Towards Petro-Objectivity: The Scientist's View

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experiments
petroleum engineering
crude oil
Hele-Shaw cell
tipping point
pore space
distillation
petro-objectivity
energy transition

The climate crisis causes society to rethink. We are questioning our lifestyles and energy consumption. We are aware—at least in part—of the consequences of our actions and our climate targets are becoming more ambitious. But despite all these good intentions, our climate footprint is, unfortunately, not changing, or only insufficiently, and we are unable to reduce our dependence on fossil resources—why is that? Perhaps we need to start with an analysis.

Technology: Technologies to help with the energy transition are constantly being developed and refined. Technical prerequisites are necessary to achieve the energy and climate transition, but alone they are not sufficient. We have enough mature technologies at hand for a rethink and to switch to a sustainable energy supply, so this is not about our technological maturity, it is about our maturity as a society. The question we need to ask ourselves is: how long will it take to rebuild our existing infrastructure into something capable of supplying society with enough energy and all kinds of goods, while also maintaining our prosperity and protecting the climate? In other words, what is required for such a reorganization? Or, is the transformation of our "energy-hungry" society into a sustainable version of itself realistic? Probably not!

Attempting to deal with the substance of oil is important because, despite all our efforts to reduce our dependency on them, fossil fuels will likely remain with us for some time to come.[1] Social change is slow for many reasons, including a lack of available alternatives, raw materials, investment funds, labor, etc. All socio-economic energy and climate scenarios point in the same direction.[2] Consequently, this means that not only must we move away from fossil fuels, we must also learn to deal with them and their proxy—crude oil. And this involves rethinking many aspects of our lives, from increasing energy efficiency to controlling emissions and reviewing our high-energy lifestyles.

Figure 1
Hele-Shaw experiment where crude oil is displaced by milk. The complex pattern is a result of instable displacement.

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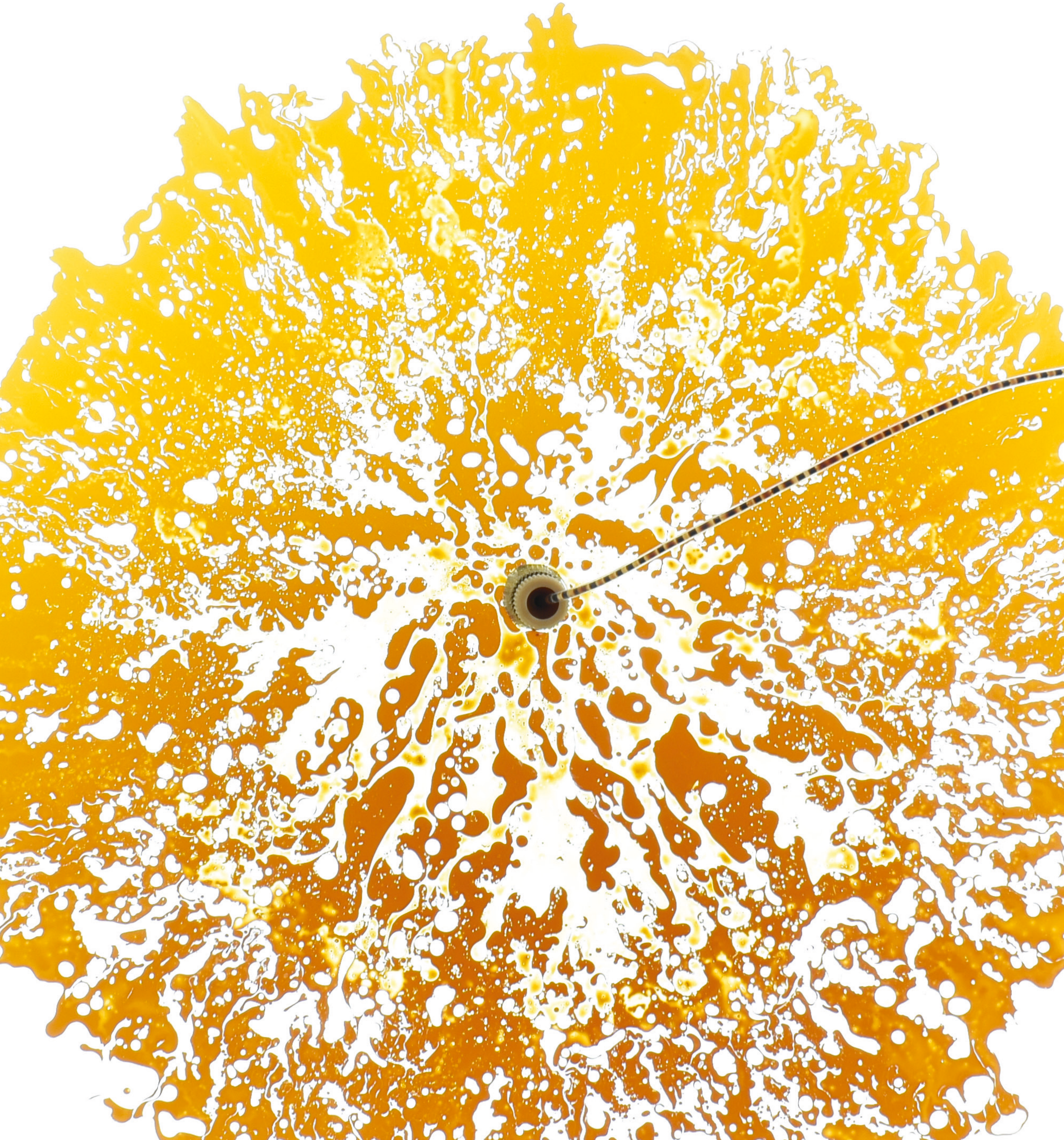

