Situated Green Chemistries: a starting proposal

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« Verde que te quiero verde…
[…]
Pero yo ya no soy yo,
ni mi casa es ya mi casa. »

Federico García Lorca

Abstract

Green Chemistry is already co-defined thanks to alliances across several cross-disciplinary fields including toxicology, environment, economy, computer sciences, earth sciences, and engineering. This paper is a further proposal in that direction, arguing for the need to extend the alliance by integrating considerations from the social sciences, particularly focusing on Haraway's situated knowledge framework. I argue that situating our research around several different core drivers (among which social justice-driven driver, "do-no-harm"- driver, economic growth-driver, etc.) can improve the quality of the green chemistry produced (see the "strong objectivity" claim of situated knowledge) while simultaneously expanding the diversity and pertinence of Green chemistries.

1. Introduction

Green Chemistry principles strive to improve chemical sciences through avoiding or at least reducing by design the presence of chemicals and practices connected to polluting or hazardous chemical transformations.[1]

At the same time, Green Chemistry *principles* are not conceived as "stand-alone" to achieve Green chemistry's *horizon* of sustainability, or benign-by-design chemistry.[2] On their own, the principles can fall short of providing an adequate framework to answer questions relevant to our community; this short-fall is linked in part to the mostly chemistry-focused nature of principles (e.g., better atom economy, use of catalysts, planning for benign degradation, etc.). Although important guides within the chemistry perimeter of a reaction, these principles may only be partly adapted to answering complex, systemically interconnected sustainability-related Green Chemistry questions.[3]

It is already clear that green and sustainable chemistry benefits from reaching beyond chemistry. This has led to alliances across several cross-disciplinary fields with which we already are familiar such as toxicology, environment, economy, computer sciences, earth sciences, engineering, among others. This interdisciplinarity makes it possible to gather scientifically-informed data and methods to improve the reach and understanding of the impacts of green chemistry, and hence to improve the definition of the green Chemistry perimeter, and thereby the definition of what makes chemistry research "green". In other words, these allied disciplines are co-constructing a green chemistry horizon of sustainability and hence co-defining the research performed within Green chemistry. As already listed elsewhere,[4] several sustainability-driven systemic frameworks for chemistry or by chemists have been proposed (e.g., "green & sustainable periodic table",[2] "one-world-chemistry,[5] "circular chemistry for circular economy"[6]).

This paper is a further proposal in that direction. Its originality is its resolute reach—well beyond the proximal allied disciplines named above—through an attempt

to intertwine green chemistry with scientific frameworks originating from the social sciences beyond economy, an already well-established allied discipline, as the importance of, for example, techno-economic analyses in our research practices shows. Foremost, among these "not-(yet?-)proximal" social science fields is the situated knowledge framework.[7] Through this alliance, I am attempting to propose a framework aiming at co-constructing in an original way green chemistry's horizons of sustainability.

2. The disciplinary dilemma

We (and I will situate this "we" a little further down) have inherited our current discipline-based scientific organization from 19th-century positivism; this has led to tremendous scientific advances.[8] The foundational cartesian doubt was the spearhead that reclaimed the freedom to think—and act—for one's self, distinguishing between faith and reason, beyond dogma. The cartesian approach also gave access to power to change the world. Since the cartesian method aimed to turn "reason-informed knowledge into practical power" with a view to mastering and owning Nature,[9] echoing Bacon's "knowledge itself is power", the scientific method was, or at least eventually became, a powerful tool to help shaping our modern globalized world.

From this doubt-wielding power stemmed, among other effects, a fact-informed method of acquiring new knowledge, which was mostly associated with necessary simplifications, among which the reductionist approach, to convert complex, integrated, dynamic and unstable "real-life" conditions into lab-compatible reproducible settings. This reproducibility was necessary to allow precise investigation of the specific doubt under scrutiny and to produce cumulative, transformative and hence powerful scientific knowledge. This is the first characteristic of the "we" I belong to with: I believe in the transformative power of this method.

The laboratory-centered reliable method to address well-formulated questions around lingering doubts, coupled with a positivist conception of science,[10] formed the

basis of modern scientific research. The diversity and capacity to formulate ever more precise questions, and to obtain increasingly focused answers, contributed to specialization within disciplines. As by ricochet effect, the number of disciplines and subdisciplines we specialize in seems to have exploded (just look at the drop-down menu when you next apply for European funding—this is another aspect of my "we": I was born and raised in Europe with some excursions to the US, but I have little-to-no experience outside a European/US-centric focus). Gaining this specialization and developing practices specific to our disciplines has made these subdivisions an efficient tool for knowledge production. However, it simultaneously led to a loss of connections between disciplines and among ourselves—the community of scientists.

The complexity and systemic nature of the rapid and interconnected changes we observe strengthen calls for profound changes to disciplinary separations, in line with the need to overcome these separations if we are to improve science.[8] New ways to conceive of and perform scientific research that are adapted to its complexity, uncertainty, urgency and systemic nature are sought.[11]

3. When who we are pokes through our research output …

3.1. "Human reasoners as collective-knowledge acquirers and cultural-identity protectors"[12]

As a possible answer to the call to surpass disciplinary separation that concluded the previous paragraph, a paper on political psychology offers a good entry point to justify a central assertion of this manuscript: that is, that scientific disciplines, such as social sciences, generally considered outside the fold of the allied disciplines of green chemistry should be brought closer to green chemistry, maybe even intertwined with it.

In the specific case studied in the 2015 paper "*Climate-Science Communication and the Measurement Problem*", scientific proficiency is used by the polled individuals to align their assessment of the evidence with the prevailing position in their political group (see fig 1).[12] The more scientifically proficient an individual is—and members of the academic green chemistry community would definitely rank high in these proficiency tests—the stronger their capacity to adapt their interpretation of the available experimental data to fit their preexisting political identity. The opposite effect is not observed. In this work, under the hypothesis of good faith, and recognizing that the question was very politically divisive in the place and at the time the survey was conducted, political identity appears to orient how data are interpreted more than convergent scientific reading.

Yes, science has a specific method of correcting its stances over time.

In the mid-19th-century, the question "do living creatures arise from non-living matter as their main reproductive route?", the so-called spontaneous generation theory, created division between scientists. These divisions were not around politically-explicit dividing lines like the example above, but they nevertheless cleaved the scientific community, with eminent members of the community on both sides of the fence. This same question is now scientifically superseded: zero-to-none partition. [13] We therefore have a method that may allow us to correct our collective scientific knowledge.

However, it will take time to converge beyond these dividing lines, to reach a solid scientific consensus. These lines—what we believe in and that which is not yet a solid scientific fact, in our eyes or in the eyes of people we interact with—orient how we shape our scientific understanding of the parts of the world being discussed. Are they compatible with the urgency of some of the issues at stake? Do I need to exemplify the issues? Loss of biodiversity, climate change, disruption of P- and N- based geochemical cycles, to name just three.[14,15] And I did not even mention wars, poverty,

undernourishment and other global plagues. Do I need to explain the acceleration of this timeframe? The great acceleration study[16] and the update from the Club of Rome[17] do a good job at that, but so do our everyday lives.

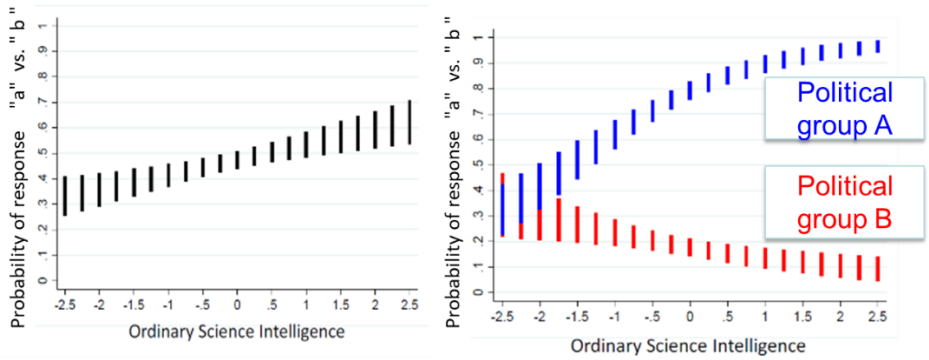

Figure 1. Distribution of answers to the question "[Is the earth] getting warmer (a) mostly because of human activity such as burning fossil fuels or (b) mostly because of natural patterns in the earth's environment" *vs.* the ordinary science intelligence test result of the polled people in D. M. Kahan (2015).[12] Left: all poll responses. Right: blue, poll responses from people who self-identified with values of political group A; red, poll responses from people who self-identified with values of political group B in the survey by Kahan. Visual adapted from the original paper.[12] See original paper for more information.

