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- Advanced systems for the use of mixed gas and diesel in internal combustion engines for methane emission mitigation

- Feasibility/design of efficient and environmentally friendly ship concepts with natural gas as fuel

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- Studies of the application of laser (LIDAR) for atmospheric pollution measurements

- Design optimization of labyrinth seals

- Development of an hybrid penta-fuel flex vehicle
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• Development of an advanced natural gas burner using the flameless concept
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• Synthesis gas production by methane tri-reforming
• Methanol production by CO2 hydrogenation
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• A hybrid solar-gas system for natural gas steam reforming
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• Microbial production of polyhydroxybutyrate (PHB) from methane (CH4)
• Structured ceramic membrane and supersonic device for CH4 / CO2 separation
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Summary (click on the desired topic)

RCGI Energy Policies and Economics Programme

• Creation of the brazilian and São Paulo legal service of natural gas

• Producing studies “benchmark” about the efficient use of natural gas in the industrial sector

• Brazilian inventory of greenhouse gases and scenarios for reducing emissions related to natural gas

• Estimation of price elasticities and income of natural gas in Brazil

• Natural gas sustainability of integrated analysis as a transportation fuel in heavy vehicles: the Blue Corridor Paulista

• Evaluation of small LNG and CNG drives as options for the supply, transmission and distribution in Brazil

• The biomethane’s contribution prospects to increase the supply of natural gas

• Analysis of the potential household use of natural gas integrated to electricity system in the city of São Paulo
The SGI White Paper Series - Policy facing research through Systematic Review and primary analysis

AUTHOR: Dr Jamie Speirs (Imperial College London)

ABSTRACT:

The Sustainable Gas institute (SGI) has recently begun work on the third White Paper in its ongoing series. This talk will begin by describing the approach taken by the SGI White Paper Series and the value of this type of research. The presentation will then introduce the topic of White Paper 3 and discuss the progress to date. White Paper 3 will assess the future decarbonisation options for existing gas network infrastructure.

The SGI White Paper Series provides globally impactful policy facing analysis, bringing clarity to contentious topics in the energy sector. The SGI delivers this through the use of systematic review of the contemporary evidence base and primary analysis to fill gaps in current knowledge.
**Distribution of methane and carbon dioxide (CO₂) emissions from the natural gas supply chain**

**AUTHOR:** Dr Paul Balcombe (Imperial College London)

**ABSTRACT:**

There has been growing concern that fugitive and vented emissions from the natural gas supply chain is larger and more variable than previously thought. The first White Paper by the Sustainable Gas Institute revealed an extremely large range of emissions across different supply chain stages, regions, geologies, processes and operational practises, not to mention estimation methodologies. However, there remains a lack of understanding about why we see such variation and the factors affecting these emissions. In order to minimise supply chain emissions, a greater understanding of the characterisation and distribution of emissions across the range is required.

In this study, a large set of emissions data aggregated from the White Paper is analysed to define the distribution of methane and CO₂ emissions from each stage of the supply chain. The factors affecting emissions are defined and quantified, including reservoir type, size and supply chain route. This inventory was then used to perform a Monte Carlo simulation to determine the overall distribution of methane and CO₂ emissions for various supply chain scenarios.

This probabilistic assessment gives a clear insight into the variation of emissions and the causes of these variations and the study identifies where there is greatest potential to reduce supply chain emissions. This greater understanding of natural gas emissions is vital in informing policy decisions as the drive to decarbonise energy systems gathers pace and gas production is set to increase: but what are the likely impacts and how can we minimise these?
Can technology unlock unburnable carbon?

AUTHOR: Dr Sara Budinis (Imperial College London)

ABSTRACT:

To stay within the 2°C carbon budget, a very significant reduction in fossil fuel consumption is required. If we are to meet our carbon budget the majority of global fossil fuel reserves cannot be combusted: the unburnable carbon.

The role of technologies such as Carbon Capture and Storage (CCS) may be critical in enabling a greater quantity of fossil fuel to be combusted within a low-carbon framework. However, the potential for CCS to alleviate the carbon constraint is still controversial and uncertain, with a number of studies reaching different conclusions.

This extensive review paper has assessed the current state of knowledge regarding the ‘unburnable carbon’ issue, and provided clarity by quantitatively defining the potential role of CCS in unlocking the unburnable carbon over the next 85 years.
MUSE: a novel approach to energy systems modelling

AUTHORS: Dr Adam Hawkes, Dr Sara Giarola, Dr Daniel Crow from Imperial College London

ABSTRACT:

MUSE is designed to generate plausible transitions of energy systems towards a low carbon economy with a specific focus on the role of gas in delivering a more sustainable future.

We first describe the novel approach to energy systems modelling under development in the MUSE model (the Modular Universal energy systems Simulation Environment) at the SGI, and give an overview of the range of potential applications of the MUSE model, with details of the project timeline as well as an introduction to the team of academics involved in its development. We then discuss the distinctive features of MUSE in the context of Energy Systems Models, highlighting its global scope, modularity, flexibility, technological detail and treatment of uncertainty (both supply- and demand-side) in future time periods.

We then provide a more technical overview of how MUSE runs, including the main Input/Output channels and libraries, describing in particular the core MUSE module – the Market Clearing Algorithm – which balances trade in energy commodities over all modules and world regions.