Culture: The energy transition is, therefore, not just about technological change; socio-economic and cultural aspects also need to be taken into account—this is where *Reflecting Oil* comes into play. The *Reflecting Oil* project takes a science-based arts approach whereby a multidisciplinary team is tasked with looking at and reflecting on crude oil—one of the most important fossil resources in modern society—from different perspectives. The focus is on experiments that provide an intuitive, rather than a quantitative, approach to the substance and its materiality. The aim is to try to understand crude oil both in itself and in relation to the materiality of other more familiar substances that are part of our daily lives. By building a relationship with the otherwise abstract substance of petroleum, we can find ways to handle it more effectively for as long as is necessary as well as find a way out of our dependency. To give the reader an impression of what this endeavor has involved, I would like to describe a few of the experiments/installations that were carried out as part of the project. As a scientist, I find technical approaches far more intuitive; however, *Reflecting Oil* is less about quantitative analyses than about experiencing the properties of crude oil and interpreting them in the context of personal behaviors, energy, and the climate.

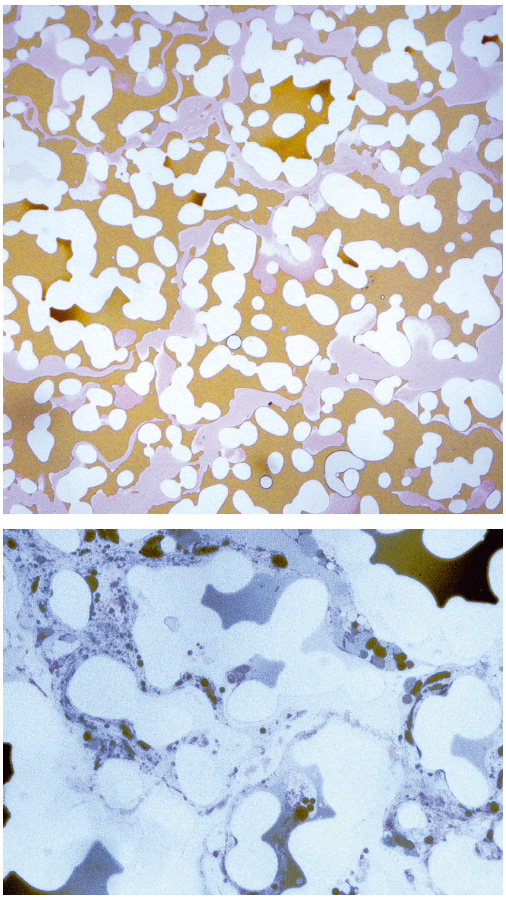

Figure 2
Microfluidic experiments showing the mixing of relevant cultural substances during the displacement of crude oil. The different magnification levels are chosen to show the typical structure formation. Upper image: While human blood (light red) emulsifies oil (light brown) with an immiscible percolation pattern, milk (lower image), which is itself a stable emulsion, is able to emulsify crude oil to a certain extent; microscopic structures form, which are partially resolved by optical imaging.