3.2. Science, science and research

In typographical echo to Bruno Latour,[18] let's define Science as the ideal state of knowledge where all the slag of scientific errancy due to the coexistence of contradictory scientific hypotheses and interpretations consubstantial with new knowledge production has been shed. For argument's sake, let's say that neither systemic complexity nor emergence[8] are epistemologically insurmountable obstacles for Science. If there is a chance that the appropriate timeframe for Science is too long with respect to the timeframe within which some ways of running human affairs must be deflected, and if indeed we agree that there is an ongoing great acceleration[16] which

is shrinking that timeframe and accelerating the degrees of interconnectedness, then we probably need to come to terms with a certain number of factors.

If we believe that the production of scientific knowledge can help, and I still do, then we have to come to term with the fact that we might not be producing *S*cience fast enough.

My proposal is not to produce faster Green chemistry, it is to produce *larger* Green chemistry. Mine is definitely not a call to produce research faster with the aim of hopefully attaining *S*cience on time. Maybe producing research faster is a useful way forward, but I certainly hope there is room for other ways to advance our research. I belong to the group of scientists that do not believe we need to just go faster.[19] In alignment with Funtowicz and Ravetz's pleas "for a plurality of legitimate perspectives" in sciences,[11] I believe we need to produce more diverse green chemistries than what currently exists. The question then becomes: how?

4. Lets' embrace it: Situated Knowledge

4.1. The foundational situated knowledge paper

So, if we cannot reach *S*cience on time, or if, *a minima*, we agree that trying to get there faster is not the only possible route, then we have to settle for producing science—rather than *S*cience—and cope with its imperfections. This attitude can allow us to preserve the power to contribute to knowledge-producing activities that influence the course of human affairs.[7]

The social sciences, using scientific methods—with Science & Technology Studies (STS) foremost among them—teach us that scientific knowledge production is a human endeavor, constructed through the constant interactions between the social, physical

and ecological worlds. The human component that keeps science from becoming Science cannot be overcome[20], but should be taken into consideration as far as possible.

A foundational paper by D. Haraway[7] suggests that embracing of the consubstantial imperfection within science can actually become a key for producing better science, rather than viewing the situation as preventing us from gaining knowledge or as a surmountable bias that can be dealt with by sufficient self-reflexivity[21]. Haraway's framework proposes that strong objectivity in sciences can be attained by making the perspective from which the knowledge is produced less implicit and by intersecting different perspectives. Situating the knowledge contributes to specifying the perspective from which it is developed; combining this approach with a crossing of different perspectives can improve the overall quality of the knowledge produced.

4.2. The risk connected to non-situated Green chemistry

Added to this potential improvement to the quality of the science produced through this type of approach, there is an ethical aspect connected with introducing situated knowledge. Non-situated knowledge ignores the partiality of the perspective, and therefore perpetuates injustices by serving the interests of those (individuals or systems) who benefit from this partiality. Non-situated knowledge is—simply put—situated knowledge that is unaware of the perspective from which it is built. This definition includes knowledge that concerns us here: the results of research in non-situated green chemistry.

Two examples of non-situated knowledge that I have encountered in my professional career around green chemistry corroborate this statement.

Figure 2a presents a schematic representation of the “peak shaving strategy”. In the presence of fluctuating electricity prices (for example day/night differences due to grid overload during day-time hours) a battery technology that is too expensive to be competitive with average grid electricity prices can become viable. This is because a judicious choice of charging and discharging times can make it competitive as a back-up solution during peak hours. I have encountered this type of reasoning in many settings, including green-chemistry-oriented studies discussing how to cope with overloaded electric grids. Among climate-mitigating activities, accompanying measures to handle overloaded electric grids is one element contributing to the energy transition away from fossil fuel use. All well and good. However, this figure was presented as the introductory slide of a conference held in a country with little access to electricity (see figure 2b). The introduction was tone-deaf in that setting, and can be seen as a metaphor for a broader argument. Worldwide, 940 million people (13% of the world's population) have no access to electricity. Therefore, notwithstanding the universality that the proposed broad framework would tend to suggest ("the fight against global warming"), this type of research is part of a specific framework responding to a problem that is relevant to a subset of people. It is not a universal problem. I’m not saying there’s anything wrong with the research topic, it is good, it is green chemistry, and global warming needs to be fought. What I am trying to emphasize is that the universality of the backdrop omits the specificity of the solution, and the loss of universality somewhere within the argument.

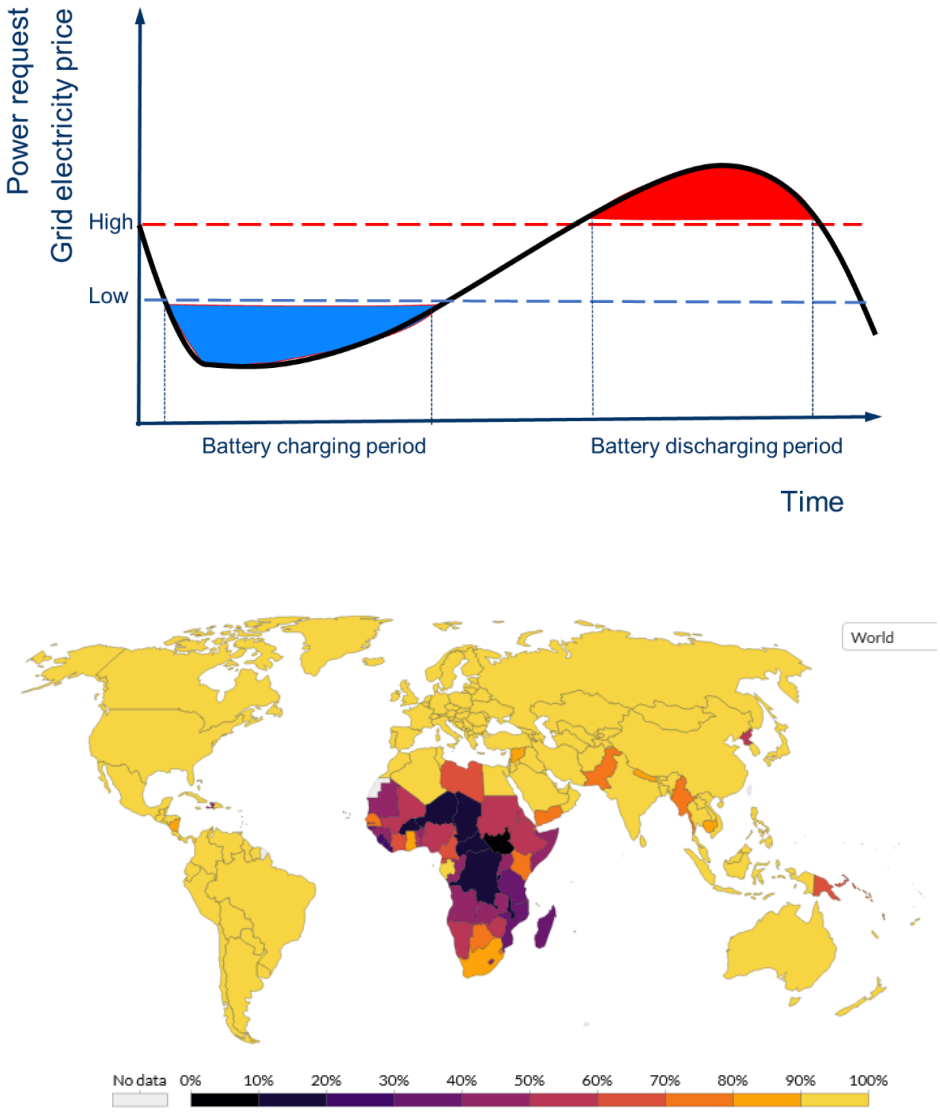

Figure 2. (a) schematic principle of peak shaving applied to overloaded electricity grids. (b) Share of population with access to electricity (2020). Data source: ourworldindata.org/energy (CC BY) with data compiled from multiple sources by World Bank.[22] –

The second example is more personal, it arose during my attendance of a Green chemistry conference. The speaker was presenting one of their recent research achievements under the heading “from biomass to beauty”. A very nice set of green chemistry-abiding reactions were showcased for the elegant catalytic conversion of a major platform chemical from biomass into a skin-whitening product. Again, I have nothing against the elegant chemistry that makes it possible to offer a less fossil-fuel-intensive route to an active pharmaceutical ingredient that has a market and some medical applications—so it is also justified. However, not all beauty requires a lighter shade of skin.

