Research Activities in Energy and Opportunities for Collaboration

Athanasiou G. Konstandopoulos

Member of the JRC Board of Governors
Chairman of the Board and Managing Director
Centre for Research & Technology - Hellas
“...γῆ μὲν ὄπόση πόσους σώφρονας ὄντας ἴκανη τρέφειν, πλείονος δὲ οὐδὲν προσδεῖ...”
Πλάτων, Νόμοι, 360 π.Χ.

“The land must be sufficient to support no more than a certain number of people living with moderation...”
Plato, Laws, 360 B.C.
Outline

- CERTH overview
- Energy, Environment and Sustainable Mobility Research
- Opportunities for Collaboration in the Region
- Epilogue
Centre for Research and Technology-Hellas (CERTH)

- 5 Institutes
- Emphasis on RTD & Innovation
- Strong collaboration with international industry
- Strong co-operation with Universities and Research Institutes worldwide
- Unique Infrastructures especially in Energy, Environment and Sustainable Mobility
CERTH at a Glance
www.certh.gr

- **Established:** in 2000 (CPERI existing since 1985)
- **Personnel:** 600+ with majority being engineers
- **Annual Turnover:** € 20+ Million yearly average for the last 10 years.
  - >30% from bilateral industrial research contracts
  - >60% from competitive research projects and
  - <10% as government institutional funding
- **Return-on-Investment 9:1** for each € of institutional funding
- **Center of Excellence** Top-20 (16th) EU Research Centers in FP7 competitive grants (2007=today). 300+ active projects/year (>3000 total)
- **Numerous awards and distinctions** (including EU Descartes Prize, ERC and REG-POT Grants and many more)
- **Spin-offs:** 5 started (4 active), 2 in preparation **Incubator:** 8 companies
Goal for Today’s Talk:
Stairway to (Energy) Heaven

Energy Content

High

CH₄

-4

CₓHᵧ

-2

hydrocarbons, oil, alcohols

-1

carbon, carbohydrates

0

carbons, carbohydrates

-2

CO

+2

carbonates, oxygenated organics

-1

CO₂

+4

polymers
Some Unique Infrastructures in Energy and Supporting Material Technologies

Nanoparticle Synthesis

Ceramics Processing

Coating/Functionalization
Some Unique Infrastructures in Energy and Supporting Material Technologies

- Specialized Laboratories
- Pilot Plants
- Solar Simulator
- Vehicle Simulator
- Engine and Vehicle Testing
- Field Testing
The Concept of the Energy Corridor: A Holistic Approach to Sustainability
### International Network of Industrial Collaborations

**Scope:** Energy, Transport, Environment, Materials

<table>
<thead>
<tr>
<th>USA</th>
<th>Europe</th>
<th>Greece</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>- CORNING</td>
<td>- DAIMLER (Germany)</td>
<td>- S &amp; B INDUSTRIAL MINERALS</td>
<td>- HONDA</td>
</tr>
<tr>
<td>- DOW CHEMICAL CO</td>
<td>- FIAT (Italy)</td>
<td>- BEDA EXHAUST SYSTEMS</td>
<td>- IBIDEN</td>
</tr>
<tr>
<td>- DUPONT</td>
<td>- RENAULT (France)</td>
<td>- PPC</td>
<td>- NGK</td>
</tr>
<tr>
<td>- DELPHI</td>
<td>- VW (Germany)</td>
<td>- THERMOLITH</td>
<td>- TOYOTA</td>
</tr>
<tr>
<td>- GEO2</td>
<td>- PSA (France)</td>
<td>- KELIM</td>
<td>- SUMITOMO</td>
</tr>
<tr>
<td>- JOHN DEERE</td>
<td>- JOHNSON MATTHEY (UK)</td>
<td>- IDEAL STANDARD</td>
<td></td>
</tr>
</tbody>
</table>
Domestic Contribution to SME Growth

Knowledge Creation & Transfer

Renewables / Low Carbon Energy Sources
Energy Efficiency/Emission Control

Novel Products & Markets
Energy Corridors in Macedonia and Thrace

Regional Innovation and Smart Specialization
Some Representative Technologies

- CO$_2$ emissions reduction (energy efficiency, capture and management/reuse of CO$_2$)
- Zero/Neutral Carbon Fuels (biofuels/biorefinery, solar fuels)
- Sustainable transport (Green mobility)
- Smart Grids, Smart environments, Smart neighborhoods/cities
- Tools for Mapping the Exposome
Some Success Stories: Emission Control

Diesel Exhaust Aftertreatment (DEXA)

Establishment of
- Catalytic DPF technology
- Integrated Simulation
- Nanoparticle Measurement
Dear Athanasios

As chief designer of diesel particulate filter for Audi R10, no one could tell more than I do about the contributions from you and your team's productive work. It would be impossible for Dow to bring such a new DPF technology to the world without collaborating and working with your group in the past six years.

