France-Japan Joint Forum on Solar Energy

8-9 October, 2018

University of Perpignan Via Domitia (UPVD)

Perpignan, France

UPVD Université de Perpignan Via Domitia

JSPS

cnrs PROMES

Perspective

The forum, jointly organized by the Japan Society for the Promotion of Science (JSPS) and the University of Perpignan Via Domitia (UPVD), the Processes, Materials and Solar Energy (PROMES-CNRS) laboratory will give the opportunity to researchers, university lecturers, and industrial engineers to investigate social issues and technological challenges related to the large-scale deployment of solar technologies such as solar thermal, solar photovoltaics, concentrator photovoltaics, and concentrated solar power. Not only appealing to scientists committed to solar energy, but also to a large audience by promoting scientific popularization, the forum will aim to establish a holistic view of the industrial sector, particularly in France and Japan. First and foremost, it will address the main scientific and technical bottlenecks to overcome in order to support this sector, as well as performance-enhancing levers, to ultimately favor the deployment of such technologies and reduce their cost.

Among other things, the forum will focus on technological advances in photovoltaic conversion and solar to hydrogen conversion. Furthermore, energy vectors from solar concentrated solar energy, solar resource assessment and forecasting, and penetration of distributed generation into the power system, especially solar photovoltaics, will be addressed. Finally, new valuation and storage methods for solar energy will be presented, thermochemical processes and solar advanced oxidation processes for water treatment to name a few.

Organizing Institutions

UPVD Université de Perpignan Via Domitia — JSPS — cnrs — PROMES

Organizers

France-side: Stéphane Grieu (UPVD, PROMES-CNRS, France)
Japan-side: Masakazu Sugiyama (The University of Tokyo, Japan)

Local Organizing Committee

Prof. Stéphane Grieu, UPVD, PROMES-CNRS
Prof. Didier Aussel, UPVD, PROMES-CNRS
Ass. Prof. Julien Eynard, UPVD, PROMES-CNRS
Ass. Prof. Stéphane Thil, UPVD, PROMES-CNRS
Nouha Dkhili, PhD student, UPVD, PROMES-CNRS
Julien Nou, postdoctoral fellow, PROMES-CNRS

Program

October 8, 2018

Session 1 (lecture theatre 5, building U, UPVD, Perpignan)

08:30 - 08:45	Kazuhiko Saigo, JSPS, Stéphane Grieu, UPVD/PROMES-CNRS, *Opening of the forum*
08:45 - 09:30	Alain Dollet, PROMES-CNRS, *Energy vectors from concentrated solar energy*
09:30 - 10:15	Kensuke Nishioka, Miyazaki University, *Solar to hydrogen conversion system by combining concentrator photovoltaic modules and electrochemical cells*
10:15 - 10:45	Coffee break
10:45 - 11:30	Tatsuoki Kono, Tohoku University, *Hydrogen energy system by using solar energy*
11:30 - 12:15	Masakazu Sugiyama, The University of Tokyo, *A global network of hydrogen for disruptive installation of renewable energy*

Session 2 (lecture theatre 5, building U, UPVD, Perpignan)

14:00 - 14:45	Philippe Blanc, Mines ParisTech, *Earth observation for solar resource assessment and forecasting*
14:45 - 15:30	Stéphane Grieu, UPVD/PROMES-CNRS, *Towards the intrahour forecasting of direct normal irradiance using sky-imaging data*
15:30 - 16:00	Coffee break
16:00 - 16:45	Tomoyoshi Motohiro, Nagoya University, *Development of compact solar-pumped laser systems and their application to photovoltaics*
16:45 - 17:30	Nathalie Mazet, PROMES-CNRS, *Solar energy storage by thermochemical processes*
17:30 - 18:15	Vincent Goetz, PROMES-CNRS, *Solar advanced oxidation processes for water treatment*

October 9, 2018

Session 3 (lecture theatre 5, building U, UPVD, Perpignan)

08:30 - 09:15	Yoshiaki Nakano, The University of Tokyo, *High-efficiency & low-cost photovoltaic using III-V compound semiconductors*
09:15 - 10:00	Jean-François Guillemoles, IPVF/NextPV, *High efficiency and low cost PV: new materials? New concepts? Or both?*
10:00 - 10:30	Coffee break
10:30 - 11:15	Olivier Carré, ENEDIS, *How Enedis (the French DSO) tackles the DER insertion challenges on its MV and LV networks*
11:15 - 11:45	Sataro Yamaguchi, Chubu University, *Thermo-hydrodynamic analysis and cable design for 10 km to 100 km superconducting DC power transmission line using Ishikari experimental data and their perspective*

Alain DOLLET

Processes, Materials and Solar Energy laboratory

CNRS - FRANCE

Education:

- Dr. Alain Dollet is research director (senior researcher) at the French National Centre for Scientific Research (CNRS). Graduated in Chemical Engineering from "Ecole Nationale Supérieure d'Ingénieurs en Génie Chimique de Toulouse "(ENSIGC) in 1988, he obtained his PhD in the field of plasma processes in 1993 at Toulouse University. He joined CNRS as researcher in 1994, starting his carrier in PROMES (Processes, Materials and Solar Energy) laboratory in Odeillo. His first research works at CNRS focused on modeling of chemical vapor deposition. In 2005, he started developing a new research activity in the field of photovoltaic conversion of concentrated solar energy (CPV). His current research works are mainly focused on ultra-high concentration PV (HCPV) and characterization of cells under natural concentrated sunlight. He has published about 80 papers in international journals and conferences and he is member of the scientific board of the International Conference on Photovoltaic conversion under concentration (CPV-x) for several years.
- Dr. Alain Dollet is currently the head of PROMES (Processes, Materials and Solar Energy) laboratory. He is also co-director of the international research network SINERGIE, a French-Singaporean network dedicated to Renewable Energy which was created from a joint initiative of CNRS and NTU (Singapore) in 2016. From 2012 to 2016, before being appointed director of PROMES laboratory, he was in charge of the energy sector at CNRS and scientific deputy director of the Institute of Engineering and Systems Sciences (INSIS), one of the ten CNRS institutes. He has also been deputy director of PROMES laboratory from 2004 to 2010.
  He is also coordinator of the "Energy" editorial committee at ISTE- Wiley editions for several years.

Scientific Interests :

- Concentrating Photovoltaics. Concentrated Solar Energy. Renewable Energy. Heat and Mass transfer modeling. Multi-junction solar cells.

Recent papers :

- J. Zeitouny, N. Lalau, J. M. Gordon, E. A. Katz, G. Flamant, A. Dollet, A. Vossier, "Assessing high-temperature photovoltaic performance for solar hybrid power plants", Solar Energy Materials and Solar Cells 182 (2018) 61–67
- A. Vossier, J. Zeitouny, E. A. Katz, A. Dollet, G. Flamant, J. M. Gordon, "Performance bounds and perspective for hybrid solar photovoltaic/thermal electricity-generation strategies", Sustainable Energy & Fuels,2 (2018) 2060-2067
- J. Zeitouny, E. A. Katz, A. Dollet, A. Vossier "Band Gap Engineering of Multi-Junction Solar Cells: Effects of Series Resistances and Solar Concentration", Scientific Reports 7 (2017) 1766

Energy vectors from concentrated solar energy

Alain DOLLET

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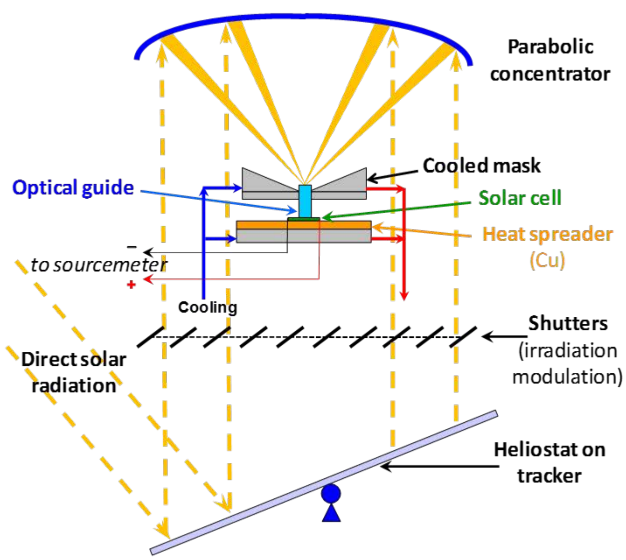
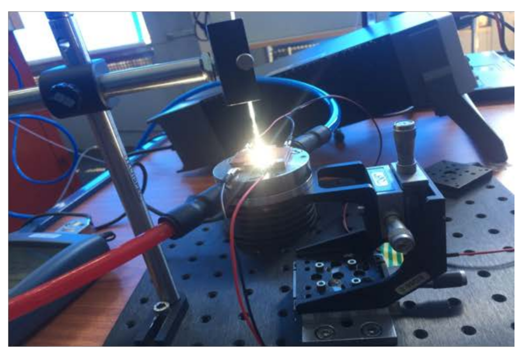
Concentrated Solar technologies are usually associated to Concentrated Solar Power (CSP), that is, to rather large plants generating electricity from fluids heated by concentrated solar radiation and expanded in gas or vapour turbines. Concentrating Photovoltaics (CPV) is another technology based on solar concentration which turn out to be very interesting for green electricity generation. CPV received increasing attention over the last 15 years owing to the development of multi-junction cells which demonstrated solar-to-electricity conversion efficiencies up to 46 %. Despite higher system costs as compared to Photovoltaics (CPV or conventional PV), Concentrating Solar Thermal remain very attractive because it allows larger capacity and cheaper energy storage as well as the possible direct generation of medium to high temperature heat. CST related technologies can be used for the production of electricity and heat but also for the production of solar fuels such as hydrogen or syngas.

