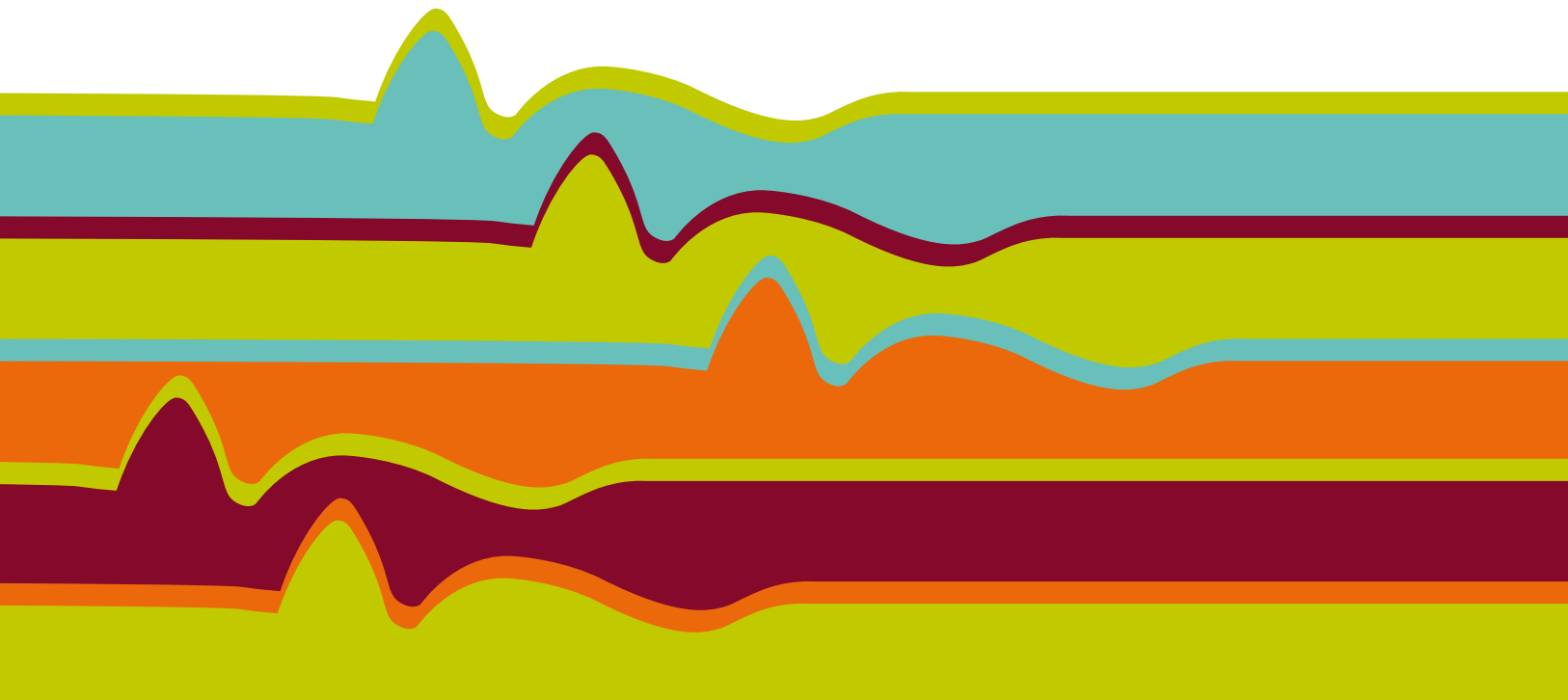


The sustainable future



Technology and innovation
for a green economy and
eradication of poverty

The sustainable future

Coppe and its partners at Rio+20

RIO DE JANEIRO | 13 TO 24 JUNE 2012

Tractebel Energia
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HALLIBURTON



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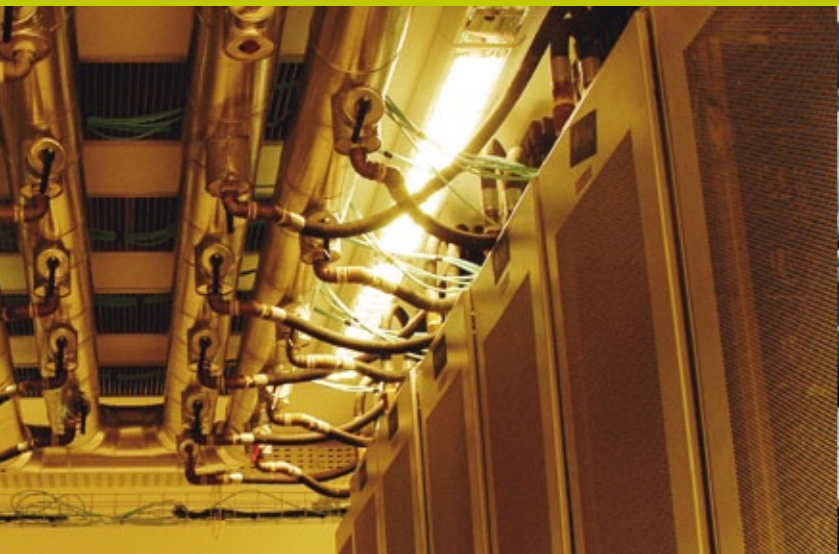
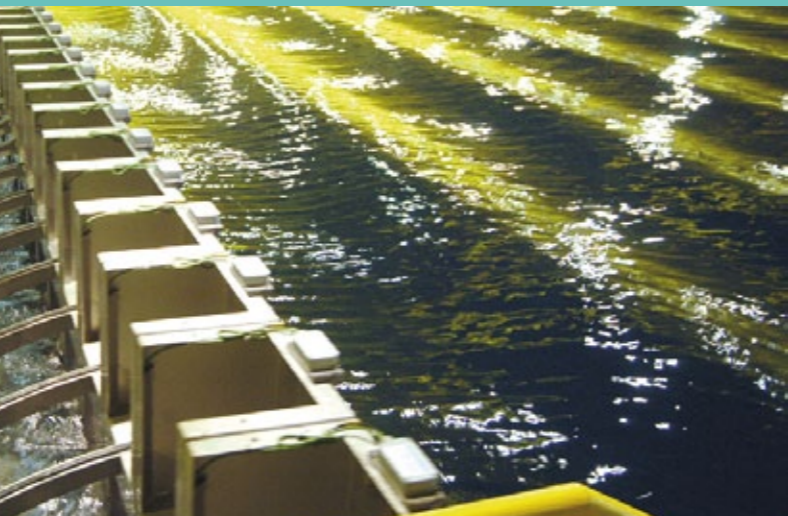
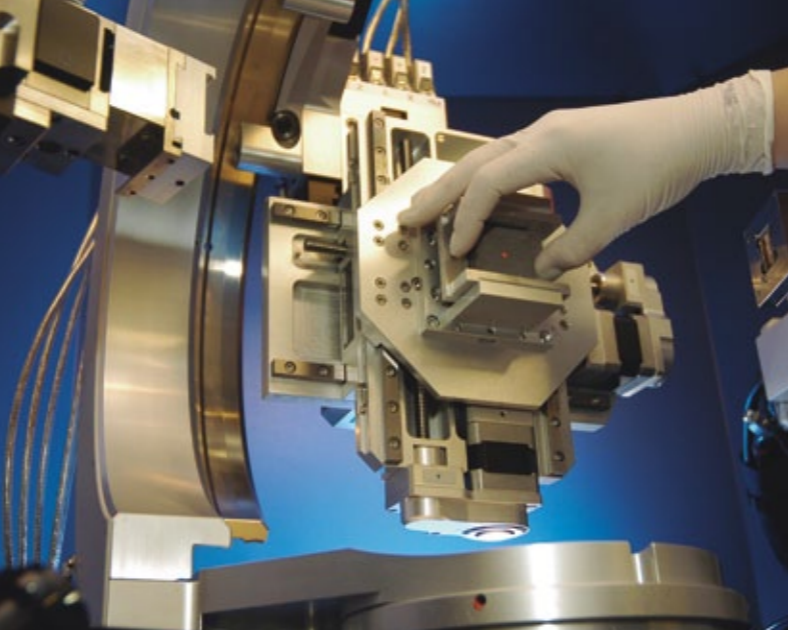
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To build a sustainable future is the greatest challenge of this century. This means that the growing world energy consumption must be brought to heel to check global warming and we must meet the increased demand for food, raw materials and water without depleting natural resources. It means, above all, to balance the need to reduce pressures on the environment with a just and fair economic development, capable of promoting dignity and quality of life for all.

