Hydrogen futures on the lab bench

A SOCIOLOGICAL INVESTIGATION OF AN INTERDISCIPLINARY RESEARCH PROJECT ON BIOHYDROGEN

Practical engagements and the socio-spatial dimension of the post-petroleum future – Tours, 7 November 2016

Context

- Social science embedded in a large interdisciplinary project on the theme of bioenergy

> "Novel concepts such as the large-scale production of biohydrogen and the conversion of oil stored in microalgae into biodiesel are very promising but are still relatively far from economic viability."
>
> An "integrated approach" to remove "the constraints on production of advanced biofuels"

- A dozen laboratories
- Biology, bioinformatics, chemistry, physics, process engineering, economics, sociology…
- Fundamental research perspective dominant

Context

"We've been living [on Hydrogen] for ten years."

- Project leader, 2016

- Many discourses and visions of the "Hydrogen economy" (e.g. Eames et al., 2007)
- But what of its enactment in practice?

→ An opportunity to observe scientists at work on a topic that is heavily loaded with promises and future visions

Promises and expectations in technoscience

- Idea of a "strategic turn" in science and technology (Borup et al., 2006), a "regime of promising" (Audétat, 2015)
  - Translate in explicit objectives for research and innovation policy

- Role of expectations and promises in directing innovation and establishing new research fields
  - e.g. van Lente, 1993; Brown, 2003; Borup et al., 2006; Audétat, 2015…

- Project-based research, expectations *for researchers*

Research questions

How do promises and visions of the future associated with emergent energy technologies unfold in the world of R&D?

How do scientists and research institutions take up incentives to investigate topics relevant to technological promises, and what part do they play in materialising them?

→ An ethnographic approach inspired by early STS and laboratory studies (e.g. Latour & Woolgar, 1997; Latour, 1986; Akrich, 1992; Knorr-Cetina, 1999) to describe:

- "Dynamics between the imagination and materiality" (Borup et al., 2006; Brown & Kraft, 2006)
- The daily life of scientific promises

The Microbio-E project

"Biomass valorization by MICRObes for BIOEnergy production"

- 2-year project
- Funded by the University and the *Investissements d'Avenir* (IDEX) to:
  - Federate local research around the shared perspective of advanced bioenergy
  - Foster interdisciplinary collaborations
  - Scale-up, link basic research with more applied approaches and concerns