In this presentation, we will first briefly review the state-of-the-art of the main Concentrated Solar technologies before discussing the related challenges that will be illustrated by several examples of the research conducted in PROMES laboratory.





Setup for HCPV cells characterization developed in PROMES

Kensuke NISHIOKA

University of Miyazaki

Faculty of Engineering

Education:

- March, 1998 Bachelor of chemical engineering, Osaka University, Osaka, Japan
- March, 2001 Master of materials science, Nara Institute of Science and Technology, Nara, Japan
- March, 2004 Doctor of materials science, Nara Institute of Science and Technology, Nara, Japan (Ph. D)

Scientific Interests:

- Renewable energy
- Concentrator photovoltaic (CPV)
- Solar-to-hydrogen conversion

Recent papers :

- Accurate measurement and estimation of solar cell temperature in photovoltaic module operating in real environmental conditions: Kensuke Nishioka*, Kazuyuki Miyamura, Yasuyuki Ota, Minoru Akitomi, Yasuo Chiba, and Atsushi Masuda: Japanese Journal of Applied Physics, Volume 57, Number 8S3, 08RG08-1 – 08RG08-5, 2018/7/13
- Highly efficient 470W solar-to-hydrogen conversion system based on concentrator photovoltaic modules with dynamic control of operating point: Yasuyuki Ota*, Daiji Yamashita, Hiroshi Nakao, Yu Yonezawa, Yoshiyasu Nakashima, Hiroji Ebe, Makoto Inagaki, Rui Mikami, Yoshiya Abiko, Takashi Iwasaki, Masakazu Sugiyama, and Kensuke Nishioka: Applied Physics Express, Volume 11, Number 7, 077101-1 - 077101-4, 2018/6/20

Solar to hydrogen conversion system by combining concentrator photovoltaic modules and electrochemical cells

Kensuke NISHIOKA

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Solar to chemical conversion systems have become vital in today's energy environment because of the long-term storage potential of solar energy and its ability to be effectively transformed into useful substances. The simplest and most widely conducted solar to chemical conversion is solar hydrogen production, which can be performed by water electrolysis. The chemical free energy of hydrogen converted from solar energy can then be used to generate electricity on demand. One of the methods for splitting water into hydrogen and oxygen is the combined use of a photovoltaic (PV) system and electrochemical (EC) cells. In particular, with the combined use of a PV system and a EC cell, the solar–to-hydrogen (STH) conversion efficiency has been steadily improving.

Using an optimized system comprising concentrator photovoltaic (CPV) modules, electrolyzers, and DC/DC converters for dynamic control (Fig. 1), we achieved a one-day STH efficiency of 18.78%—the highest value for a sub-kilowatt-scale PV system under outdoor operation.

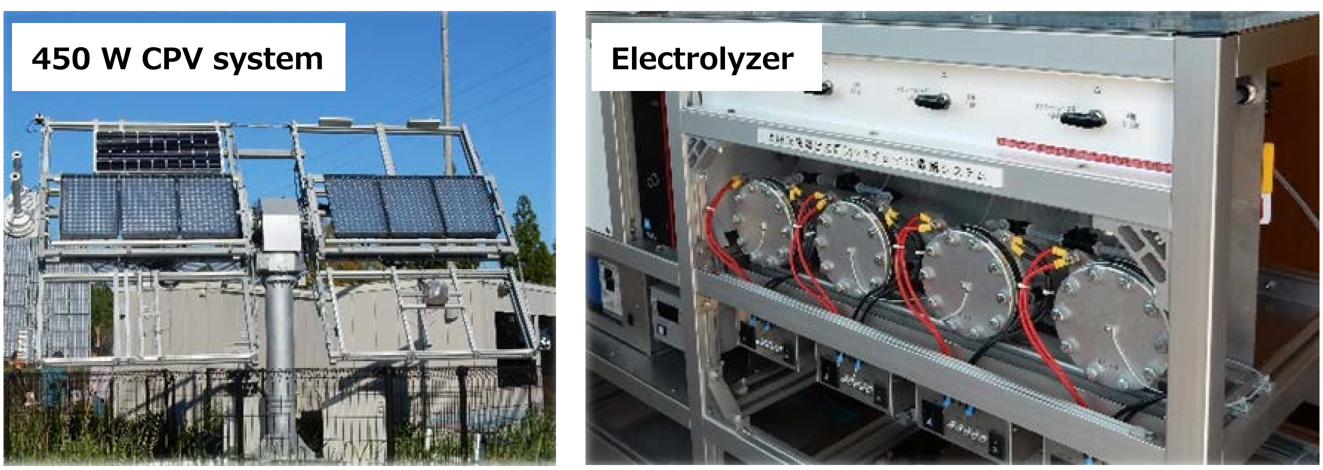

Fig. 1 STH system comprising CPV modules, electrolyzers, and DC/DC converters.

Prof. Tatsuoki KONO, Ph. D.

Institute for Materials Research /
Material Solutions Center

Tohoku University

Experience:

- 1993-2012 : Chief Scientist, R&D center of Toshiba Corpration
- 2012-2014 : Head, Aqua Research Centre of Toshiba Asia Pacific, Singapore
- 2014-2016 : Senior manager, New Energy Solution Project, Toshiba Corpration
- 2016- : Professor, Institute for Materials Research, Tohoku University
- 2017- : Project Leader, Material Solutions Center, Tohoku University

Invention :

- “Super Lattice” Hydrogen storage Alloy : La-Mg-Ni_{3-4} system alloy
  applied for Nickel-Hydride Battery : Eneloop (https://en.wikipedia.org/wiki/Eneloop)
- Hydrogen Energy supply system : H_2One (https://www.toshiba-newenergy.com/en/products)
  The hydrogen Energy Supply System, H_2One, equipped with solar power generation system, batteries, electrolyzer, hydrogen storage alloy tank and water tank, and fuel cells will be an attractive way to improve the conventional energy storage technologies including pumped or reservoir-based hydro-electric facilities, and conventional type batteries.
- Water Treatment System : Functional Powder technology
  (https://www.toshiba.co.jp/about/press/2012_06/pr2701.htm)
  “Functional Powder” technology can not only absorb toxic elements from used water, but also extract valuable elements for recycling, including rare metals. The powder can replace the chemicals used in conventional industrial used water treatment processes for the removal of such toxic compounds and is more cost efficient as it can be reused.

Recent papers :

- Tatsuoki KONO, "Hydrogen Energy System by using Hydrogen Storage alloy", Journal of the Hydrogen Energy Systems Society of Japan, 2017, 42(4), 218-221.
- Ryo NAKAJIMA, Tatsuoki KONO, Kentaro MATSUNAGA, “Energy Storage and Supply Systems by Utilizing Hydrogen Derived from Renewable Energy”, Journal of the Hydrogen Energy Systems Society of Japan, 2015, 40(4), 215-222.

Hydrogen energy system by using solar energy

Prof. Tatsuoki KONO, Ph. D.

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http://www.masc.tohoku.ac.jp/english/projects/10.html

Hydrogen Energy system contains solar power generation system, lithium ion batteries, electrolyzer, hydrogen storage alloy (MH) tank and water tank, and pure hydrogen fuel cells. The hydrogen energy supply system, H_2One™ designed as Resort Model made by Toshiba corporation, was already launched and commercialized in 2016 has entered operation in the building of the smart hotel named Henn na Hotel, at the Huis Ten Bosch theme park in Nagasaki, Kyushu, Japan. By using this energy system, long hours of sunshine allow solar power generation to provide more than enough electricity to power the 12 rooms of Hennna Hotel in summer time. This system will be able to use surplus power to electrolyze pure water and produce hydrogen. This hydrogen will be stored in hydrogen storage alloy tank, for use on demand, and in winter time it will be used to pure hydrogen fuel cells that generate electricity and warm water. The H_2One™ as Resort Model is also equipped with the new MH tank that contains AB_5 type alloy supporting much improved high-energy density. This MH tank is less than one-tenth of the size of the conventional type gas tank it replaces, and suitable for use in small area.

