



# Projects and research related to green H<sub>2</sub> at U. CHILE (FCFM)

Francisco Gracia

Oct 5, 2021



- Materials Science
- Sustainability and circular economy
- Green Mining

- Materials Science
  - *Water splitting and SOFC*
  - *2D materials for electrochemistry and CO<sub>2</sub> capture and conversion*

# Water splitting and SOFC

Lab. Electrochemistry (Dr. M. Colet, mcolet@ing.uchile.cl)

- New anode materials for solid oxide fuel cells using hydrogen, syngas or other carbonaceous fuels, as well as for H<sub>2</sub> production.

Currently, solid oxide fuel cells anode materials are mainly based on nickel. Our research is focused in the fabrication and testing of new anode materials based on ceria and transition metals which are highly electrocatalytically active

## Water splitting and SOFC

Lab. Electrochemistry (Dr. M. Colet, mcolet@ing.uchile.cl)

- New anode materials for solid oxide fuel cells using hydrogen, syngas or other carbonaceous fuels, as well as for H<sub>2</sub> production.

Currently, solid oxide fuel cells anode materials are mainly based on nickel. Our research is focused in the fabrication and testing of new anode materials based on ceria and transition metals which are highly electrocatalytically active

Research Article

*J. Electrochem. Sci. Technol.*, **2021**, 12(2), 246-256

### **Mo,Cu-doped CeO<sub>2</sub> as Anode Material of Solid Oxide Fuel Cells (SOFCs) using Syngas as Fuel**

Isaac Díaz-Aburto<sup>1,2</sup>, Jacqueline Hidalgo<sup>1,3</sup>, Eliana Fuentes-Mendoza<sup>1,3</sup>, Sergio González-Poggini<sup>1,3</sup>, Humberto Estay<sup>1</sup>, and Melanie Colet-Lagrille<sup>1,3\*</sup>

# Water splitting and SOFC

Lab. Electrochemistry (Dr. M. Colet, mcolet@ing.uchile.cl)

- New anode materials for solid oxide fuel cells using hydrogen, syngas or other carbonaceous fuels, as well as for H<sub>2</sub> production.

Currently, solid oxide fuel cells anode materials are mainly based on nickel. Our research is focused on the fabrication and testing of new anode materials based on ceria and transition metals which are highly electrocatalytically active

## ECS Transactions

### Research Article

### Mo,Cu-doped CeO<sub>2</sub> as Anode (SOFCs) using Syngas as Fu

Isaac Díaz-Aburto<sup>1,2</sup>, Jacqueline Hidalgo<sup>1,3</sup>, Humberto Estay<sup>1</sup>, and Melanie Colet-Lagrille

### Electrochemical Fabrication of MoO<sub>2</sub>/MoO<sub>3</sub>-Based Photo-Anodes for Water Splitting

Matías García-García<sup>1</sup> and Melanie Colet-Lagrille<sup>1</sup>

© 2017 ECS - The Electrochemical Society

[ECS Transactions](#), [Volume 77](#), [Number 9](#)

Citation Matías García-García and Melanie Colet-Lagrille 2017 *ECS Trans.* 77 77

# 2D materials for H<sub>2</sub> production and CO<sub>2</sub> capture and conversion

Dr. A. Rosenkranz (arosenkranz@ing.uchile.cl),

Dr, M. Soler (msoler@ing.uchile.cl)

Dr. R. Espinoza (roespino@ing.uchile.cl),

Dr, F. Gracia (fgracia@ing.uchile.cl)

MXene nano-sheets are one of the hot topics in materials science and engineering due to their outstanding materials properties (2D layered structure, electrical conductivity, enhanced inter- and intra-layer bonding characteristics, among others). These nano-sheets are being extensively used in energy storage and catalysis.

