation of the society toward a democratic decision on a topic that affects everyone's lives.



THE MEETING OF THE BRAZILIAN FORUM FOR CLIMATE CHANGE, IN NOVEMBER 2009.

6 Removing Barriers ■ between Disciplines

Climate is a complex system. The elements involved in the production of climate phenomena – wind, rain, oceans, rivers, lakes, ice, solar radiation, fauna, flora and human activities – are complementary. In order to manage this complex system, understand the variations and climate changes and deal with them, it is necessary to have an interdisciplinary attitude.

Coppe is used to producing knowledge in an interdisciplinary way and many factors have contributed to this: being in a university environment (the Federal University of Rio de Janeiro), dealing with different engineering areas since Coppe's creation, in 1963, and working in partnership with other academic or non-academic institutions.

The recent creation of the Global Change Technology and Engineering Institute (also known as the Coppeclima Institute), in liaison with the Brazilian Ministry of Science and Technology, will make it possible to deepen Coppe's activities, by encouraging partnerships with other institutions and different programs within Coppe.

According to Pedro Leite da Silva Dias — a climate expert mathematician who is a professor at the Institute of Astronomy, Geophysics and Atmospheric Sciences of the University of São Paulo and the di-

rector of the National Laboratory for Scientific Computation (LNCC) — “Coppe is successful due to the capability to interact with other knowledge areas. That is what always called my attention. At Coppe, it's possible to exchange ideas with experts from different areas, and this is not very common in engineering schools. There is a favorable environment at Coppe.”

The role of the LNCC is to establish partnerships with various excellence groups in Brazil's different knowledge areas. “Coppe does this naturally,” adds Pedro, while explaining why he is interested in establishing joint research projects with Coppe in the field of modeling.

The interaction with other research institutions became strong in 2008, due to the creation of the Brazilian national virtual institutes by the Ministry of Science and Technology, to bring together researchers from different excellence



institutions for the discussion of common topics. Coppe is the home to three institutes. One of them is dedicated to the research on innovative nuclear reactors and operates in the Nuclear Engineering Program. The second one, in the field of computer sciences, is linked to the Systems Engineering Program and the third one, in the Civil Engineering Program, is dedicated to the research on the stabilization of flat and sloping grounds.

Intra-wall Interdisciplinarity

Some of Coppe programs' faculty members include biologists, economists, geographers, mathematicians, physicists and engineers. Various projects involve professionals from other fields.

As an example, there is a project conducted by Coppe's team that will begin

to assess the emissions of greenhouse gases in the Tucuruí, Balbina, Xingó, Segredo, Três Marias, Itaipu and Serra da Mesa hydroelectric power plants and in the areas of the future reservoirs of the Xingu and Madeira Rivers.

Another example is the Climate Center Institute, which establishes the interaction with other programs, groups and knowledge areas.

The Technological and Environmental Risk Analysis Group (Garta) is developing a method based on artificial intelligence, in order to define sites for the implementation of nuclear power plants. In addition, the group is planning to build, together with the Production Engineering Program, a fuzzy logic laboratory. Fuzzy logic is a research area that deals with uncertainties and may be applied to control and decision-making.

The Garta, which was originated in the Energy Interdisciplinary Area, is actually a radical example of overcoming obstacles, including the academic ones. The Garta is not formally linked to any program, but, depending on the type of project or research developed, it can interact with all of them. According to Moacyr Duarte, a researcher who is also the group's coordinator, "the Garta has been operating for 18 years and it only exists because it's part of Coppe. It's a common model in American universities, but it is still rare in Brazil."

The International Virtual Institute for Global Change (Ivig), to which Garta is linked, is another institute within Coppe. It is not an academic program, but it actively interacts with Coppe programs and with other research institutions. Even though it has 'virtual' in its name, Ivig does not have any virtual laboratory. At

Ivig installations, researchers carry out studies on biodiesel and test green building techniques.