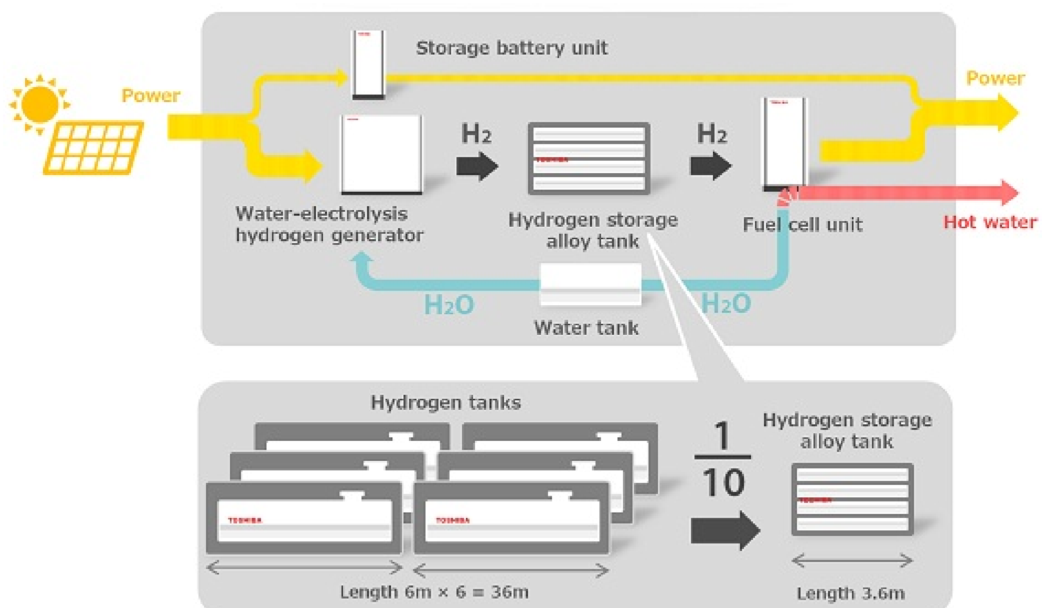

Fig. 1 System structure of hydrogen energy supply system[1)]

[1] http://www.toshiba.co.jp/about/press/2015_10/pr0701.htm

Masakazu SUGIYAMA

Research Center for Advanced Science and Technology

The University of Tokyo

Education:

- 2000 Ph.D, Chemical System Engineering, The University of Tokyo (UTokyo)
- 2000 Research Associate, Department of Chemical System Engineering, UTokyo
- 2002 Lecturer, Department of Electronic Engineering, School of Engineering, UTokyo
- 2005 Associate Professor, 2016 Professor in the same department
- 2017 Professor, Research Center for Advanced Science and Technology, UTokyo

Scientific Interests :

- High-efficiency solar cells using III-V semiconductors
- Crystal growth of III-V semiconductors
- Energy systems coupled with high-efficiency solar cells

Recent papers :

- M. Sugiyama, K. Fujii and S. Nakamura (eds.), "Solar to Chemical Energy Conversion — Theory and Applications —," Springer, ISSN 2195-1284 (2016).
- M. Sugiyama, "Photovoltaic power generation." A chapter in "Energy Technology Roadmaps of Japan —Future Energy Systems Based on Feasible Technologies Beyond 2030—," by Y. Kato, M. Koyama, Y. Kukushima, T. Nakagaki (eds.), Springer, ISBN 978-4-431-55951-1.
- Y. Ota, D. Yamashita, H. Nakao, Y. Yonezawa, Y. Nakashima, H. Ebe, M. Inagaki, R. Mikami, Y. Abiko, T. Iwasaki, M. Sugiyama, K. Nishioka, "Highly efficient 470 W solar-to-hydrogen conversion system based on concentrator photovoltaic modules with dynamic control of operating point," Appl. Phys. Express v. 11, no. 7, p. 077101 (2018)
- H. Sodabanlu, A. Ubukata, K. Watanabe, T. Sugaya, Y. Nakano, M. Sugiyama, "Extremely High-Speed GaAs Growth by MOVPE for Low-Cost PV Application," IEEE J. Photovoltaics 8 (3), 887-894 (2018)
- A. Nakamura, M. Suzuki, K. Fujii, Y. Nakano, M. Sugiyama, "Low-temperature growth of AlN and GaN by metal organic vapor phase epitaxy for polarization engineered water splitting photocathode," J. Crystal Growth, 464, 180-184 (2017)
- M. Sugiyama, H. Fujii, T. Katoh, K. Toprasertpong, H. Sodabanlu, K. Watanabe, D. Alonso-Álvarez, N. J. Ekins-Daukes and Y. Nakano, "Quantum Wire-on-Well (WoW) Cell with Long Carrier Lifetime for Efficient Carrier Transport," Prog. Photovoltaics Res. Appl., **24**, 1606-14 (2016).
- A. Nakamura, Y. Ota, K. Koike, Y. Hidaka, K. Nishioka, M. Sugiyama, K. Fujii, "A 24.4% solar to hydrogen energy conversion efficiency by combining concentrator photovoltaic modules and electrochemical cells," Appl. Phys. Express, 8 (10), 107101 (2015).

A global network of hydrogen for disruptive installation of renewable energy

Masakazu SUGIYAMA

Research Center for Advanced Science and Technology, The University of Tokyo
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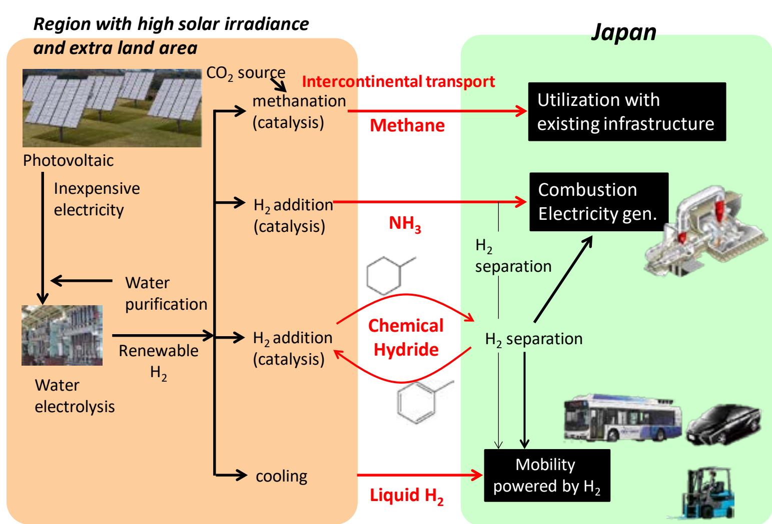
Covering a substantial fraction of world primary energy supply by solar-based renewable energy is the first-priority task for human being, not only for mitigating global warming through the reduction of CO_2 emission but also for coping with the depletion of fossil fuel that must take place in the future. There are two serious deficiencies that prevent solar energy to be a major primary energy source:

(1) temporal fluctuation (only available in shiny daytime),

(2) uneven spatial distribution (not abundant in most of the energy consumption sites).

The most promising technology which allows human being to overcome these deficiencies is the storage of solar energy in chemical substances. High energy density and long-term stability of chemical substances make it possible to store and transport solar energy “packed” into the substance. Among numerous candidates for such “chemical energy container”, hydrogen is the only substance that can be generated using solar energy with realistic efficiency. The combination of renewable power generation and water electrolysis is the most efficient way to generate hydrogen. This would be the most realistic approach which can transport solar energy from the region with abundant sunlight to other regions of huge energy consumption. Japanese government declared initiative to expand the usage of hydrogen, not only for transport sector such as fuel-cell vehicles but also for power generation using hydrogen by both fuel cells and combustion, accompanied by the development of “carrier technology” for oversea transport of hydrogen including liquefaction, chemical hydride and ammonia. However, to complete this transition of energy system as a sustainable one, we need to secure hydrogen from renewable sources. Combination of photovoltaic and water electrolysis (PV-electrolysis) is one of the most promising technology to produce renewable hydrogen. Its cost has been extremely high, but recent cost reduction in photovoltaic makes PV-electrolysis as a realistic choice.



Prof. Philippe BLANC

Center Observation, Impacts, Energy (OIE)

MINES ParisTech – PSL Research University

Education:

2015 **« Habilitation à Diriger des Recherches »** from **University of Grenoble Alpes**
French professorial accreditation

1999 **Ph.D. in Sciences** from **Ecole Nationale Supérieure des Mines de Paris (MINES ParisTech)**
Real Time – Robotics – Automatic

1995 **Engineer** of the **Ecole Nationale Supérieure des Télécommunications de Bretagne**
Master of advanced studies of the **University of Rennes**
Signal, Telecommunications, Images and Radar (option Image processing)

Scientific Interests:

Associated Editor for *Solar Energy* – Elsevier - International Solar Energy Society (ISES), since 2016
Expert for the International Energy Agency in the framework of the task 16 «*Solar resource for high penetration and large scale applications* » of the program PVPS « *Photovoltaic Power System* » (Subtask leader « Enhanced data Enhanced data & bankable products »), since 2017
Since 2017: Head of research activities for Renewable Energy resource assessment (Center OIE, MINES ParisTech)
Main topics:

- Meteorology for Energy (modelling and satellite-based estimation, resource mapping and GIS, forecasting, metrology)
- Earth observation with space-borne high resolution imaging systems
- Image and signal processing, estimation, algorithmic, applied mathematics

2000-2007: Research engineer in image processing and applied mathematics (Thales Alenia Space)
Main topics:

- System engineer, responsible of the image quality for the extremely high resolution imaging systems
- Numerical cartography (photogrammetry, mosaicking, sub-pixel co-registration) ;
- Architecture of optical space-borne imaging systems

Recent papers:

Marc Bengulescu, Philippe Blanc, Lucien Wald. On the intrinsic timescales of temporal variability in measurements of the surface solar radiation. Nonlinear Processes in Geophysics, European Geosciences Union (EGU), 2018, 25 (1), pp.19 – 37. DOI:10.5194/npg-25-19-2018

Yehia Eissa, Philippe Blanc, Hosni Ghedira, Armel Oumbe, Lucien Wald. A fast and simple model to estimate the contribution of the circumsolar irradiance to measured broadband beam irradiance under cloud-free conditions in desert environment. Solar Energy, Elsevier, 2018, 163, pp.497 - 509. DOI: 10.1016/j.solener.2018.02.015