*Int. J. Electrochem. Sci.*, 16 (2021) Article ID: 210517

---

**International Journal of  
ELECTROCHEMICAL  
SCIENCE**  
[www.electrochemsci.org](http://www.electrochemsci.org)

---

*Short Communication*

**Effects of Ti<sub>3</sub>C<sub>2</sub>T<sub>x</sub> nano-sheets (MXenes) on the microstructural and electrochemical properties of SnO<sub>2</sub>/Ti anodes**

*Sergio González-Poggini<sup>1</sup>, Andreas Rosenkranz<sup>1</sup>, Bo Wang<sup>2</sup>, Samuel Hevia<sup>3</sup>, Jinhong Yu<sup>2</sup>,  
Melanie Colet-Lagrille<sup>1,\*</sup>*



# 2D materials for H<sub>2</sub> production and CO<sub>2</sub> capture and conversion

Dr. A. Rosenkranz (arosenkranz@ing.uchile.cl),

Dr, M. Soler (msoler@ing.uchile.cl)


Dr. R. Espinoza (roespino@ing.uchile.cl),

Dr, F. Gracia (fgracia@ing.uchile.cl)

MXene nano-sheets are one of the hot topics in materials science and engineering due to their outstanding materials properties (2D layered structure, electrical conductivity, enhanced inter- and intra-layer bonding characteristics, among others). These nano-sheets are being extensively used in energy storage and catalysis.

*Int. J. Electrochem. Sci.*, 16 (2021) Article ID: 210517

Applied Materials Today 20 (2020) 100769



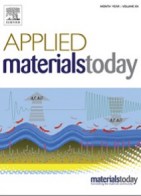
Intern  
ELEC

W  
ELSEVIER

Contents lists available at [ScienceDirect](#)

Applied Materials Today

journal homepage: [www.elsevier.com/locate/apmt](http://www.elsevier.com/locate/apmt)



*Short Communication*

## Effects of Ti<sub>3</sub>C<sub>2</sub>T<sub>x</sub> nano-sheets (MXenes) on the microstructure and electrochemical properties of SnO<sub>2</sub>/Ti anodes

Sergio González-Poggini<sup>1</sup>, Andreas Rosenkranz<sup>1</sup>, Bo Wang<sup>2</sup>, Samuel Hevia<sup>3</sup>, Jir Melanie Colet-Lagrille<sup>1,\*</sup>

Unprecedented arsenic photo-oxidation behavior of few- and multi-layer Ti<sub>3</sub>C<sub>2</sub>T<sub>x</sub> nano-sheets

Maibelin Rosales<sup>a,b</sup>, Andreina Garcia<sup>a,\*</sup>, Victor M. Fuenzalida<sup>c</sup>, Rodrigo Espinoza-González<sup>b</sup>, Guichen Song<sup>d</sup>, Bo Wang<sup>d</sup>, Jinhong Yu<sup>d</sup>, Francisco Gracia<sup>b</sup>, Andreas Rosenkranz<sup>b,\*</sup>



## 2D materials for H<sub>2</sub> production and CO<sub>2</sub> capture and conversion

Dr. A. Rosenkranz (arosenkranz@ing.uchile.cl),

Dr, M. Soler (msoler@ing.uchile.cl)

Dr. R. Espinoza (roespino@ing.uchile.cl),

Dr, F. Gracia (fgracia@ing.uchile.cl)

Research during the last years has focused in the synthesis, modification, and study of transition metal oxides (TMOs), perovskites and MOFs for gas (H<sub>2</sub> and CO<sub>2</sub>) adsorption and catalytic applications. Particularly, 2D thin films of metal oxide or perovskite nanosheets that expose or support catalytically active metal nanoparticles.

## 2D materials for H<sub>2</sub> production and CO<sub>2</sub> capture and conversion

Dr. A. Rosenkranz (arosenkranz@ing.uchile.cl),

Dr. M. Soler (msoler@ing.uchile.cl)

Dr. R. Espinoza (roespino@ing.uchile.cl),

Dr. F. Gracia (fgracia@ing.uchile.cl)

Research during the last years has focused in the synthesis, modification, and study of transition metal oxides (TMOs), perovskites and MOFs for gas (H<sub>2</sub> and CO<sub>2</sub>) adsorption and catalytic applications. Particularly, 2D thin films of metal oxide or perovskite nanosheets that expose or support catalytically active

Journal of Power Sources 466 (2020) 228305

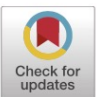


ELSEVIER

Contents lists available at [ScienceDirect](#)

Journal of Power Sources

journal homepage: [www.elsevier.com/locate/jpowsour](http://www.elsevier.com/locate/jpowsour)