The MUSE Upstream Gas Module is then discussed in detail given its importance to the overall development aims of MUSE.
Economic analysis of offshore gas field development

AUTHORS: Dr Kris Anderson

ABSTRACT:

The year, 2016, has seen Japanese Liquefied Natural Gas (LNG) import prices fall below 6 USD/mmBTU from highs of over 18 USD/mmBTU in 2012. This has led to several high profile deep water LNG projects being either delayed or cancelled. There is therefore an urgent need for deep water operators to find ways to reduce costs so that deep water assets can be profitable. Smaller gas fields are typically the most challenging to develop, as the small volumes of gas make it difficult to obtain a return on the large capital expenditure necessary to develop deep water fields. A successful approach commonly utilised in the North Sea sector is to tie-back smaller fields to existing infrastructure. Subsea boosting technology has made long distance tie-backs a commercial reality, creating the potential to produce deep water gas fields that are too small to justify dedicated infrastructure. This presentation will discuss some of the economic and technical aspects associated with long distance tie-backs either to shore or to existing offshore infrastructure.
**Thermoelectric ceramic module**

**AUTHOR:** Prof Daniel Thomazini (University of Itajuba)

**ABSTRACT:**

Currently fossil fuels are widely consumed for power generation, causing the inconvenience of greenhouse gases emissions, one of the greatest villains in the global warming. One way to reduce the emission of these gases is by increasing the efficiency of heating systems, by reusing the waste heat which can be done with the use of thermoelectric materials. Ceramic thermoelectric materials are able to directly convert heat into electricity via the Seebeck effect that these materials present.

Thermoelectric ceramics have several advantages over conventional thermoelectric as low processing costs are physically and chemically resistant to hostile environments, and can operate from ambient temperature to 1000°C without degradation of its properties. Thus, this project aims to produce a ceramic thermoelectric module to be applied in thermal systems embedded in Floating Production Storage and Offloading (FPSO) platforms, in order to increase their energy efficiency. In this study, micro and nanometric ceramic powders based on Ca3Cu4O9, SrTiO3, CaCu3Ti4O12 and PZT systems were produced by solid state reaction, chemical coprecipitate and microwave assisted hydrothermal synthesis. During sintering, oxidizing and reducing atmospheres were used to enhance the presence of defects and evaluate its effect on thermoelectric properties of these ceramics. To date, the ceramics with more efficient energy conversion were those produced in a reducing atmosphere, showing a great potential in the application for the production of thermoelectric modules.
Unconventional waste heat recovery bottoming cycles

AUTHOR: Prof Dr Marco Antonio Rosa do Nascimento (UNIFEI)

ABSTRACT:

This presentation is about a proposal to expand electricity power generation at offshore Floating Production Storage and Offloading (FPSO). Increasing energy efficiency these platforms requires a commitment to cost and compactness of the equipment. The Organic Rankine Cycle (ORC) is a promising technology for energy conversion by means of low and average sources temperature. Thus, the cycle is an alternative to expansion of electricity power generation in platforms, in order to maximize energy efficiency as well as reduce environmental impacts by thermal pollution. The aim is to assess the availability of low-grade waste heat from different processes in a FPSO. The study of energy flow in this platform indicated the processes with the greatest potential for energy recovery. A genetic algorithm has been developed to optimize the thermodynamic parameters of different working fluids and a multi-objective optimization is carried out to maximize thermal performance of the work cycle and minimize costs by reducing the ORC module area.
**Sustainable configurations of FPSO primary petroleum processing plants**

**ABSTRACT:**

This project aims at developing and applying a method to evaluate and optimize the energy and environmental behaviour of energy conversion processes that take place in utilities and process plants of Floating Production Storage and Offloading (FPSO).

The application of this method will quantify the thermodynamic performance of the analysed processes, as well as determining the costs of the products and wastes generated as well as the \( \text{CO}_2 \) emissions during the operation of FPSOs in the Pre-Salt region.

The thermodynamic and environmental optimization of the offshore plants will be conducted by means of the combined use of the First and Second Laws of Thermodynamics (Exergy analysis) and will be implemented through an optimization algorithm conceived during the project.

Based on the obtained results, for every production step and for the chosen wells production curves, technologies diagrams [including new technologies such as combined cycle, Organic Rankine Cycle (ORC), oxi-fuel combustors, (OTEC)] will indicate the best equipment sets and configurations for each type of well exploitation scenario and destination of the products of the FPSOs (for instance, if oil and gas will be directly exported from the FPSOs).

**TEAM:**

Silvio de Oliveira Junior (POLI-USP)
*Project Coordinator*

Jurandir Itizo Yanagihara (POLI-USP)
Guenther Carlos Krieger Filho (POLI-USP)
Julio Augusto Mendes da Silva (UFBa)
Cyro Albuquerque Neto (FEI)
Ali Allayarzadeh Bidgoli (POLI-USP)
Yamid Alberto Carranza Sánchez (POLI-USP)
Rafael da Cruz Ribeiro Berti (POLI-USP)
Yuri Moreira Barbosa (UFBa)
Caio Gracco Fonseca do Val (UFBa)
Energy efficiency and reduction of CO$_2$ emissions at maritime operations in the oil industry

AUTHOR: Prof Dr Waldyr L R Gallo (UNICAMP)

ABSTRACT:

The main objective of this project is reducing equivalent CO$_2$ (or CO$_2$ eq) emissions in the offshore oil and gas production, the main objective of this Project is to identify, analyze and propose actions and/or technologies aimed at improving energy efficiency and reducing greenhouse gas (GHG) emissions in a typical Floating Production Storage and Offloading (FPSO).

Since a FPSO must produce locally all needed energy (thermal and electrical) for its operation, the increase in the efficiency of energy generation and use is closely related with its GHG emissions. A reduction in the fossil fuel needs is directly associated with a reduction in the GHG emissions.

Energy and GHG emissions diagnosis for a typical FPSO was made in three different operation conditions, with published results. The different technological options and strategies to reduce fuel consumption and GHG emissions are being studied and will be published as Technical Reports for BG. Waste Heat Recovery, cogeneration, alternative power cycles, CO$_2$ capture in the oil field, increase in the energy efficiency in the end use, power island concepts and local LNG production are being studied. Apart from these thermodynamic studies, the project also deals with electrical energy distribution and its quality, as well as with the hydrodynamic unhyphenate of the FPSO.

Seven principal researchers, four PhD students (two scholarships), four MSc students (three scholarships) and four undergraduate students (scientific initiation scholarships) compose the research team. Two MSc Dissertations and two Graduate Monographies were concluded within the scope of this Project.