Laurent Vuilleumier, Christian Félix, Frank Vignola, Philippe Blanc, Jordi Badosa, et al.. Performance Evaluation of Radiation Sensors for the Solar Energy Sector. *Meteorologische Zeitschrift*, Berlin: A. Asher & Co., 2017, DOI:10.1127/metz/2017/0836

Philippe Blanc, Pierre Massip, Andreas Kazantzidis, Panagiotis Tzoumanikas, Pascal Kuhn, et al.. Short-term forecasting of high resolution local DNI maps with multiple fish-eye cameras in stereoscopic mode . *AIP Conference Proceedings*, American Institute of Physics, 2017, SOLARPACES 2016: International Conference on Concentrating Solar Power and Chemical Energy Systems, 1850 (1), pp.140004. DOI: 10.1063/1.4984512

Zhipeng Qu, Armel Oumbe, Philippe Blanc, Bella Espinar, Gerhard Gesell, et al.. Fast radiative transfer parameterisation for assessing the surface solar irradiance: The Heliosat-4 method. *Meteorologische Zeitschrift*, Berlin: A. Asher & Co., 2017, 26 (1), pp.33-57. DOI: 10.1127/metz/2016/0781

Earth Observation for solar resource assessment and forecasting

Philippe BLANC

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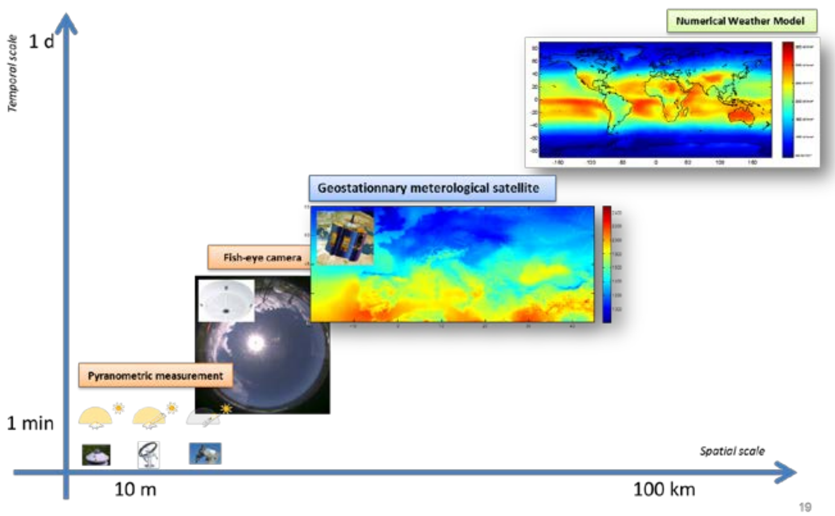

Surface solar irradiance (SSI) is a measure of solar radiation at the surface of the Earth. SSI is identified as an essential climate variable by the Global Climate Observing System[1] and is also of high interest in domains as varied as health, architecture, agriculture, and forestry and, of course, Solar Energy. The objective of this talk is to present some of the state-of-the-art techniques based on single or combined Earth Observation sources (numerical weather models, geostationary satellites, *in-situ* pyranometric sensors, hemispherical cameras) to provide solar resource assessment and forecasting, depending on the spatial and temporal resolutions required by applications. This presentation will also provide some links with the work plans of the task 16 "*Solar resource for high penetration and large scale applications"* of the International Energy Agency (IEA) program PVPS and of the task V "*Solar Resource Assessment and Forecasting*" of the IEA program SolarPACES.

[1] Essential Climate Variables, www.wmo.int/pages/prog/gcos/index.php?name=EssentialClimateVariables

Stéphane Grieu

PROMES-CNRS

University of Perpignan Via Domitia (UPVD)

Education:

- 2010-2014: head of the master's degree program “Electrical engineering, Automatic control and Informatics” (EAI), UPVD, Perpignan, France.
- Since 2014: head of the master's degree program “Electrical Engineering and Automatic control” (EEA), UPVD, Perpignan, France.
- 2011-2016: head of the research team ELIAUS (*Electronics, Automatic control and Systems*), PROMES laboratory, Perpignan, France.
- Since 2016: head of the research team COSMIC (*System Control, Instrumentation and Characterization*), PROMES laboratory, Perpignan, France.

- 1998: B.S. degree in engineering science, UPVD, Perpignan, France.
- 2000: M.S. degree in engineering science, UPVD, Perpignan, France.
- 2003: Ph.D. in engineering science, ELIAUS laboratory, UPVD, Perpignan, France.
- 2003-2005: Assistant Lecturer in engineering science/automatic control, ELIAUS laboratory, UPVD, Perpignan, France.
- 2005-2011: Associate Professor in engineering science/automatic control, ELIAUS laboratory, UPVD, Perpignan, France.
- Since 2011: Professor in engineering science/automatic control, PROMES-CNRS laboratory, UPVD, Perpignan, France.

Scientific Interests:

- Solar resource assessment and forecasting.
- Modelling and control of energy systems, in particular solar systems.
- Distributed generation management (smart grids).
- Smart buildings and microgrids.
- Heat networks management.
- Keywords: model predictive control, artificial intelligence, system identification.

Recent papers:

1. Julien Nou, Rémi Chauvin, Julien Eynard, Stéphane Thil, Stéphane Grieu, *Towards the short-term forecasting of direct normal irradiance using sky-imaging data*, Heliyon 4 (4) (2018) e00598.
2. Rémi Chauvin, Julien Nou, Julien Eynard, Stéphane Thil, Stéphane Grieu, *A new approach to the real-time assessment and intrahour forecasting of clear-sky direct normal irradiance*, Solar Energy 167 (2018) 35-51.
3. Aurélie Chabaud, Julien Eynard, Stéphane Grieu, *A rule-based strategy to the predictive management of a grid-connected residential building in southern France*, Sustainable Cities and Society 30 (2017) 18-36.

4. Mouchira Labidi, Julien Eynard, Olivier Faugeroux, Stéphane Grieu, *A new strategy based on power demand forecasting to the management of multi-energy district boilers equipped with hot water tanks*, Applied Thermal Engineering 113 (2017) 1366-1380.
5. Julien Nou, Rémi Chauvin, Stéphane Thil, Stéphane Grieu, *A new approach to the intra-hour forecasting of direct normal irradiance using sky-imaging data*, 23th SolarPACES Conference, Santiago de Chile, Chile, September 26-29, 2017.
6. Rémi Chauvin, Julien Nou, Stéphane Thil, Stéphane Grieu, *Generating high dynamic range images using a sky imager*, 23th SolarPACES Conference, Santiago de Chile, Chile, September 26-29, 2017.
7. Julien Nou, Rémi Chauvin, Julien Eynard, Stéphane Thil, Stéphane Grieu, *Towards the short-term forecasting of direct normal irradiance using a sky imager*, 20th World Congress of the International Federation of Automatic Control, Toulouse, France, July 9-14, 2017.
8. Rémi Chauvin, Julien Nou, Stéphane Thil, Stéphane Grieu, *Generating high dynamic range images using a sky imager*, 20th World Congress of the International Federation of Automatic Control, Toulouse, France, July 9-14, 2017.
9. Ali Zaher, Julien Nou, Adama Traoré, Stéphane Thil, Stéphane Grieu, *Comparative study of algorithms for cloud motion estimation using sky-imaging data*, 20th World Congress of the International Federation of Automatic Control, Toulouse, France, July 9-14, 2017.
10. Julien Nou, Rémi Chauvin, Stéphane Thil, Stéphane Grieu, *A new approach to the real-time assessment of the clear-sky DNI*, Applied Mathematical Modelling 40 (15-16) (2016) 7245-7264.
11. Rémi Chauvin, Julien Nou, Stéphane Thil, Stéphane Grieu, *Short-term DNI forecasting using a sky-imager*, 22th SolarPACES Conference, Abu Dhabi, UAE, October 11-14, 2016.
12. Rémi Chauvin, Julien Nou, Stéphane Thil, Stéphane Grieu, *A new approach for assessing the clear-sky DNI in real-time*, 22th SolarPACES Conference, Abu Dhabi, UAE, October 11-14, 2016.
13. Stéphane Grieu, Olivier Faugeroux, Adama Traoré, Bernard Claudet, Jean-Luc Bodnar, *Side-by-side ANFIS as a useful tool for estimating correlated thermophysical properties*, European Physical Journal Plus 130 (12) (2015) 241.
14. Antoine Garnier, Julien Eynard, Matthieu Caussanel, Stéphane Grieu, *Predictive control of multizone heating, ventilation and air-conditioning systems in non-residential buildings*, Applied Soft Computing 37 (2015) 847-862.
15. Rémi Chauvin, Julien Nou, Stéphane Thil, Stéphane Grieu, *Modelling the clear-sky intensity distribution using a sky imager*, Solar Energy 119 (2015) 1-17.