Photosynthesis of H<sub>2</sub> and its storage on the Bandgap Engineered Mesoporous (Ni<sup>2+</sup>/Ni<sup>3+</sup>)O @ TiO<sub>2</sub> heterostructure

12 Kumar Raju <sup>a</sup>, Saravanan Rajendran <sup>b,\*</sup>, Tuan K.A. Hoang <sup>c</sup>, D. Durgalakshmi <sup>d</sup>, Jiaqian Qin <sup>e</sup>, D. E. Diaz-Droguett <sup>f</sup>, F. Gracia <sup>g</sup>, M.A. Gracia-Pinilla <sup>h,i</sup>

## 2D materials for H<sub>2</sub> production and CO<sub>2</sub> capture and conversion

[Dr. A. Rosenkranz \(arosenkranz@ing.uchile.cl\)](mailto:arosenkranz@ing.uchile.cl),

[Dr, M. Soler \(msoler@ing.uchile.cl\)](mailto:msoler@ing.uchile.cl)

[Dr. R. Espinoza \(roespino@ing.uchile.cl\)](mailto:roespino@ing.uchile.cl),

[Dr, F. Gracia \(fgracia@ing.uchile.cl\)](mailto:fgracia@ing.uchile.cl)

Research during the last years has focused in the synthesis, modification, and study of transition metal oxides (TMOs), perovskites and MOFs for gas (H<sub>2</sub> and CO<sub>2</sub>) adsorption and catalytic applications. Particularly, 2D thin films of metal oxide or perovskite nanosheets that expose or support catalytically active metal nanoparticles.

Several MOFs have been prepared and studied, such as UiO66 or UiO67, as well as some of their derivatives for the CO<sub>2</sub> hydrogenation, using metal nanoparticles inside the MOF. In addition, some attempts have been made to isolate 2D MOF or prepare SURMOFs

## 2D materials for H<sub>2</sub> production and CO<sub>2</sub> capture and conversion

Dr. A. Rosenkranz (arosenkranz@ing.uchile.cl),

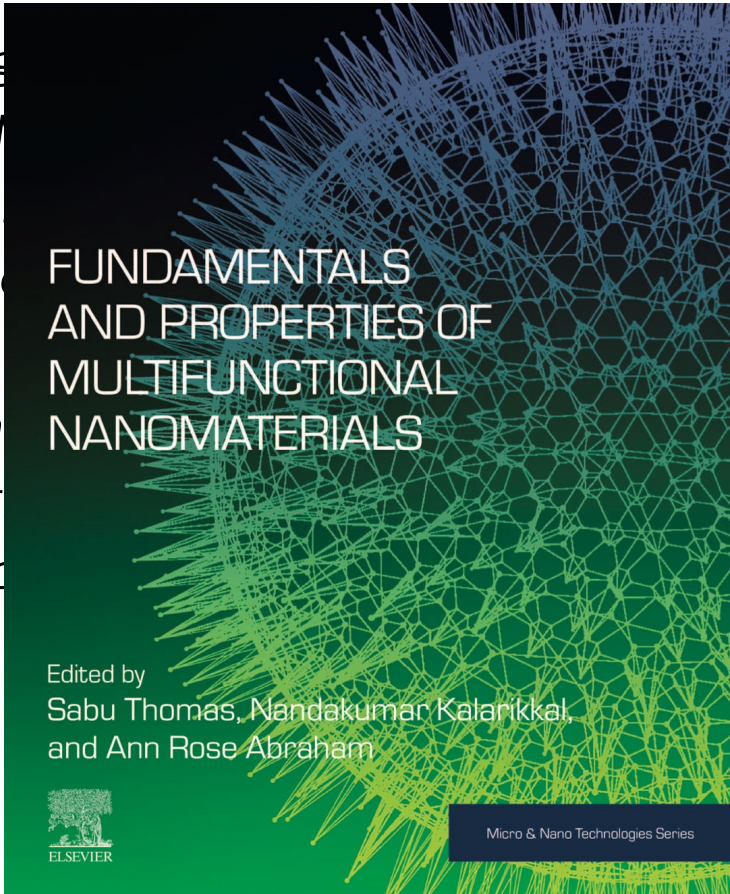
Dr, M. Soler (msoler@ing.uchile.cl)