As a nation which has recently resumed the path of economic growth and at the same time is managing to reduce its historical social inequalities, Brazil has an important role to play in tackling this global challenge. Along these lines, Coppe / UFRJ, which is Brazil's largest institution in engineering for education and research, has made contributions in terms of technology, actions and initiatives in tune with the new national and global needs for a sustainable future. They are innovative technologies that include more efficient alternatives for inner-city transport; energy from the sea; reuse of agricultural waste; municipal and industrial production of biofuels and biomaterials; green buildings; and creative methodologies to include historically excluded populations into the world of entrepreneurship and the workplace.

These and other contributions can be seen at *The Sustainable Future - Technology and Innovation for a Green Economy and Eradication of Poverty* event, which is being promoted by Coppe and its partners during Rio+20, the United Nations Conference on Sustainable Development 2012 in Rio de Janeiro. The event, which has been organized into three main points - Climate, Energy, Oceans; Sustainable Cities; and Eradication of Poverty, offers an exhibition of various technologies developed at Coppe and a series of conferences where important national and foreign figures of academic, economic and political thought will be gathered together to share their reflections and enrich the debate on the future we want - A sustainable future.

Reduce the impact of consumption and production of energy on climate and oceans. Coppe has been working to overcome these challenges with technologies that help reduce the environmental consequences of burning fossil fuels and at the same time offer creative and efficient options for the use of new sources of clean and renewable energy from the land and sea.



Climate, energy,
oceans

The energy that comes from the sea

Wave motion is converted into electricity in Ceará

Brazil, with its 8,000 km coastline, has many possibilities to explore the ocean as a source of clean and renewable energy. One such possibility is emerging in the green seas of Ceará, where the first plant in Latin America to harness waves to produce electricity has just been built.

Located in the port of Pecem, 60 kilometers from Fortaleza, the pilot plant is a Coppe project, financed by Tractebel Energia SA, within the Re-

search and Technological Development Program of ANEEL - the National Agency of Electrical Energy and supported by the Ceará state government.

Conceived and designed at the Coppe Subsea Technology Laboratory, the Pecém plant places Brazil among the select group of countries that are testing different concepts to achieve the same goal: to prove that waves are a reliable source of electricity at a viable cost.

The main distinctive feature of the Brazilian technology is the use of a high pressure system to rotate the turbine and generator; a concept de-

veloped and patented by Coppe. A float connected to the end of a mechanical arm is set in motion by the waves. This up and down motion activates a pump that pressurizes fresh water stored in an accumulator connected to a hyperbaric chamber, where the pressure is equivalent to a 200 to 400 meter water column, similar to a hydroelectric plant. The pressurized water in the form of a jet drives the turbine, which in turn drives the generator to produce electricity.

The Brazilian wave energy potential is estimated at 87 gigawatts. Coppe has evaluated that it is possible to convert about 20% of this potential into electricity, which is equal to 17% of the total installed capacity in the country today.

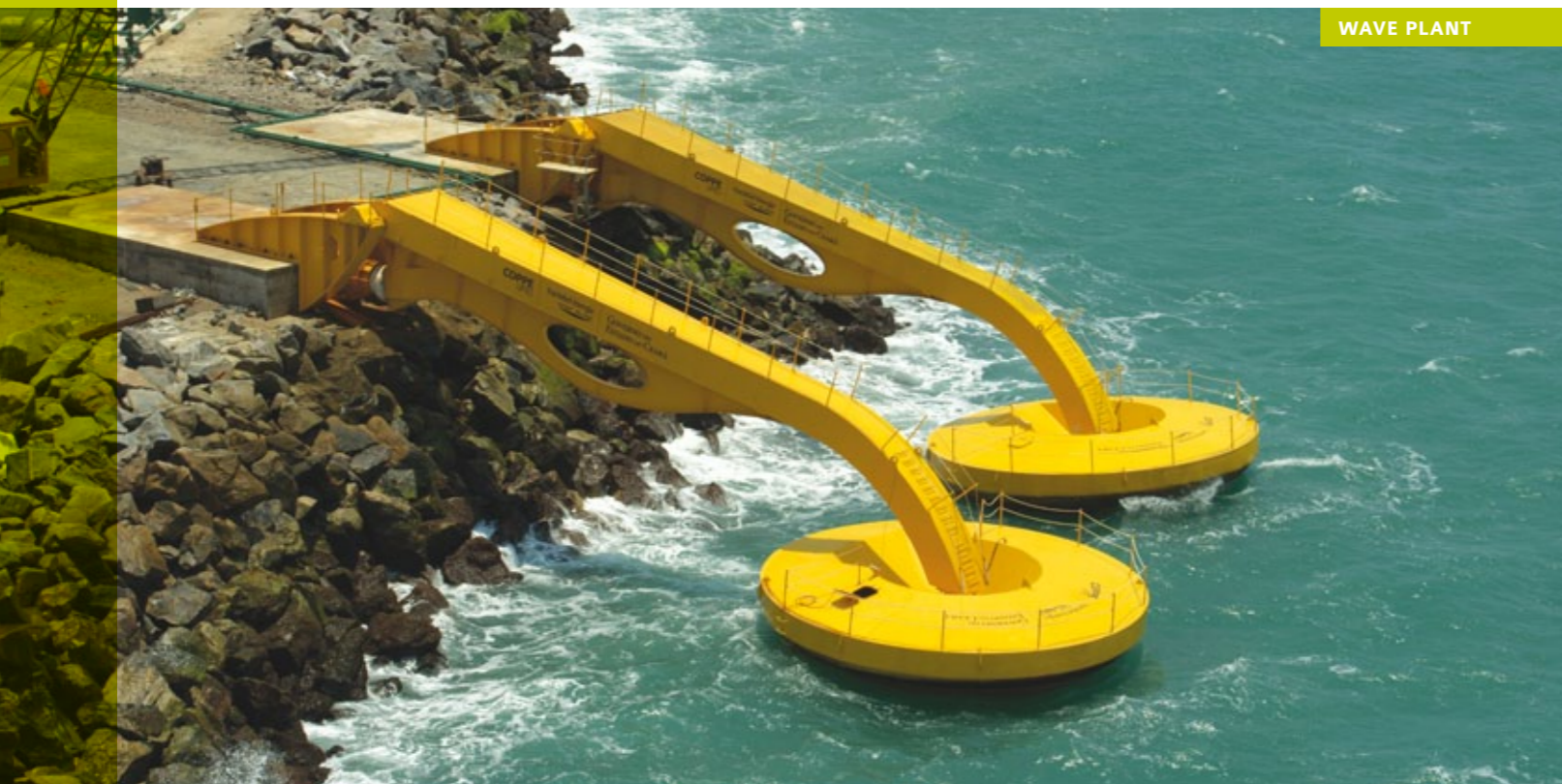
Capturing “blue energy” where river water meets sea water