While it is personally uncomfortable to discuss this specific example, I think it is fitting as it reflects how I felt in my body—because I could feel that something was off and hurtful to me, a brown-skinned woman. This state of being made me identify the partiality of the perspective at hand. I know that it is not necessary to belong to a racialized group to object to a racially-loaded situation—the support messages received from many non-BIPOC conference attendees during the conference after my intervention are evidence enough. Nevertheless, I know that the alarms ringing in my body can be allies to fight racially-loaded situations. But how many alarms does my body lack? How many does our collective community lack? How many points of view are we missing? Can we use the “*Situated Green Chemistries*” proposal to expand the perspectives from which green chemistry is built?

In summary, I believe the “*Situated Green Chemistries*” project can help correct some of the (unbe)known-to-us partiality of this journal and our community (how diverse are we? I think we can do better). In turn, this rectification can help improve the quality of the science we produce, since it clarifies the relevant situations, it contributes to paving the way to fighting and correcting the narrowness present before this clarification. Such a reframing will affect research subjects and, in an interconnected

way—as the situated knowledge framework suggests—researchers and other knowledge-producing stakeholders, because their bodies and their "bells" can also help shape the questions to be addressed.

5. The situated Green Chemistries framework

5.1. Foreword

So, let's see if and how the intersections between the situated knowledge framework and Green Chemistry can lead to a more diverse, more engaged community of green chemists, and concurrently to better science.

Scramming to better understand How this "situating one's self" works by trying to educate myself on the topic,[7, 23,24,25,26,27,28,29] I perceive that several relevant levels can be brought into focus, including the following:

- elements of historical, societal, social, economic, cultural and political context (which naturally interact, and shift, and change)
- the personal experiences that one has (or seeks, avoids, provokes, endures, enjoys, pursues, etc.) within this shifting context, and the power dynamics that feed into them, affecting the personal experiences over time
- the personal choices that one makes with respect to their contextual elements and personal experiences
- the aspirations, kinships, values and ensuing projections of desirable futures that one develops in this journey
- etc.[30]

A person can situate themselves through an opening statement to a body of work. This is the "from where I speak" or "lieu d'énonciation/locus of enunciation/lugar de enunciación" of counter-hegemonic feminist, black feminist, subaltern studies or

decolonial tradition that characterizes some position statements.[31–33] A third party can also be situated, when analyses are performed by an external actor who specifies the perspective from which the third party operates.[34] But to be completely transparent, I am still struggling with this for myself.[35] Consequently, I have dispersed throughout this paper timorous crumbs of my "lieu d'énonciation" and will propose a more consensual view of "how we situate ourselves" in the next paragraph as stepping stones for the "*Situated green chemistries*" framework.

5.2. The power of imagining desirable futures

I find that one aspect of the list's last item above can be an interesting door to propose an expansion of the perspectives from which green chemistry can be built: the aspirations and projections of desirable futures.

Indeed, one person's aspirations for and projections of desirable futures can be powerful drivers of transition. A case in point is Anne-Françoise Garçon's historic study, as cited by Beltran et Carré,[36] on why electric cars "lost the competition" to internal combustion engines in Paris in the early 20th century. At a certain moment, both types of cars coexisted in Paris' streets, and it was unclear if one type would establish itself over the other. Eventually, internal combustion cars did. Anne-Françoise Garçon shows that, while technical innovation, economics and societal organization all played a role in this outcome, the main driver that shaped the future of urban mobility was the construction of a shared imaginary: "Electric motors were soon confronted with the problems of batteries, recharging and costs. [...] Moreover, [...] the inventiveness and haphazard disorder of the engineers clashed with the advocates of a centralized network [...]. **More fundamentally, [...] the automobile was gradually invested with an imaginary of its own**. Thought to be confined [...] to the sphere of urban mobility, it has been invested with an imaginary of its own. […], we quickly realized that it opened up

new perspectives: those of distant travel. …" (bold by me).[37] To me, the echo with some current dynamics is resounding. Today in Europe, without the powerful shared projection of the desirability of a fossil-fuel-sober future, would electric vehicles be attracting such attention? Would research in the field, which contributed to our arrival at this point, have moved along as smoothly and as fast?

From this relationship between shared projections and research feeding into them, part of the situated green chemistries framework emerges. Can we use a driver defined at an individual level[38] as an entry point to eventually create shared visions shaping the future? And, ultimately (this is just a start), to guide our research within our community *en route* to transformative projects? The connection with the conceptual tool of "Sociotechnical imaginaries" developed by STS might be a goal.[39] But I leave this reflection to pertinent scholars, and I continue to trudge along my green chemistry lane.

5.3. The heart of the proposal: the initial core drivers

The "Situated Green Chemistries" framework is resolutely turned to one of the goals of green chemistry: building sustainable solutions for the future. Therefore, it asks the questions "*What core driver moves you? What driver do you rely on to help steer toward desirable futures with Green chemistry? Through which door do you want to usher in the future?*". Based on my experience of the field as an active experimental chemistry researcher (in-training and then as staff) since the beginning of my PhD in 1994, through the literature and through exchanges with fellow researchers over the course of my career and based on my own sensitivity, I propose 12 entries. I start by announcing the presence of the "**yet to be determined**" driver to underline the fact that this framework is a "work in progress" and that it will continue to evolve. For each core driver, I will give some examples of academic papers that might illustrate it. Among the examples that could fit, there is often a preference for papers presented at the Green

Chemistry Gordon conference in 2022 in Casteldefels (Spain),[40] because that is when I first presented this work (see next section).

Here is the list of the 12 initial drivers of the "Situated Green chemistries" framework:

- **Force of Nature**: Green chemistry has the capacity to provide answers that can be "of geological magnitude",[14] to echo Crutzen's Anthropocene focus, or at least scalable, possibly to a global scale. As a main driver, **"force of nature**" translates the conviction that the best path forward for one's own research is by seeking the largest green effect possible by interacting with the biggest current stakeholders. Hence, "**force of nature**" green chemistry solutions can typically be deployed with socio-economic stakeholders with global reach. Some possible illustrative works include:
    - *E.g.* Advances in Geoengineering: "*Stratospheric solar geoengineering without ozone loss*", by DW Keith, DK Weisenstein, JA Dykema, FN Keutsch, in **Proc. Nat. Ac. Sc.** (2016).[41]
    - *E.g.* Contributing to sustainable industry: "*Products and processes for a sustainable chemical industry: a review of achievements and prospects*" by J. F. Jenck, F. Agterberg and M. J. Droescherc in **Green Chem**. (2004).[42]

- **Speedboat to market:** Startups stemming from scientific breakthroughs and innovations in green chemistry can provide an efficient setting to circumvent the hurdle of inertia of well-established groups, while simultaneously retaining the capacity to tap into the boost that marketable solutions can get if they eventually deploy at scale. Academic research -> patenting -> startup is a road of choice for researchers adhering to the "**Speedboat to market**" driver

- *E.g.* "*Separation of bio-based glucaric acid via antisolvent crystallization and azeotropic drying*" by H. Choi *et al.* ***Green Chem.*** (2022).[43] Involvement of Kalion.inc, one of the EPA's "Small businesses" Green chemistry Challenge awardees.[44]

- **Social justice:** This entry point frames the reason to carry out research as some type of (perceived) social injustice. It drives the production of new knowledge that is relevant to grounding the debate, thanks to scientifically-informed data. The research can be in chemistry. For the connections between green and sustainable chemistry and justice-seeking topics, see for example Anastas and Zimmer's green and sustainable periodic table (in particular element 37 and the "noble goals" group).
    - *E.g. "Is Lithium Brine water?*" by M. Ejeian, A. Grant, H.-K. Shon, A. Razmjou in *Desalination* (2021).[45] In this paper, theoretical chemists frame the justification for their research in the criticism that evaporative processing of brines has faced from some indigenous communities, researchers, environmentalists, lithium buyers, and lithium project investors. In their view, in some brine fields, the efforts to address the environmental issues have been hindered since the brine is not considered "water" but instead regulated as if it was a mineral.[45,46] The DFT calculation by Ejeian *et al.*[45] helps understand if brine is more akin to water or to a mineral. The framing of the introduction directly exposes the authors' interest in contributing to this ongoing point of social tension. For this reason, I associate this work with a "social justice" driver.
    - *E.g. "The Open Insulin Project: A Case Study for 'Biohacked' Medicines" by* J. E. Gallegos, C. Boyer, E. Pauwels, W. A. Kaplan, J. Peccoud in *Trends in Biotechnology* (2018).[47] The paper narrates how biochemists,

considering that prohibitive prices make access to vital medicine socially unjust, organized in community biolabs and a DIYbio movement to develop and share useful knowledge to counteract this injustice.