Dr. R. Espinoza (roespino@ing.uchile.cl),

Dr, F. Gracia (fgracia@ing.uchile.cl)

Research during  
metal oxides (TiO<sub>2</sub>, ZnO, Fe<sub>2</sub>O<sub>3</sub>)  
applications. Pa  
support catalytic

Several MOFs h  
derivatives for t  
attempts have b



### FUNDAMENTALS AND PROPERTIES OF MULTIFUNCTIONAL NANOMATERIALS

Edited by  
Sabu Thomas, Nandakumar Kalarikkal,  
and Ann Rose Abraham



Micro & Nano Technologies Series

synthesis, modification, and study of transition  
metal oxides (TiO<sub>2</sub>, ZnO, Fe<sub>2</sub>O<sub>3</sub>) adsorption and catalytic  
activity. The book focuses on the synthesis of metal oxide or perovskite nanosheets that expose or

CHAPTER 15

## ***The key role of metal nanoparticle in metal organic frameworks of UiO family (MOFs) for the application of CO<sub>2</sub> capture and heterogeneous catalysis***

Thirunarayanan Ayyavu<sup>1,\*</sup>, Hemamalini Arasappan<sup>2</sup>, Francisco Gracia<sup>1</sup>,  
Monica Soler<sup>1</sup>

- Sustainability and circular economy

Dr. Felipe Díaz (felidiaz@ing.uchile.cl)

The Center for Sustainable Design and Process Systems Engineering (ProSus) has formulated and solved a multi-objective optimization problem so as to propose future changes in an urban water network, with focus on environmental and economic impacts, and on resilience to water demand and Climate Change effects.

We have also developed a resilience indicator for Eco-industrial Parks. This indicator has been constructed through the study of the internal structure (topology) of the Eco-industrial Parks and has been applied to assess real parks in Ulsan, Korea, and Kalundborg, Denmark. We have a methodology to plan new Eco-industrial Parks or to modify the existing ones.

A LCA to compare energy storage systems using green  $H_2$  or Li batteries has recently started.



Dr. Felipe Díaz (felidiaz@ing.uchile.cl)

The Center for Sustainable Design and Process Systems Engineering (ProSus) has formulated and solved a multi-objective optimization problem so as to propose future changes in an urban water network, with focus on environmental and economic impacts, and on resilience to water demand and Climate Change effects.

Journal of Cleaner Production 243 (2020) 118610

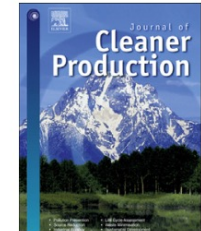
We have also developed a methodology to be constructed through multi-objective optimization and has been applied to a methodology to



Contents lists available at [ScienceDirect](#)

Journal of Cleaner Production

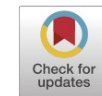
journal homepage: [www.elsevier.com/locate/jclepro](http://www.elsevier.com/locate/jclepro)



Design of sustainable and resilient eco-industrial parks: Planning the flows integration network through multi-objective optimization

Guillermo Valenzuela-Venegas, Gabriela Vera-Hofmann, Felipe A. Díaz-Alvarado\*

Department of Chemical Engineering, Biotechnology, and Materials, Faculty of Physical and Mathematical Sciences, Universidad de Chile, Av. Beauchef 851, Piso 6-poniente, Center for Sustainable Design and Process Systems Engineering, 8370456 Santiago, Chile



Dr. Felipe Díaz (felidiaz@ing.uchile.cl)

The Center for Sustainable Design and Process Systems Engineering (ProSus) has formulated and solved a multi-objective optimization problem so as to propose future changes in an urban water network

Journal of Cleaner Production 164 (2017) 242–249

demand

We have

constructed

and has

a method

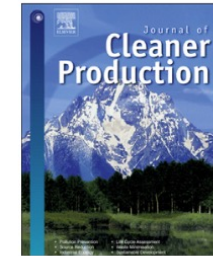


ELSEVIER

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: [www.elsevier.com/locate/jclepro](http://www.elsevier.com/locate/jclepro)



Towards solar power supply for copper production in Chile:  
Assessment of global warming potential using a life-cycle approach