When a river drains into the sea, it is in fact pouring out energy from the sun. The sun evaporates seawater and condenses it in the form of rain clouds. The rain in turn falls on the land and now as fresh water the rivers returned it to the sea. An ongoing project at Coppe wants to recover this energy where the fresh water from the rivers meets the salt water of the seas and turn it into electricity. This energy is known as “blue energy”, obtained only from water and with virtually no environmental impact.

Funded by Tractebel Energia SA under the Research and Technological Development Program of ANEEL - the National Agency of Electrical Energy, the project aims to develop a system to take advantage of a natural process - osmosis. In this process, the unsalted water naturally tends to migrate to salt water and, if nothing prevents this, the osmotic energy contained therein is dispersed in the sea. But if it is possible to insert a membrane between the fresh river water and the salty sea water, then a pressure will build up in the part of the system containing the salty sea water. This pressure can be used to rotate a turbo-generator and produce electricity.

There is already a prototype osmotic power plant undergoing tests in Norway. Established in 2009, it uses meltwater from the Norwegian fjords. The idea is especially attractive for Brazil, which has an abundance of rivers with large flows. The greater the river flow, the greater the pressure and therefore the greater the potential to generate energy.

The Coppe membrane is being developed at the Membrane and Polymers Separation Processes Laboratory. At this lab, the researchers are working to enhance the capacity of the polymeric material chosen to receive larger water flows and to retain greater quantities of dissolved salts. At the same time, the Power Electronics Laboratory is developing a generator for the system. The coupling of the membrane to the generator will be the next challenge.



WAVE PLANT



AERIAL VIEW OF PECÉM PORT (CE)

The energy that comes from the land

2G Ethanol biofuel without competing with food

Brazilian ethanol production, according to estimates, could be doubled without increasing the current acreage - and therefore would not compete with food production and consequently there would be no need to cut down forests for new agricultural frontiers. This can be achieved by submitting agro-industrial residues from sugarcane, corn and wheat to a new technology based on enzymatic hydrolysis whereby the cellulose content in these wastes is broken down by enzymes.

The Bioethanol Laboratory, that will be inaugurated shortly, is a modern biomass processing laboratory located on the campus of the University Federal of Rio de Janeiro. The lab is starting

trials on a semi-pilot scale using Brazilian technology for all stages of 2G ethanol production - the so-called second generation alcohol or bioethanol. The project, which is the result of a partnership between the Instituto de Química (Chemistry Institute) and Coppe, will have the participation of a large network of research institutions in Brazil and Japan. The Bioethanol laboratory is funded by Financiadora de Estudos e Projetos (FINEP) and supported by Japan International Cooperation Agency (JICA).

Brazil, is one of the world's largest ethanol producers. However, its production around 30 billion liters a year is unable to meet market demands. The so-called first-generation (1G) ethanol is insufficient to meet the growing domestic and foreign demands because the conventional technology only extracts a third of the energy from the plant.

A key contribution to improve this scenario will come from 2G ethanol produced from the biomass of agro-industrial residues. Sugarcane offers the best prospect for 2G ethanol because two-thirds of the energy not converted to ethanol by the traditional process is retained in the bagasse - waste after the extraction of the raw sugarcane juice - and the straw that used to be burned at the manual sugarcane harvests. The most efficient way to extract this remaining energy is to use enzymes to hydrolyze the cellulose; that is to "break" the cellulose molecules into glucose that is converted into



SUGARCANE BAGASSE

BIOMASS ETHANOL

alcohol via the traditional fermentation process. The residue of this process, rich in lignin, can be used in cogeneration plants, a technology already well established in Brazil. The economic potential of this technology is enormous, because Brazil produces more than 400 million tons of sugarcane waste per year.

The first and major step for the production of bioethanol in the country was taken in 2007, when the Enzyme Technology Laboratory (ENZITEC) of the Institute of Chemistry, UFRJ, managed to produce an enzymatic mixture to carry out the cellulose hydrolysis as efficiently as the enzymes marketed by the international enzymes companies. The high cost of imported enzymes is the bottleneck preventing industrial production of 2G from taking off.

At the Bioethanol laboratory the enzymes and the other stages for 2G ethanol production will be developed and tested to find a robust technology that is sustainable and in tune with the current technology for 1G ethanol. One of the key points of sustainability will be the production of enzymes *in loco*. The enzymes will be produced

at the sugar / alcohol mills where the sugarcane bagasse and straw are already available, thus eliminating long distance transport costs. The Coppe International Virtual Institute of Global Change (IVIG) will analyze the life cycle of the new process. One of the goals is to identify any possible environmental impact from any stage of the 2G ethanol production process, including the decentralized production of enzymes.

Another Coppe contribution is the membrane technology that will be used at different stages of separation and concentration of the biomaterials through the 2G ethanol process. The membrane systems will be provided by PAM-Membranas Seletivas - a spin-off company from the Coppe Membrane Separation Processes and Polymers Laboratory.

On developing and mastering the technology for the production of 2G ethanol Brazil will add another competitive advantage to what it already has: climate, soil, four centuries of know-how in sugarcane cultivation and four decades of experience producing and using alcohol as an automotive fuel.

The result of a partnership between Coppe and the Chemistry Institute, the Bioethanol Laboratory on the UFRJ campus will soon be inaugurated



Protection for the Oceans

Satellite and robots to monitor the sea and uncover its secrets

Technology developed at Coppe, which combines environmental computer modeling, satellite images and data analysis of meteorological, oceanographic and geological information, identifies and tracks offshore oil spills and points to where they are heading and where they are coming from - whether they are natural seepages, or accidental spills caused by wells, platforms or ships. This technology has already been used in the Campos Basin, in several African countries and the Gulf of Mexico, both to help oil companies identify potential areas for exploitation as well as to locate environmental damage and identify those responsible.

Encouraged by the results, researchers at the Coppe Computational Methods in Engi-

neering Laboratory have just embarked on a new endeavor, unprecedented in Brazil: to develop an oceanographic observation system, which will combine the information from satellite images with data collected by robot divers directly from water depths of up to 2,000 meters. Called Projeto Azul (Project Blue), the project is being set up in the Santos Basin, the next great oil exploration frontier in Brazil. The goal is to gather information on the dynamics of ocean currents and movement of pollutants. The data collected will be made available on the Internet.