Towards the intrahour forecasting of direct normal irradiance using sky-imaging data

Stéphane Grieu

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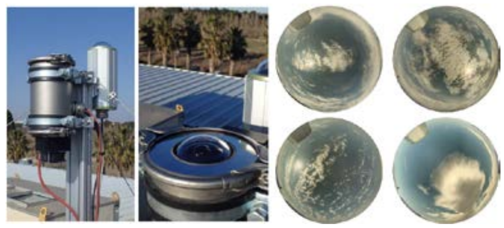

Increasing power plant efficiency through improved operation is key in the development of Concentrating Solar Power (CSP) technologies. To this end, one of the most challenging topics remains accurately forecasting the solar resource at a short-term horizon. Indeed, in CSP plants, production is directly impacted by both the availability and variability of the solar resource and, more specifically, by Direct Normal Irradiance (DNI). The present paper deals with a new approach to the intrahour forecasting (the forecast horizon Δt_f is up to 30 minutes ahead) of DNI, taking advantage of the fact that this quantity can be split into two terms, i.e. clear-sky DNI and the clear sky index. Clear-sky DNI is forecasted from DNI measurements, using an empirical model[1] combined with a persistence of atmospheric turbidity. Moreover, in the framework of the CSPIMP (Concentrating Solar Power plant efficiency IMProvement) research project, PROMES-CNRS has developed a sky imager able to provide High Dynamic Range (HDR) images. So, regarding the clear-sky index, it is forecasted from sky-imaging data, using an Adaptive Network-based Fuzzy Inference System (ANFIS). A hybrid algorithm that takes inspiration from the classification algorithm proposed by Ghonima et al.[2] when clear-sky anisotropy is known and from the hybrid thresholding algorithm proposed by Li et al.[3] in the opposite case has been developed to the detection of clouds. Performance is evaluated via a comparative study in which persistence models – either a persistence of DNI or a persistence of the clear-sky index – are included. Preliminary results highlight that the proposed approach has the potential to outperform these models (both persistence models achieve similar performance) in terms of forecasting accuracy: over the test data used, RMSE (the Root Mean Square Error) is reduced of about 20 W.m^{-2}, with Δt_f = 15 minutes, and 40 W.m^{-2}, with Δt_f = 30 minutes.

[1] Ineichen, P.; Perez, R. *Solar Energy* **2002**, *73 (3)*, 151.
[2] Ghonima, M. S.; Urquhart, B.; Chow, C. W.; Shields, J. E.; Cazorla, A.; Kleissl, J. *Atmospheric Measurement Techniques* **2012**, *5 (11)*, 2881.
[3] Li, Q.; Lu, W.; Yang, J. *Journal of Atmospheric and Oceanic Technology* **2011**, *28 (10)*, 1286.

Tomoyoshi Motohiro

Nagoya University, Japan

Prof., Institutes of Innovation for Future Society, and Dept. of Materials Process Eng., Graduate School of Eng.

Education:

(1) March 1978: Completion of master course of Applied Physics, Graduate School of Engineering, The University of Tokyo. Diploma work: In-situ X-ray diffraction study of order-disorder transition of Au_3Cu alloy by using a position sensitive proportional counter.
(2) April 1978-Sep.2012 Toyota Central R&D Labs.,Inc.(TCRDL) : thin films and surface science, catalysis, optical discs, solar cells (PV), artificial photosynthesis, thermoelectric converters, solar-pumped lasers (SPLs), laser fusion and nuclear transmutation.
(3) June 1986 Doctoral Degree (Dr. Eng.), The University of Tokyo (Prof. A. Kimbara) Dissertation: Study of transport process of sputtered particles by Monte-Carlo Simulation.
(4) April 2006-March 2017 Visiting Professor of Collaborative Graduate School of TOYOTA Technological Institue(TTI) with TCRDL : surface catalytic reaction, pulsed laser deposition, superconducting magnetic energy storage (SMES)
(5) Oct. 2012- Full Professor, Green Mobility Research Center (reorganized to Green Mobility Reserach Institute, Institutes of Innovation for Future Society) and Department of Materials Science and Engineering (reorganized to Department of Materials Process Engineering), Graduate school of Engineering, Nagoya University.

Scientific Interests:

- Interests and activities

(1) Electric generation by combination of SPLs and PV devices specially designed for monochromatic laser light.(JST-ALCA: Advanced Low Carbon Technology R&D program, Nagoya Univ. & TCRDL, Oct.2013-March2018)
(2) Compact SMES System based on MEMS technologies. (JSPS, Grant-in-Aid for Scientific Research"<KAKENHI>", Nagoya Univ. & TCRDL, April 2014-March 2017 / NEDO Advanced Research Program for Energy and Environmental Technologies, Nagoya Univ., TTI, Kanto Gakuin Univ., D-process Inc. and AISIN SEIKI Co.,Ltd., Nov. 2015-Jan.2018)
(3) Laser fusion by high-repetition (>1Hz) laser-implosion by counter-illumination (Collaborative R&D project by The Graduate School for the Creation of New Photonic Industries, Hamamatsu Photonics K.K., TOYOTA Motor Corporation and related research groups including Nagoya Univ., 2008-2018)
(4) Excess heat evolution from nanocomposite samples under exposure to hydrogen isotope gases (NEDO Advanced Research Program for Energy and Environmental Technologies, Tohoku Univ., Technova Inc., Kobe Univ., Nagoya Univ., NISSAN MOTOR CORPORATION and Kyusyu Univ., Nov. 2015-Oct.2017)

- Main keywords

  Thin films, SPL, PV, SMES, Laser fusion, Condensed matter nuclear science

Recent papers :

- T. Motohiro, Y. Takeda, H. Ito, K. Hasegawa, A. Ikesue, T. Ichikawa, K. Higuchi, A. Ichiki, S. Mizuno, T. Ito, N. Yamada, H.N. Luitel, T. Kajino, H. Terazawa, S. Takimoto and K. Watanabe, "Concept of the solar-pumped laser-photovoltaics combined system and its application to laser beam power feeding to electric vehicles", Jpn. J. Appl. Phys. 56, 08MA07(2017).
- K. Hasegawa, T. Ichikawa, Y. Takeda, A. Ikesue, H. Ito and T. Motohiro,"Lasing characteristics of refractive-index-matched composite $Y_3Al_5O_{12}$ rods employing transparent ceramics for solar-pumped lasers", Jpn. J. Appl. Phys. 57, 042701(2018).
- A. Kitamura, A. Takahashi, K. Takahashi, R. Seto, T. Hatano, Y. Iwamura, T. Itoh, J. Kasagi, M. Nakamura, M. Uchiyama, H. Takahashi, S. Sumitomo, T. Hioki, T. Motohiro, Y. Furuyama, M. Kishida an H. Matsune,"Excess heat evolution from nanocomposite samples under exposure to hydrogen isotope gases", International Journal of Hydrogen Energy 43, 16187-16200(2018)
- Y. Ichiki, K. Adach, Y. Suzuki, M. Kawahara, A. Ichiki, T. Hioki, C-W Hsu, S. Kumagai, M. Sasaki, J-H. Noh, Y. Sakurahara, O. Takai, H. Honma and T. Motohiro, "Replacement of NbN by $YBa_2Cu_3O_{7-\delta}$ in superconducting thin film coil in a spiral trench on a Si-wafer for compact SMESs", IOP Conf, Series: Journal of Physics: Conf. Series 1054, 012065 (2018).
- T. Motohiro, "Backgrounds and research activities on nuclear fusion in Toyota Central R&D Labs.,Inc. including recent collaborative R&D project on high-repetition (>1Hz) laser-implosion by counter-illumination", R&D Review of Toyota CRDL 48(1), 51-69(2017).
- N. Sugimoto, N. Iguchi, Y. Kusano, T. Fukano, T. Hioki, A. Ichiki, T. Bessho and T. Motohiro, "Compact SMES with a superconducting film in a spiral groove on a Si wafer formed by MEMS technology with possible high-energy storage volume density comparable to that of rechargeable batteries", Superconductor Science anf Technology 30,015014(2017)

Development of compact solar-pumped laser systems and their application to photovoltaics

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Originally designed compact solar-pumped laser (μSPL) systems were developed employing a rigid 50.8 or 76.2 mm caliber off-axis parabolic mirror and a 5 mm-long, 1-mm-square or 10 mm-long, 1 mm diameter transparent Cr, Nd co-doped YAG ceramic rod as the laser medium. Rapid cooling of the small laser medium by free/natural air convection and increased mechanical stability of the compact system during wind exposure are favorable for realizing more stable oscillation in contrast to the conventional large SPLs employing typically 2-m-square conversing lens or mirror. Record-long continuous oscillation of the μSPL for more than 6.5 hours from 11:00 to 17:33 tracking the sun was attained. The laser oscillation wavelength of μSPL:1.06 μm, just below the wavelength of optical absorption edge of Si photovoltaic (PV) cells, is suitable for photoelectric conversion with minimal thermal loss. Since the power density of the laser output can be 1000 times as high as 100 mW/cm^2 of the sunlight, specially designed 50 μm thick Si PV cells were fabricated to reduce resistive loss with an optical confinement structure comprised of a (TiO_2/SiO_2) multilayer band path filter on the front side for normally incident 1.06 μm laser light and of an alkaline etched and Ag coated diffuse reflector on the rear side of the cell. The energy conversion efficiency: 30% of 1.06 μm laser light of 20 W/cm^2 was experimentally confirmed whereas the theoretical limit was calculated to be over 50% at 100 W/cm^2. The laser output of μSPL could be transported via 100 m-long optical fibers with a loss below 0.18 dB to PV cells located at a distant place such as an indoor temperature and humidity controlled laboratory as shown in Fig.1. The output of μSPLs can be also transported in free space without optical fibers and used for laser beam power feeding [1] To harvest sunlight with low areal energy density as much as possible, coordinated solar tracking of arrangement of μSPLs in a large area was developed and tested for 5×5 arrangement. [2]

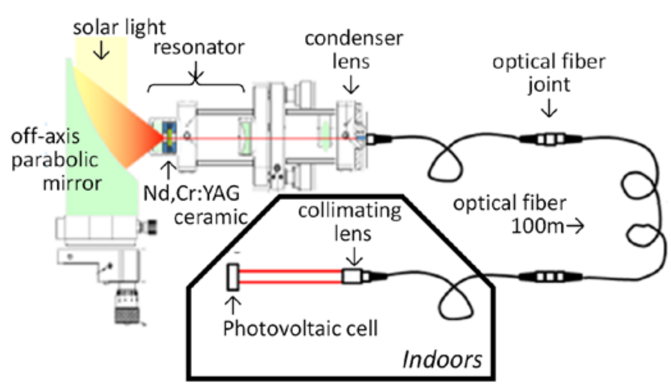
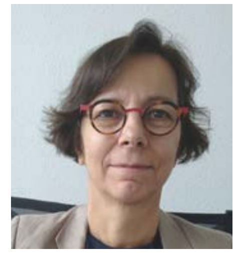


Fig.1 Schematic drawing of μSPL-PV combined system.