This Project is scheduled to end by April 2017.
Development of an advanced natural gas burner using the oxy-fuel concept

RCGI ENGINEERING PROGRAMME - PROJECT 1

ABSTRACT:

The main objective of this project is to develop a burner for Natural Gas based on the concept of the oxy-fuel. In this concept, the oxygen required for the combustion is separated from air prior to its combustion, which takes place in an environment composed of recycled flue gas instead of air. One way of reducing the CO$_2$ emissions of combustion processes is the Carbon Capture and Storage technique. The oxy-fuel concept makes it easier to capture the CO$_2$ from flue gases. The burner will be investigated for CH$_4$/H$_2$/C$_3$H$_8$/CO$_2$ blends, using state-of-the-art laser diagnostic systems and computational methods.

TEAM:

Guenther C Krieger Filho (POLI-USP)
*Project Coordinator*

Jurandir Itizo Yanagihara (POLI-USP)

Antônio Luis Pacífico (POLI-USP)
Laboratory of advanced combustion diagnostics

RCGI ENGINEERING PROGRAMME - PROJECT 2

ABSTRACT:

The main objective of this project is to provide the RCGI with state-of-the-art infrastructure for the development of advanced combustion systems. The laser measurements systems together with a single cylinder research engine with optical access will allow the development of efficient combustion chambers and burners. The advanced combustion concepts aim to minimize of emissions such as slip methane, unburned non methane hydrocarbon and NOx. The advanced diagnostics tools for the laboratory are: Laser Doppler Anemometry (LDA); Time-Resolved Planar Laser Induced Fluorescence (TR-PLIF); Phase Doppler Anemometry (PDA); Laser Induced Phosphorescence for Temperature Measurements (T-LIP) and Tomographic Particle Imaging Velocimetry.

TEAM:

Guenther C Krieger Filho (POLI-USP)
*Project Coordinator*

Jurandir Itizo Yanagihara (POLI-USP)
Antônio Luis Pacífico (POLI-USP)
Mauricio Ferreira (POLI-USP)
Advanced systems for the use of mixed gas and diesel in internal combustion engines for methane emission mitigation

RCGI ENGINEERING PROGRAMME - PROJECT 3

ABSTRACT:

This project aims to develop combustion systems using diesel and natural gas blends for Internal Combustion Engine (ICE) applications. There is a need for ICE running on natural gas blends for remote power plants and natural-gas-based hybrid powertrains for vessels. Although there are already commercial systems available, there is a lack of knowledge on combustion of natural gas blends. The sub-optimal fuel air mixture or local extinction result in emissions of unburned hydrocarbon (UHC). One of the most severe UHC emissions is the release of the unburned greenhouse gas methane into the atmosphere (methane slip). To better understand the methane slip, an in-depth knowledge of the turbulent mixture formation and combustion process is required. The main goal of this project is to investigate this focusing on the fundamental physical processes, and the combustion of natural gas blends ignited by pilot diesel sprays. The experimental research will be carried out on a constant volume combustion chamber and on a single cylinder research engine with optical access. Laser measurement techniques will be applied in order to gather information on gas velocity field, droplets diameter and velocity as well as OH distribution on the flame. Numerical simulation models will be developed and validated with the experimental data. The project will develop an experimental database of burning natural gas blends ignited by pilot diesel spray. This data will support the validation of computational model, which in turn can assist in the design of ICE running on both diesel and blends of natural gas. The knowledge acquired by this project will be employed to increase the efficiency of large engines (e.g. ship and thermo-power engines) running with mixtures of diesel and natural gas (NG) as well those employed in medium-size applications. For example, this project will investigate the mitigation of emissions of greenhouse gases (GHG) on large trucks employed in the mining industry.

TEAM:

Guenther C Krieger Filho (POLI-USP)
Project Coordinator

Celso Argachoy (IMT)
Feasibility/design of efficient and environmentally friendly ship concepts with natural gas as fuel

RCGI ENGINEERING PROGRAMME - PROJECT 4

ABSTRACT:

This project proposes to develop conceptual studies on three natural gas fueled vessels. The study will develop a roadmap on the possibilities of natural gas considering available resources, analyzing political, financial, geographical, technical and logistics conditions/restrictions and evaluating adequacy to actual/future environmental regulations with a final focus on the possibilities of natural gas (LNG) as a fuel for the Brazilian shipping sector.

In addition, a review on new technologies available for vessels/terminals for LNG operation will be undertaken considering market trends, ship owner requirements, environmental conditions, ports/terminals regulations as well as required supply/storage infrastructure. Considering the importance of onshore installations, a survey on port/terminal infrastructure requirements and regulations for storage/bunkering/operating on liquefied natural gas (LNG) will be conducted, including the views of national authorities and evaluating national industry capability to produce/supply equipment and to provide maintenance.

On the LNG fuel vessels studies, three conceptual designs, at different levels of detail, will be developed; the vessels being an offshore supply vessel, a shuttle tanker and a Floating Storage Regasification Unit (FSRU) unit. As most of the vessels are usually designed abroad, the proposed designs intend to offer customized versions for Brazilian conditions. The development will be based on parametric model simulations of the vessels dimensions and shape that adhere to functional design constrains (e.g. equipment layout, weights and centers, resistance, stability, hull/propeller/engine selection, …), safety rules in using LNG and national content laws. Finally, the economics of the new vessels will be compared with traditional alternatives taking into account the fuel consumption, amount of pollution emissions and an estimation of costs.