Science-based Arts—An Experimental Approach

It is the meeting of two worlds, two ways of thinking, and two approaches—one scientific and technical, the other artistic. Both come together and utilize each other, resulting in a symbiosis. The experiments carried out for the project are partly based on scientific approaches that, in a certain way, share the same goal of "experiencing" oil. Nonetheless, this experience is slightly different in that it is not about quantifying the chemical and physical properties of oil, but about experiencing them through the senses. Because this sensory experience is a personal and individual one, it requires references in order to provide it with attributes. The comparison to reference substances we are all familiar with allows crude oil to be categorized in a personal coordinate system. These reference substances, also referred to as cultural substances, could include water, honey, milk, blood, etc.—things that have certain personal associations and allow for a common understanding. The quantity of substances, their properties, and the experimental possibilities they offer open up a rich, multidimensional space of experience.

The experiments that were carried out for the project are extremely diverse and, for me, some were also very expressive. For example, the Hele-Shaw experiments[3] (explained below) express both predictability and loss of control. The future cannot be predicted and depends on critical parameters in analogy to the mobility of oil. It is not necessarily the interpretation of experiments that differentiates artistic approaches from scientific ones, but rather the personal, cultural, geopolitical associations that are made. The experiments themselves are really only a vehicle for understanding. Actual insights come from very different people with diverse backgrounds coming together to reflect in groups, which always brings new and surprising aspects to light.

Hele-Shaw experiments: In these experiments, various liquids such as oil and water are injected into a narrow gap between two glass plates, displacing the liquid already present in the gap. Technically speaking, this process is very similar to the displacement of oil in reservoirs by water injection, a common method of oil production. This displacement process can lead to instabilities,[4] the occurrence of which is predictable but very difficult to control. As there are ways to avoid these instabilities, they are not symptomatic of oil recovery, but are metaphorical for fossil fuels that are provided in abundance and the consequences that develop as a result of their use. Technically, such flow instabilities occur at a "tipping point"[5] when the mobility ratio of injected and displaced fluids becomes greater than one.[6] Once this tipping point is reached, we can say with certainty that instabilities will occur, but it is difficult to predict the exact extent—this is quite comparable to tipping points and instabilities in climate physics or metaphorically for conflicts and wars in the context of access to oil. Repeating such an experiment, or variations of it, results in patterns that are structurally similar but different in detail, highlighting the unpredictability of the exact outcome. This serves as a reminder of the different potential paths our future may take, which may follow certain broad patterns but remain inherently unpredictable in their specific details.[7]

Mixing and dynamics: Contact between fluids can result in miscible or immiscible mixing, depending on their interfacial tension. Water and oil are naturally in contact in the subsurface as a result of hydrocarbon formation and migration processes. They are typically immiscible and coexist in the pore space of the reservoir rock. In petroleum engineering, fluids are injected into oil reservoirs to displace and recover the crude oil. Interfacial tension, wettability (the affinity of fluids to wet the rock-forming minerals), and fluid viscosities are classical design parameters that can be modified for efficient oil recovery.[8] These effects can be studied visually in microfluidic chips that mimic the pore structure of porous rocks. Fluids can be injected into and recovered from the chip, and the displacement process in the pore space can be observed using optical microscopy.