Enzyme engineering for biofuels

Microalgae as biofuel factories

Biohydrogen production and use

The Microbio-E project

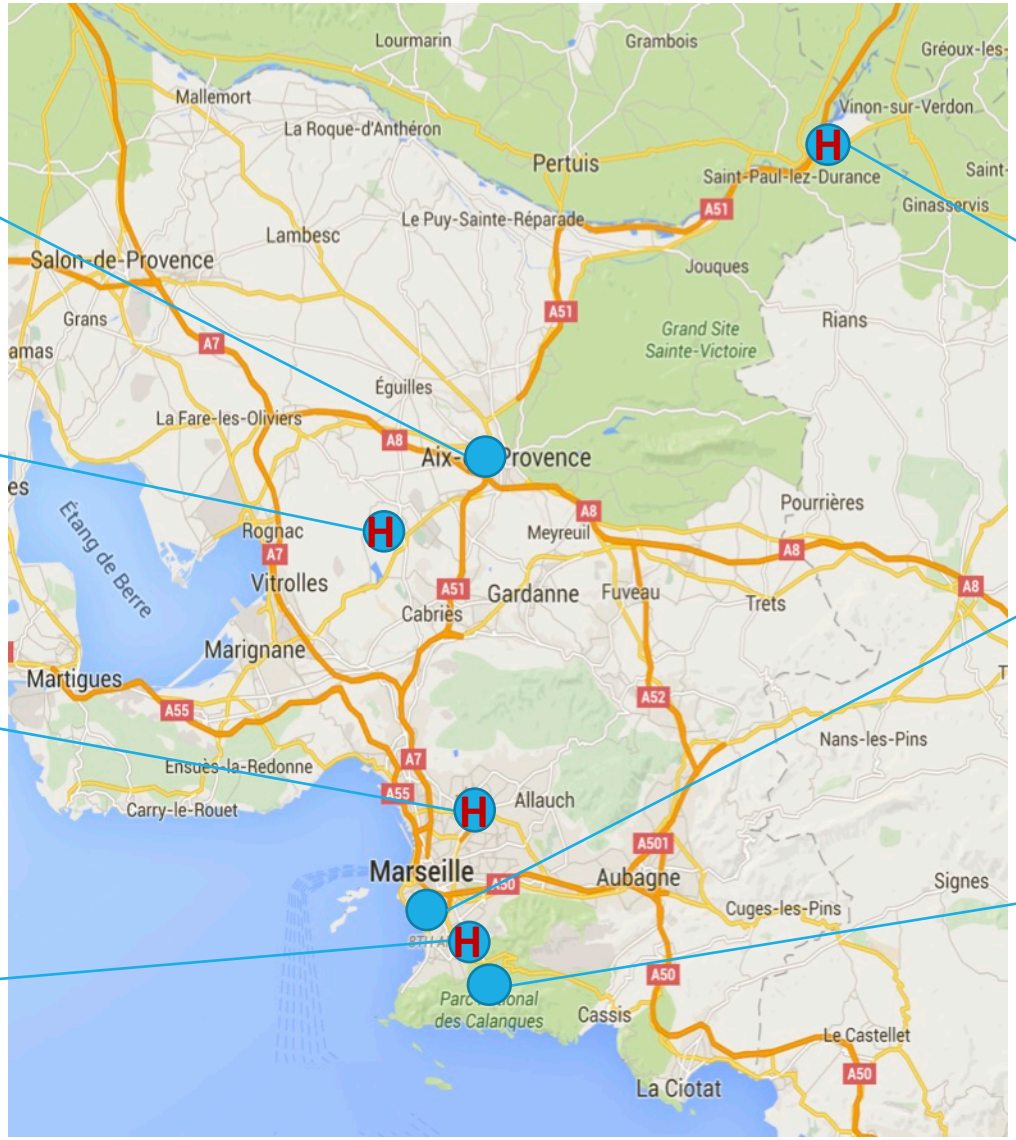
Teams	Disciplines and expertise	Approximate number of researchers actively involved	Topics
BIP	Biology, electrochemistry, biophysics	15-20	Enzymes, Microalgae, Hydrogen
LCB	Biology	~7	Enzymes, microalgae
IGS	Bioinformatics	2	Microalgae
BBF	Biology, enzymology, bioprocess	5	Enzymes
AFMB	Biology, enzymology	4	Enzymes
M2P2	Bioprocess engineering	3	Hydrogen
IUSTI	Heat transfers, study of porous media	2	Hydrogen
LB3M	Biology (algae, lipids)	6	Microalgae
LEMIRE	Microbial ecology, microbial fuel cells	4-5	Biofuel cells
LBC	Biology, enzymology, cristallography	1-2	Enzymes
Cité des Energies	Bioprocess	2	Microalgae
LAMES	Sociology	2	Socio-economic aspects
GREQAM	Economics	1	Socio-economic aspects

MMSH
LAMES

Europôle de l'Arbois
M2P2

Château Gombert
IUSTI

IMM Joseph Aiguier
BIP
LCB



CEA Cadarache
SBVME
- *LB3M*
- ***LEMIRE***
- *LBC*
Cité des Energies

Vieille Charité
GREQAM

Luminy
IGS
AFMB
BBF Inra
SBVME (LGBP)

Field work and methods

Direct and participatory observation, document collections, visits to labs…

41 interviews in 11 teams ; 12 interviews with people involved in the bioH_2 task

PhD Students	7 (3)
Post-docs	10 (3)
Lecturers (PR, MCF)	9 (2)
CNRS (DR, CR, ITA)	13 (4)
INRA	2
CEA	4

Task 1 (Enzymes)	12
Task 2 (Microalgae)	15
Task 3 (Hydrogen)	**12**
Not in Microbio-E	4
Management/administrative	2

Field work and methods

Attention to 3 dimensions:

- Characteristics of their everyday scientific work (practices, devices, topics, theories…)
- Role within the project, collaborations and involvement
- Research strategies and policies, especially as they play out in relation with the MICROBIO-E project; positioning within the current science, technology and innovation environment.