[1] Motohito T. et al. *Jpn. J. Appl. Phys.* **2017**, *56,* 08MA07.
[2] Motohiro T. et al. *Jpn. J. Appl. Phys.* **2015**, *54,* 08KE04.

Nathalie MAZET



Senior Researcher CNRS

PROMES Processes, materials and Solar Energy Lab

Team TES Thermodynmics, Energetics and reactive Systems.

Education:

- Physics (general), Master degree, Montpellier University, France
- Energy systems and solar energy, Master thesis, Perpignan, 1984
- Thermochemical systems for energy management. Research associate, INRS Energy, Montreal, Canada, 1985
- Transfers and kinetics in reactive porous media, PhD, Perpignan, 1988
- From the reactive compounds to thermochemical processes for energy storage and conversion, HdR (accreditation to supervise research), Perpignan, 1998

Scientific Interests :

- Processes for energy management applications: thermodynamic analysis, dynamic simulations
- Thermochemical processes for a large range of applications using solar energy: cold production, heat upgrading, long distance transportation of heat, thermal storage, at low temperature for buildings needs, up to high temperature for concentrated solar power plants.
- Implementation of the reactive porous materials in such thermochemical processes: characterization and optimization of heat and mass transfer, kinetics, and energy density.

Recent papers :

- SALAS D., TAPACHES E., MAZET N., AUSSEL D. Economical optimization of thermochemical storage in concentrated solar power plants via pre-scenarios. Energy Conversion and Management, 174, 2018, 932-954
- B. MICHEL, N. MAZET, P. NEVEU. Experimental investigation of an innovative thermochemical process operating with moist air for thermal storage of solar energy: global performances. Applied Energy, vol.129, 2014, 177–186
- P. NEVEU, S. TESCARI, D. AUSSEL, N. MAZET. Combined constructal and exergy optimization of thermochemical reactors for high temperature heat storage. Energy Conversion and Management,Vol.71,2013,pp186-198
- D. STITOU, N. MAZET, S.MAURAN. Experimental investigation of a solid/gas thermochemical storage process for solar air-conditioning . ENERGY, 41, 1, 261-270, 2012
- J. VALLADE, N. MAZET, P. NEVEU, D. STITOU. Comparative Assessment of Processes for the Transportation of Thermal Energy Over Long Distances. IJoT, 15 (3),177-185, 2012
- S. TESCARI, N. MAZET, P. NEVEU, S. ABANADES. Optimization Model for Solar Thermochemical Reactor: Efficiency Increase by a Nonuniform Heat Sink Distribution. Journal of Solar Energy Engineering-Transactions of the ASME, 133, 3, 2011
- LE PIERRES N., MAZET N., STITOU D. Modeling and Performances of a deep freezing process using low grade heat. ENERGY, 32, 2, 154-164, 2007

Solar energy storage by thermochemical processes.

Nathalie MAZET

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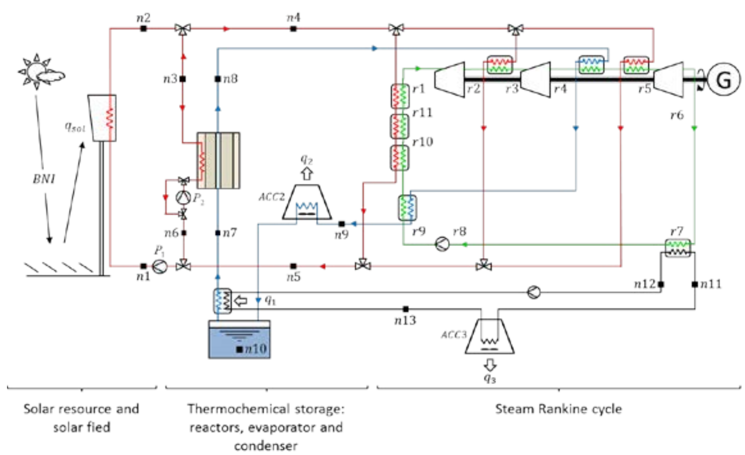
Thermochemical processes are based on the thermal effects provided by chemical reactions or sorption processes such as the capture of a reactive gas by a solid. They allow cold production[1] or heat upgrading by relevantly managing the endothermal and exothermal workings of all the components. Moreover, they are promising thermal storage processes given their high-energy densities and the low thermal losses between the storage and recovery steps (because energy is stored as chemical potential), and their wide range of operating temperatures (80–1000°C) depending on reactive pairs.

An overview of these thermochemical process applications will be presented. Recent works dealing with the implementation of a high temperature thermochemical storage process in a concentrated solar power plant will be detailed with a focus on the optimization from an economic point of view of both the thermochemical storage and the strategies of storage/discharge/production of the solar plant[2].



Integration of a thermochemical storage process in a concentrated solar power plant .

(red loop: heat transfer fluid; green loop: power block; blue loop: thermochemical storage process)

[1] Le Pierrès, N. ; Mazet, N. ; Stitou, D. Experimental results of a solar powered cooling system at low temperature. Int. J of refrigeration, **2007**, *30, 6*, 1050.
[2] Salas, D.; Tapachès; E., Mazet, N.; Aussel, D. Economical optimization of thermochemical storage in concentrated solar power plants via pre-scenarios. Energy Conversion and Management, **2018**, *174*, 932.

Vincent Goetz

Processes, Materials and Solar Energy Laboratory

UPR 8521, CNRS

Education: Dipl. Engineer (1988), ENSIGC Toulouse. (National High School of Chemical Engineering) - Doctor in Science Engineering (October 1991), Perpignan University - Habilitation à Diriger des Recherches (Juillet 2001), Perpignan University

Current position : Researcher Director at the National Center of Scientific Research (CNRS). Years within the organization: 22. Leader of the SHPE team of the Promes-CNRS laboratory (www.promes.cnrs.fr: Storage for Photochemical and Energetical Helioprocesses);

Directed Doctoral Thesis: 16 doctoral Thesis defended and 3 under progress.

Publications: Articles in international journals included in the Science Citation Index (SCI): 68 - Patents: 10 - Oral and poster communications at Congress and International Conferences: 82 - A Hirsh index of 23.

Professorship: 100 hours per year of teaching at the Renewable Engineer School (Master level, Polytech Montpellier – France) and the Academic Technologic Institute (IUT Perpignan – France).

Contracts and valorization: I was involved as scientific responsible in more than 20 research and development contracts between CNRS and private companies, 10 national projects including project funded by ANR and have participated to European projects (3).

Organization of scientific meeting. Member of the Scientific and/or organization Committees: Solarpaces (2010), Carbon for Energy Storage and Environment Protection (2011), National Journey on Solar Energy (since 2014), 9^{ieme} European Meeting on Solar Chemistry and Photocatalysis SPEA9 (2016). CIFEM 2018, L'accès durable au service énergétique au sud, Cotonou, 25-28 Avril 2018.

Key qualification/skills: Solar Engineering in the field of high temperature storage and water detoxification with AOP: simulation, kinetic and reactor modelling, dimensioning, outdoor experimentations.

10 recent papers focus on AOPs:

Plantard, G., Goetz, V., Correlations between optical, specific surface and photocatalytic properties of media integrated in a photo-reactor.*Chemical Engineering Journal*, **2014**, 252, 194-201.