- *E.g.* The chemistry research performed as part of a citizen science project to measure air pollution recounted in "*A critical air quality science perspective on citizen science in action*" by D. Booker, G. Walker, P J. Young & A. Porroche-Escudero in *Local Environment* (2023).[48] This line of research is connected to the "science undone" concept, when groups of people perform research to defend their interests and overcome a lack of official data (or their suppression, underfunding or defunding, or malicious discredit) in established (including academic) arenas. This "**social justice**" driver could therefore also help introduce topics into the academic arena, particularly topics that are, for various reasons, on the fringe.

- **Local solutions, developed and maintained at community-level** For some, desirable futures do not rhyme with scalability[49] but rather with tools developed and maintained by a community of users.[50]
  - *E.g.* The insulin project presented above[47] could again be an example, since the "**community-level**" can also be a community of shared interest. This goes to show that it is not the work itself that decides the classification in the "*Situated green chemistries"* framework, but the intention of the authors. In this sense, most of the examples that I give throughout this manuscript are really just attempts to illustrate what I have in mind, since the authors rarely share their position in terms of a situated green chemistry core driver in their paper.

- *E.g.* Low tech for conviviality is a type of technology that could resonate with this core driver. Several existing examples applied to the energy transition are therefore green-chemistry-related.[51] Tellingly, most of the examples I found in the academic literature offer low tech not as the core driver, the desirable future, but as a necessity for use in some parts of the world (not where the authors are based most of the time) that cannot attain the "state-of-the-art" or that are "developing countries" or "low and lower-middle income" countries.[52]
  - *E.g. "Comparison of Different Pretreatment Strategies for Ethanol Production of West African Biomass"* by S. T Thomsen, J. E. G. Londoño, J. E. Schmidt and Z. Kádár. in *Appl. Biochem. Biotechnol.* (2015).[53]
  - *E.g. "Local manufacturing of perovskite solar cells, a game-changer for low- and lower-middle income countries?" by* B. Roose, E. M. Tennyson, G. Meheretu, A. Kassaw, S. A.; Tilahun, L.; Allen, and S. D. Stranks *in Energy Environ. Sci.* (2022). [54]

  Even if the points of view that can be inferred from the opening statements and introduction to these two papers ("low tech" as a solution for others, who do not have the economic conditions to go "high tech") do not fit the "low tech core driver", their presence here adds another layer to the framework. Indeed, inspiration for green chemistry associated with one core driver can come from works linked to other core drivers. Situated green chemistry is open to cross-fertilization and dialog (or confrontation) between distinct visions.

- **<u>In Scientia Veritas—"Libido Sciendi"</u>** Many of us, professional researchers, have experienced *libido sciendi*, the drive to understanding as the guiding force. For this

core driver, researchers feel the *libido sciendi* or recognize faith in "Science as a route to truth" as the main driver for their research. I do not think examples are needed. I also think this is a very personal, almost intimate, driver that would not translate in the opening statement of a paper (the same applies to other drivers I omit: career advancement, etc. etc.).

- **5 °C fighters.** Like Emergency Room (ER) doctors in hospitals, **5 °C fighters** in situated green chemistries are attracted by the mission of developing new scientific knowledge that could become relevant if the future were to be severely disrupted due to untempered global warming, or other catastrophic events (biodiversity collapse, profound social unrest, substantial increase of inhabitable land, …). I have chosen the extreme "+5 °C" scenario that is the highest temperature taken into consideration for 2100 by the 6th IPCC assessment report,[55] to stress the "brace-for-worst" state of mind underpinning this core driver. While I personally recoil from such a (hopefully…) dystopic future narrative, I can see the usefulness of (and indeed personally know at least a couple of green chemists who adhere to) this sort of projection. Investing in producing the requisite new knowledge could become a motor to their science (if they had been medical doctors, they would have worked in ER). In the scenario where our globalized exchange routes and globalized dynamics are substantially disrupted in the next decades, what new green chemistry knowledge do we need to develop now to cope with this possible future?

    - The example of insulin above[47] can open the discussion. What drugs do we need if the 5 °C (or lower) disruption occurs? And how can we produce them? Necessary drugs are just one of the aspects. What about access to water? To other resources? Knowledge connected to material circularity on a local scale might have a definition of circularity that is not the same as the one presented in

most papers now. The experimental part of these new research papers would probably not begin with "purchased from a commercial source", and the goal of scalability might or might not be presented. This example, for me, is an important one showcasing the fact that these different entry points to green chemistry create green chemistries with distinct primary objectives, means and practices.

- **Cure and repair**. I originally considered presenting these two drivers together (see next section) to (metaphorically?) connect curing a sick body and repairing a damaged Planet. However, the two items can also be explained separately.
    - Driven by the "**Cure"** core driver, this green chemist develops research that contributes to new knowledge that is directly relevant to the medical field.

      E.g., "*Continuous-flow synthesis of the anti-malaria drug artemisinin*" by Lévesque, P. H. Seeberger in *Angew. Chemie* (2012).[56]

    - The "**Repair"** core driver moves researchers in green chemistry interested in repairing environmental damage. Even though "end-of-the-line" remediation solutions are not the principal target of green chemistry, some interesting examples come from our community:

      E.g., The development of 'OleoSponge' adsorbing materials to clean up oil spills in open waters. "*Filtration membranes* " by S. B. Darling, J. W. Elam, R. Waldman, US patent.. No.: US 2019/0054426 A1 Pub. Date: Feb. 21st, 2019 and "*Montmorillonite Membranes with*

Tunable Ion Transport by Controlling Interlayer Spacing" by Liu *et al.* in *ACS Appl. Mater. Interfaces* (2023).[57]

- **The power of art**. Some chemistry researchers like to think of our craft mostly as an art, in so far as chemists create their own object. The connection between performing research and aesthetics has also been drawn,[58] with research uniting beauty, imagination and understanding. This freedom to create can be a potent driver for performing research.[59]

- **Do no harm**. Some researchers take the "benign-by-design" principle as the guide star feeding directly into their research this principle of precaution.
    - "*Going All In: A Strategic Investment in In Silico Toxicology" by* J. Kosta and A. Voutchkova-Kostal in *Chem. Res. Toxicol.* (2020).[60] The authors embed absence of toxicity from the start in computer-aided drug design.
    - "*EISA-EXPOSOME: One Highly Sensitive and Autonomous Exposomic Platform with Enhanced in-Source Fragmentation/Annotation" by* J. Xue *et al.* in Anal. Chem. (2023).[61] The authors contribute to advancing exposomic research[62] by developing novel analytical chemistry approaches.

  The two "do no harm" examples given above target human health. This core driven can also targets broader, as well as disruptive ethical and political definition of whom are we taking into account (and whom are not taking in to account) in the targets of benign care (human beings, non-human beings, non-living?),[29c] thus extending such «principle of precaution » into a question about whom do we choose to "make kin" with.

- **North <-> South**. The core driver here is to lessen North-South injustice. More specifically, this core driver is addressed to those, like me, that feel that we can collectively do better with respect to the inherited injustices that have helped widen the global North-global South divide. I am among those who consider that some current scientific production in the academic global North, including in green chemistry, bears the defects of its imperial/colonial inheritance.[4] For example, this includes pollution displacement that disproportionately affects the South, extractivism that disproportionately takes resources from the global South for use in the global North, and epistemicide—not giving due credit to the original source of knowledge.[4,31,63–65] The North <->South driver is for green chemists who feel that it is essential to overcome these defects and develop research in chemistry that can both correct and propose new routes. Some examples that have inspired my current reflections are:
    - Attempts to curb ongoing epistemicide regarding knowledge produced in the global South,[65] by, for example, helping reinstate the validity of, *inter alia*, suppressed ancestral forms on knowledge. *"In Vitro Characterization of a Nineteenth-Century Therapy for Smallpox"* W Arndt, *PLoS One*, 2012.[66] In this case too, the practices and motivation of science, and not just the scientific results emerge as relevant features that must be co-developed with the investigative topic itself to align with the core driver. For example, each element of new knowledge produced can provide gains. If we limit the discussion here to academic capital generated by research (rather than, say, financial benefits) one question is how this academic capital is distributed: How does the list of co-authors reflect the value represented by the core driver? Are the original "owners" of the knowledge considered? Does the knowledge produced proportionately benefit the North<->South dynamic?

These types of questions reveal one of several missing aspects of this preliminary "Situated green chemistries" framework proposal. No research subject is completely disconnected from practices, and presenting one without the other provides only a fragmented view. At the same time, this proposal is made to launch a collective construction, one of the goals of which is to invite individuals to identify a personal and political (as in value-grounded society-shaping) connection that is important to them. By doing so, they will become more involved in their research;

- Find resources in our own end-of-life waste that can reduce our dependence on resources from elsewhere. The importation of resources is a practice that can be considered a throw-back to colonial dynamics.[63,64]

  E.g. "*Simultaneous CO_2 capture and metal purification from waste streams using triple-level dynamic combinatorial chemistry"* by J. Septavaux, C. Tosi, P. Jame, C. Nervi, R. Gobetto and J. Leclaire in *Nature Chem. (2020).*[67] Using elegant CO_2-triggered combinatorial chemistry to help recycle metallic elements from spent batteries.