Despite the intense activity of exploration and oil production off the southeastern coast, Brazil does not have a systematic and continuous ocean monitoring program, with data available and open to the public in real time. Project Azul is the first step in that direction. Funded by BG

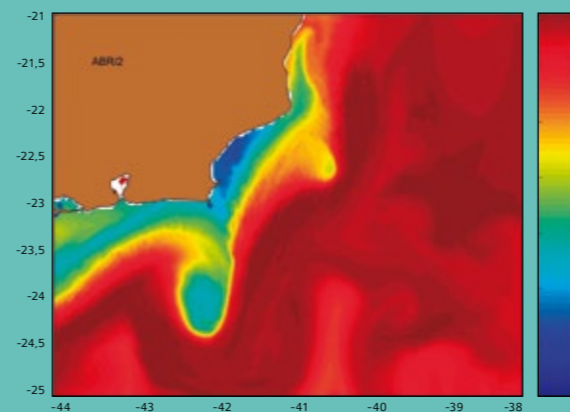
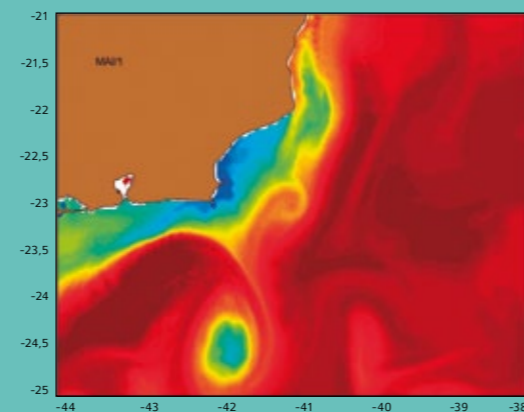
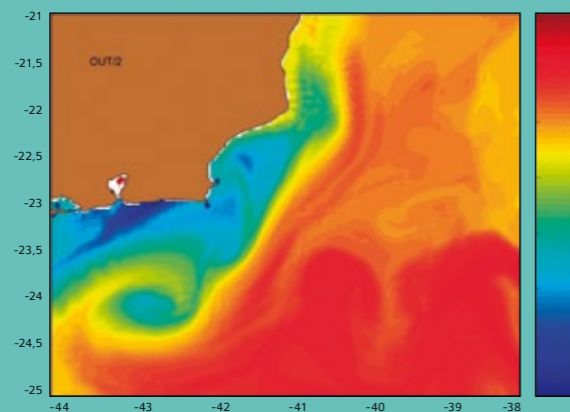


ROBOT DIVER

Group and coordinated by Coppe, the project brings together an interdisciplinary team of several Brazilian research institutions.

The robots and other equipment for data collection at sea will be launched and controlled by Prooceano, a company originated at Coppe. Information on seawater flow, temperature and

salinity, dissolved oxygen, chlorophyll and organic matter will be collected and transmitted via satellite in real time. This information, of interest to both oil companies and for environmental monitoring, will be incorporated into the Coppe modeling system, making it even more refined and precise.



Underwater robot collects data in the South Atlantic (picture above)

On the left: Computer simulated images from the Coppe laboratory portray the sea surface temperatures in the Campos Basin

Sustainable Cities

Around the world, many countries, including Brazil, are going through or have gone through intense processes of urbanization which require new solutions to make our cities more human. Researchers at Coppe are developing technologies to improve urban mobility and so recover the fundamental right to come and go. Also new solutions for the intelligent use of waste are being studied to contribute to the well-being of millions of people living in urban centers.



Urban Mobility

A bold and silent option for urban chaos

The solution comes in the form of a light and compact train without wheels or tracks that floats silently along and is electrically powered, so it does not emit greenhouse gases like cars and buses. It slides gracefully along a slender elevated rail that does not compete for the already congested space in cities. It does not require the expenses and impacts of civil works needed for subways and conventional surface trains.

The solution called Maglev-Cobra is the magnetic levitation train that is under development at the Coppe Laboratory of Applied Superconductivity (Lasup). In the laboratory, a full-scale model levitates on a 12-meter-long line, while awaiting the construction of a 200 meter demonstration line. The project is funded by FAPERJ and BNDES (National Economic and Social development

Bank). The model under test can carry up to thirty passengers (5 passengers per m^2). The project is designed to operate in modules - as many as necessary to meet demand.

The Maglev-Cobra, so named because the modules resemble the "rings" of a snake, levitates using superconductors; a class of materials, which have been known since the early 20th century but have only just begun to find industrial applications. Designed to travel at 70 kph, it is ideal for urban transport, replacing or complementing cars, buses and subways.

In 2000, when researchers at Coppe decided to develop a magnetic train for urban uses they chose a completely different direction to their European and Asian counterparts who were designing long distance magnetic trains to connect cities with speeds of up to 500 kph.

Now, ten years on, that choice has shown itself to be prudent. While the long distance and high-speed Maglev trains are experiencing difficulties to expand or even establish themselves, there is a strong tendency appearing around the world to develop urban maglev trains. This is because cities are becoming increasingly congested and are facing difficulties to extend their subway systems without further disruption of urban life. Research groups in the United States, Germany, China, Japan and South Korea have a total of ten urban maglev train projects underway. In



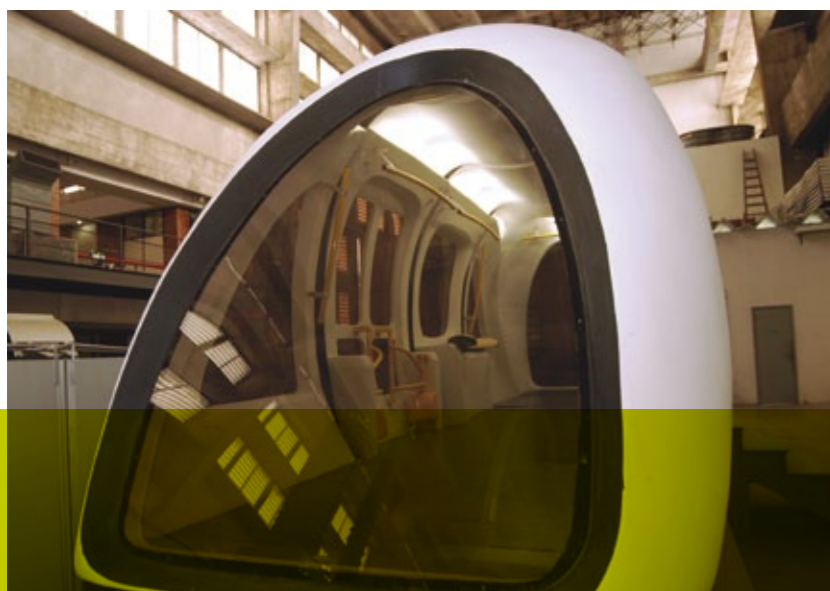
MAGLEV-COBRA

Japan, there is already a small business line of 9 km in the city of Nagoya, and South Korea is completing the construction of a 6 km line from the Incheon International Airport in Seoul.

Another different decision was the choice of the magnetic levitation technique based on superconductors and permanent magnets, which in fact only became possible after the first superconducting materials, cooled by liquid nitrogen, and powerful rare earth magnets were synthesized in the late 20th century. The other magnetic train projects for both long and for short distances use one of two levitation techniques that have been through a longer period of development: the electromagnetic, which is based on

attracting magnetic forces and the electrodynamic technique, based on repulsing magnetic forces. Superconductors and magnets are more expensive than the materials used in the electromagnetic technique, which is the most developed system used today. On the other hand the superconductor levitation is based on stable forces, which do not require complex control and safety devices to ensure operational stability.