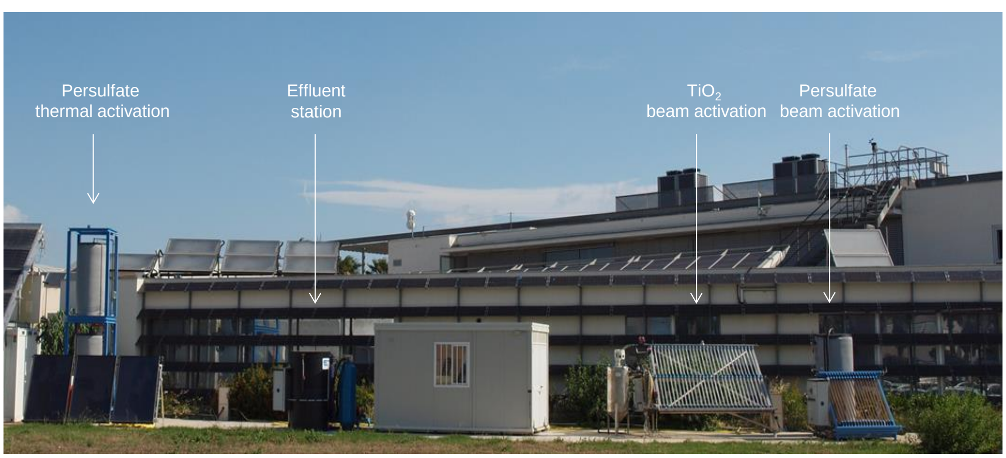
Brienza M., Mahdi Ahmed M., Escande A., Plantard G., Scrano L., Chiron S., Bufo S.A. and Goetz V., Relevance of a photo-Fenton like technology based on peroxymonosulphate for 17β–estradiol removal from wastewater. *Chemical Engineering Journal*,**2014**, 257, 191–199.
Kacem M., Goetz V. Plantard G., Wery N.; Modeling heterogeneous photocatalytic inactivation ofE.coli using suspended and immobilized TiO2 reactors. *AIChE Journal*,**2015**, 61 (8), 2532-2542.
Miguet M. ; Goetz V. ; Plantard G.; Jaegger Y. ; "Removal of a chlorinated volatile organic compound (perchloroethylene) from aqueous phase by adsorption on activated carbon". *Industrial Engineering&Chemistry Research*, **2015**, 54 (40), 9813-9823.
Brienza M.; Mahdi Ahmed M.; Escande A.; Plantard G.; Scrano L.; Chiron S.; Bufo S.; Goetz V.; Use of solar advanced oxidation processes for wastewater treatment: follow-up on degradation products, acute toxicity, genotoxicity and estrogenicity, *Chemosphere*, **2016**, 148, 473-480**.**
Plantard G.; Rosset A.; Djessas K.; Goetz V. "Correlation between gap energy and photocatalytic efficiencies of nanocatalyst under solar irradiation conditions", *Journal of Materials Science: Materials in Electronics,* **2017**, 28 (12), 8739-8748.
Telegang Chekem C.; Richardson Y.; Plantard G.; Blin J.; Goetz V.; "From biomass residues titania-coated carbonaceous photocatalysts: a comparative analysis of different preparation routes for water treatment application", *Waste and Biomass Valorization*, **2017**, 8 (8), 2721-2733.
Telegang Chekem C.; Richardson Y.; Drobek M.; Plantard G.; Blin J.; Goetz V.; "Effective coupling of phenol adsorption and photodegradation at the surface of micro-and mesoporous TiO2-activated carbon materials", *Reaction Kinetics Mechanisms and Catalysis,* **2017**, 122 (2), 1297-1321.
Kacem M.; Plantard G.; Brienza M.; Goetz V., "A continuous-flow aqueous system for heterogeneous photocatalytic disinfection of gram-negative Escherichia coli", *Industrial Engineering & Chemistry Research,* **201**7, 56 (51), 15001–15007, DOI: 10.1021/acs.iecr.7b03644.
Brienza M.; Nir S.; Plantard G.; Goetz V.;Chiron S.;"Combining micelle-clay sorption to solar photo fenton processes for domestic wastewater treatment", *Environmental Science and Pollution Research*, **accepted 01/06/2018**.

Solar Advanced Oxidation for Water Treatment

Vincent Goetz[1] and Gael Plantard[1,2]

[1] Promes Lab., Rambla de la Thermodynamic, 66100 Perpignan France Promes Lab.,
[2] University of Perpignan, UPVD, 52 Av. Villeneuve, 66100 Perpignan France
Phone: int+33 4 68 68 22 36
e-mail: vincent.goetz@promes.cnrs.fr https://www.promes.cnrs.fr/

The solar advanced oxidation processes (AOPs) make it possible to consider a large number of detoxification operations (depollution and / or disinfection). They are very attractive because in agreement with the principle of sustainable development. These eco-technologies are basically competitive from the environmental but also economic point of view. They are today mainly considered in the case of niche applications that generate low volumes to treat. This is compatible with dissemination in the southern countries with high solar radiation available, that needs energy-efficient, simple and robust self-treatment processes, with the lowest possible investment and operating costs. After remiding the principles of photoactivation of a catalyst for the production of radical species in a homogeneous or heterogeneous medium and the main associated limitations, the different types of solar photo-reactors are presented. Issues of the qualification of the performance of the AOPs are illustrated through laboratory scale tests carried out under natural radiation on real effluents. If the literature is now abundant on the subject of advanced oxidation treatment, it is much scarcer on the specific subject of this type of rejects treated by solar AOPs. This is the consequence of the difficulties generated by experiments requiring detection of micropollutants present in complex matrices at environmental concentrations. Presentation ends with few recent data obtained from the solar facilities available at Promes laboratory.



The AOPs solar facilities at Promes laboratory.

Yoshiaki NAKANO

Graduate School of Engineering

The University of Tokyo

Education:

- 1982 BE in Electronic Eng., the Univ. of Tokyo
- 1984 MS in Electronic Eng., the Univ. of Tokyo
- 1987 PhD in Electronic Eng., the Univ. of Tokyo

Career:

- 1987 Research Associate, School of Eng., the Univ. of Tokyo
- 1992 Assoc. Professor, School of Eng., the Univ. of Tokyo
- 2000 Professor, School of Eng., the the Univ. of Tokyo
- 2002 Professor, RCAST, the Univ. of Tokyo
- 2010 Director General, RCAST, the Univ. of Tokyo
- 2013 Professor, Grad. School of Eng., the Univ. of Tokyo
- 2017 Member, Science Council of Japan

Scientific Interests :

- Optoelectronics, semiconductor photonic device
- Compound semiconductor photovoltaic cell
- Solar energy storage, solar fuel
- Metal-organic vapor phase epitaxy
- GaAs, InP, GaN, InGaAsP, InGaAlAs, InGaAlN
- Quantum well, quantum nanostructure
- Integrated photonics, photonic integrated circuit
- Semiconductor laser, light emitting diode, optical modulator/switch

Recent papers :

- Kasidit Toprasertpong, Stephen M. Goodnick, Yoshiaki Nakano, and Masakazu Sugiyama, “Effective mobility for sequential carrier transport in multiple quantum well structures”, Physical Review B, vol. 96, issue 7, pp. 075441-1-10, August 15, 2017.
- Boram Kim, Kasidit Toprasertpong, Agnieszka Paszuk, Oliver Supplie, Yoshiaki Nakano, Thomas Hannappel, and Masakazu Sugiyama, “GaAsP/Si tandem solar cells: realistic prediction of efficiency gain by applying strain-balanced multiple quantum wells”, Solar Energy Materials and Solar Cells, vol. 180, pp. 303-310, June 15, 2018.

High-Efficiency and Low-Cost Photovoltaics Using III-V Compound Semiconductors

Yoshiaki NAKANO

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e-mail: nakano@ee.t.u-tokyo.ac.jp, http://www.ee.t.u-tokyo.ac.jp/~nakano/lab/

Large-scale photovoltaic (PV) power generation systems are essential to realize a fully-renewable-energy-driven society. Multiple junction (or tandem) solar cells that use epitaxial crystals of III–V compound semiconductors play a main role of photoelectric energy conversion in such PV power generation systems due to their high-efficiency property. Because these solar cells operate under a sunlight concentration of a few hundreds to thousands, the cost of cells that use the epitaxial crystal does not pose much of a problem. In the concentrator PV, the increased cost of cells is compensated by less costly focusing optics.

The photons reaching the earth from the sun have a wide range of energy distribution, from the ultraviolet to the infrared regions. Multi-junction solar cells, which are laminated with multilayers of p–n junctions configured by using materials with different band gaps, show promise in absorbing as much of these photons as possible, and converting the photon energy into electricity with minimum loss to obtain high voltage. Among various types of multi-junction solar cells, InGaP/GaAs/Ge triple-junction cells have the advantage of high conversion efficiency because of their high-quality single crystal with a uniform-size crystal lattice. So far, a conversion efficiency exceeding 41% under conditions where sunlight is concentrated to an intensity of approximately 500 times has been reported.

To develop an even higher efficiency tandem cell, it is necessary to use a material with a band gap narrower than that of GaAs for the middle cell. In order to obtain maximum conversion efficiency in triple-junction solar cells, it is essential to narrow down the middle cell band gap to 1.2 eV and increase the short-circuit current density by 2mA/cm2 compared with that of the GaAs middle cell. When the material is replaced with a narrower band gap, the output voltage will drop. However, the effect of improving the electric current balance outperforms this drop in output voltage and boosts the efficiency of the entire multi-junction cell.

Researchers from the University of Tokyo, together with NextPV/CNRS, aim to obtain novel materials and structures that have the narrow band gaps while maintaining lattice matching with Ge or GaAs. This talk will review their recent progress. [1]

[1] Nakano, Y.; *AMBIO* **2012**, vol. *41,* pp. 125-131.