TEAM:

Claudio Mueller Prado Sampaio (POLI-USP)  
Gustavo Roque da Silva Assi (POLI-USP)  
Kazuo Nishimoto (POLI-USP)  
Julio R Meneghini (POLI-USP)  
Project Coordinators
Design and optimization of storage systems by adsorption for natural gas

RCGI ENGINEERING PROGRAMME - PROJECT 5

ABSTRACT:

Adsorption consists of the molecular adhesion onto surfaces by van der Waals forces and covalent bonds. The Adsorbed Natural Gas (ANG) vessels store gas in adsorbents in their interior relying on the adsorption effect. When compared to traditional transport and storage systems, ANG requires less pressure to operate (35atm to 50atm), which is considerably below Compressed Natural Gas (200atm), and works in ambient temperature, higher than the Liquefied Natural Gas (113K), obtaining the storage capacity of 164V/V, comparable to the Compressed Natural Gas (200V/V). The adsorption phenomena demands thermal management in order to become more efficient once adsorption is an exothermic phenomena and with the temperature raise occurs the loss of the adsorption capacity while a similar effect is observed in the desorption phenomena although the loss of the desorption rate is proportional to the temperature fall. This project aims to reduce the time needed to charge and discharge adsorbed natural gas (ANG) vessels and increase the maximum amount of gas stored and delivered by these systems. The study employs optimization techniques (such as the topology optimization method) to optimally distribute materials and its properties in the vessels’ interior. The employment of heterogeneous porosity adsorbents and Phase Change Materials (PCM) are the explored solutions to improve ANG systems efficiency. The current competitiveness of ANG when compared to other gas systems such as Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG) is also discussed. The results are presented as possible solutions for ANG enhancements in transportation and storage for natural gas systems.

TEAM:

Emilio C N Silva (POLI-USP)
*Project Coordinator*

Bruno S Carmo (POLI-USP)
Rob W Hewson (IC)
Julio R Meneghini (POLI-USP)
Marcelo M Seckler (POLI-USP)
Ernani V Volpi (POLI-USP)
Optimization based on the adjoint method for natural gas storage systems

RCGI ENGINEERING PROGRAMME - PROJECT 6

ABSTRACT:

Worldwide, the energy market is going through a phase of intense research and development efforts. In several countries, the energy matrices are undergoing progressive changes, in order to adapt to more stringent environmental laws and to the global economy instabilities. In this scenario, natural gas appears as a source of energy of growing relevance, owing to both its direct uses and to the possibilities it offers regarding the process of gas reform, for hydrogen production and carbon capture. The growth of its share of the energy market prompts the need to optimize the chain of production, processing and storage of natural gas. Optimal solutions should allow significant savings in the implementation and operational costs of the natural gas industry.

Amongst the most relevant approaches to optimization, the adjoint method stands out as it allows an exceptional reduction in the computational costs of sensitivity derivatives. This makes for a more efficient analysis of design alternatives, without compromising accuracy of results. This method is also attractive for its high fidelity to the flow physics, and for the great diversity of its applications. This project aims to use the adjoint method to optimize Natural Gas Adsorption Systems for storage. The study focuses on gas flow through porous media that adequately represent those systems. Moreover, the study is not limited to the search for optimal geometries for the adsorption beds in reservoirs as it will also consider the optimization of the filling and emptying operations of such reservoirs.

TEAM:

E V Volpe (POLI-USP)
Project Coordinator

Julio R Meneghini (POLI-USP)
Emílio C N Silva (POLI-USP)
Bruno S Carmo (POLI-USP)
Rafael S Gioria (POLI-USP)
X Mao (Durham University)
Hybrid power systems for ships

RCGI ENGINEERING PROGRAMME - PROJECT 7

ABSTRACT:

Nowadays, there is a growing concern about decreasing pollutant emissions from marine vessels in order to minimise the impact on atmospheric pollution. This means that the naval industry needs to be prepared for this scenario and develop cleaner and more efficient powertrains. Hybrid systems are a viable approach to reach this goal. They employ batteries to store energy, in order to eliminate engine transients, leaving it running in its optimal condition and using the stored energy to supply the extra demands. The use of hybrid systems in marine vessels brings a number of new challenges, which are mainly related to the order of magnitude of the power supplied and risk management. Besides hybrid systems, using alternative fuels with low sulphur levels is also an option that could be considered to diminish pollutant emission. Liquefied Natural Gas (LNG) is a viable short term alternative to substitute the bunker oils currently employed as fuel in vessels. A promising option for the long term is to use natural gas in fuel cells, which are very efficient systems, although its technology is not sufficiently mature to secure safe use in vessels. We are going to analyse all these alternatives, investigating performance, cost, safety and infrastructure needs in order to quantify the economic gains, fuel savings, performance improvements and emissions reduction.

TEAM:

Bruno Souza Carmo (POLI-USP)
Project Coordinator

Silvio de Oliveira Junior (POLI-USP)
Mauricio Salles (POLI-USP)
Marcelo Ramos Martins (POLI-USP)
Gustavo Roque da Silva Assi (POLI-USP)
Modeling and numerical simulation

RCGI ENGINEERING PROGRAMME - PROJECT 8

ABSTRACT:

In previous decades, numerical modelling and simulation techniques have become vital in many areas of fundamental and applied research. However, there are still many situations in which computational simulations could be of great help to advance the development of a research in this area, but they are not properly employed or not employed at all. This usually happens because the researchers involved do not necessarily have a background in numerical methods that could be applied to these problems, and instead resort to other techniques such as physical experiments. This project assembles a team of specialists in the use of various numerical methods and high performance computing, as well as in the application of these tools in challenging problems, with the purpose of identifying opportunities in which those computational analyses could be used to aggregate value to the research, and provide support in the use of these tools. The objective of this group within the RCGI is to help all the other projects in the Centre in any activities that involve or could benefit from numerical modelling and simulation. More specifically, the group will focus on the identification of opportunities for numerical modelling, choosing the best numerical methods or software for each application, specifically the necessary infrastructure and computational resources, problem modelling, model validation, simulation and data processing.

TEAM:

Bruno Souza Carmo (POLI-USP)  
Project Coordinator

Julio Romano Meneghini (POLI-USP)  
Emilio Carlos Nelli Silva (POLI-USP)  
Celma Ribeiro de Oliveira (POLI-USP)  
Erik Eduardo Rego (POLI-USP)  
Linda Lee Ho (POLI-USP)  
Oswaldo V Costa (POLI-USP)  
Julio M Stern (IME-USP)  
Ivan Korkischko (POLI-USP)  
Reinaldo Marcondes Orselli (POLI-USP)  
Jairo Paes Cavalcante Filho (POLI-USP)  
Ulisses Adonis Silva Costa (POLI-USP)  
Matheus Augusto Pires (POLI-USP)
Studies of the application of laser (LIDAR) for atmospheric pollution measurements

RCGI ENGINEERING PROGRAMME - PROJECT 9

ABSTRACT:

The present research project focuses on the application of a laser-based remote sensing technique (known as “LIDAR – light detection and ranging”) to measure fugitive emissions associated with the petroleum industry. The study consists initially of improving the existing laboratory capacity by adding new equipments to the existing LIDAR system: specifically, a Lidar fluorescence spectrometer will be acquired. The system will be used in a number of planned monitoring campaigns, aimed at acquiring data from industrial flares, and fugitive emissions from tanks, (e.g., storage systems used for petroleum and petroleum products). The data collected will be used to develop of data processing algorithms based on optical models and multivariate analysis, for the estimation of the concentration of important chemical species contained in fugitive emissions, like aerosols, \( \text{SO}_2 \), \( \text{NOx} \), and volatile organic compounds.