Cheng G. Li (PhD)
Development Scientist
Dow Automotive
Biological Effects of Nanoparticles - Exposomics

Size Specific Particle Sampler (SPS)

Multiculture Exposure Chamber (MEC)

Oxidative stress response

NFκb gene promoter activity

Top-10 Finalist in “Greece Innovates” Competition
Morphology and mobility of synthetic colloidal aggregates

Anastasios D. Melas\textsuperscript{a,b,*}, Lorenzo Isella\textsuperscript{c}, Athanasios G. Konstandopoulos\textsuperscript{b,d}, Yannis Drossinos\textsuperscript{a}

\textsuperscript{a} European Commission, Joint Research Centre, I-21027 Ispra, VA, Italy
\textsuperscript{b} Department of Chemical Engineering, Aristotle University, GR-54124 Thessaloniki, Greece
\textsuperscript{c} European Commission, DG Energy, I-2530 Luxembourg, Luxembourg
\textsuperscript{d} Aerosol & Particle Technology Laboratory, CERTH/CPERI, P.O. Box 60361, GR-57001 Thessaloniki, Greece

\textbf{ARTICLE INFO}

Article history:
Received 16 May 2013

\textbf{ABSTRACT}

The relationship between geometric and dynamic properties of fractal-like aggregates is studied in the continuum mass and momentum-transfer regimes. The synthetic aggregates were generated by a clus-
FLAGSHIP IN CLEAN ENERGY:
Carbon Neutral Solar Fuel Technology

EXPO 2005
IPHE 2006
Descartes Prize 2007
EU IDEAS Award 2010
Key Enabling Technology: Redox Materials

Oxidation of reduced oxide

\[
\begin{align*}
M_x O_{y-\delta} + \delta & \rightarrow \delta H_2 + M_x O_y \\
CO_2 & \rightarrow \delta CO + M_x O_y \\
1/2O_2 & \rightarrow Q + M_x O_y
\end{align*}
\]

\(\text{Syngas (H}_2\text{+CO)}\)

Thermal reduction of oxide

\[
M_x O_y + Q \rightarrow M_x O_{y-\delta} + \delta/2O_2
\]

\(\text{Heat storage}\)
Clean Energy & Materials from Sun, H$_2$O & CO$_2$

H$_2$ + CO $\rightarrow$ C$_x$H$_y$ (Liquid Fuels/Fischer-Tropsch process)

4H$_2$ + CO$_2$ $\rightarrow$ CH$_4$ + 2H$_2$O (Gas fuels, methane/Sabatier process)

H$_2$ + CO $\rightarrow$ C$_x$H$_y$ (Plastics)

Sustainable Storage of Carbon AND Hydrogen!
Technology Evolution

- **HYDROSOL-I**: 3 kW, first production of solar H₂
- **HYDROSOL-II**: 3 kW x 2, continuous H₂ production
- **HYDROSOL-3D**: 100 kW x 2, pilot plant
- **HYDROSOL-PLANT**: 1 MW plant design
- **PROMETHEUS**: 1 MW installation

Timeline:
- 2004: HYDROSOL-I
- 2005: HYDROSOL-II
- 2008: HYDROSOL-3D
- 2011: HYDROSOL-PLANT
- 2014: PROMETHEUS
- 2015: 750 kW plant
Wide Appeal of Our Solar Fuels Concept


A power plant that makes hydrogen by splitting water with concentrated sunlight launches in Almeria, Spain, on 31 March. It’s a glimpse into a possible carbon-free future that uses solar-driven chemical reactions to produce the gas.

The reactor, Hydrosol II, is the largest pilot-scale project of its kind, though hundreds of thermochemical water splitting schemes have been sketched out on paper and tested in laboratories. The system will take half a litre of water every minute and should produce around 3 kilograms of hydrogen an hour—equivalent to a thermal output of 800kW, explains project coordinator Athanasios Konstandopoulos, who works for the Chemical Process Engineering Research Institute based in Thessaloniki, Greece.