The decision by Coppe to choose superconducting levitation has begun to show promise. Research groups in Germany and China also started projects along these lines at the turn of the century and there is an interchange of cooperation with Brazilian researchers.



Hybrid hydrogen bus with electric powertrain: well used renewable energy

A state-of-the-art electric bus that consumes the energy produced on board using hydrogen, combined with the energy obtained from the national electric grid is Coppe's response in regard to two major environmental and economic problems: the heavy use of diesel to move the collective fleet of vehicles – a polluting and non-renewable fuel; and the inefficiency of internal combustion motors that use on average only 15 percent of the fuel's energy content.

Apart from using renewable sources of energy, everything on this vehicle was carefully thought out in order to guarantee its maximum energy efficiency and its minimal – or null – emission of pollution. The key is an intelligent system of hybridization and energy management aboard. Contrary to conventional electric vehicles, that can only use electrical outlets to charge their batteries, this bus also produces electricity aboard due to a fuel cell fed by hydrogen. Not only that: it also takes full advantage of kinetic energy – the energy that is acquired by the movement of the vehicle. In conventional vehicles, kinetic energy is lost in deceleration and braking. On the bus made by Coppe, that energy is regenerated into electric energy. The vehicle's movement comes from the action of a very efficient electric motor that is fed by three different sources: energy from the conventional electric grid that is stored aboard in a bank of batteries, electricity produced by the hydrogen fuel cell and electric energy that is produced by the regeneration of kinetic energy, as it decelerates or break.

The vehicle made by Coppe is in its second version. The first one debuted in May 2010. In its two years of tests, apart from emitting zero pollutants, the bus demonstrated an energy efficiency superior to that of diesel powered vehicles. Developed by Coppe's Hydrogen Laboratory, the bus received funding from Finep, Petrobras, the National Council for Scientific and Technologic Development (CNPq), the Carlos Chagas Filho Foundation for Research Support in Rio de Janeiro – (FAPERJ) and from partnerships with local companies.

Enthusiastic with the results of the first prototype and using financial support from Coppe and business partners, LabH2 researchers have developed a second version, the "H2+2", to be presented to the public during the Rio+20. With a new and still more energy efficient hybrid-electric powertrain technology, the vehicle is so well thought out that the researchers were able to offer additional on board comforts for the passengers, such as electrical outlets for charging cell phones, laptops and other mobile devices.

The fuel cell that transforms hydrogen into electric energy, and that had a power of 77 kilowatts in the first version, was substituted by a new set of low-power fuel cells, modularized and transformed into a versatile onboard electric generator. The energy management system continuously selects the operational power needed. In addition to that, all the Brazilian-developed electro-electronic devices for the electric powertrain and auxiliary systems were re-designed, optimized and miniaturized. Hence, the H2+2 consumes less hydrogen per-kilometer.



A HYDROGEN BUS

Although using a fuel whose technology is still not fully taken advantage of in Brazil and throughout the world, and of which there is no structure for its distribution, the new Coppe hybrid hydrogen bus has the advantage of being still less pollutant than the first prototype launched in 2010. Only water vapor exits the exhaust pipe and it is pure enough to drink. For this reason, many consider hydrogen as the fuel of the future. This becomes still more important in Brazil, a country possessing an energy matrix with almost 50% of renewable origin that has enormous availability of biomasses, hydroelectricity and solar and wind energies, which are important sources for large scale production of renewable hydrogen.

In this electric powertrain bus engineered by Coppe, the hybridization of energy has the additional advantage of eliminating the biggest inconvenience of electric-fueled vehicles: low autonomy. Coppe's hydrogen fuel cell hybrid bus has an autonomy of 300 kilometers, the equivalent to a normal urban diesel bus ran. With its battery charged in the garage, it begins its route with half of this guaranteed au-

tonomy. During its route, the smart energy management system liberates the other sources, depending on its necessities, always selecting the most efficient option for each situation.

Just like in other big cities across the globe, Brazil's largest cities consume a high amount of fossil fuels for their urban transport. In the 14 Brazilian cities that have a population of more than 1 million inhabitants, buses make 9.2 billion trips per-year. They burn 2.7 billion liters of diesel and emit 6.5 million tons per-year of pollutants, such as CO₂, CO, NO_x, SO_x, non-reacted hydrocarbons and particulate matter. The transportation sector of Brazil responds to more than half of the use of petroleum derivatives and only 0.04 percent of electrical consumption. Coppe's electric hybrid bus broadens the perspective of electrification for transportation throughout the country. Taking into consideration that the majority of Brazil's electricity comes from a renewable and non-polluting source, this is an opportunity for the country to completely invert the panorama of its urban transport system and become one of the most sustainable in the world.

Wastes and recycling

A new look at plastics

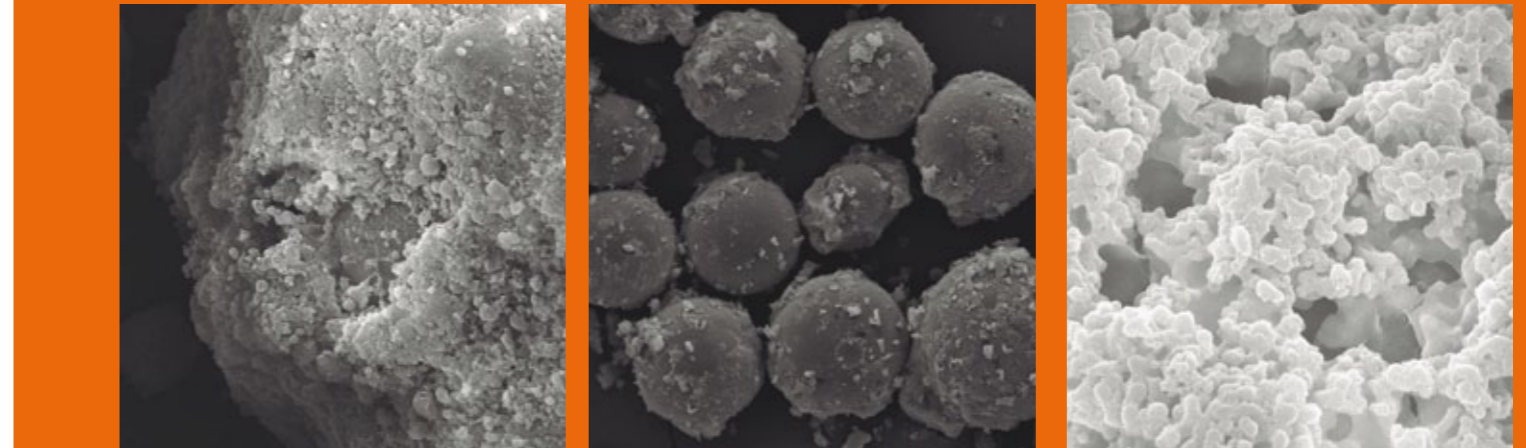
Sustainability means that the whole production chain and life cycle of a product must be taken into account, not just its final use. Based on this premise, researchers at the Modeling, Simulation and Process Control Laboratory of Coppe have proposed a radically innovative solution for the plastics we use and throw out. The researchers of this laboratory are not seeking biodegradable plastics, which are seen as a waste of raw material and energy, but aim to recycle them as raw materials for new and different products thereby increasing their life cycle.