Besides the inherent activities of research, which include producing technical – scientific publications and theses, the present study, due to its creative features, is expected to generate innovative technology to study the presence of several compounds of interest in fugitive emissions, allowing further development of studies on pollutant dispersion and on interactions between different chemical species under different weather conditions.

The project deliverables consist of specific research products, including papers and theses, as well as producing detailed documentation on the developed methodology, such as specifications and procedures about the equipment, measurement procedures, data treatment algorithms, and corresponding computer codes.

TEAM:

Roberto Guardani (POLI-USP)
Project Coordinator

Claudio A O do Nascimento (POLI-USP)

Eduardo Landulfo (POLI-USP)
Design optimization of labyrinth seals

RCGI ENGINEERING PROGRAMME - PROJECT 10

ABSTRACT:

Labyrinth seals are essential for sealing rotating parts subject to high temperatures. Currently, 60% of methane emissions are caused by leakage from turbines and pneumatic devices. Due to the growth in the demand for lower pollutant emissions and the need for more efficient devices, leakage of labyrinth seals is becoming more of a problem. Therefore, this project intends to develop a methodology to design labyrinth seals to minimize the leakage problem. The main concept of the labyrinth is based on two requirements. First, there is always a gap between the parts, so the shaft can rotate without any contact, which avoids any premature wear on the system. Then, there are recirculation chambers in order to maximize the turbulence flow and, as a result, minimize the fluid flow. However, its design is not very straightforward to solve, because the interaction fluid-structure, which occurs in this region, brings the challenge of developing a robust and systematic methodology to the labyrinth seals design. Therefore, this work contains two different kinds of numerical analysis, FENICS and Isogeometric Analysis, with Topology Optimization. This is a computational optimization method that allows the design of structures with two or more materials in an optimized shape, so the objective function can be maximized or minimized. The project intends to maximize the pressure drop or the energy flow in the labyrinth seals, including some restrictions, in order to make possible the manufacture of the found solutions by using 3D printers.

TEAM:

Emilio C N Silva (POLI-USP)
Project Coordinator

Bruno Caldas de Souza (POLI-USP)
Sandro Luis Vatanabe (POLI-USP)
Development of an hybrid penta-fuel flex vehicle

RCGI ENGINEERING PROGRAMME - PROJECT 29

ABSTRACT:

The knowledge acquired by the Laboratory Advanced Combustion DIAGNOSTICS will be used to increase the efficiency of large engines (e.g. ship and thermo-power engines) as well those employed in small applications. This Lab will develop the first hybrid penta-fuel automobile, which will run on pure petrol, petrol + ethanol, ethanol, natural gas for vehicles (NGV) and electricity.

TEAM:

Julio R Meneghini (POLI-USP)  
*Project Coordinator*

Guenther C Krieger Filho (POLI-USP)  
Bruno S Carmo (POLI-USP)  
Clayton B Zabeu (Escola de Engenharia Mauá)  
Waldyr L Ri Gallo (Unicamp)
Development of an advanced natural gas burner using the flameless concept

RCGI PHYSICAL/CHEMISTRY PROGRAMME - PROJECT 11

ABSTRACT:

The main objective of this project is to develop a burner for natural gas blends based on the Flameless Oxidation concept. This advanced combustion technology is applied to increase the energy efficiency and to reduce the emissions of nitric oxide. In the flameless concept, the air is preheated above the self-ignition temperature of the fuel/air mixture using regenerative systems. The air is diluted with high-temperature recirculated exhaust gases inside the burner prior to combustion, lowering the oxygen concentration, which subsequently reduces the NO\textsubscript{X} emissions. The burner will be investigated for CH\textsubscript{4}/H\textsubscript{2}/C\textsubscript{3}H\textsubscript{8}/CO\textsubscript{2} blends, using state-of-the-art laser diagnostic systems and computational methods.

TEAM:

Guenther Carlos Krieger
*Project Coordinator*

Jurandir Itizo Yanagihara
Antônio Luis Pacífico
Advancing fuel cells for operation on natural gas

RCGI PHYSICAL/CHEMISTRY PROGRAMME - PROJECT 12

ABSTRACT:

The project aims to address some of the main technological and scientific challenges in the use of natural gas in fuel cells. The research topics are focused on two technologies: proton exchange membrane fuel cell (PEMFC) and solid oxide fuel cell (SOFC). The main topics to be studied are: i) anodes for efficient electro-oxidation of methane and/or more tolerant to gas fuel mixtures containing H$_2$/CO; ii) membranes for high-temperature PEMFC; and iii) carbon resistant anode materials and catalytic layers for direct natural gas SOFC’s. The main objective is to advance our knowledge to expand the use of natural gas in fuel cells.