In the course of several experimental sessions, known cultural substances were brought in contact with crude oil. Typically, the individual fluids are filled into test tubes and mixed through shaking before being left to stand for a period of time so as to allow the fluids to separate by gravity into new and thermodynamically stable fluid phases. This mixing is turbulent. In microfluidics or porous media, the flow is laminar, and this mixing has been observed in detail.[9]

In these experiments, crude oil was brought into contact with substances that are very familiar to us: honey, milk, and Coca-Cola. They mixed with the crude oil in different ways, resulting in new optically homogeneous or heterogeneous liquid phases of different colors and structures. The observations can be explained by miscible or immiscible behavior. Depending on how compatible or different the liquid is from crude oil, the liquids mix, ignore each other, or form emulsions which have been observed optically.[10] In microfluidics, the liquids appear almost transparent or very light, which is due to the very thin pore space of the chip used. Coca-Cola and oil were found to be immiscible and separated from the remaining oil phase in a percolating cola phase. Milk, on the other hand, has a certain fat content and is itself a stable emulsion: upon contact with crude oil, both liquids formed emulsion-like structures in the pore space. This indicates an exchange of substances between crude oil and milk and a certain affinity between them.

In these experiments, the properties of crude oil can be understood through cultural substances that are known to us. It turns out that the behavior of these substances during mixing corresponds to our everyday experience of bringing oily and watery substances into contact and possibly emulsifying them with more complex substances such as surfactants.[11] Examples include the homogenization of milk, or the stabilizing of vinegar and olive oil to form a homogeneous salad dressing. Thus, we are actually very familiar with the behavior and interactions of crude oil from ordinary household substances.

Distillation, smell, and appearance experiments: In petroleum engineering, the appearance (color) and smell of crude oil do play a role in characterizing it, but only a minor one. Gaining an intuitive understanding of the appearance and smell of oil requires appealing to two of our most important senses. In a series of experiments, we investigated the smell and appearance of crude oil. We focused not only on crude oil as a whole, but also on its coarse components. Although crude oil is a homogeneous substance, its chemical composition is very complex and individual. This complexity is difficult, if not impossible, to characterize or visualize. A simple approach to differentiation is distillation, in which light fractions of the crude oil are evaporated at gradually increasing temperatures and liquefied again by condensation elsewhere. This separates different fractions with increasing boiling points. Distillation is a fundamental industrial process that starts with crude oil to create other products or fuels. We carried out this fractionation on a small scale in the laboratory and observed—visually, by smell, or by other means—the different fractions separately. I, however, want to focus on their smell and appearance.

As expected, the lighter fractions are more volatile and less viscous. Still, what was surprising, though not unanticipated, was that we obtained a transparent and colorless liquid phase as the light fraction, which is completely counterintuitive when you actually see it happen—to extract a transparent liquid, a type of naphtha, from deep dark crude oil is an experience in itself. What remains in the flask after several distillation steps can be better described as a deep, dark solid; the type of material used in road construction. Not only does the appearance and viscosity vary greatly from fraction to fraction, but the smell does too. The light fraction developed a very intense and pungent odor. Since these are the most volatile components, the intensity is understandable, as the most volatile components have the lowest vapor pressure and escape easily into the surrounding air. The pungent smell of the distillate, on the other hand, was also somewhat surprising and had nothing in common with the smell of undistilled crude oil, which to the untrained nose smelled a little strange, if not as unpleasant. Although naphtha is a direct distillate of crude oil, the derivatives or fuels that we personally come into contact with are not comparable to crude oil itself, which remains an abstract substance for most people.

But let us go back to the basics of oil for a moment—this project is about crude oil as a cultural yet abstract substance. Is crude oil crude oil? As mentioned above, and as has become clearer to us in the course of the project, crude oil is a very complex substance with a molecular composition that can only be incompletely characterized scientifically. This composition and the associated properties vary not only from reservoir to reservoir, but also within reservoirs, and not just in small ways either; for example, naturally occurring hydrocarbons vary from the gaseous state (natural gas fields) to the solid state (tar sands). Our project has focused primarily on conventional oil. In order to characterize crude oil, various samples from Austria, Norway, Central Asia, and the Middle East were filled into glass bottles and evaluated visually and by their smell. The goal was to develop categories or a coordinate system in which all the oils could be represented. The procedure was similar to a wine tasting, where color, texture, aroma, and flavor are analyzed. While the color of such dark substances could be seen with an appropriate light exposure, varying between greenish and reddish brown and degrees of darkness, their smell was much more subtle and tricky to discern. Overall, the attributes we found varied between, for example, “pungent aggressive” and “creamy soft,” and between “herbal” and “wet asphalt.” These descriptors were recorded in a jointly developed “olfactory crude oil wheel.” As in wine tasting, the differences between the oils were subtle and could only be worked out iteratively.