Using a new and sophisticated form of recycling, chemical recycling, the researchers at Coppe are developing technologies to reincorporate the discarded plastics back into the productive chain, at the very earliest stages of its manufacture in the petrochemical industry - so that they can be made into products very different from the original product.

Several theories and applications for patents have been produced in the laboratory involving the throw-away cups and other products based on polystyrene. These coffee cups are designed to have a life span of a few seconds. But the technologies under development at Coppe seek to extend the useful life span of the materials that they are made from.

The production of plastics from the very start goes through a series of steps at the petrochemical complexes. Depending on the final product the production lines use different mixtures that will give different properties, such as strength, flexibility, toughness, to each type of plastic. The coffee cups, for example, can be made from high impact polystyrene, a mixture of materials which gives them temperature and tear resistant properties. Similarly, a mixture of polyethylene, the material of supermarket carrier bags, with polypropylene results in a completely different material, suitable, for example, for a car bumper.

Materials made from polystyrene, with different quantities of recycled plastic cups



In conventional mechanical recycling the discarded plastic is processed and reused for purposes very close to its original use as its properties and characteristics remain the same. In the chemical recycling, the material may undergo mixing and manipulating processes such as the petrochemical complexes use on the original virgin materials. In this way a wide range of opportunities are created for this recycled material.

The types of technologies being developed at Coppe are mostly related to innovations in the suspension and emulsion processes, using a technique called in-situ blending. Instead of mechanically mixing polystyrene with polymethylmethacrylate, for example, the technique consists of making a plastic in the presence of another. For example by putting polymethylmethacrylate in the reactor and mixing it in the raw material for polystyrene, which is styrene. This technique allows a very precise control of the interaction between materials, ensuring mechanical properties and allowing superior uses of the recycled product compared with the conventional recycling technique.

Chemical recycling is not just reusing materials considered disposable and thrown away, but

it is a process of up-grading them so they are technologically more sophisticated than the original product and consequently find more uses. By making such materials more valuable, this technology enhances recycling and reduces the amount of waste discarded in the environment.

The sequence above shows new materials produced from the deposition of plastic materials. The new product is used as a biodiesel catalyst

Below, the production of polymers from recycled plastic in the laboratory at Coppe / UFRJ



Too much water, Not enough water

Innovative solutions for the plight of floods

Coppe and the state government of Rio de Janeiro cooperated on a very wide-ranging and creative project to deal with the phenomenon of flooding in the Baixada Fluminense (low lying urban area in the greater Rio de Janeiro). The region is especially susceptible to the effects of the heavy summer rains due to its geographical situation which is aggravated by the disorderly occupation of river banks and hillsides with low-income housing without sanitation and garbage collection.

as the Iguaçu Project. Funded by the Growth Acceleration Program (PAC) of the federal government, the project covered an area of 726 square kilometers, home to 2.5 million people in six municipalities – Nova Iguaçu, Mesquita, Belford Roxo, Nilópolis, São João de Meriti and Duque de Caxias. The project is a combination of civil works, including drainage, damming, reforestation of hillsides and recuperation of springs as well as creative urbanization of the river banks: canal-streets and recreational facilities to discourage occupation along the banks and, in areas most prone to flooding, flood

ers, the residents have already recovered their ability to start saving and are investing in home improvements and small businesses such as bars and grocery stores. Thus breaking the cycle of impoverishment.

The Iguaçu Project was supported by innovative technology developed at the Coppe Water Resources Laboratory to define areas of intervention and the uses to be given to each. This model simulates the flow of water when a river overflows. Unlike conventional models that see the inundated area as a flood plain (the water overflows, builds up and then returns to



Frequent floods and inundations add to the chronic impoverishment of families that every summer see their few possessions, accumulated over the year, swept away. Thus the population is unable to save and gets poorer year by year.

The picture in the Baixada (lowlands) began to change in 2007 with the Flood Control and Environmental Restoration of the Iguaçu/Botas and Sarapuí River Basins Project - better known

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the river), the Coppe model sees it as a dynamic flow basin. The model demonstrates more accurately what really happens: not all the water flows back to where it was before; part evaporates, part percolates into the soil and part returns to the river, but not necessarily at the same point it left.

Images reveal the results of the Iguaçu Project. The bold engineering works are already a reality for the lives of 2.5 million people living in six municipalities in the Baixada Fluminense region

ventions of the Iguaçu Project works with more accuracy. Thus, it is expected that the solutions that have already been set up will be long lasting and efficient and consequently more economical in the long run.



Intelligence to anticipate and manage the shortage

Reflection and inquiry are part of everyday life at Coppe and often result in identifying problems and indicate trends that help managers and policy makers to make decisions.

Based on decades of studies, the Coppe Water Resources Laboratory has issued the warning signs: the risk of water shortages due to waste, economic growth and disorderly urban growth. Although Brazil has 13% of the world's freshwater and only 3% of the world's population, 70% of these reserves are in the Amazon, far from large urban centers, which are already starting to show signs of water shortages.

Studies at Coppe have raised a potential dispute between the two largest cities in Brazil – Rio de Janeiro and Sao Paulo – for the waters of the Paraíba do Sul River, which flows through both states. The Metropolitan Region of Rio de Janeiro basically depends on the Guandu system, which is not sustainable without the Paraíba waters. The Sao Paulo state capital on the other hand has been transferring waters from municipalities that are further and further away from its main consumer center. Therefore it is quite possible that in the near future the city will want to have its share of the Paraíba do Sul waters too.

Contracted by the federal government, Coppe produced a master plan for the Guandu system, which combined engineering works – some very simple – with smart management systems for water distribution and usage. The result increases the capacity of the Guandu system to meet the ever growing demands in Rio de Janeiro for the next ten years. This study also facilitated the continuation of massive investments at the Itaguaí industrial complex, with port expansion and large steel mill projects.

However Rio's economy continues to grow. Therefore, Coppe is preparing a water resources master plan for the state government. Unlike conventional basin plans, the work will cover the entire state, and rather than go into specific details will give a long-term strategic vision. One of the most innovative proposals under consideration is the cost that any decision of Sao Paulo to use the waters of the Paraíba would cause the state of Rio and also on the other side the costs that alternative options would generate for Sao Paulo. Ultimately, the two states could negotiate a system of mutual compensation - something never before done in Brazil

National technology for water and air quality

The growth of industrial activities in Brazil and the world is facing a problem of clean water, an increasingly scarce commodity. The conventional methods for purifying water or for the treatment of effluents, for reuse, employ several chemical products. These methods are energy-intensive with environmental impacts. A more environmentally friendly alternative is the use of micro-filtration membranes, high-tech plastic materials operating on a scale of less than one micrometer, which are able to retain micro-organisms as well as materials in suspension.

The only Latin American company capable of producing such membranes was incubated inside Coppe and was born in 2005. Today PAM-Membranas Seletivas is in the Technological Park of UFRJ and it industrializes technologies developed by the Coppe Membrane Separation Processes and Polymers Laboratory. It has 30 employees, and some of its clients are heavy-weights such as Petrobras, FMC and Dupont.