TEAM:

Fabio Coral Fonseca  
*Project Coordinator*

Marcelo Linardi  
Estevam Spinacé

GO TO THE SUMMARY
Synthesis gas production by methane tri-reforming

ABSTRACT:

The high hydrogen-carbon ratio and the absence of heteroatoms make natural gas an attractive feedstock for synthetic fuels and chemicals that can replace those typically from petroleum-derived sources. The search for efficient routes, both direct and indirect, to convert methane to other higher value-added products is a challenge for the scientific community. Additionally, the new fields of oil and gas located in the pre-salt basin of the Brazilian coast contain associated Carbon dioxide ($\text{CO}_2$) (8-18%) and, in some specific fields, the associated gas contain even higher $\text{CO}_2$ content (79%). Thus, the aim of this project is to use methane ($\text{CH}_4$) and $\text{CO}_2$ as raw materials (chemistry of C1) to produce synthesis gas ($\text{H}_2 + \text{carbon monoxide [CO]}$), including catalyst development, proof of concept and technological applications, design and optimization of processes. This project will develop a process called methane tri-reforming, in which water, $\text{CO}_2$ and $\text{O}_2$ are used to produce synthesis gas with $\text{H}_2/\text{CO}$ ratio suitable for synthesis of fuels.

TEAM:

Reinaldo Giudici (POLI-USP)
Project Coordinator

Claudio A O do Nascimento (POLI-USP)
Rita Maria de Brito Alves (POLI-USP)
José Mansur Assaf (EQUFSCar)
Elisabete Moreira Assaf (IQSC-USP)
Methanol production by $CO_2$ hydrogenation

RCGI PHYSICAL/CHEMISTRY PROGRAMME - PROJECT 14

ABSTRACT:

Methanol is an important solvent extensively used in the plastics industry and in the organic synthesis of various chemical intermediates, such as formaldehyde, methyl chloride, acetic acid, methylamines, methyl methacrylate, among others. In addition, it is used in the transesterification of triglycerides to produce biodiesel. The use of methanol feedstock tends to increase. Overall methanol demand is increasing by significant levels – from a demand of 60 million metric tons in 2013 to over 106 million metric tons in 2023. With rising demand, it is necessary to develop more selective and inexpensive routes for the synthesis of methanol. Carbon dioxide is an alternative raw material for this synthesis, substituting carbon monoxide (CO). This project will evaluate the methanol production routes through the hydrogenation of $CO_2$, in order to take advantage of the associated gas in oil fields as well as from other fossil fuels sources, such as natural gas fields in Brazil, that are rich in $CO_2$. The effects of catalyst preparation methods based on copper supported on ceramic materials will be investigated.

TEAM:

Reinaldo Giudici (POLI-USP)
*Project Coordinator*

Claudio A O do Nascimento (POLI-USP)
Rita Maria de Brito Alves (POLI-USP)
José Mansur Assaf (EQUFSCar)
Elisabete Moreira Assaf (IQSC-USP)
**Advanced catalyst for Fischer-Tropsch Synthesis**

RCGI PHYSICAL/CHEMISTRY PROGRAMME - PROJECT 15

**ABSTRACT:**

Fischer–Tropsch synthesis (FTS) is a set of catalytic processes that can be used to produce fuels and chemicals from synthesis gas (a mixture of CO and H2), which can be derived from natural gas. The development of novel catalysts with high activity and selectivity is desirable as it leads to improved quality and value of FTS products. This project focuses on the application of nanomaterials, mainly graphene and its oxides, as catalyst to FTS. Addition of cobalt and ruthenium to Co/Nb2O5 catalysts and its effects on the FTS using monolith catalysts/reactors will also be evaluated.

**TEAM:**

Reinaldo Giudici (POLI-USP)  
*Project Coordinator*

Claudio A O do Nascimento (POLI-USP)  
Rita Maria de Brito Alves (POLI-USP)
A hybrid solar-gas system for natural gas steam reforming

RCGI PHYSICAL/CHEMISTRY PROGRAMME - PROJECT 16

ABSTRACT:

This project deals with developing a novel system for natural gas reforming using solar energy as the main energy source. The sun can provide radiation that, when concentrated, can reach high temperatures. Such high temperatures are necessary to trigger some important thermochemical reactions, such as the one to produce syngas, or even hydrogen gas alone. The solar reactor may operate alone or in a hybrid configuration supplying considerable amount of the necessary thermal energy for triggering and keeping the chemical reaction. The main goals of this project are: (i) to carry out an up-to-date study on steam reforming processes for natural gas; (ii) to build a solar simulator for laboratory studies of low power in the 10 kW to 20 kW range; (iii) to design and build a black body cavity coupled with a thermo reactor to carry out the steam reforming in natural gas; (iv) and to carry out experimental and numerical work of solar simulator and the thermochemical reactions.

TEAM:

José Roberto Simões Moreira (POLI-USP)

Project Coordinator
Converting biogas to bioproducts

RCGI PHYSICAL/CHEMISTRY PROGRAMME - PROJECT 17

ABSTRACT:

The emission of carbon dioxide (CO₂) and methane (CH₄) gases are considered to be major contributors to warming and climate change, although the expanding use of fossil fuels and changes in land use are also among the causes. Among these emissions, CO₂ represents 63%, with CH₄ and N₂O representing the 24% and 3%, respectively. These gases are typically converted into electricity and low value heat, but also can be microbially transformed into valuable bioproducts. There are many reports focusing on CO₂ or CH₄ microbial sequestration, but to enable microbial conversions of both biogases into bioproducts, a microbial consortium involving algae and bacteria can be used. Together, these microorganisms could rapidly metabolize high concentrations of CO₂ and CH₄, transforming them in valuable bioproducts.

TEAM:

Elen Aquino Perpetuo
*Project Coordinator*

Claudio A O do Nascimento (POLI-USP)
Maria Anita Mendes (POLI-USP)
Microbial production of polyhydroxybutyrate (PHB) from methane (CH₄)

RCGI PHYSICAL/CHEMISTRY PROGRAMME - PROJECT 18

ABSTRACT:

Polyhydroxybutyrate (PHB) is an attractive substitute for petroleum based plastic due to its similar properties, biocompatibility, and biodegradability. Among cheap substrates which are used for reducing total cost of PHB production, some C1 carbon sources, e.g., methane, methanol, and CO₂ have received a great deal of attention due to their serious role in environmental problems. Recently, many authors have reported the isolation and cultivation of methanotrophic bacteria that are able to produce PHB from methane and the feasibility of growing methanotrophic biomass in a fed batch reactor at ambient temperature and non-sterile conditions. Based on these findings, methane could be utilized as the carbon source of mixed culture to grow and produce PHB in a brief non-sterile process. These results will be very important to scale-up as an industrial process, where sterility could represent a problem. In this context, biotechnological process could be used to transform methane into value-added products. The challenge for this research is the establishment of optimal conditions for a high yield of product by methanotrophic bacteria in non-sterile conditions.