- **<u>…… "yet to be determined"</u>** these are all the missing drivers that I have not identified, but that should be added, for example through feedback from community (see SI) to ensure that this framework reflects our wide and changing diversities

- In addition, among the **<u>drivers</u>** listed above, some **<u>may need to be removed or changed or merged</u>**, depending on community feedback.

In summary, the situated green chemistries framework aims to propose a first set of possible value-based drivers (social justice-driven green chemistry, human health-driven green chemistry, economic growth-driven green chemistry, etc.), see figure 3.

This first set of drivers results from my desire to propose ways to expand green chemistry. The proposal is nourished by my experience of the community from my position as a researcher in green chemistry, involved in community-relevant events such as participation in and co-organization of green-chemistry-related conferences. I can also mention the influence of activities connected to my roles as member of the editorial board of the Royal society of chemistry (RSC)'s journal *Green chemistry* for 11 years (2013-2024), and as associate editor of the same journal for 7 years (2017-2024). This framework is partly a self-reflexive tool from within the community for the community. I am looking forward to seeing its community-led evolution and its emergence as a useful shared tool. If this progression is successful, the necessary next step will be to relinquish the non-democratic dynamic of researchers shaping their own agenda in an insular manner.

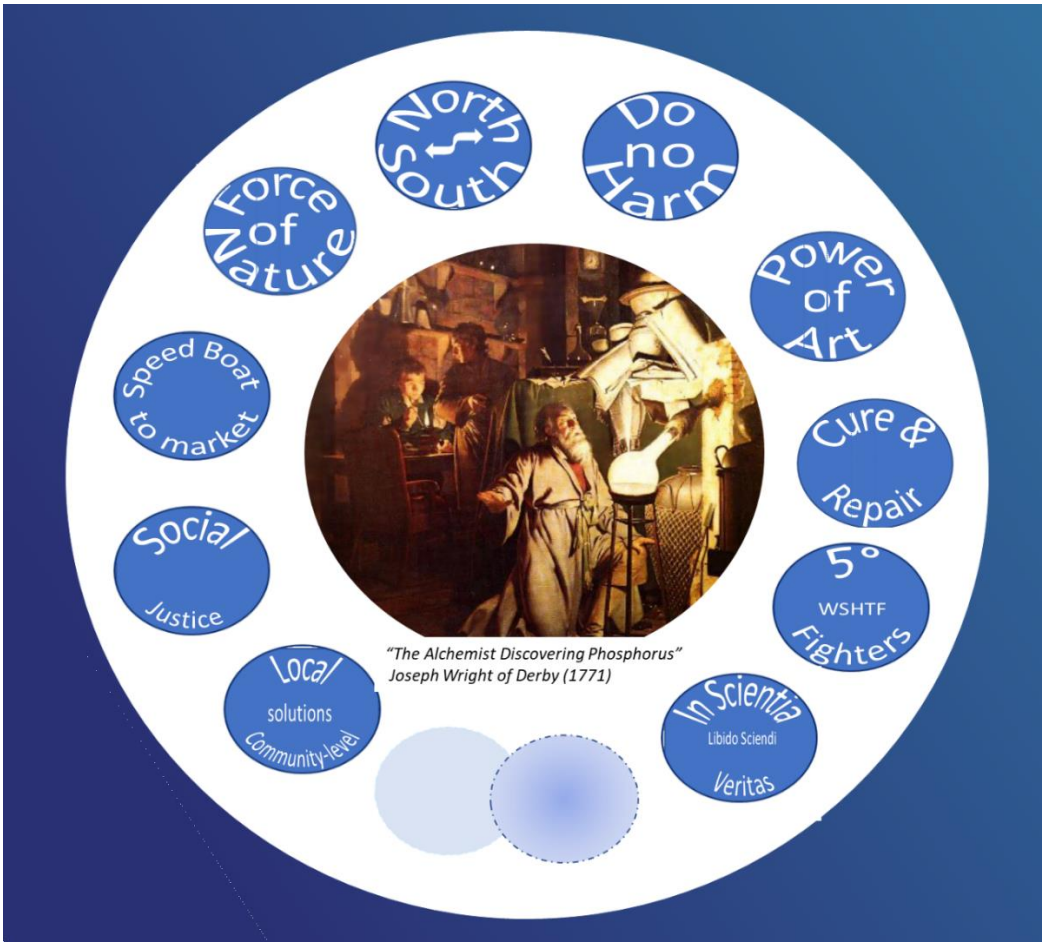

Figure 3. Pictorial representation of the initial *Situated Green Chemistries* Framework described in the text.

5.4. First feedback from part of the community

I consider my first attempt to test the "*Situated green chemistries*" framework successful. The instant poll around the "*Situated green chemistries*" framework performed as part of the conclusion to my intervention during the 2022 edition of the "Green chemistry Gordon Conference",[40] engaged a large portion of the audience. This poll was conducted following a presentation retracing the content discussed above, and the results showed that it could capture a diversity of opinions and drivers within our community. No unproductive antagonism was expressed, and substantial support was indicated. Analysis of the results (See figure 4 and table 1) shows that about 90% of the lecture attendees registered to "vote", and 70% of them cast their "ballot". A "vote" required respondents to tap an area of their smartphone display that reproduced the slide projected on the main screen of the conference room. Participants tapped from their seat (and hence I assume in private), each tap made a blue marker appear on the corresponding zone of the main screen in the room. Figure 4 reproduces the image on the main screen once the votes had stopped coming in. There were 17 possible options (the colored circles in figure 4; the gray, blue and green lines in table 1).

- Out of these 17 options, three could express skepticism, confusion or criticism (red and gray colored circles and bottom left "thumbs down" circle in figure 3; blue lines in table 1). Only one vote (1/68) went to one of these options, and it was the milder stance "I do not get [this framework]" (gray circle).
- The bulk of the 17 options (12/17) consisted in one core driver or a generic "thumbs up" (the green and blue colored circles and central bottom thumbs up in figure 3; gray lines in table 1). 63/68 votes picked one of these options; 7 of the 11 different "core drivers" were selected (see table 1 for details).
- Out of these 17 options, two explicitly expressed very strong support (yellow circle "Forget picking. I want to say: way to go!!" or double thumbs up circle in figure 4, and green line in table 1). 4/68 votes expressed this very strong support.

In summary, we can propose an indicator of support for the project, a percentage ranging between 60% (67 votes in favor/110 people present) and 98% (67 votes in favor/68 votes expressed). This is an estimate of the positive engagement spurred by the framework proposal at the time of polling. At the same time, the setting of the poll probably skewed the results , and reproducing this sort of polling (see SI) could probably be insightful.