The PAM-Membranas micro-filtration membranes are flexible plastic capillaries with pores

that have an average diameter of 0.2 micrometer (equivalent to 0.0002 mm). The company also produces membranes with even smaller pores, called ultrafiltration membranes, which have applications for food, drinks and health, including for hemodialysis machines.

Back at the Coppe laboratory the researchers also work on the nanometer scale, in search of membranes capable of separating substances at the molecular level. One application is the separation of gases. The laboratory is developing membranes to remove carbon dioxide (CO₂) from effluents released into the atmosphere by coal-fired thermal plants, one of the villains of the greenhouse effect.

The challenge is to make membranes from materials which withstand temperatures of 200°C to 300°C. The researchers at Coppe have already developed a membrane that can stand temperatures of up to 800°C and it works well to allow hydrogen molecules to pass through. Now they are adapting the material for CO₂ molecules.



Hollow fiber membranes used in microfiltration processes are produced by PAM- Membranas, a company born at Coppe



In search of energy from garbage and sewage

Several countries are working on how to use the residues coming from recycling and treatment of garbage and sewage as a source of energy. The challenge is to increase the efficiency of the technologies used in order to overcome the economic barriers for commercial use - an even greater difficulty in developing countries, where collection and treatment costs are much lower than those in richer nations.

Using technologies developed at Coppe in pilot demonstration plants at partner companies,

exciting new prospects are opening up. A major achievement was obtained at the pilot plant for energy from sewage installed at the Cedae sewage treatment plant in the Caju district, Rio de Janeiro. The project succeeded in demonstrating that it is feasible to treat the biogas from sewage decomposition so that it is comparable with conventional VNG in terms of quality and price.

More ambitious still, the sewage utilization plant plans to create more noble ends for the fats and sludge residues that traditionally have the greatest environmental impact. The fats can be processed into biodiesel and the sludge



Left: waste in the grease traps at the Cedae treatment plant (Estação de Alegria).
Above: biodiesel a product of the grease traps at the treatment plant



GREEN PLANT - UFRJ CAMPUS

can result in syngas (CH₄, H₂ and CO), bio-oil and biochar. Experience has shown that the addition of glycerol (a byproduct of biodiesel production) in the sludge can generate up to ten times more gas than the sludge alone. Other mixtures can be made with organic residues from urban waste in a trash/sewer co-digester. There are only two other plants in the world working on such technologies.

Usina verde (Green Plant), a private enterprise on the UFRJ campus, is another example of the advanced use of waste as an energy source. It is a pilot plant, designed with the help of the International Virtual Institute of Global Change (IVIG) and Coppe to produce electricity from the incineration of waste that remains after

the removal of recyclable materials. The technology used at the plant is now ready to move up from a pilot plant of 30 tons/day to a commercial scale of 150 tons/day.

Optimizing available technologies, the researchers managed to make the Usina Verde as efficient as waste treatment plants abroad. This was due to two major improvements. The first, developed by the company itself is a gas cleaning system with water for reuse, eliminating solid or chemical filtration systems. The second, developed at Coppe is a combined cycle system, which increases the use of the heat generated from burning the waste, by connecting a gas combustion system to the incineration, giving a superior result than the sum of the parts.

Sustainable construction

Energy and strength from plants

Concrete is the most widely used building material in the world. In recent years the use of concrete, with or without steel rods, has grown by leaps and bounds, driven by the economic development of countries like China, India and Brazil.

Both the cement and steel industries are large emitters of CO₂, the main greenhouse gas responsibility for climate change. The cement in-

dustry alone accounts for 5% to 7% of global CO₂ emissions, coming from a global production of 2.5 billion tons of cement per year. In Brazil, production is in the 60 million tons/year range and is projected to reach 100 million soon.

With an eye on these numbers, researchers at the Laboratory of Structures and Materials of Coppe /UFRJ have been looking through the vast amount of Brazilian agricultural products and the diversity of the rainforests for natural and renewable materials that could help reduce the im-



pacts of concrete on climate change. On the one hand, a technology to use the ash of sugarcane bagasse, a residue from the sugar and alcohol industry, as a partial substitute for cement, is being developed and on the other hand, sisal cultivated in the Northeast and plant fibers from the Amazon are being researched as substitutes for steel rods, synthetic fibers and asbestos in fiber cement products.

The technology for the use of sugarcane bagasse ash is almost ready; there are still some durability tests to be completed. The results until now show that by replacing up to 10% of the cement by sugar cane bagasse ash there is an increase in quality in comparison with conventional concrete, and up to 20%, maintains the quality of the original product.

Brazil is one of the few countries in the world where the use of sugarcane bagasse ash is feasible and with sufficient scale of production. Brazil is the largest producer of sugarcane, with 500 million tons/year, with an estimated production of 400,000 tons/year of ash. The ash is a sub-product coming from the bagasse burnt at the sugar/alcohol mills to produce steam.

In addition to developing and testing the cement/ash mixture, Coppe carried out studies to demonstrate its economic viability. As cement

can not be transported over large distances, due to the freight charges, the ash can only be used if the cement plant and the sugar/alcohol mill are close together. Studies have shown that the operation is viable over an average distance of 180 km. The Southeast region of Brazil offers these conditions, and projects such as these meet the requirements for carbon credits.

On another front of the research, tests with sisal and coconut fibers are beginning to show that these natural fibers are as effective for reinforcing concrete as synthetic fibers of polypropylene, nylon and asbestos. In some cases, sisal could be even more effective because it allots the concrete cracks more evenly and gives it ductility - the ability to stretch without breaking easily.

Similar studies are being made with Amazonian plants such as aruma (*Ischnosiphon spp*), jute, piaçaba and curaua (*Ananas erectifolius*), which can help to create economic uses of the forest, without destroying it. Sisal is grown in Paraíba, Pernambuco and Bahia and in the semi-arid Northeast, one of the poorest regions of Brazil. There are 800,000 families who live from the cultivation of sisal and so a new use for the plant could bring positive benefits to this population.

Researchers test the ecological concrete at the Coppe Structures and Materials Laboratory

On the left: building on the UFRJ campus made with soil cement and ecological concrete, both developed in Coppe laboratories



Reintroduce the human and social dimension in economic and technological activities. With this goal in mind, researchers are working on a new engineering that takes into account the socio-economic inequalities which contribute to make life on the planet unsustainable.



Elimination of poverty

Work, income, dignity

Incubator for cooperatives and technology for the 'invisible' Brazil

Since 1995, Coppe has been working to get economically and socially excluded groups out of invisibility and turn them into entrepreneurs able to generate and control their own affairs. They are street scavengers, patients from the mental health system, peasant farmers, small service providers and former prisoners, among others. The initiative organizes them into cooperatives and supports them with training and qualification.

Using management and production engineering techniques, and combining these with the knowledge of other areas and partners, the Technological Incubator of Popular Cooperatives (ITCP) creates and develops methodologies and actions of inclusion and valorization of the work of these groups that are on the edge of the informal economy and therefore are not 'seen' by the formal economy.

The ITCP of Coppe, with funds from FINEP and Fundação Banco do Brasil, stimulated the creation of the University Network of Incubators of Popular Cooperatives. Today 40 universities,

Art and skill in pieces created by the Maré Artisans

Training courses in Mozambique offered by the Coppe Cooperative Incubator (picture on the right)



from almost all Brazilian states, are now part of this movement.