TEAM:

Elen Aquino Perpetuo
Project Coordinator

Claudio A O do Nascimento (POLI-USP)
Maria Anita Mendes (POLI-USP)
Structured ceramic membrane and supersonic device for $\text{CH}_4 / \text{CO}_2$ separation

RCGI PHYSICAL/CHEMISTRY PROGRAMME - PROJECT 19

ABSTRACT:

This project aims to develop ceramic composite membranes of hollow fiber for the physical separation of $\text{CO}_2$ from natural gas. These membranes must be stable and durable in the long term. A modular reactor containing the hollow fiber membranes will also be designed and built to assess their performance on a pilot scale. A second route of separation is also investigated: the development of a supersonic separator. The design of this particular device will employ state of the art optimization tools and numerical simulation techniques.

TEAM:

José Carlos Mierzwa  
*Project Coordinator*

Kang Li
**Supported metal nanoparticles as catalyst for the PROX reaction**

RCGI PHYSICAL/CHEMISTRY PROGRAMME - PROJECT 20

**ABSTRACT:**

The preferential CO oxidation (PROX) have been one of the most suitable methods of purification for hydrogen (H₂) in meeting the requirement for the Proton Exchange Membrane Fuel Cell (PEMFC) application, where the CO concentration should be controlled to be less than 10 ppm to avoid the degradation of fuel cell performance. Moreover, PROX catalysts that can selectively remove high concentrations of CO (above 1% volume) could contribute to reduce the size of fuel processors by minimizing the water-gas shift reactor. Despite these advances, the development of more active and stable catalysts is still in need. This research project aims to aid the development of supported nanostructured metals catalysts more active and stable for PROX reaction at low temperatures (around 100°C). Recent research has shown that a high dispersion of the noble metal nanoparticles as well the presence of metal species (that could adsorb and activate oxygen species) leads to a more active and stable catalysts at low reaction temperature. In this study, the catalyst will be prepared by two methodologies: an alcohol-reduction process developed at IPEN and by sol-gel, which permit to obtain a high dispersion of metal nanoparticles. Also, the composition of the catalyst will contain a combination of a noble and oxophilic metals.

**TEAM:**

Reinaldo Giudici  
*Project Coordinator*

Estevam Vitorio Spinacé (IPEN)  
Jorge Moreira Vaz (IPEN)  
Vanderlei Sergio Bergamaschi (IPEN)  
Rita Maria de Brito Alves (POLI-USP)  
José Mansur Assaf (EQ-UFSCar)  
Elisabete Moreira Assaf (IQSC-USP)
**Creation of the brazilian and São Paulo legal service of natural gas**

**RCGI ENERGY POLICIES AND ECONOMICS PROGRAMME - PROJECT 21**

**ABSTRACT:**

The scope of the project is to analyze the legal and regulatory frameworks applied to the natural gas sector in Brazil and Canada, considering specifically the states of São Paulo and Alberta, as well as to assess the impact of various natural gas regimes within the context of these countries. The project aims to organize a legal center that adds legal, regulatory and political natural gas. In addition to the compilation of federal and state legislation, specifically in the state of São Paulo, the legal center also aims to encourage comments and encourage discussions from the main natural gas experts from Brazil.

**TEAM:**

Hirdan Katarina de Medeiros Costa (IEE-USP)  
*Project Coordinator*

Edmilson Moutinho dos Santos (IEE-USP)  
Isabela Morbach Machado e Silva (FD-USP)  
Haline V Rocha (IEE-USP)  
Renata Rodrigues de Araújo (IEE-USP)  
Vitor Emanoel Siqueira Santos (IEE-USP)  
Luisa Weichert (FD-USP)
Producing studies “benchmark” about the efficient use of natural gas in the industrial sector

RCGI ENERGY POLICIES AND ECONOMICS PROGRAMME - PROJECT 22

ABSTRACT:

This project aims to globally monitor the development of compliance standards and energy management models applicable to sectors and processes related to the use of natural gas between the main international organizations, especially UNIDO (UN – Industrial Development Organization) and ISO (International Organization for Standardization). It seeks to identify the main line control initiatives and promotion of energy management systems, and to monitor international efforts for regulation and standards related to the use of gas. The main objective of this research is to identify industrial policies and strategies that lead to the development of unconventional natural gas markets in the industrial sectors. The project’s aims are not only to identify and evaluate specific technologies of industrial end-use of gas, but also produce reference studies on such technologies and policy and regulation tools that can improve their accessibility and use in the domestic industry.

TEAM:

Murilo Tadeu Werneck Fagá (IEE-USP)
Alberto José Fossa (ABRINSTAL)
Project Coordinator

Edmilson Moutinho dos Santos (IEE-USP)
Paul L Poulallion (SINDE)
Brazilian inventory of greenhouse gases and scenarios for reducing emissions related to natural gas

RCGI ENERGY POLICIES AND ECONOMICS PROGRAMME - PROJECT 23

ABSTRACT:

The main objective of this project is to estimate the current (2014) and future Greenhouse Gases (GHG) emissions in Brazil, as well as, to develop tools to estimate the impact related to natural gas use. For this, we will develop long-term energy scenarios in order to analyze the impact of different scenarios related to natural gas use and its contribution to the Brazilian GHG emission reductions commitments.