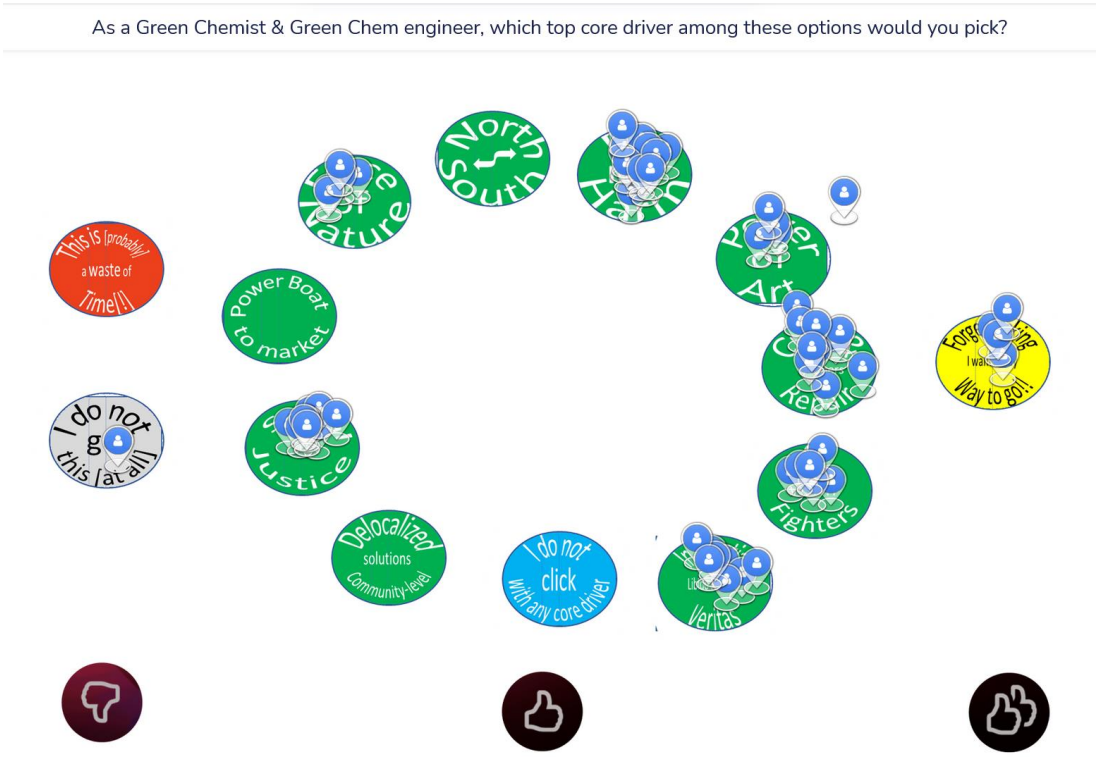

Figure 4. Pictorial representation of the instant polling results based on the "Situated Green chemistries" framework. Poll conducted during the 2022 edition of the "Green chemistry Gordon Conference" (a blue marker represents a vote by an individual respondent). Only one vote was allowed per participant (software used: Wooclap). For more details see Table 1 and main text.

Table 1 Summary of results of the audience poll at the end of my lecture "*What is "Sustainable Green Chemistry" through systems thinking?"* during the 2022 edition of the "Green chemistry Gordon Conference".[40] 68 votes were expressed by the 97 registered voters (Wooclap), among the approximately 105 (±5) people present in the conference room at the moment of the poll. Column 1: name of the core driver, columns 2 and 3 succinct explanation and literature example given during the lecture preceding the vote. Column 4, reference cited (in this article), column 5, results of the polling (extracted from figure 4).

Core driver proposed	**Succinct explanation**	**Example given**	**Reference cited**	**Votes**
Repair & Cure	Repair: develop new solutions for remediation Cure: Use GC to improve access to key drugs	Sponge to absorb oil spills in open waters Continuous-Flow Synthesis of the Anti-Malaria Drug Artemisinin	[57] [56]	11 (16%)
Social Justice	Green Chemistry focused on promoting social justice	"Computational chemistry could help clear up Chile's lithium brine controversy"[46]	[45]	7 (10%)
Level North<-> South Inequalities				0
Delocalized small-scale solution		Produce insulin outside centralized large suppliers	[47]	0
Prepare for 4 °C scenarios				6 (9%)
Do no harm	Ensure absence of harmful consequences	Embed absence of toxicity in design for example in computer-aided drug design	[60]	23 (33%)
Speedboat marketing	Favor Green Chemistry Startups	BIOWEG, Germany		0
Forces of Nature	Engage the major industrial stakeholders in green chemistry	Shell Global Solutions Int. B.V		4 (6%)
Power of art	Chemists are artists			5 (7%)
Libido sciendi	Nurture the pleasure of discovery and science to advance knowledge			7 (10%)
Single thumbs up				0 (0%)
Further options given to voters as part of the anonymous instant poll				
This is (probably) a waste of time	Displeased with framework			0
I do not get this/ I do not get this at all	Framework not clear			1 (1%)
Single thumbs down				0 (0%)
Forget picking. Way to go	Explicit enthusiastic support for framework			4 (6%)
Double thumbs up				0 (0%)
Total votes				68 expressed votes

5.5. Pick a lane

While several of these drivers might resonate for some people, I set a polling condition that each respondent could pick just one. Picking just one can help avoid implicit hierarchies of values that can exist in our field, even for values presented on the same level. For example, the three Ps (People Planet and Profit) in the "triple bottom line" definition of sustainability are projected as equivalent, but one is often respected while the other two are not systematically.[4]

Picking a single core driver rather than several also leaves room for new, and as yet underexplored, questions to emerge: are new specific research subjects needed? Are some specific (new) stakeholders missing from the group performing the research? Are changes to research practices needed? Are the current criteria used to establish the sustainability and quality of research relevant or should new ones be defined in complement to the existing ones? …. I therefore think picking one and only one core driver and "running with it" can be a useful route to letting the diversity of green chemistries bloom.

6. Indicators of success

6.1. Trusty metrics

Metrics and quantitative evaluations have become trusted companions in green and sustainable chemistry.[68] Examples include the seminal atom economy and e-factor indicators, focused on minimizing the mass intensity of a reaction at a molecular level, multi-parametric environment-oriented calculations such as life cycle analyses, human health-focused metrics—like the chemical body burden[2,69]—or economic considerations, such as techno-economic analyses.

If the situated green chemistries approach were to become successful in helping "hedge our bets" in order to expand the types of futures we could prepare for in these unsettling times through our research, then more diverse and sometimes radically diverse objectives could become a focus. In addition, different objectives can also mean new metrics. For example, the "*5° fighters*" as well as "*delocalized community-level solutions*" would most likely need to develop ways of assessing the robustness of supply and local-sourcing for resources. While these types of metrics in combination with others will be necessary to judge the appropriateness of the research produced within these core drivers, they might be less critical for other core drivers.

In summary, just like research topics, indicators and metrics are situated in an underlying, and often implicit, shared context of values, cultural habits, social organizations, and other overarching elements. There is work to be done to understand the value behind the metrics, the driving force leading to the existence of a specific metric, and the values that are legitimate for our enlarged community and that we may not have seen yet. Creating a larger space for chemistries also implies expanding the space for evaluation criteria and metrics.

6.2. Step outside your comfort zone

However, it is not always possible to measure things. Anastas and Zimmerman propose as element 51 of their "periodic table of the elements of green and sustainable chemistry" the element Ql for Qualitative metrics: "*While most traditional assessment is based around quantitative metrics, qualitative metrics may be equally necessary in providing understanding related to sustainability. The nature and character of aspects of sustainable chemistry are not always reductionist exercises."*[2] This sensibility is synoptic with what I am trying to propose here.

The need to expand in directions that are currently outside our traditional analytical frameworks is also connected to the rapidly changing—and sometimes

catastrophically so—and systemically entangled pace of this Anthropocene-framed epoch.[4] In this unsettled and unsettling context, research output in green chemistry, just as in physics, mathematics, biology and computer science, among other scientific fields, may reveal an ambivalent role with respect to some of these systemic changes. The role is ambivalent because it can be difficult to fully comprehend the impact(s): amplification of adverse changes (e.g., reinforced overproduction, development of new entities that are ultimately incompatible with the biosphere), provision of knowledge and practices that can adequately respond to the period's challenges.

Ambivalence can permeate some research to the point where it becomes impossible to assert a position within this context. A fitting example in the field of green chemistry is the editorial "The subject of 'fracking' in *Green Chemistry*".[70] The editor had to decide whether the topic of the manuscript entitled "*Stimuli-responsive/rheoreversible hydraulic fracturing fluids as a greener alternative to support geothermal and fossil energy production*"[71] belonged to the journal. In a nutshell, the question the editor faced was: "Is there a contradiction between making fossil-fuel related technology greener and Green Chemistry? How, if at all, is moving away from fossil sources—a shared goal of all green chemists in the long-term—compatible with making fossil-based technologies less un-/more sustainable in the short- to mid-term? " The editorial acknowledges our limitations as a community of green chemists to answer this type of questions : "We do not know; *In dubio pro reo*" concedes the editorial. Other such undecided/undecidable (for now) subjects also exist. And no number, no metric is probably pertinent at this level of undecidability. Opening a transdisciplinary reflection associating green chemists and experts on the problem from outside chemistry and its proximal disciplines might be an interesting route for this and other questions. This will help us to shape an intellectually-informed and science-sourced approach to addressing the key systemic questions central to green chemists' concerns. "Where should we go?" is one among others.

6.3. Inspirational data scientists that go beyond bias and metrics

An inspirational scientific community that is forging ahead through this type of entanglement is a group of data scientists working in predictive programing through artificial intelligence (AI). This group revolves around the “ACM Conference on Fairness, Accountability, and Transparency (ACM FAccT)”. This computer science conference has a cross-disciplinary focus that brings together researchers and practitioners interested in fairness, accountability, and transparency in sociotechnical systems”.[72] As a possibly archetypical example of scientists achieving warp speed in knowledge production, this community was involved in *FairMachineLearning (FairML)*, and spawned an interdisciplinary practice aiming to help shape answers to questions akin, *mutatis mutandis*, to those mentioned above.[73,74] For example, how can we ensure that AI-informed decisions for social applications (e.g., bank loans, college admissions, parole hearings) are fair? The ACM FAccT strives to address these issues while actively producing new knowledge.