Hydrogen promises in Microbio-E

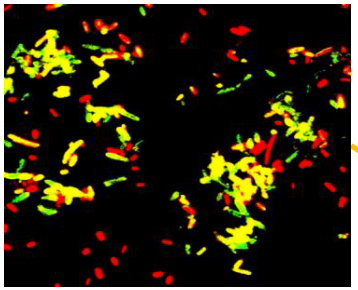
"Some **microorganisms** (fermentative bacteria, photosynthetic micro-organisms, nitrogen-fixing bacteria) **produce H_2 naturally** (biohydrogen); the development of **biotechnologies** based on these microbial systems **could lead to clean, renewable sources of H_2**.

However, the development of a sustainable energetic alternative based on bioH_2 **still awaits a major breakthrough in the yield of H_2 production** and needs research on the development of microbial consortia, genetic modification of micro-organisms and metabolic engineering, enzyme engineering…"

MICROBIO-E Project proposal, 2014 (p. 9)

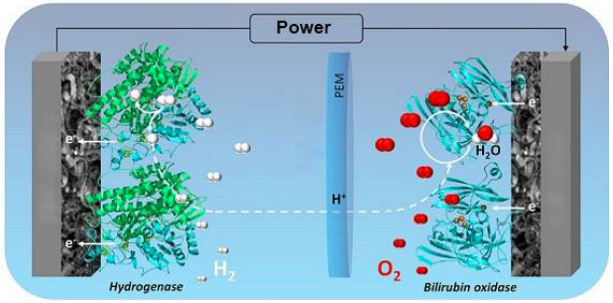
“Biofuel production from waste water: H_2 and electricity”

Microbial consortium



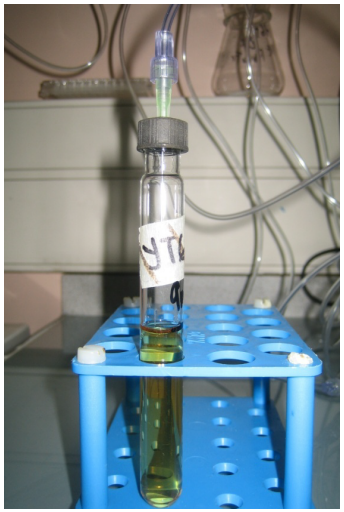
Bioreactor

Enzymatic biofuel cell



From consortia to reactors…

Batch

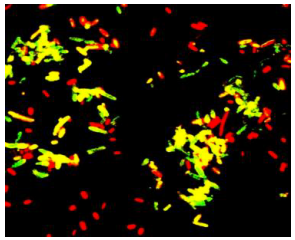


~10 mL
Sterile conditions
Pure culture

Microbiology
Senior researcher
Research Engineers
PhD students

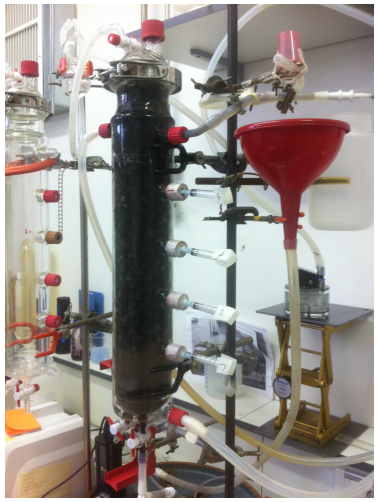
Bioprocess

2 researchers
Post-doc
Intern



C.acetobutylicum
D. vulgaris
E. coli

Bioreactor



~2 L
Usually waste water
Continuous operation over several weeks

From consortia to reactors…

- Translation of objects, organisms, methods across distinct laboratory settings
- Necessary adaptions spark new inspirations for researchers to take *their* research further