Team Reflections
The *experiments* are reflected upon in meetings attended by members of the project’s multidisciplinary team: artists, art historians, engineers, and scientists who bring very different perspectives to the discussions and interpretations. In addition, guests from all over the world and different disciplines are invited to participate in workshops or *experiments* in Leoben and Vienna; the workshops broaden the team’s perspective through presentations and discussions on topics ranging from proletarian ecology and game design, to oil and climate change. In this way, the team expands its multi-perspectival view of oil, leading to a comprehensive understanding of its properties and role in society. This approach has made me personally aware of the value of gaining a comprehensive understanding of this

The Revised Game of Life *experiment*, Department Petroleum Engineering (DPE) laboratory University of Leoben, 2024 substance and our cultural dependence on it, and that a more holistic approach is needed to solve our current problems, one that goes beyond just its technical, economic, or cultural aspects.

Reflecting Oil in Education

A primary goal of the project is to share the team's experience of this "science-based art approach" with students from various disciplines in order to inspire them and raise their awareness of the energy transition. The involvement of students means that the concepts developed during our investigations can be tested all while infusing the project with fresh ideas and creativity. The Petroculture[12] and Energy Transition Seminar, held in Leoben and Vienna, brought together students and faculty members from engineering and the arts to discuss our deep cultural dependence on fossil fuels and possible ways out. The group explored the historical, technical, and cultural aspects of the culture-energy complex and sought solutions. Groups of engineering and art students conducted scientific experiments and produced artworks that demonstrate the role of the science-based art approach in addressing contemporary energy issues. The perspectives developed help bridge the gap between scientific concepts and public awareness, making complex issues more intuitive and accessible to all. In particular, final presentations introducing the students' creative output and joint discussions show that such work is mutually inspiring and that students from different disciplines learn from each other. Critical questions are asked across disciplines and discussions are held outside personal comfort zones. New spaces open up! It turns out that simple truths are not enough and solutions require an interdisciplinary approach. This seminar and other activities are the first steps towards a multidisciplinary education in petroculture.

My Learning and Potential Project Impact

Let us return to the problem. Our planet is home to seven billion people, most of whom are increasingly dependent on energy. Fossil fuels currently provide over 80 percent of this energy.[13] This is an enormous dependency—it is not only a dependency on energy, but also a dependency on specific energy sources and their characteristics (high energy density, cheap to extract, easy to transport). So, our reliance on crude oil is not only technical, but, as I have come to realize in the course of the project, also social and cultural, all of which are closely linked to these characteristics.[14] Therefore, it is not enough to rely on technical solutions alone; a cultural change also needs to take place, starting with me as an individual. A term that captures this problem is "petro-subjectivity" as defined by Brett Bloom.[15] Petro-subjectivity refers to the way our understanding of ourselves and the world around us is shaped by the use of oil.

Mitigating the effects of our petroculture, of which climate change is the most dramatic element, requires us to look not only at ways to turn away from oil but also at how we deal with oil. But this is an ideologically charged issue that polarizes society. This polarization is unhelpful and prevents constructive solutions. For this reason, and now that our goals have been defined, it is also appropriate, necessary even, to look at the problem, and therefore at oil, analytically and perhaps even dispassionately—objectively! Let us try another term: "petro-objectivity," which may refer to the ability to look at oil as a fuel from an objective perspective, without being influenced by personal beliefs or interests. It is important to understand the environmental, economic, and social impacts of oil in order to take the right actions to reduce our dependence on fossil fuels. An objective view of oil can help inform policy decisions based on facts and data, rather than personal beliefs or interests. In the *Reflecting Oil* project, we try to grasp the materiality of the substance with our senses, which is a subjective approach. On the other hand, we also strive for a shared and interdisciplinary understanding of the material, which means objectivity in the best sense of the word. This is why I believe that *Reflecting Oil*, with its shared understanding of the material, can grow beyond previous approaches.

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