In the article Bias in Computer Systems,[75] that irrigates the *FairML* dynamic, Friedman and Nissenbaum describe three types of bias in software systems. In the context of the situated green chemistries framework, helped by the explanation of Benbouzid,[74] I really resonated with their classification of three types of bias: (1) “preexisting bias” from previously involved stakeholders, (2) “technical bias", which stems from "the quantification of the qualitative, the discretization of the continuous and the formalization of the abstract, formalization of the informal", all of which inevitably bias algorithmic decisions, and (3) “emergent bias” when the software system interacts with a changing world. This classification can help green chemists to: determine the technical bias of our craft, stop expecting that success requires measurable indicators, cope with a constantly shifting context.

FairML analyses can also help us to acknowledge that overcoming bias itself is a (most likely) unattainable goal. Therefore, like them, we might as well adopt a posture similar to Haraway’s “situated knowledge” position. This paper is a step in that direction.

This Fair Machine Learning (*FairML*) community strives to come up with calculation procedures that must be simultaneously robust and reliable while also remaining aware of and managing the historically-, politically- and socially-constructed aspects of their craft. In Green chemistry, we can also adopt this attitude.

The FairML community suggests a truly interdisciplinary communion of analyses, such as implemented during the AFM FAccT conferences, where data scientists, philosophers and sociologist mingle. This type of exchange will help us forge ahead without losing steam or direction. I really believe that rather than (or at least in addition to) finding new metrics to shape our field, we should invest in finding new companions to reflect with.

7. Conclusion

Green chemistry, like all sciences, is constructed; it is constructed through the constant interactions between the social, physical and ecological worlds; it is constructed by the practices that the social and physical worlds in which they take place let emerge. Some of these interactions can lead to avenues of research that are narrower than they could be and more politically oriented than they should be. The Anthropocene background framing the current period increases the risks connected to foregoing some of the potentially relevant avenues of research and the risks connected to restricting the breadth of possible research for politically unsound reasons.

The Haraway-inspired situated green chemistries framework presented here is a very down-to-earth starting proposal: “pick your core driver for performing green chemistry and take it from there to your desirable future”. At the same time, it is ambitious since it aims to improve the quality of the green chemistry produced (see the “strong objectivity” claim of situated knowledge) while simultaneously expanding the diversity of Green chemistries. In addition to strong objectivity and ethical implications,

situating knowledge helps specify the power struggles associated with knowledge production—and can deflect them where needed. The situated green chemistries proposal is therefore both an epistemological and a political self-improvement project that attempts to avoid the two pitfalls mentioned in the opening sentence of this conclusion: narrowness of themes and unchecked political orientation.

This project can also help structure our identities in these changing times, where building research communities around our main core drivers (social justice-driven green chemists, "do-no-harm"-driven green chemists, economic growth-driven green chemists, etc.) and not—as is often the case—around our disciplinary area of expertise (catalysis, synthetic chemistry, biomass conversion, etc.) can offer a new layer of motivation and creativity, and a new framework allowing constructive synergies to emerge. Explicit articulation between the researcher's aspiration with their topic of research could increase the transformative power of both.

Although the ultimate goal is to produce a spacious tool that captures the questions and practices we consider worthy of shaping an expanded Green chemistry perimeter, the situated green chemistries framework is currently a very rough preliminary proposal. Firstly because, while researchers at the individual level are responsible for aligning the research they perform with their ethics—and we must reclaim this agency where we have lost it—the choice of research orientation cannot be left to individual researchers or to self-organized groups of researchers alone (which is where the current version of the "Situated Green chemistries" framework stops). Research orientation is political, and as such, the framework requires consideration at a level that is larger than academia. Secondly, along the road of the "chemists-meet Harawayan social scientists and philosophers" journey, my preliminary ongoing readings[76,77] indicate that the very powerful way of conceiving the world in terms of chemical elements that characterizes some chemists (including me) will be subsumed into broader understandings. Some of

these will link chemistry, ecology and practice in ways that, to me at least, are thought-provoking, soul-searching and politically inspirational.[76] In this journey, I suspect the current "Green Chemistries Framework" presented hereto to be "down-to-earth" (code for "unsophisticated") because it does not alter the fundamental ontologies and epistemologies that we chemists use and cherish. I am looking forward to those encounters and am also very eager to perform these first steps: "pick your core driver for performing green chemistry and go from there", using the means, techniques and modes that are still very much part of today's Green chemistry territory. Because this is where we are now, and we will build larger and better green chemistries from here.

8. Acknowledgment and some more elements on "from where I speak".

As a chemist, with the strong awareness of *being* a chemist and the desire to better define my direction through science-sourced methods and data, I am both excited and daunted to find myself in social sciences and humanities territory, and to consider it necessary to integrate this landscape in my personal maps.

The support, patience and willingness to teach of several colleagues that inhabit these lands is paramount: Thank you. Among those who guided me toward the situated knowledge framework, I would like to mention: Patrick Degeorges, philosopher, founder of the Institute of Advanced Studies in the Practices and Arts of Transformation (IASPAT), and the engineering school CPE LYON. He provided me with the means to explore the field of "engineering of interdisciplinary pedagogy" and to improve my shaky grasp of the history of philosophy (any mistakes and approximations are my own). Maria-Grace Salamanca, philosopher (Epistemologies of the South) and theater actress (decolonial aesthetics), who introduced me to both. The supporting entities—in particular CPE

LYON, Ecole Urbaine de Lyon, now Cité anthropocène, CNRS and IRCE LYON—for the organization of the CATENERCHEM interdisciplinary school. Cité anthropocène, when they were still the Ecole Urbaine de Lyon, and Michel Lussault in particular, for inviting me to give a public course on the situated green chemistries framework.[78] Dimitris Papadopoulos from the History of Consciousness Department at University of California, Santa Cruz and my companions from the "primer in situated research" project [28] for helping me lift the first veils around situated knowledge (here again, mistakes and approximations are my own)

If social sciences and humanities is the new land, I am indebted to the green chemists that I feel provided security in my risky mountaineering-like bids. And in the numerous rope-teams that tethered me in the land of green chemistry, which include many members of the RSC's Green chemistry editorial team and board . I would like to express my gratitude to Paul Anastas, who started so many of the threads that I have tried to explore here, Phil Jessop, Walter Leitner, Carolina Ojeda Porras, Gisela Scott and Michael Rowan.

My conditions as permanent senior researcher with a large degree of independence and the stable conditions in my professional and personal life provide the means by which I can effectively turn some of the independence-in-theory into independence-in-action. Thank you to colleagues and students, for accepting our uneven re-distribution of the tasks undertaken to acquire, capitalize on and reap the benefits of our research. Thank you in particular to Jerome Canivet, whose leadership in most of the scientific work I am associated with nowadays allows me to explore more distant lands, thank you to Catherine Pinel, director of IRCELYON and my encouraging colleagues at IRCELYON and elsewhere for supporting this exploration.

I would also like to acknowledge Camille Noûs,[79] the collective name that was given to this powerful and, for me, precious societal organization of academic science production in France, and in the CNRS in particular. The overall personal conditions, also linked to but not strictly determined by where and how I live [some aspects I consider relevant here are: French urban city, comfortable socio-economic situation, large cultural and symbolic capital, formative and energizing political experiences, personally simple, resourceful and empowering family trajectory], have allowed me to work to the best of my abilities, remaining true to my values and to my scientific ethos. In these unsettling changing times of the Anthropocene, I have been able to combine the mission of civil servant with my attempts to produce new scientific knowledge of benefit to society while working as a researcher in chemical sciences. These conditions were bestowed upon me partly because of who I am and partly because of the alignment, over the course of my journey, between what was expected by those who had power over my journey and who I was at the time.

9. References and footnotes

Note on *, *NAR* and **COR-AKC-EEX**references: I have used a bold type-face to mark references with the following three-letter acronyms: (i) those related to my core academic expertise, **COR**, referring to or close to topics on which I have performed primary research over the course of my academic career (e.g., chemistry, green chemistry), (ii) with which I am familiar due to my overall academic knowledge and culture, **AKC**, (e.g., sustainability in the broader sense), or (iii) for which I consider my experiential expertise relevant, **EEX**, even if I have not been formally or academically trained in the subject (e.g., political feminism). In contrast, the lack of three-letter acronym beside a reference alerts the reader that I have mobilized references that I do not consider to belong to any of these groups. Among them, starred (*) references highlight some possible in-depth information for interested readers. I, the author, have not perused these starred (*) references fully but have relied on exchanges with more knowledgeable colleagues, to extract what I could from my own partial reading of the source. *Non-academic resources*, denoted *NAR*, include primers and text books, reliable

(in my view) websites, and artistic productions that I find relevant (see some examples in the reference list below).