TEAM:

Edmilson Moutinho dos Santos (IEE/USP)
Adelino Ricardo J Esparta (IEE/USP)
Oswaldo Lucon (IEE/USP)
Luz Dondero (IEE/USP)
Denis Fraga (IEE/USP)
Estimation of price elasticities and income of natural gas in Brazil

RCGI ENERGY POLICIES AND ECONOMICS PROGRAMME - PROJECT 24

ABSTRACT:

The objective of this research is to undertake econometric estimate of price elasticity and income elasticity for demand for natural gas in Brazil. The work will pay special attention to the industrial sector of the country, which has been responsible for over 60% of total firm Brazilian natural gas consumption, but also factor in the recent change in the electricity generation mix, including a higher share of thermo plants. Terms of reducing carbon emissions to promote reductions mainly by switching to lower carbon alternatives will be considered for possible scenarios. To estimate price and income elasticities for Brazilian demand natural gas in several segments, the project will apply econometric tools. The main objective is to examine how demand reacts to increase / decrease in energy prices and disposable income. The modeling and analysis will take into account the dynamics and the prospects for increased international pressure to reduce emissions and the Brazilian short and long-term prospects for electricity generation.

TEAM:

Virginia Parente (IEE-USP)  
Project Coordinator

Marcio Issao Nakane (FEA-USP)
Natural gas sustainability of integrated analysis as a transportation fuel in heavy vehicles:
the Blue Corridor Paulista

RCGI ENERGY POLICIES AND ECONOMICS PROGRAMME - PROJECT 25

ABSTRACT:

This project will develop a simulation model inspired by the blue corridors concept. This idea was proposed and has been debated for nearly a decade, and some experiments are already active in Europe and the United States. Blue corridors are routes for road transport (usually trucks) using natural gas (compressed – CNG – or liquefied – LNG). The diesel, mainly used by trucks, is the energy source that most presses Brazilian refining capacity, generating deficits of billions of dollars annually in the Brazilian trade balance. However, Brazil has abundant natural gas reserves and currently the world has recognized natural gas as a more sustainable energy solution for the transport sector, especially loads road transport (trucks). The objectives of this study are:

• To set the location of a blue corridor in the State of São Paulo;
• To carry out a survey of the necessary infrastructure for its deployment, including the costs of adapting vehicles to use natural gas;
• To conduct a substitution simulation of the diesel fuelled truck fleet for same size vehicles powered by natural gas, and estimate fuel consumption and pollutants and greenhouse gases emissions.
• To propose industrial policies and strategies that could lead to development and implementation of the blue corridor in São Paulo.

TEAM:

Dominique Mouette (EACH-USP)
Project Coordinator

Rodrigo Galbieri (IEE-USP)
Thiago Brito (IEE-USP)
Evaluation of small LNG and CNG drives as options for the supply, transmission and distribution in Brazil

RCGI ENERGY POLICIES AND ECONOMICS PROGRAMME - PROJECT 26

ABSTRACT:

The objective of this research is to analyze and evaluate alternatives for any tablet or liquefy natural gas (LNG) in small plants and compressed natural gas (CNG) transportation / LNG by truck (or other transportation modes such as barges on waterways, rail or coastal vessels) to serve consumers in remote off-grid areas in southeastern Brazil. The research will also investigate the potential to create hybrid LNG-CNG corridors along the main Brazilian highways to attract long-haul transport and intercity buses and trucks. The project will also carry out a critical analysis and integrated planning methodologies for expansion and operation of integrated multimodal networks, including the review of some of the technical and economic parameters used by the Federal Government in its natural gas logistics plan (Pemat). The project will develop an economic alternative modeling based on a broader and more integrated view of gas logistics. The project aims to identify viable alternatives for extension or expansion of the infrastructure of natural gas structure, in addition to the pipeline network, as well as identify solutions for the operational planning of the most sophisticated and complex networks. The project analyzes the extensive international experience of the main cases in which (at least initially) the expansion of the gas logistics did not occur with plumbing, but with distribution networks in mass with natural gas in the form of LNG or CNG.

TEAM:

Edmilson Moutinho dos Santos (IEE-USP)
Project Coordinator

Ieda Gomes
Paul L Poulallion
The biomethane’s contribution prospects to increase the supply of natural gas

ABSTRACT:

The objective of this research is to analyze prospects, their corresponding benefits and potential barriers and to propose appropriate policies for integrated solutions using biomethane [1] as a contributor to the supply of natural gas (NG). The objective is to analyze the contribution of these solutions to increase the supply of biomethane and natural gas to the energy matrix of the State of São Paulo. The project also includes the creation of a greenhouse gas emissions reduction framework for full or partial replacement of diesel by biomethane, a renewable natural gas.

The research will include reviewing and evaluating processes involved in: production i) biogas from vinasse, urban and rural waste and the different options for its use (biogas, biomethane, hydrogen production, biomethane injection pipelines natural gas or as compressed natural gas (CNG); and ii) biomethane fueling motor vehicles (with particular emphasis on transport and agricultural equipment used for the production of sugarcane in the state of São Paulo). In summary, this proposal aims to analyze the technical and economic perspectives of biogas production and upgrading, both in urban and rural areas, taking into account the integration of biomethane and natural gas. The project will assess the corresponding potential barriers and benefits, and will propose appropriate public policies to achieve solutions.

TEAM:

Suani Coelho
Project Coordinator – GBIO/IEE/USP

Alessandro Sanches Pereira (IEE/USP- Post Doctoral Fellow)
Marilin Mariano dos Santos (IEE/USP- Post Doctoral Fellow)
Vanessa Pecora Garcilasso (IEE/USP – Post Doctoral Fellow)
Manuel Moreno Poveda (Bioenergy Program USP PhD Candidate)
Danilo Perecin (IEE/USP-Master student)
Analysis of the potential household use of natural gas integrated to electricity system in the city of São Paulo

RCGI ENERGY POLICIES AND ECONOMICS PROGRAMME - PROJECT 28

ABSTRACT:

In the context of the city of São Paulo, where domestic use of electricity is highly predominant, this project aims to demonstrate the hypothesis that gas and electricity could be equally used in households in an complementary way.

TEAM:

Luis Antonio Bittar Venturi (Prof Dept of Geograph - USP)  
Project Coordinator

Alexandre Vastella Ferreira de Melo (Master Researcher)  
Felipe Ferraz Machado (Research Assistant)  
Greta Yale Lima dos Santos (IC Researcher)  
Pedro Paulo Fernandes da Silva (Msc Researcher)