Projects undertaken directly by the ITCP, in partnership with government agencies, have resulted in the creation of official national programs throughout the country. This is the case of more than 600 psychosocial care centers (PCCs), to generate employment and income for patients of the mental health services. These were set up by the Ministry of Health based on an experience of the ITCP with patients from the Philippe Pinel Psychiatric Institute of Rio de Janeiro. The re-

sults showed a reduction in hospitalizations and quantities of drugs taken by the participants. The ITCP regularly trains doctors, occupational therapists, psychologists, social workers and also users to learn to make business plans.

Another project that has become public policy of the Ministries of Labor and Tourism is the incubation program of popular cooperatives and community organizations in areas with high tourist potential and low human development. The program began in the Northeast, covering the Lençóis Maranhenses (Sand dunes) in Mara-



nhão; the Parque Nacional da Serra da Capivara and Parnaíba delta in Piauí, and the Jericoacoara beach in Ceará. The focus is to change the look of the local tourist industries, which only uses the local population – if at all – as maids in hotels and restaurants. Thus, the small service providers, like taxi drivers and beach buggy drivers, remain in the informal economy and have no say, for example, with the agencies that send tourists to the region. The program uses local solutions and stimulates the setting up of cooperatives to formalize and enhance local employment.

The ITCP is also helping to bring the street scavengers in Brazilian cities out of exclusion and turn them into waste recyclers where they are encouraged to organize themselves into cooperatives. These people are given training



in safety and logistics and learn to recognize different materials and their market values, so they can select them and sell them at a profit.

Today, the incubator of Coppe exports its methodology. Within an official program of the Brazilian government that is supporting the construction of houses in the countryside of Mozambique, Coppe is helping to set up an incubator and is training local workers that do the construction work on a community system paid by the Mozambican government. The goal is to change them into small entrepreneurial cooperatives. Among other techniques, they learn to make business plans, so that they will become structured and strengthened and consequently will be able to keep the business going after the present public work is finished.

On the left (page 34) women at the Trama Feminina Cooperative finishing off their work on the loom

“The tide will rise”: a project to recovery the mangrove areas in The Complexo da Maré region

Environment, economy and poverty: an essential dialogue

The Herbert de Souza Laboratory of Social Technologies, which was recently inaugurated at Coppe, came about after works with low-income communities showed that environmental issues are at the heart of the great challenges faced by economically and socially excluded populations.

These issues include problems such as a lack of sanitation, no running water and food security and vulnerability to natural disasters and especially, in Brazil, disasters due to climate variability.

Several Coppe surveys have shown that the poorest populations and regions are the main victims of climate change in Brazil – whether they are residents of urban areas affected by floods and landslides, or are small family farmers in the semiarid regions of the northeast. The purpose of the new laboratory is to bring engineers into closer contact with professionals from the humanities and social sciences that traditionally have focused on the more vulnerable or socially excluded communities.

The laboratory is the result of a partnership between Coppe with the National Network of Social Mobilization (Coep), established in 1993 by the sociologist Herbert de Souza - Betinho. In two decades of activity, Coep has accumulated a vast experience of direct action in excluded communities and of research and reflection on the causes of poverty. The Coep network combines

1,100 organizations, 110 low-income communities and 27,000 people, who together have built a set of methods for community organizing, community development (income generation) and social mobilization through the Internet.

The new lab set in a 200 square meter area at Coppe has ambitious plans: to influence academic thinking so that with the arrival of a new environmentally responsible economy, the views and needs of economically and socially vulnerable populations are taken into account, thus promoting social inclusion.

The laboratory is preparing projects for technology development in three main areas: the link between climate change and poverty; the eradication of poverty; the link between rights, participation and social mobilization. In all these areas, researchers from various programs of Coppe have valuable contributions to make, whether for developing specific technologies for social applications, or whether for incorporating the social vision in the different technologies developed for environmental and economic applications.



On the right, Jorge Streit, president of Fundação Banco do Brasil; Luiz Pinguelli Rosa, director of Coppe; and André Spitz, president of Coep, at the inauguration of the laboratory

Coppe – Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering – was started up to be a fresh boost to Brazilian universities and to contribute to the development of the country. Founded in 1963 by Alberto Luiz Coimbra, an engineer, the Institute helped set up post-graduation courses in Brazil and over these last almost five decades has become the largest center for teaching and research in engineering in Latin America.

More than 12,000 students have received their Master's and Doctoral degrees from its 12 post-graduate programs. Based on three fundamental guiding principles - academic excellence; the full dedication of teachers and students; and a close relation with society - Coppe stands out as a disseminator of knowledge and teaching methods and is a hub for qualified professionals, serving as a model for universities and research institutes throughout the country.

The standard of excellence is reflected in its academic production. And also at the latest appraisal by CAPES, released in September 2010, Coppe was the Brazilian post-graduate engineering institute that received the largest number of 7s - the maximum score - attributed to courses with an equivalent performance to the most important centers of education and research in the world.

Expanding horizons

The professionals and infrastructure of the institute are always at hand to meet the needs of economic, technological and social development. Thanks to this "being-in-tune" with the future, Coppe has become a national and international reference for teaching and research in engineering and has helped Brazil to face some of the most important challenges in its recent history.

On the international scene, Coppe has projects in cooperation with other world renowned scientific institutions. Many of the teaching staff are members of international committees in various countries and multilateral agencies such as the Intergovernmental Panel on Climate Change (IPCC), awarded the Nobel Peace Prize in 2007.

In 2008, the institute expanded its international scope of activities by setting up the China-Brazil Center on Climate Change and Innovative Technologies for Energy, a partnership with Tsinghua University, the leading Chinese university in engineering. The Center is housed on the campus of Tsinghua University in Beijing from where Coppe coordinates its activities and makes contact with Brazilian and Chinese companies that are bilaterally interested in developing new technologies.

Commitment to the country and society

A pioneer in bringing the scientific academy and society closer together, Coppe has turned results into wealth. In 1994, it set up an Incubator of Businesses that placed around 100 different services and innovative products onto the market.

Also Coppe has always directed its engineering skills and technological innovations to address poverty and social inequalities, building a bridge between the haves and have nots, between the included and the excluded. This attitude resulted in the opening of the Technological Incubator of Popular Cooperatives in 1995. This is now a reference model for popular cooperatives and has been replicated in other states and countries. Already 118 cooperatives have been set up and about 2,100 jobs have been created.

Coppe in numbers

Total number of titles issued (up to 2011)

9,754 master's degrees

3,205 doctorate degrees

Annual academic production (in 2011)

336 master's dissertations

168 doctoral theses

1,620 scientific papers

Interaction with society (governments, companies and civil society)

12,700 contracts (up to 2011)

95 patents deposited (up to 2010)

14 softwares registered (up to 2010)

Infrastructure and Human Resources (in 2012)

12 programs of post-graduate studies (masters and doctorate)

339 teachers with PhDs

2,729 students (1,643 masters and 1,086 doctoral students)

50 post-doctoral researchers

350 employees

120 laboratories

An incubator for technology-based companies

A technology incubator for popular cooperatives

A core service in high performance computing (Nacad)

COPPE / UFRJ

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Address: Coppe Stand at the Parque
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To learn more about other technologies created at Coppe visit

www.coppenario20.coppe.ufrj.br