A LCA by Simón Moreno-Leiva <sup>a, \*</sup>, Gustavo Díaz-Ferrán <sup>a</sup>, Jannik Haas <sup>a, d</sup>, Thomas Telsnig <sup>c, 1</sup>, Felipe A. Díaz-Alvarado <sup>b</sup>, Rodrigo Palma-Behnke <sup>a</sup>, Willy Kracht <sup>e, f</sup>, Roberto Román <sup>a</sup>, Dimitrij Chudinow <sup>c</sup>, Ludger Eltrop <sup>c</sup>





- Green Mining

## Solar – Green mining



*Solar Chile Mining focuses on the synergetic potential between solar energy and mining, allowing a more sustainable mineral extraction. Given the intensive energy use of the mining sector, studying this potential is relevant for the country's goal in terms of energy costs, emissions and competitive and sustainable mineral extraction.*

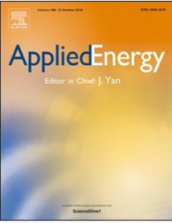
# Solar – Green mining



Contents lists available at ScienceDirect

## Applied Energy

journal homepage: [www.elsevier.com/locate/apenergy](http://www.elsevier.com/locate/apenergy)



## Copper mining: 100% solar electricity by 2030?

Jannik Haas<sup>a,b,\*</sup>, Simón Moreno-Leiva<sup>a</sup>, Tobias Junne<sup>b</sup>, Po-Jung Chen<sup>c</sup>, Giovanni Pamparana<sup>d</sup>, Wolfgang Nowak<sup>a</sup>, Willy Kracht<sup>e,f</sup>, Julián M. Ortiz<sup>g</sup>

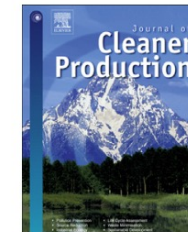
Journal of Cleaner Production 246 (2020) 118978



Contents lists available at ScienceDirect

## Journal of Cleaner Production

journal homepage: [www.elsevier.com/locate/jclepro](http://www.elsevier.com/locate/jclepro)



and mining,  
of the mining  
energy costs,

Review

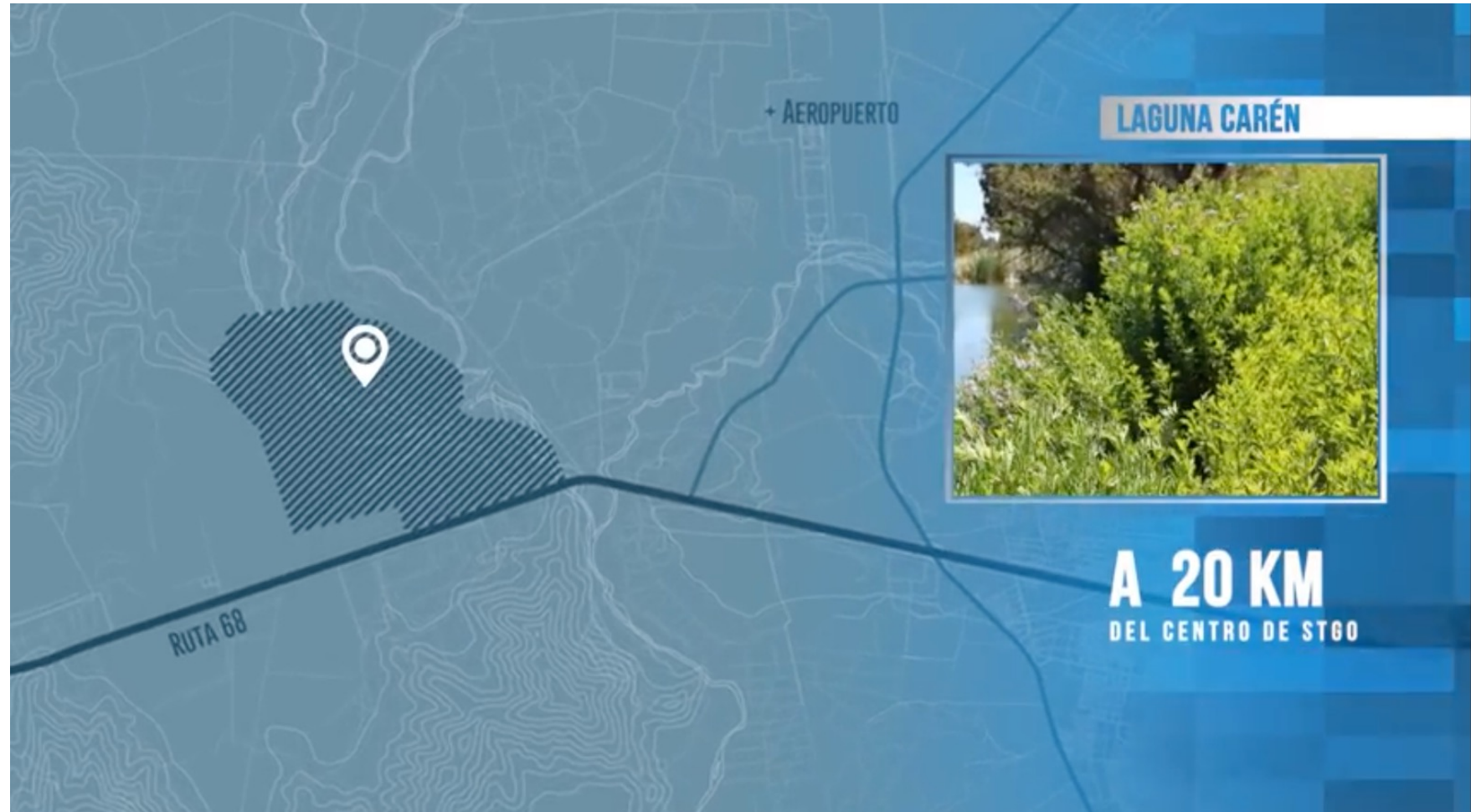
## Renewable energy in copper production: A review on systems design and methodological approaches