Jean-François GUILLEMOLES

UMR IPVF /CNRS, Palaiseau, France

LIA NextPV /CNRS, RCAST, U. Tokyo, Japan

Recent Appointments

- IPVF, UMR CNRS-X-ENSCP-IPVF-EDF-TOTAL-AIRLIQUIDE, Director (2018-)
- Member of CNRS National Committee, Section 14 - Interfaces and Catalysis (2016-2021)
- RCAST, The University of Tokyo, Visiting Professor (2015-2018)
- Director of NextPV, Tokyo (Joint International Lab. U. Tokyo-CNRS, 2014 -)
- Progress in Photovoltaics: R&A, Wiley, Editor (2014-)
- IPVF: coordinator of New concept program & High efficiency project leader (2012-)
- Part-time Professor, Ecole Polytechnique, Palaiseau (2009-2014 and 2016-)
- IRDEP, UMR 7174 EDF-CNRS-ENSCP, Deputy Director (2009-2013 and 2016-2017)

Education and sabbaticals:

- Habilitation in Material Science, Pierre & Marie Curie University, Paris 2003
- PhD, Material Science, Pierre & Marie Curie University, Paris 1994
- ENS Ulm, Physics (entered in 1984)
- Visiting scientist at the Weizmann Institute, Israel (1994-1997)
- Visiting scientist at UNSW, Sydney, Australia (2005)
- JSPS fellow at RCAST, U. Tokyo, Japan (2013)

Scientific Interests :

- New systems for photovoltaic conversion (nanostructures, up/down conversion, hot carriers, intermediate bands, perovskites …), with a focus on high efficiency concepts.
- Discovery of compounds with potential interest for photovoltaic, study of their stability, point defects, transport properties using e.g. ab initio (esp. band structure) calculations
- Developing techniques for solar cells material and device characterization, esp. based on electro/photoluminescence
- Synthesis of semiconductors of interest for solar energy and control of their electronic properties, investigation of chemical-electronic properties relationships of their surfaces and interfaces

Recent papers :

Most publications are accessible online: www.researchgate.net/profile/Jean_Francois_Guillemoles

- Some representative papers:
  - Nguyen dac Trung, Laurent Lombez, François Gibelli, Soline Boyer-Richard, Olivier Durand, Jean-François Guillemoles, "Quantitative experimental assessment of hot

carrier-enhanced solar cells at room temperature", Nature Energy volume 3, pages236–242 (2018) ; doi:10.1038/s41560-018-0106-3

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"High efficiency and low cost PV: new materials? New concepts? Or both?"

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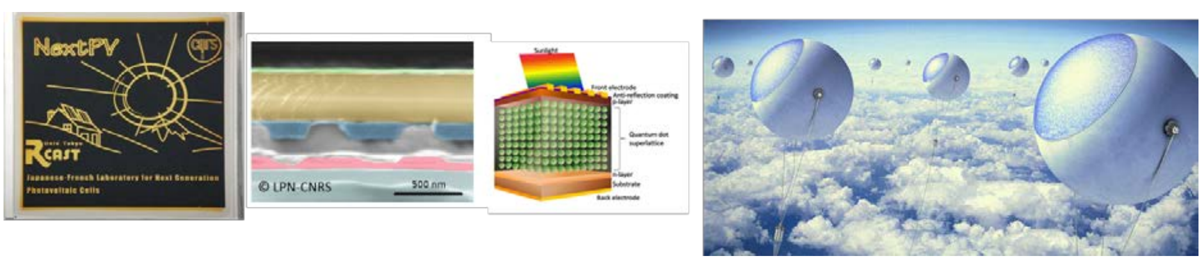
Photovoltaic generation has stepped up within the last decade from outsider status to one of the important contributors of the ongoing energy transition, with about 1.7 % of world electricity provided by solar cells. Progress in materials and production processes has played an important part in this development. Yet there are many challenges before photovoltaics could provide clean, abundant and cheap energy.

The presentation will showcase research carried out in bilateral Japan-French collaborations as well as in the new IPVF institute on the main challenges for solar energy conversion[1]. Particular attention will be paid to approaches to high efficiencies and their potential compatibility with scale up. The research has been carried out on thin film materials as well as on alternative concepts for solar energy conversion (intermediate band[2], hot carriers[3], ratchets[4]).



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Olivier CARRÉ

Enedis

How Enedis (the French DSO) tackles DER insertion challenges on its MV and LV networks

Sataro YAMAGUCHI

Chubu University

Center of Applied Superconductivity and Sustainable Energy Research

Education:

- I studied physics in undergraduate and graduate school, and got the doctor degree. Its field was plasma spectroscopy and magneto-hydrodynamics (MHD) to confine high temperature plasma for fusion reactor. I worked for the electric company, the national institute and the private university in Japan. I also work for MIT in Boston/USA as a visiting scientist from 2001. My basis is physics, and working fields extend some applications of electric power system mainly. I also am interesting with several different fields, such as semiconductor devices and its transport phenomena and machining and manufacturing. In 2018, I also started to develop a new electric instrument for cancer treatment with a medical doctor team.

Graduated	:	1980	Graduate School of Science, Nagoya University
Degree	:	1982	Doctor of Science, Nagoya University
Work experience	:	1981	Department of Nuclear Fusion, Mitsubishi Electric Corporation
		1992	National Institute for Fusion Science
		2001	Chubu University（to Now）

Scientific Interests :

- A short list of interests and activities
  Superconducting DC power transmission, electric power system and its related fields
  Transport Phenomena of Semi-conductor device, Pedestal physics

- Main keywords
  Electric power transmission, Applied Superconductivity, Transport phenomena of semiconductor device, Application of electric power system

- Recently I am interesting with economy, politics and history to connect power transmission line all over the world because of many reasons.

Recent papers :

①S.Yamaguchi, at et., “Research, Fabrication and Applications of Bi-2223 HTS wires, Section 3.8, “DC Cable for Data Center”, pp. 301-314, World Scientific Series in Applications of Superconductivity and Related Phenomena - Vol. 1, 2016. ISBN: 978-981-4749-25-1

②S. Yamaguchi, T. Iitsuka, M. Osada, R. Yokoyama,“Asian international grid connection and potentiality of DC superconducting power transmission”, Global Energy Interconnection Vol.1, No.1 pp.11-19, January 2018

③S. Yamaguchi,「超伝導直流送電システムの研究開発と 2050 年への将来展望」、JMA Research Inc.（株式会社日本能率協会総合研究所）、MDB Digital Search（MDB 技術予測レポート）、January 2018

Thermo-Hydrodynamic Analysis and Cable Design for 10km to 100km Superconducting DC Power Transmission Line using Ishikari experimental data and their perspective

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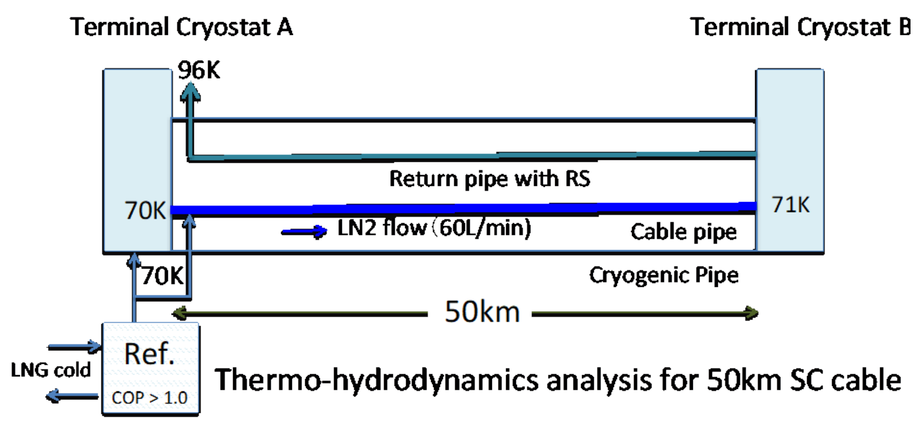

A Main merit of the DC superconducting power transmission line is low loss even in low voltage power transmission. It will be realized when the transmission length is long because the loss is proportional to the length. Since it is a small system, its system cost will be cheaper than that of the copper cable system finally. The loss of the DC superconducting power transmission line depends on the heat leak from the cryogenic pipe mainly, therefore the main subject is to realize low heat leak from the cryogenic pipe. We also need to use a high COP of the refrigerator, too. At the same time, low circulation power of cryogen such as liquid nitrogen is also necessary. After these subjects are solved, we will be able to construct an ultra-long transmission line to connect all over the world. The target values of the heat leak and the COP of refrigerator were defined in 1990's, and they are 1.0W/m and 0.1, respectively. The COP of refrigerator has the upper limit because of Carnot cycle efficiency.

The heat leak of cryogenic pipe lower than 1 W/m for round trip was realized in Ishikari project[1] in 2016 in very low pressure drop of the cryogen circulation[2]. We also pay attention on the temperature rise of the cable for a longer transmission because if it is usual experimental value, we should install the cooling station each 5 km along the transmission line for a short distance. In order to keep the operational current of a longer cable, the temperature rise of the liquid nitrogen in cryogenic pipe should be minimized, and its values are 0.03 – 0.04 K/km for usual flow rate in the Ishikari project. The output pressure of the cryogenic pump should be proportional to the cubic of the length[3],[4], and since the pump power is also proportional to the fourth power of length, the pressure drop should be minimized. After we got the set of the experimental data in Ishikari project, we started to make the design of 10km ~ 100km transmission line, and the cooling stations are located only at both ends basically.

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Themis Solar Tower Power Plant in Targassonne (PROMES-CNRS)

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Cover photo: Odeillo Solar Furnace (PROMES-CNRS)