This surprising note is firstly an invitation to recognize and let go of some of my (our?) practices that project—including through habitual referencing approaches making no distinctions between all the literature elements—an immodest posture suggesting (projecting) mastery of knowledge that encompasses sources from fields where we have variable degrees of competence. Secondly, it is also an attempt to acknowledge the value and necessity of some knowledge contained in *NAR*.

My journey—and the journey I invite you to join me on if you have not already embarked—into inter- and trans-disciplinarity, attempting to re-articulate distant disciplines requires this "shake-it-off" attitude. I hope this type of self-evaluation on expertise (while I am aware of some of the limitations and traps of self-evaluation), helps normalize more "down-to-earth" behaviors. It proposes some ways to remain accountable to the sources chosen, while remaining transparent on which ones are mastered from a scientific, experiential or other point of view, and which are not. This is reflected by the clear distinction between sources that meet the academic tradition of peer-reviewing and publication, and those conforming to other standards.

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(12) Kahan, D. M. Climate-Science Communication and the Measurement Problem. *Polit. Psychol.* **2015**, *36* (S1), 1–43. https://doi.org/10.1111/pops.12244.

(13) a) Oh boy. Truth to be said, I just read a great paper[13b] on how viruses actually can be seen as blurring the lines between living and non-living even in our societies characterized by the naturalist ontology – aka big divide between Nature and Society.[13c] But allow me to stay in the planes of discussion where the divide between living and non-living matter is “obvious” or at least it is the practical simplification we use in our everyday life, where this shared knowledge is among the things that define the “we”. The paragraph is constructed using this “we” which I belong to. (b) Schrader, A. Elemental Ghosts, Haunted Carbon Imaginaries, and Living Matter at the Edge of Life. **2021**. https://doi.org/10.1215/9781478021674-006. (c)**-***P. Descola, *Beyond Nature and Culture*, University of Chicago Press, Chicago, IL, 2014.

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(18) -* Latour, B. *Politics of Nature: How to Bring the Sciences into Democracy*; Porter, C., Translator; Harvard University Press: Cambridge, Mass, 2004.

(19) I repel the mantra “If you fail, at least fail fast”. Just as there is a limit to growth, there might also be a limit to failure. And one of the possible limits is one we do not want to reach.

(20) In time or ever, depending on interesting epistemological considerations hinted to above but that in practice lead us close us to the same point within the frame of this perspective. *En passant*, I refute, as many other, the anti-science position that considering that this imperfection as well as other flaws of science compromise it irremediably.
(21) Bourdieu, P. *Science de la science et réflexivité*, Raison d'agir.; Cours et Travaux; 2001.
(22) -**NAR** *Share of the population with access to electricity*. Our World in Data. https://ourworldindata.org/grapher/share-of-the-population-with-access-to-electricity (accessed 2024-03-15).
(23) -**NAR (movie)** *Donna Haraway: Story Telling for Earthly Survival*; Fabrizio Terranova, 1h21 (2016). https://earthlysurvival.org/ (accessed 2024-03-15).
(24)-* Puig de la Bellacasa, M. *LES SAVOIRS SITUÉS DE SANDRA HARDING ET DONNA HARAWAY - Science et épistémologies féministes*; Editions Harmattan (2014).
(25) -**NAR (festival)** Édition 2023 - La Manufacture d'idées. https://lamanufacturedidees.org/edition-2023/ (accessed 2024-03-15).
(26) -**EEX** Zitouni, B. With whose blood were my eyes crafted? (D. Haraway) Les savoirs situés comme la proposition d'une autre objectivité Benedikte Zitouni. In *Penser avec Donna Haraway*; Dorlin, E., Rodriguez, E., Series Eds.; Actuel Marx confrontation; 2012.
(27) -**NAR (online course)** *Sciences et Machines #6/6 - Pablo Jensen - Cours Public 2022*; 2022. https://www.youtube.com/watch?v=EJpcbNpSUac (accessed 2024-04-02).
(28) Meetings for the collective préparation of : Gourarier, M.; Jensen, P.; Boumediene, S.; Santolini, J.; Li Vigni, F.; Quadrelli, E. A. "Recherches Situées" (Titre Prov.).
(29) -**NAR (online course)** Hinterberger, A. Objectivity and Situated Knowledge- Social Research Methods, 2014. https://www.slideserve.com/john/o-bjectivity-and-situated-k-nowledge (accessed 2024-04-03).
(30) (a) This "how-to-situate-oneself" list is make-shift tool that I have tinkered the best I could give my too recent acquaintance with this found topic. To share a sense of timeframe, I heard for the first time a lecture mentioning Haraway's work only two years ago during a lecture on "science and machines" on June 30th, 2022.[27] (b) Stengers, I. Events and Histories of Knowledge. *Rev. Fernand Braudel Cent.* **2005**, *28* (2), 143–159.
(31) Diniz De Figueiredo, E. H.; Martinez, J. The Locus of Enunciation as a Way to Confront Epistemological Racism and Decolonize Scholarly Knowledge. *Appl. Linguist.* **2021**, *42* (2), 355–359. https://doi.org/10.1093/applin/amz061.
(32) Quiroz, L. *Le leurre de l'objectivité scientifique. Lieu d'énonciation et colonialité du savoir*. Perspectives décoloniales d'Abya Yala. https://doi.org/10.58079/nhio.
(33)-* Castro-Gómez, S.; Díaz Moreno, D.; López Jiménez, C. A.; Melgarejo Acosta, M. del P.; Pedraza Gómez, Z.; Restrepo, E.; Saldarriaga Vélez, Ó. de J.; Sánchez Lopera, A.; Sánchez Mojica, D. A. *Genealogías de La Colombianidad Formaciones Discursivas y Tecnologías de Gobierno En Los Siglos XIX y XX Editores Santiago Castro-Gómez y Eduardo Restrepo ; Daniel Díaz [y Otros]*; 2008.

(34) One possible example: Li Vigni, F. Hayek at the Santa Fe Institute: Origins, Models, and Organization of the Cradle of Complexity Sciences. *Centaurus* **2022**, *64* (2), 443–481. https://doi.org/10.1484/J.CNT.5.131461.

(35) I understand that who I am, my affinities, my elements of context, my situation as a person influences the questions I choose to address in my professions (within the degrees of freedom that I retain within my « agency », in my job, – which also depends on the job itself), the method I use -within the methods I have access to- to address these research questions (my job being a researcher) also influence (partly) the interpretation I probably give to this within the still unsettled frontier of science-in-the-making (…and not *S*cience, see §3) that current research is. At the same time, I am not completely sure where to draw the line between what is to be publicly shared and not. Furthermore, I do understand that there is a lot which is unbeknown to myself, thus hinting at one of the limits of self-reflexivity. It is important to me also to avoid the possibility of confusion (or ill-willed manipulation…) that sharing some of these elements might be construed as supporting the notion that I believe that I -or anyone else- is assigned by their birth and experiences to an inescapable role.

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(37) *A*ntoine Missemer (CNRS, from CIRED laboratory) is kindly acknowledged for introducing me to these works and providing the English translation during his lecture at the "Catalysis at the Energy-Chemistry Nexus - 2022 Winter School -CatEnerChem" winter school. More information on cataenerchem at https://catenerchem.cpe.fr/ (accessed on 03/04/2024) and in ref.[4] Prévot et al herein.

(38) The goal of the work is to arrive to a community-level framework (see conclusion) and go beyond the individual-level engagement. At the same time, there is an individual-level ethical responsibility of the researcher with respect to the object of their investigation that justifies this entry point at the individual level [on this aspect see also ref. Prévot et al.[4].

(39) -**NAR (academic website)** *Harvard STS Program » Research » Platforms » Sociotechnical Imaginaries » Sociotechnical Imaginaries » Frequently Asked Questions about Sociotechnical Imaginaries*. https://sts.hks.harvard.edu/research/platforms/imaginaries/imaginaries-faqs/ (accessed 2024-03-15).

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(44) **NAR** US EPA, O. *Green Chemistry Challenge Winners*. https://www.epa.gov/greenchemistry/green-chemistry-challenge-winners (accessed 2024-04-02).

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(52) I put the common expressions "developing countries" and "low-to-lower middle income" between commas to signify the fact that I perceive in this type of phrasing an underlying projection of value system, which I do not share. For example "developing countries" generally projects the idea that the "natural" destiny of each country is to become" developed", meaning a country with high-income economy and advanced technological infrastructure. see also *https://en.wikipedia.org/wiki/Developed_country#cite_note-11* .

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