Simón Moreno-Leiva<sup>a,b,\*</sup>, Jannik Haas<sup>a</sup>, Tobias Junne<sup>c</sup>, Felipe Valencia<sup>d</sup>, Hélène Godin<sup>b</sup>, Willy Kracht<sup>e,f</sup>, Wolfgang Nowak<sup>a</sup>, Ludger Eltrop<sup>b</sup>



# Laguna Caren

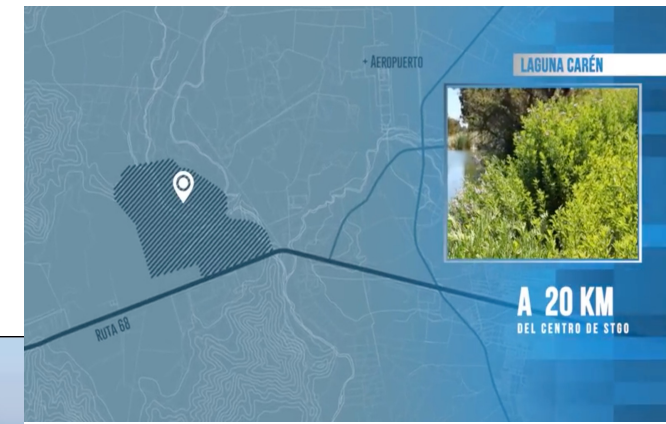
[www.youtube.com/watch?v=XzMpRVofSLE](https://www.youtube.com/watch?v=XzMpRVofSLE)





# Laguna Caren

[www.youtube.com/watch?v=XzMpRVofSLE](https://www.youtube.com/watch?v=XzMpRVofSLE)





# Laguna Caren

[www.youtube.com/watch?v=XzMpRVofSLE](https://www.youtube.com/watch?v=XzMpRVofSLE)

*U. de Chile launched this initiative, located in Pudahuel, a space that will be a platform where knowledge, natural and social sciences, technology and art will be integrated to solve in a transdisciplinary way, the demands that Chile and the world are facing.*

*The Project, located on a 1000+ ha surface in the west exit of Santiago, represents an investment of € 21,5 MM in this first phase, which includes two CORFO institutes and an institutional building.*





# Projects and research related to green H<sub>2</sub> at U. CHILE (FCFM)

Francisco Gracia

Oct 5, 2021