There is a huge project being developed at Ivig and it gathers information on the Tocantins and Madeira River Basins. The project has the participation of the professors from the Civil Engineering and Energy Planning Programs and includes geographers, biologists and meteorologists from the Federal University of Rio de Janeiro (UFRJ). But there are also other partnerships. As the Madeira River Basin is a transboundary river – only 25% of the river area is within Brazilian borders; the rest of the river belongs to Peru and Bolivia – the Ivig included researchers and students from the neighboring countries. These researchers are collecting information about rainfalls and the levels of the rivers outside Brazil. The project is aimed at understanding the climate variability of the Madeira River Basin. Brazil intends to build a hydroelectric complex in the Brazilian side of the Madeira River basin, in the state of Acre.

At the moment, Ivig's researchers, in partnership with researchers from Coppe's Ocean Engineering Programs, are conducting a project on the monitoring of the Ports of Rio de Janeiro, Itaguaí and Angra dos Reis. They are building a database of the sediments transported to these ports.

A more ambitious project is the construction of the Hydrolysis Laboratory. It is the result of a partnership between Coppe and UFRJ's Chemical Institute. Hydrolysis is a chemical process that is being studied by different research groups in Brazil, as it can be applied to the production of ethanol. Through the hydrolysis process, it is possible to produce ethanol from the sugarcane bagasse and from other discarded residues. Presently, the industrial process of ethanol production is via the distillation of the sugarcane juice. By developing the hydrolysis technology, it will be possible to double the actual Brazilian ethanol production, without having to plant more hectares of sugarcane.

At Coppe, this project is being developed by Ivig's researchers. They want to



combine their expertise in biodiesel with the Chemical Institute's experience in hydrolysis. Biodiesel is produced by the addition of methanol, but it can also be produced using ethanol as an additive. According to the director of Ivig, Marcos Freitas, "Ivig has competent researchers that can produce biodiesel by using different raw materials and following the 24 quality parameters required by Brazil's National Petroleum Agency. They are real 'wizards'. If we put together the biodiesel and the hydrolysis 'wizards', we will have great results in the future."

The Coppeclima Institute is being established within the atmosphere of multiple interfaces, inside and outside of Coppe and UFRJ – and even inside and outside of Brazil. According to the institution's director, Luiz Pinguelli Rosa, "the new institute will interconnect the existing activities within Coppe's sectors and this is beneficial to everybody".





Coppe

Coppe – The Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering – helped renew Brazilian universities and contribute to the country's overall development. Founded in 1963 by the engineer Alberto Luiz Coimbra, the institution made it possible to create graduate courses in Brazil. The Master's degree course in Chemical Engineering at the Universidade do Brasil's (now Federal University of Rio de Janeiro/ UFRJ) School of Chemistry was the seed from which Coppe has grown.

Over the course of the last four decades, Coppe has become the most important center for engineering research and education in Latin America. The institution has 12 graduate courses (both master's and doctoral), and has already awarded more than 12,000 master's and doctoral degrees. The institution now has 325 faculty members, 2,800 students and 350 employees (including staff and researchers). Coppe also has 116 modern laboratories, which together constitute the country's largest engineering laboratory complex. In addition, it has 94 patent applications filed and 13 software registered.

Based on three distinguishing features – academic excellence; full-time faculty members and students, and commitment to society – Coppe has distinguished itself through its work to increase understand-

ing and produce highly qualified professionals and innovative teaching methods; thereby serving as a model for other universities and research institutes across the country.

The academic output reflects the standard of excellence. About 200 doctoral degrees and 300 master's degrees are awarded annually. Coppe researchers publish about two thousand scientific papers in national and international journals and conferences annually. According to the last Capes evaluation (the Brazilian Federal Agency for Support and Evaluation of Graduate Courses), in September, 2010, Coppe was the leading engineering graduate institute with the highest rating (7), which is equivalent to the performance of the most important and respected research and teaching

centers in the world. Six out of the 12 courses offered by Coppe obtained the highest rating (7) and five of them obtained the second highest (6).

Coppe has a staff and a research infrastructure capable of dealing with the necessities brought about by the country's economic, technological and social development. Always looking to the future, Coppe is a national and international reference for engineering teaching and research, and has helped the country face the most important challenges in its recent history.