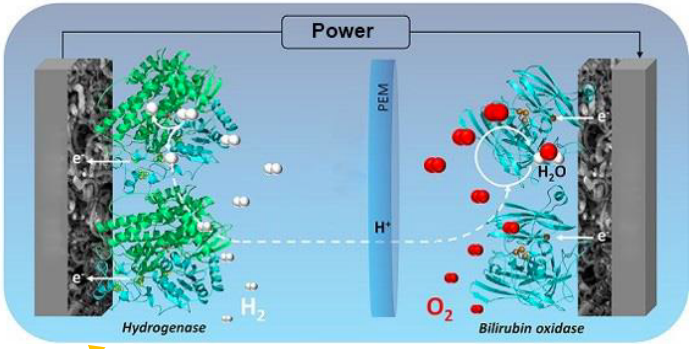
  "In the end, the scale-up needs to be a little less sudden than I had planned"
  - Bioprocess engineer, 2016 (my translation)

- Research remains confined within the lab

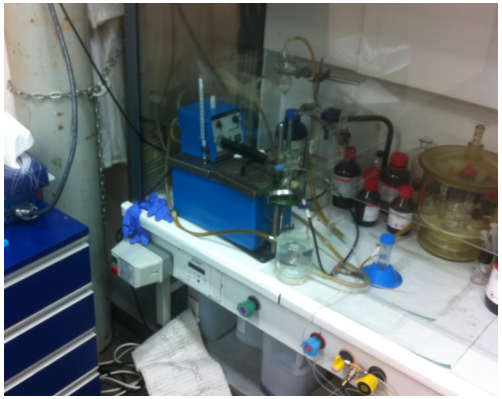
… to biofuel cells

Two teams
2 researchers, 1 research engineer,
PhD student, post-docs

Electrochemistry, biology
materials engineering, modeling



Enzyme from *Aquifex aeolicus*,
a hyperthermophilic bacteria
bred and studied in the lab



… to biofuel cells

- Biofuel cell tested with bioH_2 produced from bioreactor: it works, but what of it?

  "For me**, very difficult**. Very difficult, especially as you're not – for me, anyway – in our conditions for breeding this bacteria… we don't really know them, actually, because it's complicated to breed at 85° C, under high pressures, etc. […] The **quantities to scale up will be complicated to set up**. […] And we have no genetics for *Aquifex*. So this one, in my view, **I won't say we'll scale up."**

  - Research engineer, bio, 2016 (my translation)

  "As of now, anyway, it's **much too expensive**. **No firm can afford** to purify the enzyme. So that's a bit of a vicious circle, maybe it will not go any further, I don't care. Well – **it's not my problem**. […] We have shown there's a possibility, now… if there is not, it's not a big deal

  - Electrochemist 1, 2016 (my translation)

- Heightened competition due to increased expectations

  "What I have witnessed for the past 15 years was that [Hydrogen and hydrogenase] got much, much funding […]. What I saw is that, **when there's more money on it, it does not give people more ideas**, actually. So people all start doing the same things, because they have the same ideas, and so **everyone is doing the same things, but in competition** with one another."

  - Electriochemist 2, 2016 (my translation)

Uncertain perspectives…

Applicability is confined within the lab

→ Developed technologies are laboratory creatures

→ Scientists do not seem to imagine their innovations in other settings

"And we are rather, I think, saying that *this* can be done, could be done, **without really having an application in mind** […]. Even when we did the experiment […], in truth, we never wondered how it would be used for real. We thought: we're happy, look, what we made has worked for a week!"

"The uncertainty as I see it is more on the application, let's say, or the interest of what we do for society as a whole. We say it, because we know that we have to, that probably, we are not wrong – still and all. We think that what we're doing contributes, but we sort of have this notion that **the scale at which we work, at any rate, is disconnected for the direct applications and issues**. But on the other hand, we have to go through this scale, because if nobody does it, we'll never be able to scale-up!"

Microbiologist, project meeting, Oct. 2015 (my translation)

Concluding remarks

- Not much direct interplay between visions and day-to-day scientific work
  - Here, visions of hydrogen futures are shaped by academic calls for proposals on the topic
  - The work done on the lab bench on hydrogen is not really connected to wider imaginaries of "the hydrogen economy", nor to visions of an hydrogen industry, or strategies for commercial development, etc…
  - Does it have to do with the "fuzziness" of the hydrogen horizon?
- The relationships between promises and research exist but are not straightforward
  - Here, research topics did not emerge out of the need to work on energy
  - This framing shapes their evolution but does not necessarily increase applicability
- What role for social sciences in the initial stages in innovation processes?

Thank you for your attention !

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