12 August 2010 by Helen Knight

A renewable carbon economy? Hardly that’s a pipe dream! Perhaps not, not now that solar power facilities are cropping up in deserts across California, Spain and North Africa. The idea is to use the sun’s powerful chemical potential to split carbon dioxide—combine the resulting carbon monoxide with hydrogen and you have the beginnings of a solar fuel that could one day replace oil.

Since 2006, a European consortium led by Athanasios Konstandopoulos of the Centre for Research and Technology Hellas, Thessaloniki, Greece, has been operating a 100-kilowatt pilot plant that generates hydrogen from a combination of sunlight and steam. The plant is sited at a concentrating solar power tower—the Plataforma Solar de Almeria, in Almeria, Spain—which has a series of mirrors to concentrate the sun’s rays onto solar panels below.

The same technology can also be used to split CO₂—the resulting CO can be combined with the hydrogen to form hydrocarbons, the team say.

The pilot plant contains a ceramic reactor packed with a honeycomb network of ceramics coated in a mixed iron and cerium oxide. Concentrated solar energy heats the reactor to around 1200 °C, releasing oxygen gas, which is pumped away. The reactor is then cooled to around 600 °C before steam is fed through the honeycombs—the depleted material steams back oxygen and in the process converts the steam into hydrogen gas.

Pilot plant

The team has run the pilot plant in several week-long bursts since its launch as part of the European Commission-funded HydroSol II project. They claim that it is possible to convert up to 10 per cent of the steam into hydrogen.

Now, Konstandopoulos and colleagues have successfully used the same reactor technology and process to split carbon dioxide into carbon monoxide in the lab. Two reactions running simultaneously could generate hydrogen and carbon monoxide, which could be combined into synthetic fuel using one of two established chemical processes, says Konstandopoulos.

In the Sabatier process the five gases are heated at high pressure in the presence of a copper catalyst to produce methane or methanol, when water is added. In a second reaction, the resulting hydrogen can be split and used to generate electricity. This leaves CO₂ as a byproduct, which can be recycled into CO for use in the Sabatier process or left as a greenhouse gas.
Inventing The Future
(aka Opportunities for Collaboration in the Region)
Emission Control: New Frontiers

cabin air quality control

cabin air sensors

passenger exposure

exhaust sensors

In-Use compliance
Emission Control: New Frontiers

Diesel Locomotives

Marine Diesel Engines
- Inland waters
- Open waters

Large Ships

Off-Road Vehicles
Current Research Challenges

- **Future Emission Control** systems
  - Highly efficient and compact
  - With improved aging tolerance
  - Tailored to specific application (e.g. **hybrids**, gas-fueled engines, dual fuel systems, fuel-flexible engines, etc)
  - “Smart” – sensors/intelligent control/OBD

- **Real-driving emissions**
  (including emissions from brakes/tires/road surfaces) and their environmental and **biological impact** assessment (“exposome”)

- **Off-Road Emission Control**
  - Emission control systems for **railroads**
  - Emission control systems for **ships**

- **Carbon-Neutral Energy Carriers and Energy Storage**
  - Solar fuels
  - Thermochemical storage
  - **Electrochemical storage** (Batteries)
Vision: Sustainable Mobility and Clean Energy

Solar Fuel Reactor

Multifunctional Emission Control Reactor

CO₂, NOₓ, Soot

ICE
Biomimetic Integration of North and South: Energy Corridors

CO₂ producing Plants @ North

VEINS: CO₂ pipelines from Carbon Capture

Solar Fuel Plants @ South

ARteries: Carbon Neutral Solar Fuels Pipelines
Energy Corridor between Emirates-EU

QATAR: Solar Fuel Production

Ship carries LNG from Qatar to EU
Ship brings from EU CO₂ to Qatar

EU CO₂ export site
Epilogue: Mare Nostrum (reloaded)
Acknowledgments

- The European Commission for supporting our research in combustion engines and their emissions through >24 projects over the last 18 years including projects APT-STEP, CLEANER-D, HCV and our partners in these projects.

- The European Commission for supporting our Hydrogen and Solar Fuels research with >16 projects including projects ARMOS, RESTRUCTURE, STORRE, NEMESIS2+, ARTIPHYCION, BIOROBUR, EU-SOLARIS, HYDROSOL-3D and our partners in these projects.

- The Greek Secretariat for Research and Technology for supporting our research through projects HYDROSOL+ and NANOREDSOL.

- Past and Current Industrial Partners including Molycorp, Tenneco, Ibiden, Honda, CR Fiat, AVL

- My colleagues at CERTH