Based on the quality of its staff and its infrastructure, Coppe has launched an ambitious project in the international scenario. In 2008, Coppe formed a partnership with Tsinghua University, which is



the most prominent Chinese university in the field of engineering. The result of this partnership was the establishment of the Brazil-China Center for Climate Change and Innovative Energy Technologies. The Center is headquartered at Beijing's Tsinghua University, where an office is maintained for the coordination of activities and the establishment of contacts that are potentially interested in technologies to be jointly developed.

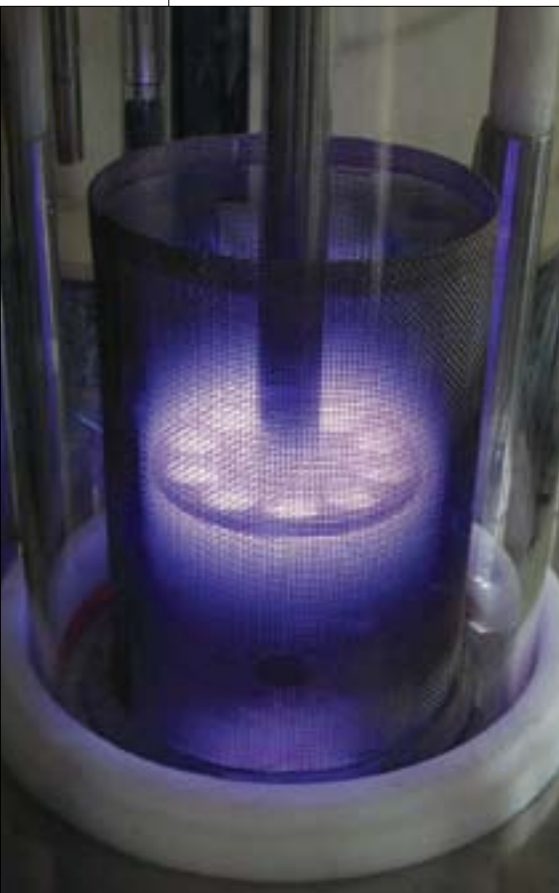
Commitment to the Country and to Society

Coppe is characterized by its ability to remain one step ahead of the needs of Brazilian society. Aware of the importance of technology and science for the development of the country, Coppe has founded the Coppetec Foundation to manage all of the ongoing partnerships and projects. Since its founding in 1970, Coppetec has administered more than 12,000 contracts and partnerships with national and international, private and state-owned companies, as well as governmental and non-governmental agencies. Presently, the Coppetec Foundation manages roughly 1,300 ongoing projects.

Coppe is a pioneer in bringing together academia and society. One of the most important ways to give back to society is to transform results into new businesses capable of creating wealth. Since 1994, Coppe's Business Incubator has facilitated the introduction of more than 100 innovative products and services to the market. Forty-three companies have already passed through the Incubator and now operate autonomously, while another seventeen are currently in the process of being developed.

In addition, the institution has also applied engineering and technology to the fight against poverty and inequality, serving as a bridge between Brazil's privileged and under-privileged classes. To succeed in this battle, Coppe founded the Technological Incubator of Popular Cooperatives in 1995. This incubator has become a reference model for other states and countries. One hundred and eighteen cooperatives have been formed and 2,100 jobs have been created.

Coppe has become a gold standard without losing its original essence: audacity, critical analysis, a deep connection to Brazilian reality, and a commitment to innovation and the development of the country.



Coppe in Numbers

Total of Academic Degrees Granted (Until 2010)

9,418 master's degrees

3,037 doctoral degrees

Academic Production (in 2010)

344 master's theses

176 doctoral dissertations

Interaction with society (governments, companies and civil society)

12,000 contracts

1,300 ongoing projects

94 patent applications filed

13 software registered

Human Resources and Infrastructure

325 faculty members

2,800 students

1,600 master's students and **1,200** doctoral students

350 employees

116 laboratories

A Technology-Based Business Incubator

A Technological Incubator of Popular Cooperatives

A High-Performance Computer Center

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